THE GLOBAL CORAL REEF CRISIS

SCIENCE - EDUCATION - MANAGEMENT

5 YEARS OF REEF CHECK

TRENDS AND SOLUTIONS

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COVER PHOTO BY

Coral Reef Adventure,
courtesy of MacGillivray Freeman Films

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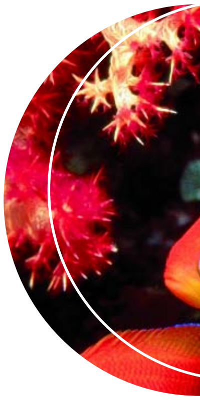
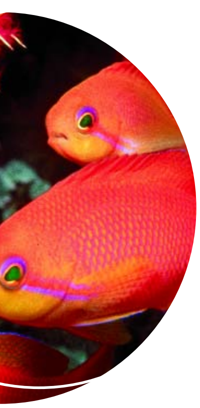
Photo by Jeff Jeffords



LIST OF ABBREVIATIONS

$	US dollars unless indicated otherwise
A	Australian dollar
AID	US Agency for International Development
AIMS	Australian Institute of Marine Science
CNMI	Commonwealth of the Northern Mariana Islands
COTS	crown-of-thorns starfish
FAO	United Nations Food and Agriculture Organization
FSM	Federated States of Micronesia
GCRMN	Global Coral Reef Monitoring Network
GIS	geographic information system
GMAD	Global Marine Aquarium Database
GPS	global positioning system
ha	hectare (10,000 square meters)
HC	hard coral
ICRAN	International Coral Reef Action Network
ICRI	International Coral Reef Initiative
MAC	Marine Aquarium Council
MAQTRAC	marine aquarium trade coral reef monitoring protocol
MDS	multi-dimensional scaling
MPA	Marine Protected Area
mt	metric ton (1000 kg)
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OT	other substratum category
PADI	Professional Association of Dive Instructors
PERSGA	Programme for the Environment of the Red Sea and Gulf of Aden
PMBC	Phuket Marine Biological Center
PRIMER	A statistical package
RB	rubble
RC	Reef Check
RKC	recently killed coral
SACEP	South Asia Cooperative Environment Programme
SC	soft coral or zooanthid substrate category
SIMPER	A statistical test for similarity from PRIMER
SMMA	Soufriere Marine Management Area, Saint Lucia
sp	species (single), spp (plural)
SP	sponge
UCLA	University of California at Los Angeles
UK	United Kingdom
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization
WCMC	World Conservation Monitoring Centre



Foreword


Jeff Hornbaker, courtesy The Crossing: Quiksilver International

The environment changes. The changes are great over human lifetimes but subtle over a few months or years. Change creeps up on us unnoticed until there are no more big fish in the sea or we run out of drinking water and we wonder why. Then we start to worry and try to decide what to do, but our standards for improvement are much lower than before because we did not notice the changes as they occurred. Fisheries biologist Daniel Pauly introduced the term "Shifting Baseline Syndrome" in reference to such declining standards and aspirations for nature. In ecological jargon, "baseline" refers to the initial, pristine state of a community of organisms. However, scientists began to study nature long after intensive exploitation and pollution had greatly reduced stocks of living resources to the point that baselines are difficult to construct.

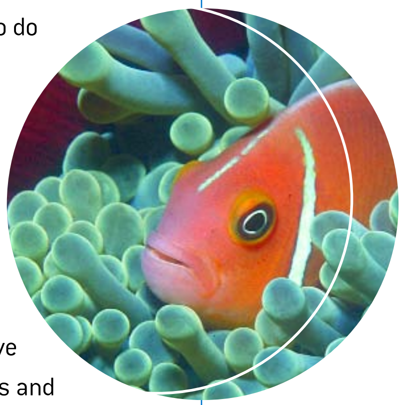
Nowhere is the problem of shifting baselines greater than for coral reefs. During my thirty-year career, I have watched every coral reef ecosystem I have studied change almost unrecognizably from the way it used to be. But when I try to explain these changes to younger scientists who were not there before they are skeptical because who could possibly imagine that such changes have occurred? There is a generation gap in scientific perspective.

The problems are the usual list of overfishing, pollution, introduced species, and global climate change – although in most cases the relative importance of these different human activities is not as well understood as we would like. The widespread occurrence of trophic cascades due to over-fishing is particularly difficult to unravel because the keystone species were so often reduced to ecological extinction decades before ecological studies began. Regardless of the exact cause, the implications are dire for coral reefs and for the people who depend upon reefs for food and other resources. The economic implications are particularly severe in developing countries that are least equipped to cope with the change.

Coral reef scientists were inexplicably reluctant to recognize the global crisis in the state of coral reefs. This was all too evident in the slow realization that outbreaks of coral disease, coral bleaching, fleshy algae, and crown-of-thorns starfish pose a genuine danger to the future of coral reefs around the world. Indeed, the first international meeting to attempt to rigorously assess the status of coral reefs worldwide was not held until 1993. At that meeting, many scientists, especially those from prosperous nations, still denied that coral reefs were in serious decline.

There is no doubt that coral cover and the abundance of fishes and numerous free-living invertebrates have greatly declined in well-studied situations such as the reefs of the Florida Keys, Jamaica, or the Netherlands Antilles. There are also excellent time series available from several sites on the Great Barrier Reef where scientists and managers are beginning to realize that even the best protected reefs in the world are exhibiting serious reasons for worry. But until very recently, coral reefs in the developing world received much less and more superficial attention, even though their reefs are subjected to more intense exploitation and damage than the reefs of wealthier nations. In addition, there has been too little attention paid to remote sites where the effects of human disturbance may be less than closer to centers of human population.

For all these reasons, it is essential that we develop a clearer understanding of the global scope of the decline of coral reefs. There are many approaches to obtaining such data, all of which revolve around the trade-offs between exclusive involvements of a few professional coral reef scientists versus increasing the numbers of observers through the use of volunteers. Volunteers greatly increase the scope of the surveys that are possible and therefore greatly increase the sample size of reefs examined. This is what Reef Check has managed to do so impressively over the last five years. The results, although preliminary, support the view that the problems of coral reefs are genuinely global in scope.



Nature is complicated and coral reefs, like other ecosystems, change for all sorts of reasons besides human actions. Thus time series of only five years duration are open to different interpretations and many more years of observations will be required to identify trends. Nevertheless, Reef Check surveys suggest several fold declines in numerous species that are cause for genuine concern. It is particularly disturbing that abundance of reef fishes like snapper, groupers, parrotfishes, and grunts continue to decline in the Caribbean where one might have expected they had already reached rock bottom.

By far the most disturbing results, however, concern the nearly universal disappearance of heavily exploited species from reefs around the world except in a few moderately well protected areas. Nassau Groupers were once among the commonest fishes throughout the Caribbean but were absent from 82% of the 162 Atlantic reefs surveyed. Likewise, bumphead parrotfish and humphead wrasse were virtually absent from the Pacific reefs surveyed except for a few protected areas. This universal rarity of once common and ecologically important species confirms the global extent of coral reef decline.

Last but not least, the volunteer program of Reef Check provides a valuable opportunity for divers and snorkelers to take a first step towards learning more about the threats to coral reefs and the importance of greater care and protection.

Reef Check is to be congratulated for their important contribution to our understanding of the magnitude and extent of the threats to coral reefs around the world.

Jeremy Jackson

Photos on pages ii, 3, and 6 courtesy of Coral Reef Adventure, MacGillivray Freeman Films

Executive Summary

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

The Global Coral Reef Crisis: Trends and Solutions 1997 – 2001

Reef Check was developed in 1996 as a volunteer, community-based monitoring protocol designed to measure the health of coral reefs on a global scale. Now in its sixth year of operation, Reef Check is active in over 60 countries and territories throughout the tropical world. During this time, Reef Check has evolved into an international environmental organization with the following goals:

- to educate the public about the coral reef crisis;
- to create a global network of volunteer teams which regularly monitor and report on reef health;
- to scientifically investigate coral reef processes;
- to facilitate collaboration among academia, NGOs, governments and the private sector;
- to stimulate local community action to protect remaining pristine reefs and rehabilitate damaged reefs worldwide using ecologically sound and economically sustainable solutions.

Reef Check scientists train teams of volunteers about the value of coral reefs, their ecology and how to scientifically monitor them. During surveys, the work is supervised and checked by a scientist. Teams are composed of a diverse range of volunteers ranging from all scientists to recreational divers to village fishermen. Through this process, Reef Check has raised public awareness about the global coral reef crisis and potential solutions. The teams have collected a wealth of valuable data from reefs around the world. These have been analyzed and the results are presented in this five-year report, providing a synoptic assessment of global coral reef health using a standard method.

Reef Check teams collect four types of data: 1) a description of each reef site based on over 30 measures of environmental conditions and expert rating of human impacts, 2) fish counts along an 800 m^2 section of shallow reef, 3) shellfish counts over the same area, and 4) a measure of the percentage of the seabed covered by different substrate types including live and dead coral. Sixteen global and eight regional indictor organisms were selected to serve as specific measures of human impacts on coral reefs. They were chosen based on their economic and ecological value as well as their sensitivity to human impacts. For example, the humphead wrasse (***Cheilinus undulatus***) is the most sought after fish in the live fish trade, whereas the banded coral shrimp (***Stenopus hispidus***) is collected for the aquarium trade. In areas where these organisms are targeted, their populations are expected to decrease.

Monitoring was carried out from 1997 through 2001 at over 1500 reefs in the Atlantic, Indo-pacific and Red Sea. Following quality assurance procedures, 1107 sites were accepted for analysis. The analyses examined spatial and temporal changes in indicator abundance and correlations between abundance and ratings of human impact provided by the teams. The key findings were:

- At the global scale, zero spiny lobster were recorded at 83% of shallow reefs indicating severe overfishing; there was a significant decline in lobster abundance in the Atlantic;

- The mean abundance of Diadema sea urchins decreased significantly in the Indo-Pacific from 1998 to 2000, approaching levels similar to those found in the Atlantic and possibly indicating ecological destabilization;
- A total of 101 triton were recorded indicating severe overfishing for the curio market;
- Globally, there was a significant decrease in the abundance of butterfly fish from 1997 to 2001;
- There were zero grouper larger than 30 cm recorded at 48% of reefs surveyed indicating overfishing of these predators;
- Four species of fish are in critical condition: Nassau grouper were absent from 82% of shallow Caribbean reefs – only eight reefs had more than one fish. Barramundi cod, bumphead parrotfish and humphead wrasse were missing from 95%, 89% and 88% of Indo-pacific reefs respectively;
- Moray eels were not recorded on 81% of reefs, and in the Indo-pacific, 55% of all reefs surveyed were devoid of parrotfish greater than 20 cm;
- Globally, the mean hard coral cover was 32%. The percent hard coral cover was significantly higher on reefs having no anthropogenic impacts than on reefs with high levels of such impacts. Only 34 reefs had greater than 70% hard coral cover and none had higher than 85% cover.
- The 1997-98 bleaching event reduced live coral cover by 10% globally, indicating that coral reefs are a sensitive indicator of global warming;
- Algal cover was higher on reefs rated as having high sewage inputs;
- Natural differences between reefs in the two oceans are the relatively high abundance of fish of the families Haemulidae and Scaridae on Atlantic reefs and fish of the families Chaeodontidae and Lutjanidae on Indo-pacific reefs.
- Marine protected areas (MPAs) in developing countries are showing some success. Five of ten fish and one of ten invertebrate indicators were significantly more abundant inside than outside MPAs.

Achievements in Education and Management

A review of the first five years of Reef Check indicates that the basic program of education and monitoring works well. Reef Check is a major partner with the International Coral Reef Initiative and the Global Coral Reef Monitoring Network (GCRMN). Dozens of Reef Check/GCRMN training workshops have been carried out at national and regional levels throughout the world. These workshops provide training in Reef Check and more taxonomically detailed protocols as well as supplying information on sustainable financing and media relations. In 2001, a Southeast Asia Regional Training Center was established in Phuket, Thailand which offers quarterly workshops. Ideally, new training centers can be set up in the Caribbean and East Africa. Reef Check supplies raw data to ReefBase and metadata to GCRMN for status reports.

Prior to 1997, coral reefs were rarely featured in the international press. Beginning that year, Reef Check has been successful in attracting mainstream media attention to the plight of coral reefs. The public awareness campaign continues to build with the help of new private sector partners including Quiksilver and MacGillivray Freeman Films whose film and advertising capabilities offer mechanisms for delivering the message to the general public.

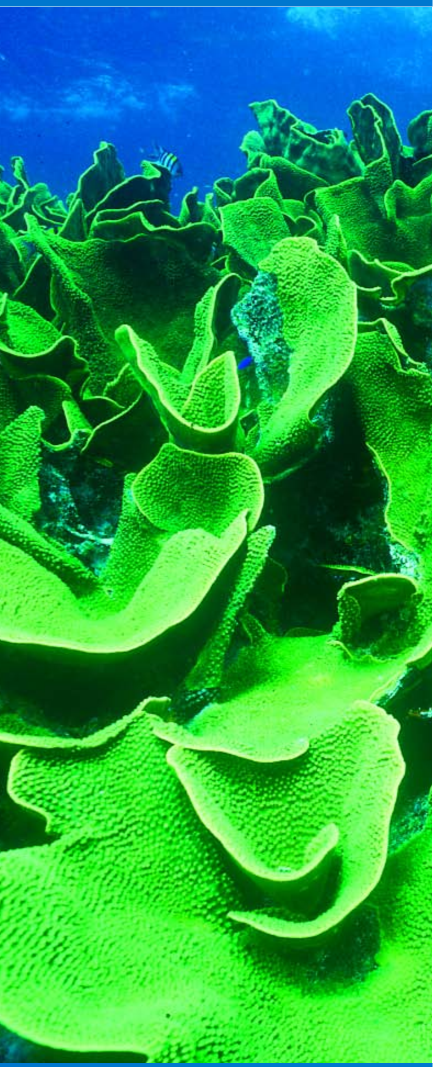
Reef Check also aims to design, test, and implement solutions to the problems facing coral reefs. As people learn more about coral reefs, they develop a sense of stewardship, and a desire to become involved in managing their local reefs.

Participation in Reef Check has already led to the initiation of new coral reef management activities such as establishment of measurably successful marine parks.

The Next Steps

During the first five years of Reef Check, over 5,000 people took part in monitoring 1,500 reefs in more than half of all coral reef countries. The Reef Check network brought together hundreds of diverse groups from all sectors to work together towards a common goal. In the future, Reef Check will devote more effort to facilitating ecologically sound and economically sustainable coral reef management.

Chapter 1 ORIGINS OF THE CORAL REEF CRISIS



courtesy of Coral Reef Adventure, MacGillivray Freeman Films

In 1944, after 17 years at sea, Lieutenant Commander Jacques Yves Cousteau of the French navy converted a 360-ton, 140-foot long decommissioned Royal Navy minesweeper into a state-of-the-art diving platform. Equipped with an innovative set of scuba equipment, the "Calypso" served as a mobile dive platform for researchers. They were the first to film organisms that had only been seen before from a diving bell or submarine.

Jacques Cousteau went on to have an illustrious second career as an adventurer and natural historian. The Cousteau name is now synonymous with marine conservation, but this was not always the case.

In his second book, ***The Living Sea***, which documents his explorations during the 1950s, Cousteau reveals what would now be regarded as a callous disregard for marine life. The Calypso aquanauts caught fish in the Red Sea using small dynamite charges, hacked huge black coral sea fans from the reef as souvenirs, spearfished with abandon, and collected giant clams just to use as fish food for their favorite reef fish. For the Calypso aquanauts of the 1950s, the living sea still seemed an endless, inexhaustible resource to be explored and exploited.

Within ten years of launching the Calypso, Cousteau's beloved marine laboratory in Monaco was threatened by pollution and sedimentation. By 1960, his attitudes had changed and he was leading a campaign to prevent the dumping of radioactive waste in the Mediterranean near Avignon. Prophetically he wrote, "Why do we think of the ocean as a mere storehouse of food, oil, and minerals? The sea is not a bargain basement."

Across the Atlantic in the United States, Rachel Carson's 1950 book, ***The Sea Around Us***, first alerted the world about the potential for environmental problems to affect the sea. She wrote in the preface to the second edition, "Although man's record as a steward of the natural resources of the earth has been a discouraging one, there has long been the belief that the sea, at least, was inviolate, beyond man's ability to change and to despoil. But this belief, unfortunately, has proved to be naïve." Carson's 1962 book, ***Silent Spring***, focused on marine pollution and is credited with spawning the global environmental movement.

The potential for humans to disturb, damage and kill coral reefs has been recognized for over a century. Charles Darwin remarked that sedimentation from freshwater discharge could prevent reef growth (Darwin, 1851). By the 1960s, high-profile news stories about oil spills and DDT led researchers to investigate the potential impacts of these chemicals on marine life. In the 1970s the first international symposium on coral reefs was held and some researchers became interested in the effects of sedimentation and pollution on coral reefs. Only recently has research focused on coral reef fisheries.

Recreational and Commercial Reef Fisheries

Most of the world's coral reefs are found in developing countries where human populations have typically doubled over the last 20 years. About 60% of these populations live within 100 km of the coast and depend on the reefs for a high proportion of their protein. Higher levels of local consumption and export of seafood has increased the demand on reefs.

Throughout the tropics, commercial coral reef fisheries have existed for hundreds of years. However, until the 1940s, most fishermen used small boats and could not venture far from shore. Prior to the 1970s, most recreational scuba divers in developed countries such as the US and Australia were hunters – hoping to spear fish or catch lobster. Divers whose primary motivation was underwater photography were rare, simply because underwater photographic equipment was unreliable, typically based on a homemade Plexiglas housing, and expensive. Groups of divers in places like Florida would gather for a "bug" dive where large sacks were filled with spiny lobster collected from the reefs. Spear fishermen would shoot the biggest reef snapper and grouper they could find. Queen conch littered seagrass beds adjacent to reefs – a seemingly inexhaustible supply. But in reality, huge numbers of reef organisms were being caught, in some cases quickly decimating local populations.

An important early account of commercial coral reef fisheries is provided in ***The Great Barrier Reef of Australia: Its Products and Potentialities*** by the Commissioner of Fisheries (Saville-Kent, 1893) which indicates the mentality of that time:

> "Some idea of the monetary importance to Queensland of the Great Barrier Coral Reef area may be gained from the fact that raw material to the value of over £100,000 is obtained annually from the reefs and the intervening waters, and exported from the colony. This sum, moreover, probably represents but a fractional portion of what it will be worth when the prolific resources of the region have been fully developed. These are capable of development to an almost unlimited extent."

For example, sea cucumbers are an ancient east Asian delicacy that have been fished commercially from reefs for hundreds of years. Between 1880 and 1889, over 40,000 tons of dried sea cucumbers collected from the Great Barrier Reef (an estimated 80 million sea cucumbers) were exported from Queensland to Hong Kong. Saville-Kent believed that sea cucumbers were able to replenish their stocks each year due to migration from deeper water.

Saville-Kent photographing sea cucumbers collected from the Great Barrier Reef in 1891. He viewed such living resources as unlimited.

As nearshore reefs became depleted during the 1950s through the 1970s, larger boats were needed to reach more distant destinations. Governments eager to please their fishermen constituents provided "perverse subsidies" to fishermen to build bigger and more powerful boats. The world's fishing industry spends $124 billion every year to produce $70 billion worth of fish – the difference ($54 billion) is paid for in subsidies (Harris, 1999). Having completely depleted their own stocks of fish and shellfish by the 1980s, commercial fishing fleets from Hong Kong, Taiwan and China expanded their fishing grounds throughout the Indo-pacific in search of reef fish and shellfish.

Commercial reef fishing is carried out using a wide array of techniques and technologies including fish traps of all shapes and sizes, fixed and free gill nets, trawlers and purse seiners, hook and line, spearing, and blast fishing. Blast fishing is practiced in many parts of the world but is particularly prevalent in SE Asia where missing limbs are a common sight among fishermen. Although it is illegal in many countries, its practice continues because it is a very efficient form of fishing in the short term, destroying the habitat for fish over the long term.

Centered in Hong Kong, the live food fish trade grew rapidly in the 1980s. Restaurant owners keep their live fish in glass tanks so that patrons can select dinner from a living menu. During the Asian economic boom years of the 1990s, this practice spread from the elite to the growing middle class, such that the number of live-fish restaurants increased rapidly, expanding from southern China throughout SE Asia. Demand soared for reef fish such as the humphead wrasse and several species of grouper.

Blast fisherman in Indonesia uses explosives in order to capture fish taking refuge inside the living reef structure. Photo by Lida Pet-Soede.

Since World War II, there has been a growing trade in reef fish and invertebrates for use in home aquaria. The marine aquarium and ornamental trade is now estimated at US $200 million per year as a result of improved husbandry techniques and an increase in the number and diversity of species. The Philippines and Indonesia account for some 80% of the trade, the majority of which is exported to the United States.

Fishermen in both the live food fish and the marine ornamental trade have historically harvested using fish poisons including natural roots and cyanide. While there is a strong economic incentive to keep fish alive by using a small amount of poison, even modest doses can injure nearby fish and invertebrates. Additional damage to corals may occur when

Coral and shells on sale in Vietnam. Photo by Gregor Hodgson.

a stunned fish swims into a coral head and a fisherman breaks it open to retrieve the fish.

Other damaging fishing practices include muro-ami. Although illegal, muro-ami is still practiced in the Philippines. Typically, 200 boys are carried on a large boat to patch reefs in the South China Sea. At the reef, each boy is given a long rope with a rock tied to the end. The boys form a line and repeatedly drop the rock onto the corals 40 feet below as they swim forward. The banging noise and tassels tied to the rope scare the reef fish into a type of purse net.

A Filipino boy in about 20 m of water is breathing from a hose held in the corner of his mouth. An old refrigerator-type compressor powered by a car battery continuously pumps fresh air through the hose from a boat on the surface. In his possession are a net, catch bag, and squirt bottle with cyanide, which he uses to stun the fish he is collecting for export.

In addition to the various fishing methods described above, women and children are encouraged to forage on the reef flat at low tide, gleaning the reef for any tiny organism that can be added to the family stewpot. Women and children are also engaged in the collection and processing of reef animals for the curio trade. This trade involves a wide variety of corals, shells, starfish and seahorses that need to be cleaned, dried and often painted before being exported to the United States and Europe.

As noted earlier, both pollution and sedimentation can damage coral reefs. Both of these anthropogenic impacts have increased since the 1940s, destroying the reefs of Jakarta and Manila Bays. In contrast, however, the adaptability of corals is shown by the surviving reefs of Hong Kong and Singapore, where sedimentaion, industrial, and sewage pollution have long been severe. While most reefs are not located near large cities, where combined anthropogenic impacts would be greatest, rivers can collect and deliver sediment, nutrients, and pollutants to coastal areas far from inland cities.

Given this long list of human impacts on coral reefs, it is not surprising that reef health has been failing for some time. Prior to 1997, there was no solid scientific evidence to judge the severity of the situation on a global basis. This vacuum was the stimulus for Reef Check.

Coral miners in Hainan, China collected these corals for export. This practice has since been banned. Photo by Gregor Hodgson.

Chapter 2 WHY REEF CHECK?

By the late 1980s, anecdotal reports of coral reef declines were becoming common. Recreational divers, now armed with underwater video and still cameras, were coming back from dives and remarking, "It just doesn't look as good as it used to." Scientists were coming back from their favorite reefs, particularly in the Caribbean, and noting that there seemed to be a decline in coral cover. One keystone coral, in particular, seemed to be disappearing from the Caribbean, the elkhorn coral ***Acropora palmata***.

In 1993, Professor Robert Ginsburg of the University of Miami, organized an international workshop on the Global Health of Coral Reefs. Ginsburg, a geologist, led some 250 of the world's coral reef researchers to try to answer the question: What is the health of the world's reefs? It quickly became apparent to the researchers that they did not have sufficient information to answer this question due a lack of long-term studies of reef health over large spatial scales.

Science as "as usual" was not tracking these changes. A new approach was needed.

Two major initiatives were developed at the workshop. The first was the decision to declare an "International Year of the Reef" to draw global attention to reef conservation issues. The second was to set up a global monitoring program to track changes in reef health. But how to establish and fund such a program? A number of researchers led by Ginsburg requested that Gregor Hodgson design a protocol (See Designing Reef Check).

The original goals of Reef Check were to carry out one synoptic survey of a selection of the world's "best" reefs. Due to a lack of external funding, the entire program had to be based on volunteer labor. The basic idea was that coral reef scientists would be willing to volunteer their time to train experienced recreational divers in fish and shellfish identification and monitoring techniques. Recreational divers would receive a lesson in reef ecology and monitoring, and the scientists would get their reef health data. But no one knew if this theory would work in practice.

The Reef Check protocol was originally designed to be carried out in 1997, the International Year of the Reef (IYOR). In 1996, the protocol was circulated by email and peer review was requested. Many scientists provided suggestions for modifications. Others wrote to say that a monitoring system based on volunteer divers could never succeed! The protocol and instructions were placed on a website and advertised on NOAA's list server.

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

A number of national and international organizations such as the US National Oceanic and Atmospheric Administration (NOAA), United Nations agencies and environmental groups promoted Reef Check as an activity of IYOR.

An environmental group called Save Our Seas under the direction of Carl Stepath organized the first Reef Check in Kauai, Hawaiian Islands, USA. Over 200 people participated in the event. Teams were comprised of a wide variety of organizations from universities, government agencies, environmental groups and the private sector. Following this success, a 2.5-month window was chosen to complete the surveys. By the end of this period 300 reefs had been surveyed in 31 countries and territories – one of the largest ecological surveys ever carried out.

The data from the monitoring program were analyzed and summary results presented at a press conference in Hong Kong in late 1997 (see Interpreting Reef Check Data). The results showed clearly for the first time that it was not just the reefs in the Philippines or Jamaica that were in trouble. Most of the best coral reefs surveyed around the world were in poor health as measured by the Reef Check indicators of human impact. In the scientific paper that followed (Hodgson, 1999), several conclusions were reached. High value indicators such as giant clams and grouper were missing from most reefs. Remote reefs were in equally bad condition as nearshore reefs, apparently due to long-distance fishing, and lack of enforcement of fisheries laws. Regionally, Red Sea reefs were in the best condition.

Ann Kitalong (left) , Reef Check Palau coordinator reviews data collected by a Palauan fisherman and fellow volunteers from the Helen Reef Monitoring project (Crispin Emilio, far right). Photo by Jennifer Liebeler.

Designing Reef Check

Bob Ginsburg, Rick Grigg, Jeremy Jackson and I had many conversations about the need to get some monitoring teams out on the reefs around the world to try to track changes. I wanted to set up teams of pure scientists. Sue Wells convinced me that we needed to engage the public in coral reef conservation. She suggested that the large pool of recreational divers could be trained to carry out reliable, meaningful surveys. There were already volunteer programs that were in operation, but none seemed appropriate for the global survey planned. Having designed large monitoring programs in Hong Kong, it was a simple matter to design Reef Check. Primary design considerations were reliability, practicality and an output that would be useful to managers. I wanted each team to be able to carry out a complete survey in one day under the supervision of a scientist who would train and lead the team. Thus the protocol was based on counting an ecoholistic array of reef organisms including invertebrates, fish and algae. Global and regional indicators were chosen based on both their ecological and economic value. Each indicator was chosen to indicate a specific human impact. Because the Reef Check protocol was purpose-built for volunteers, the taxonomic specificity required was carefully designed such that only species-level identifications would be used when the species was so unique, like a humphead wrasse, that it could not be confused with any other. Otherwise, family-level identifications were chosen. To ensure scientific rigor, a single survey covers 800 m^2 of reef – a large sample size for most indicators, with eight replicates. To try to capture large, free-swimming fish, off-transect records were allowed. A Quality Assurance system was set up to ensure that only reliable data would be entered into the database.
– Gregor Hodgson

Almost immediately there were calls to continue the program on an annual basis. A fund-raising campaign was initiated and a charitable foundation established to handle gifts. Staff were hired to help run the program. In August 2000, the program moved to the Institute of the Environment, University of California at Los Angeles.

As the Reef Check program has progressed, there has been a fundamental shift in its nature. Reef Check was coined as the name for a coral reef monitoring protocol, and has evolved into a marine education, research and management organization. While the initial target team member was the experienced recreational scuba diver, it quickly became clear that the protocol was well-adapted for use by village fishermen, surfers, marine park rangers, environmental department staff and students. By restricting the survey to shallow reefs, it was also possible to participate without scuba – using a snorkel and mask.

The establishment of a non-profit foundation opened the door to use the monitoring program to begin the process of reef rehabilitation and restoration. Sustainable management of coral reefs is now a major goal of the Reef Check program, and this fits in well with the goals of the UCLA Institute of the Environment.

Interpreting Reef Check Data

It was an incredible feeling to be sitting at a computer in Hong Kong and to have data, photographs and video coming in from Reef Check teams around the world. What was immediately clear was that participants in Reef Check were not just doing a survey and filling out forms, they were learning about reefs and having a lot of fun at the same time. My biggest fear regarding the data that were pouring in was that they would be very mixed and difficult to interpret. Those fears were quickly allayed when it became apparent that most of the data were telling the same story. While many of the reefs still had plenty of live coral cover, the high value indicator species were usually missing – Gregor Hodgson

As described in detail in the pages that follow, the theory that participation in community based monitoring would lead to the development of stewardship for coral reefs has turned into reality.

How to Monitor the World's Reefs? A Question of Scale.

When Reef Check was conceived, the idea was to investigate the question of reef health on global and regional scales. Later, the vision was expanded to consider how to answer questions about reefs on a finer geographic scale, from one nation to one bay or even one reef. A 1999 paper, "Long-term monitoring of Coral Reefs" laid out recommendations for such finer scale monitoring (Hodgson and Stepath, 1999).

The 2001 ***UNEP-WCMC World Atlas of Coral Reefs*** reported that the global coral reef area is 284,300 km^2, spread among 101 countries. While this is only 0.09 percent of the total area of the world's oceans, the reefs are widely dispersed, presenting a challenge to any monitoring design. To gain an appreciation of the magnitude of the problem, one only has to look at the Bahamas, with 700 islands, the Philippines with 7,000 or Indonesia with 30,000 – most ringed with coral reefs. The costs and number of trained personnel necessary to monitor even one transect line on one reef of each island of Indonesia would be astronomical. Clearly, a highly reduced sub-sampling program is required.

From the global perspective, it would be desirable to take a random sample from representative reef areas. If enough sites are surveyed, sampling "errors" on individual reefs are averaged out. While one team might choose a reef with above average coral cover for that region, another team might choose one below average. The more sites included, the less likely that any one set of results would bias the results for coral cover away from the true mean.

Although Reef Check was designed to assess regional and global reef health, it can also be used at a local level. For example, Hodgson (1999) recommended that typically three to five complete Reef Check surveys would be required in Hawaii on a quarterly basis (i.e. 12 to 20 per year) to obtain sufficient data on a given reef say 1 km long. These estimates have recently been assessed on the Great Barrier Reef by bootstrapping studies of multiple reef surveys in Australia by Monique Myers and Richard Ambrose (in prep.). Their analyses indicates that three to four full surveys (two depth contours) are needed to accurately assess abundance of common indicators on the reef. However, for rare organisms such as humphead wrasse, additional surveys will be required. Should this level of detail be required on a national level, an impossible task is created – several million individual surveys.

What then, is a realistic sampling goal for a global or regional monitoring program based on Reef Check? For large island countries such as the Philippines, a biogeographically representative sample of reefs would need to include 5-10 surveys from all major islands and regions in the country – with a total sample size of at least 100 reefs. In order to determine the exact number of surveys required to detect specified changes on a given reef, it is necessary to examine the abundance of the organisms being surveyed (Green, 1979).

Photo by Jeff Jeffords

Thus far, the sample sizes available from most Reef Check countries are insufficient to provide a reliable indication of reef health on an individual country or reef scale for any given year. The available results provide valuable information when interpreted on regional and global scales and over multi-year periods.

There are two major types of results that will be reported here. The first are the traditional scientific results that will be reported in Chapters Four and Five. The second are the educational and management-capacity-building results that are reported in Chapters Six and Seven. These are illustrated by case studies from different parts of the world (See Appendix).

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

The goal of Reef Check monitoring is to detect ecologically and statistically significant changes on coral reefs that are caused by human activities. A set of biological indicators was chosen to serve individually as indicators of specific types of anthropogenic impacts and collectively as a proxy for ecosystem health (Table 3.1). The organisms were chosen both for ecological and economic value and together were meant to provide an ecoholistic representation of key coral reef fish, invertebrates and plants. A detailed explanation of why each indicator was chosen is given in the following chapters on global and regional trends in reef health.

Teams were instructed to survey outer slopes of exposed reefs that were considered to be the healthiest sites in their area. Thus the surveys were intentionally biased so that anthropogenic impacts could be detected at these sites, many of which have some form of legal protection.

Given the bias inherent in this method, some critics might claim that long-term monitoring of "good" sites can only reveal degradation over time. Alternatively, it may be more likely that many sites are in a degraded state due to long-term perturbation by anthropogenic impacts, i.e. they are only considered "good" due to the "shifting baseline syndrome" (Sheppard, 1995; Jackson et al., 2001). In the latter case, there exists the possibility to see improvement if anthropogenic impacts abate.

Volunteers gather for a pre-dive briefing to review fish counting methods at Pulau Redang. This Reef Check trip was sponsored by HSBC and drew volunteers from all over Malaysia. Photo by Jamie Oliver/Reef Base.

The protocol requires collection of four types of data: a site description and surveys of fish, invertebrates and substrata. The site description is based on 37 questions designed to gather factual data such as location, distance to nearest river and population center as well as anecdotal and historical data based on expert opinion regarding the level of various types of fishing affecting the reef.

The fish, invertebrate and substrate surveys all use four 20 m long replicate transects. The fish and invertebrate transects are belt transects with a width of 5 m, while the substrate transect is point sampled and has no dimensions other than length.

Underwater surveys were made along two depth contours, 3 and 10 m. At each depth, one or more survey transects were placed along the reef contour to obtain a total length of 100 m. Fish indicator taxa were then recorded inside the four 100 m^2 belt transects (separated by 5 m gaps) for a survey area of 400 m^2 at each depth, and a total survey area of 800 m^2. A wire or plastic rod was used to estimate the distance of 2.5 m from each side of the central transect tape. Fish were recorded within each replicate 100 m^2 segment by stopping and counting at four equidistant points along the transect. Fish were thus counted in an area of 25 m^2 during each three-minute stop and during the swim to the next segment. Our field tests have shown no significant difference in fish counts when using a back-deployed transect line as long as sufficient time (15 minutes) is given for the fish to settle following transect deployment. A back-deployed transect typically results in a poor transect deployment for the purpose of substrate and invertebrate sampling.

The same belt transect was then used for the invertebrate survey. All indicator invertebrates were counted within the four 100 m^2 belt transects.

Following the invertebrate survey, the four, 20 m long transect segments were point-sampled at 0.5 m intervals and substrate type was recorded using a list of ten possible categories: live hard coral, recently killed coral, soft coral, fleshy seaweed, sponge, rock, rubble, sand, silt/clay and other. Recently killed coral was defined as coral killed within the past one year as indicated by algal growth, color and the presence or absence of corallite structures. The data were recorded on pre-formatted slates and reviewed in the field for possible errors and then transferred to pre-formatted, automated Excel spread-sheets, and emailed or faxed to Reef Check headquarters, where they were again checked for outliers and errors as part of the quality assurance protocols.

Upon receipt at Reef Check Headquarters, all data were visually reviewed to determine if any information was missing and the site description sheet was filled out correctly. Coordinates reported on the site description sheet were entered into a GIS program to check the exact location where the survey was conducted. Data were also checked for inconsistencies (any records left blank were checked to determine if data were not collected or zero organisms were recorded).

The data were then imported into the Reef Check database, which uses Microsoft Access. To avoid duplication errors, the database is programmed to only accept unique data for a given latitude and longitude, depth, and date. Values are only accepted within certain limits. For example, any water temperature entered over 35 degrees C causes the data to be rejected, avoiding possible errors introduced from teams recording temperature in Fahrenheit. A more complete explanation of the Reef Check methods can be found in the monitoring Instruction manual, which can be downloaded from **www.ReefCheck.org**.

Data were analyzed on a per-site basis. At some sites, there were four, 20 m long, replicates (one depth), while at others there were eight replicates (two depths).

Indicator Organism	Indicator for:					
	OF	BF	PF	AF	NP	CC
Global						
Banded coral shrimp (***Stenopus hispidus***)				X		
Butterfly fish (***Chaetodon*** spp.)	X		X	X		
Crown of thorns starfish (***Acanthaster planci***)	X					
Fleshy algae					X	
Grouper (>30 cm) (Serranidae)	X	X	X			
Hard coral		X	X		X	
Lobster	X					
Long-spined black sea urchins (***Diadema*** spp.)	X				X	
Moray eel (Muraenidae)	X			X		
Parrotfish (>20cm) (Scaridae)	X	X	X	X		
Pencil urchin						X
Recently killed coral		X	X		X	
Snapper (Lutjanidae)	X	X				
Sponge					X	
Sweetlips – (Haemulidae)	X	X	X	X		
Triton (***Charonia*** spp.)	X					X
Indo-pacific region only						
Barramundi cod (***Cromileptes altivelis***)	X	X	X	X		
Bumphead parrot (***Bolbometopon muricatum***)	X	X	X	X		
Giant clams (***Tridacna*** spp.)	X					X
Humphead wrasse (***Cheilinus undulatus***)	X	X	X	X		
Sea Cucumber (***Thelenota ananas, Stichopus chloronotus***)	X					
Atlantic region only						
Gorgonia					X	
Flamingo Tongue (***Cyphoma gibbosum***)						X
Nassau grouper (***Epinephelus striatus***)	X					

Table 3.1: Reef Check Indicator organisms for overfishing (OF), blast fishing (BF), poison fishing (PF), aquarium fish collecting (AF), nutrient pollution (NP) and curio collection (CC).

Ordination Analyses

Non-metric multidimensional scaling was applied to the Reef Check global database to represent the similarities and/or dissimilarities between differing countries and/or geographic regions in two-dimensional space. This ordination technique constructs a "map" of samples based on a rank (dis)similarity matrix where all the conditions imposed by a rank similarity are taken into account (Clarke and Warwick 2001). The MDS computation is an iterative procedure where the distances between points within the MDS plot have the same rank order as the corresponding dissimilarities between samples. The orientation of the ordination plot is arbitrary because the distance between points is the only factor of concern, so the plots can be rotated or inverted when viewed on the computer without influencing the interpretation.

Scientists and other volunteers from Cambodia, China, Japan, Thailand, and the United States prepare to begin a Reef Check survey on reefs in the Andaman Sea as part of a regional training program in Thailand. Photo by Jennifer Liebeler.

The global indicators butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index (percent live coral/(percent dead coral + percent live coral)) were selected for analysis. Samples with missing data for any of these indicators were removed from all multivariate analyses as similarity matrices cannot be constructed if missing values are present in the data. Data were averaged by geographic area (Indo-Pacific, Atlantic, and Red Sea) by year. Data were standardized to control for the different scale of the coral index and root transformed to add more weight to the less abundant species indicators. The Bray-Curtis coefficient was utilized to construct a similarity matrix and the MDS algorithm was applied to this matrix to produce the MDS plots.

The SIMPER procedure (Clarke and Warwick, 2001) was utilized to determine the individual indicators principally responsible for sample groupings in the ordination analyses. The similarity between reefs in analogous geographic regions (Indo-Pacific, Atlantic, and Red Sea) and the dissimilarity between groups of reefs in differing geographic regions was calculated to determine the percent contribution of individual species to the grouping patterns in the MDS ordination plots. All multivariate analyses were performed with PRIMER version 5 (Clarke and Gorley, 2001).

Chapter 4 GLOBAL TRENDS IN CORAL REEF HEALTH

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

Over the five-year period from 1997 to 2001, Reef Check monitoring was carried out at approximately 1500 coral reefs. After quality assurance procedures, data from 1,107 surveys were accepted for analysis. The most common reasons why data sets were rejected were: incomplete site description, non-standard protocol, and incomplete survey. Some of the surveys were carried out with strictly educational goals in mind, and these were not included in the analysis. The monitoring was carried out on coral reefs in 55 countries and territories (Table 4.1). For biogeographic reasons, political boundaries were sometimes ignored and some locations within one political entity were treated separately – for example, the three locations within the United States are treated as separate locations: Guam, Florida and Hawaii. The list represents about half of the 101 coral reef countries listed in the ***World Atlas of Coral Reefs***. The distribution of survey sites includes sites in all the major coral reef regions in the Indo-pacific and the Caribbean. Several remote and/or previously unsurveyed areas were surveyed by Reef Check teams e.g. Cocos Keeling, Australia, San Andreas World Heritage Site in Colombia and the Mergui Archipelago in Myanmar.

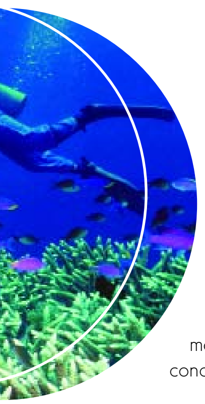
Since Reef Check is a volunteer program, there is no way to guarantee that a given site or country will be resurveyed every year. There was an obvious burst of enthusiasm during the 1997 International Year of the Reef, followed by a reduction in the number of sites surveyed for the next few years. However, with the establishment of the program headquarters in the United States, the number of sites has steadily grown. When there are a large number of surveys in one particular country in a given year, this can bias the regional and global analyses.

Reef Check encourages long-term monitoring using permanent transects, however, many teams resurvey reefs using haphazardly placed transects. Of the total surveys, 21% were surveyed two or more times over the five year period.

In this chapter, a rationale is given for the choice of each indicator followed by a presentation of results and interpretation. As explained previously in the methods section, Reef Check surveys include a Site Description that provides information on the perceived level of human impacts such as fishing on a given reef. Unless otherwise noted there was no consistent relationship between the rating of anthropogenic impacts and the number of indicator species found. All organism abundance maps depict total number of indicator organisms per transect at each site.

Table 4.1: Number of reefs surveyed in each location and accepted for analysis (1997-2001).

Country	1997	1998	1999	2000	2001	TOTAL
American Samoa	1					1
Australia	14	7	9	1	10	41
Bahamas			2	1		3
Bahrain	1	5	4	4		14
Barbados	5				8	13
Belize	2				1	3
Bonaire	2	2		1	2	7
Brunei	1					1
BVI	3	1	3		4	11
Cambodia		1			1	2
China				5	17	22
China - Hong Kong	7	9				16
China - Taiwan	3	7				10
CNMI			2	3	1	6
Colombia	2	13	9	10	2	36
Cuba					2	2
Egypt	49			10	12	71
Eritrea				2		2
Fiji	6		6	8	8	28
French Polynesia			2			2
FSM				10	13	23
Grand Cayman Island	1	1				2
Honduras	1		2			3
India		1				1
Indonesia	25	1	18	38	85	167
Iran			1	2	2	5
Israel	1	3			2	6
Jamaica		1		2	3	6
Japan	2	5	8	16	21	52
Madagascar					3	3
Malaysia	39	31	7	28		105
Maldives	30				8	38
Mauritius			6	2	2	10
Mexico	8			4	1	13
Mozambique	1			1	2	4
Myanmar					5	5
Netherlands Antilles		4		4		8
New Caledonia	5	24			6	35
Palau	2			4	2	8
Panama	1	1				2
Philippines	3	11	6	5	9	34
PNG		4	14	5	1	24
Saudi Arabia			17			17
Seychelles	6				1	7
South Africa				1	5	6
St. Lucia			4	2	2	8
Tanzania	2	3	1			6
Thailand		2	10	7	55	74
USA - FL	31	19	6	1	12	69
USA - GUAM	1	3	3		4	11
USA - HI	1	5	2	1	7	16
Vietnam		8	10	11	16	45
Yemen		1			2	3
Total	**256**	**173**	**152**	**189**	**337**	**1107**



The reef slope below 12 m depth is not monitored by Reef Check due to safety concerns. Photo by Jeff Jeffords.

INVERTEBRATES

GLOBAL INDICATORS

Spiny Lobster

(Panulirus spp.)

Spiny lobsters were chosen as a Reef Check indicator because they are universally prized as a seafood item. Many different species are harvested commercially in the Pacific and Atlantic Oceans for the global market. The five major species are *P.* ***argus*** in the Caribbean, *P.* ***cygnus*** in W. Australia, *P.* ***marginatus*** in Hawaii and *P.* ***pencillatus*** in the Pacific. In 2000, almost 36,000 metric tons were exported from the Caribbean and Central Western Pacific regions alone (FAO, 2002). Although lobster are nocturnal feeders and tend to stay in caves and crevices during the day, they are easily caught using nets, traps and spears and so are typically fished out very quickly from coral reefs. The absence of lobster on the shallow reefs monitored for Reef Check is thus a good indicator of human predation.

Of the 1,068 reefs surveyed for lobster, none were recorded on 83%; regionally the percentage of sites with zero lobster was 90% in the Indo-pacific and 49% in the Atlantic region. Only 168

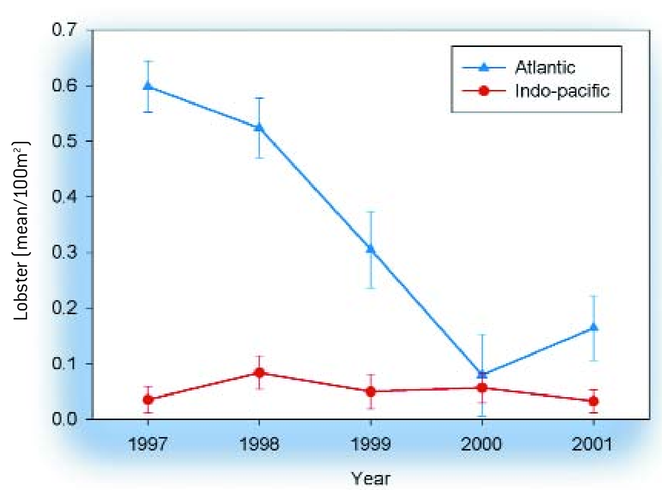
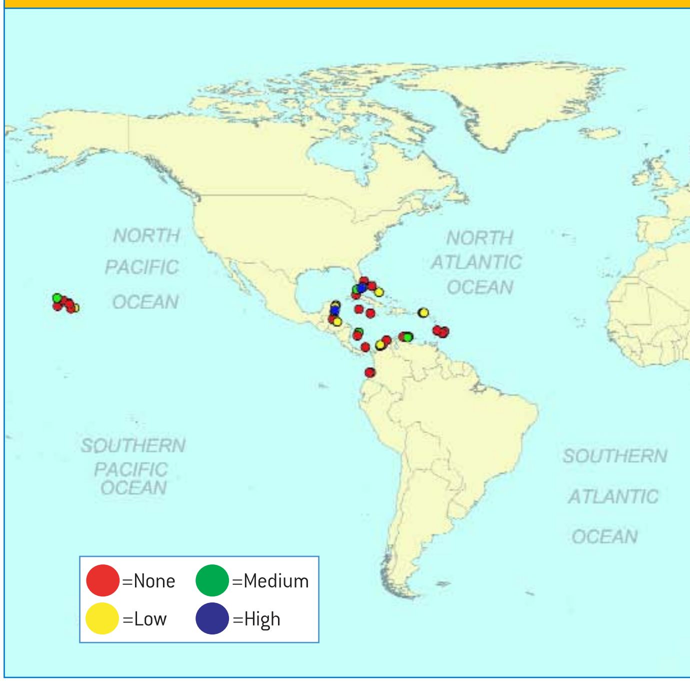


Figure 4.1: Mean abundance of lobster per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

lobsters were recorded during 888 Reef Check surveys in the Indo-pacific, an average of 0.05 ± 0.26 lobster per 100 m^2. When averaged over five years, lobster were approximately eight times more abundant in the Caribbean than in the Indo-pacific, with an average of 0.39 lobster ± 0.64 per 100 m^2 ($p \leq 0.01$) (Figure 4.2). The maximum density of lobster recorded was 5.25 per 100 m^2 on a reef in the Abrolhos Islands, Australia in 1998. This area supports the famous Western Australian lobster fishery, which brings in about A$200 million per year from an annual catch of between

Figure 4.2: relative abundance of lobster (1997-

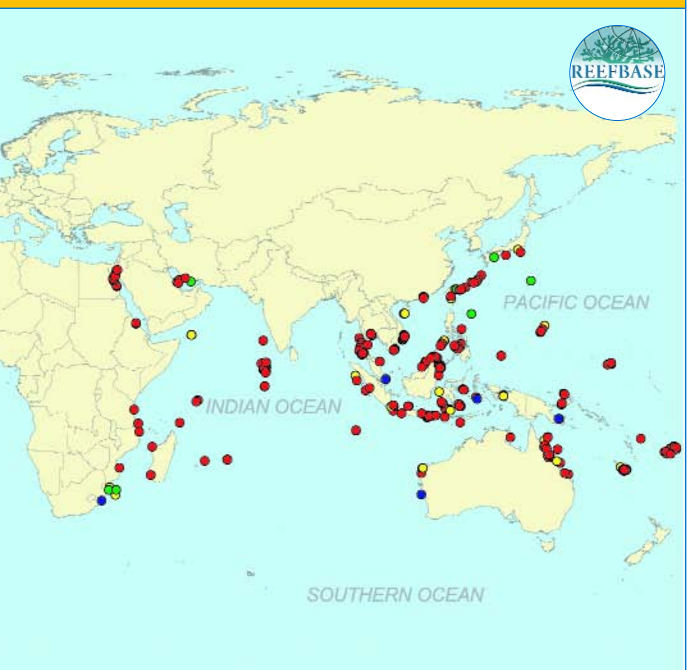


8 and 15 thousand tons of ***Panulirus cygnus***. The fishery is unusually productive for a coral reef area due to periodic nutrient rich upwelling and the Leeuwin Current. The maximum abundance of lobster in the Atlantic was 3.25 per 100 m^2, recorded at Hens and Chickens reef in the Florida Keys in 1999.

During the time period 1997-2001, the abundance of lobsters remained fairly constant in the Indo-pacific, whereas numbers of lobster in the Atlantic declined from a mean of 0.60 per 100 m^2 ± 0.69 in 1997 to a mean of 0.08 ± 0.72 ($p \leq 0.01$) in 2000 and 0.16 in 2001 ($p=0.01$) (Figure 4.1). This significant decline indicates a major change in regional lobster abundance, and is exactly the type of change that Reef Check was designed to detect. This decline occurred at the same time as an increase in lobster exports from the Caribbean from 29,226 mt in 1997 to 35,204 mt in 2000 (FAO, 2002). Fisheries managers in Atlantic countries should try to obtain more detailed independent assessments as to whether their reefs have experienced a similar trend. It should be noted that this decline was only measured on shallow reefs monitored by Reef Check.

Information on abundance of spiny lobster is rare. In Bermuda,

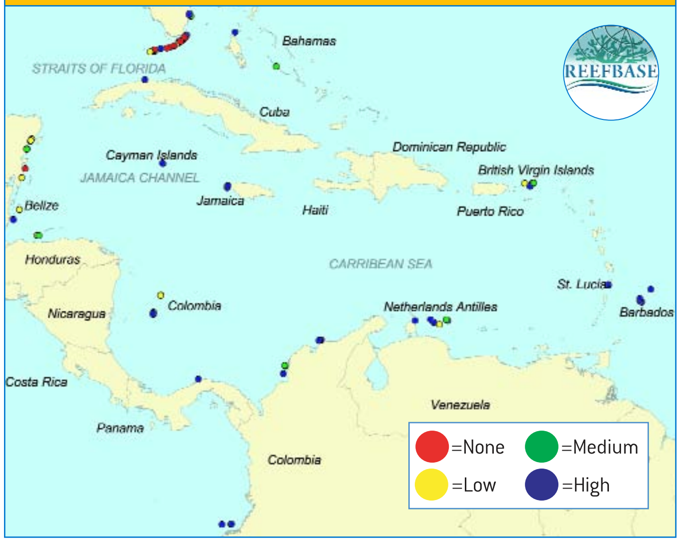
2001). None = 0; Low=1; Medium= 2-3; High>3



Evans and Evans (1996) measured 6.0 post-recruits per ha (0.06 per 100 m^2) near the reef crest and 97 under sized lobsters per ha on the outermost terraces of the platform edge.

Two studies made by Prescott (1980) in the Solomon Islands, and three by Ebert and Ford (1986) at Eniwetak for ***Panulirus penicillatus*** derived estimates of approximately 0.5 lobster per 100 m^2. This is ten times the mean obtained by Reef Check teams from a wide variety of reefs. In an article entitled, "Pacific Island Lobster Fisheries: Bonanza or Bankruptcy?" Tim Adams and Paul Dalzell (1993) hypothesized that the lack of broad continental shelves around Pacific Islands limits the amount of shallow water habitat for lobsters. This combined with the lack of nutrient inputs from

Figure 4.3: Caribbean Inset of Figure 4.2



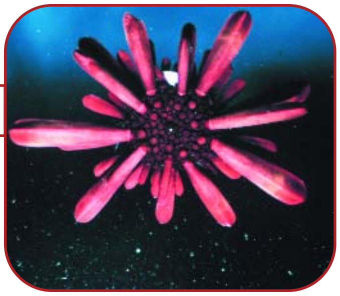
land and upwelling limits productivity such that a sustainable catch rate is estimated to be 20 kg per kilometer of reef face per year. In considering advice for investors in this fishery, they stated:

"Most Pacific Island lobster stocks are already subject to a certain level of local exploitation: catch-rates will thus not be very high..... Only very remote reefs have the possibility of supporting "virgin" stocks with densities high enough to support the expenses of a trip by a large vessel, and all of these have been prospected at least once already. The average recovery rate of these isolated reefs after being hit is unknown, but would be several years."

As with many other fisheries, overfishing has eliminated spiny lobsters from shallow reefs throughout the world. Although the explanation is obvious, this dramatic decline has not been documented prior to Reef Check. The fishermen simply shifted to new areas and deeper water. An interesting research question is why the density of lobsters is lower on Pacific than on comparable Atlantic reefs?

Pencil Urchins

(Heterocentrotus mammilatus and Eucidaris spp.)



Although many sea urchins are collected from reefs for their edible roe, pencil urchins are only prized as a curio. Their attractive thick and smooth spines are often used in decorative seashell arrangements or as wind chimes. They are also used in jewelry and sold in the marine ornamental trade. On the reef, these organisms are found in shallow water and are easily collected by free divers.

Of the 818 reefs surveyed for this indicator over the five-year period, there was a significantly higher number ($p \leq 0.01$) of pencil urchins in the Atlantic, represented by ***Eucidaris*** spp. (1.17 ± 3.0 per 100 m^2) than in the Indo-pacific, represented by ***Heterocentrotus mammilatus*** (0.40 ± 3.1 per 100 m^2). However, the greatest abundance of pencil urchins was found on two reefs in the Hawaiian Islands. A reef surveyed off Palauea Beach in Maui in 2001 had 120.7 pencil urchins per 100 m^2. Kahalu'u Beach in windward Oahu, an area with restrictions on fish feeding and collection for the aquarium trade, had an abundance of 29.25 urchins per 100 m^2 when it was surveyed in 1998.

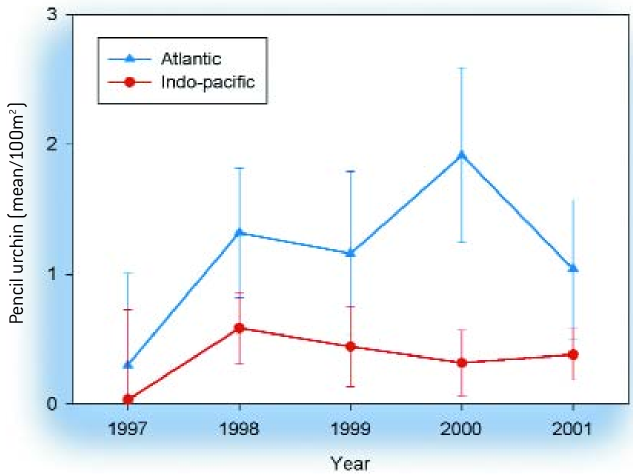


Figure 4.4: Mean abundance of pencil urchins per 100 m^2 (1997-2001) on Indo-Pacific and Atlantic reefs.

The number of pencil urchins in the Indo-pacific and Atlantic did not change significantly over time (Figure 4.4).

Banded Coral Shrimp

(Stenopus hispidus)

The banded coral shrimp was chosen as an indicator of aquarium fish collecting. The shrimp is collected in both the Atlantic and the Pacific Oceans, and currently sells for approximately US$20 per pair in United States pet shops.

Of the 820 sites surveyed for banded coral shrimp, a mean of 1.2 ± 3.3 per 100 m^2 was found in the Atlantic region during the period 1997-2001, a significantly higher number ($p \leq 0.01$) than in the Indo-pacific (0.09 ± 0.42 per 100 m^2). This order of magnitude difference in coral shrimp populations is likely a natural difference between the two oceans, however, in high collection areas such as the Philippines, Fiji and Indonesia, this may be due to much higher extraction rates. There were no obvious trends in abundance over time (Figure 4.5). The maximum number of banded coral shrimp recorded during any one survey was 46.3 per 100 m^2 in the Karpata Marine Reserve in Bonaire in 2000.

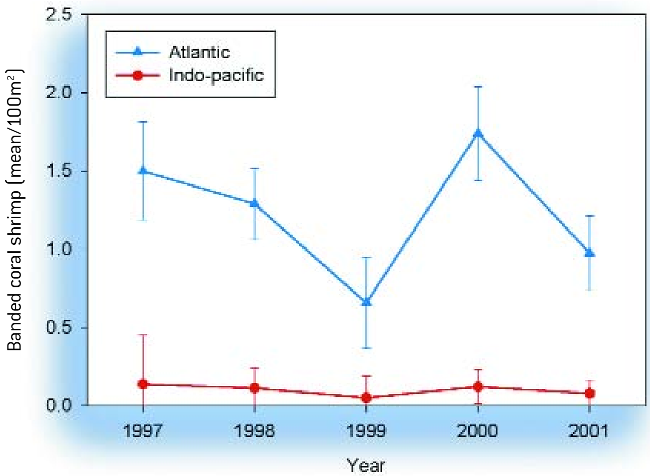


Figure 4.5: Mean abundance of banded coral shrimp per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

should not be taken as an indication that the species is on the verge of extinction. During the day when Reef Check surveys are carried out, the banded coral shrimp hides in cracks and holes under rocks. Therefore, the animals counted are those that venture near to the opening of such cracks and crevices where they can be observed. In fact, the aquarium fishermen turn over large coral heads to locate and collect these organisms.

The mean abundance of banded coral shrimp was ten times lower at sites with high perceived impacts from the aquarium trade than at sites with no perceived impacts from these activities. None of these differences were statistically significant due to the relatively low sample size of reefs rated as high for aquarium fishing impacts.

According to the GMAD database of ornamental trade maintained by WCMC/UNEP, 16,248 banded coral shrimp were exported by five companies in the Philippines in 2001. Of these, 14,805 were exported to the United States. The total exports from the Philippines and Indonesia are undoubtedly much higher. Reef Check is working closely with the Marine Aquarium Council to set up sustainable collection systems in countries where this potentially sustainable trade occurs. (See Chapter 7).

Diadema

(Diadema spp.)

The six species of long-spined black sea urchins in the genus ***Diadema*** serve as global indicators and their abundance levels indicate different problems in the two major oceans. ***Diadema*** are nocturnal grazing herbivores that decrease algal cover on reefs through their feeding activities. They feed by scraping algae from the surface of the reef. ***Diadema*** populations contribute to net reef erosion. For example, a normal population of ***Diadema*** can produce as much as 5 kg of carbonate sediment per square meter per year by scraping the carbonate rock surfaces. This corresponds to about 1 cm of reef erosion per year (Ogden and Carpenter, 1987). When ***Diadema*** population densities are high, and the urchins graze around the bases of large colonies, this bioeroding activity can destabilize coral heads, increasing their susceptibility to getting knocked over by storm waves.

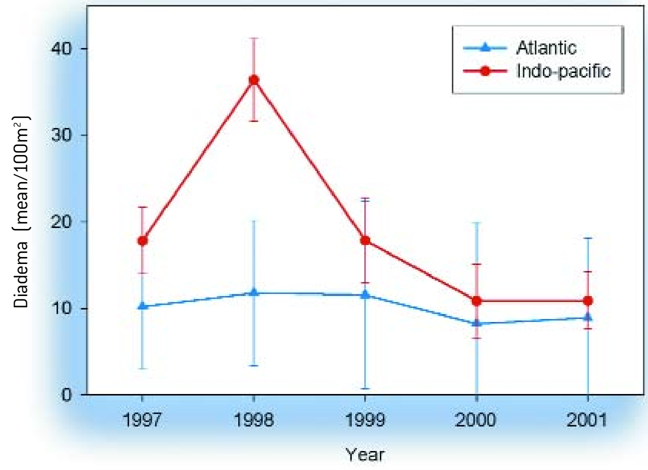


Figure 4.6: Mean abundance of ***Diadema*** per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

On overfished reefs in the Atlantic or Pacific, where there is a lack of predators on all life stages of ***Diadema***, populations can reach high levels that tip the balance towards bioerosion and make it difficult for new coral recruits to become established (Vo and Hodgson, 1997). Prior to 1983, this problem was commonly observed on reefs in both oceans.

In 1983, a species-specific pathogen hit the Caribbean, resulting in a mass die-off of up to 99% of the existing ***Diadema*** populations in some areas (Lessios, 1995). In areas where overfishing had severely reduced both predators and herbivores, such as in Jamaica, the loss of grazers led to an exponential increase in macroalgae. Reef corals, particularly those in shallow water, were overgrown by algae. Living coral cover on these reefs declined from about 30 to 70% to a mere 1 to 10% (Hughes, 1994).

Therefore, while moderate ***Diadema*** populations are critical to maintaining the natural balance between algae and coral in a

FIGURE 4.7: RELATIVE ABUNDANCE OF DIADEMA (1997-2001). NONE = 0; LOW=1-4; MEDIUM= 5-19; HIGH>19

healthy reef system, high-density populations are considered a negative indicator in all oceans. In areas where overfishing has reduced herbivore populations, a low population of ***Diadema*** is also considered to be a negative indictor. This is the present situation in most of the Caribbean.

During the period 1997-2001, 1,066 reefs were surveyed for ***Diadema*** urchins. The mean number of ***Diadema*** in the Atlantic (10.3 ± 30.9 per 100 m²) was lower than the mean number in the Indo-pacific (17.1 ± 58.3 per 100 m²) ($p=0.07$). In the Atlantic, ***Diadema*** abundance remained consistently low throughout the five-year sampling period (Figure 4.6). Mean numbers of ***Diadema*** were generally higher in the southern Caribbean when compared to the northern Caribbean and Florida Keys area (Figure 4.7). The abundance of ***Diadema*** in the Indo-pacific significantly increased from 17.82 ± 48.9 per 100 m² in 1997 to 36.41 ± 103.1 per 100 m² in 1998 ($p=0.04$) and then significantly decreased ($p = 0.01$) to 10.9 ± 42.1 per 100 m² in 2000 (Figure 4.6). From an ecological standpoint, the reduction in ***Diadema*** abundance on Indo-pacific reefs to the same level as the Atlantic is cause for concern that should be investigated in more detail.

The mean number of ***Diadema*** per 100 m² was higher (24.5 ± 68.1) at sites where anthropogenic impacts were judged high than at those judged to have no impacts (11.8 ± 29.5), although these differences were not statistically significant at a 95% confidence level.

Previously, surveys in Jamaica have recorded densities of 0.1 to 12 ***Diadema*** per m² (Edmunds and Carpenter, 2001; Miller and Gersner, 2002). Much lower numbers, 0.004-0.379 ***Diadema*** per m² were recorded in Singapore (Grignard et al., 1996). The high variation of estimates in the Caribbean may reflect different methods and scales of sampling.

FISH

GLOBAL INDICATORS

Triton

(Charonia spp.)

The triton was chosen as a global reef health indicator because it has a beautiful shell that it is very desirable and easy to collect as a curio. Like the pencil urchins, the triton is represented by a different species in the Atlantic (***Charonia variegata***) and Pacific (***Charonia tritonis***). In contrast to smaller mollusks, the triton grows so large (50 cm long) that it cannot hide in small crevices, and so is visible to the collector. Saville-Kent (1893, plate XLII-III) provided two photos and remarked, "Either singly or in artistically arranged groups, these coral-mounted shells lend themselves with remarkable suitability to the purposes of table decoration." He also correctly described how native Australians collected the shells for use as a trumpet. The triton is now protected on the Great Barrier Reef. A survey of about 1 ha of John Brewer Reef in 1988 by Chesher (1988) yielded 7 triton (equivalent to 0.07 triton/100 m^2).

In the Indo-pacific, the triton is a predator of the crown-of-thorns sea star that, in turn, preys on corals. According to Sap (1999), estimates of the harvest of triton from the Great Barrier Reef during the 1960s were 10,000 per year, potentially reducing predation on the crown of thorns.

Only 60 of the 1101 sites surveyed had at least one triton. There was a total of 101 triton found over the five year sampling period. The mean abundance of triton was 0.03 ± 0.32 per 100 m^2 in the Indo-pacific and 0.05 ± 0.24 in the Atlantic.

Unfortunately, the triton is now extremely rare, and it is difficult to know what the "normal" baseline should be for a natural population anywhere. Given the success of giant clam aquaculture and the high price of triton shells (approximately US$30-50 each), triton would be a good candidate for aquaculture research.

Butterfly Fish

(Chaetodon spp.)

Butterfly fish of the family Chaetodontidae were selected as an indicator of the ornamental fish trade. At least 30 species of butterfly fish are actively collected for the aquarium trade, despite the fact that most of the 114 species are notoriously difficult to maintain in home aquaria due to special feeding preferences. They are a medium to high-priced fish (US$15 to $300 each) depending on the species and size. It is also worth noting that butterfly fish, despite their small size, are frequently caught and eaten by people from Hawaii to the Philippines. They are caught in gill nets, traps and by spear fishermen for consumption.

During the five-year monitoring period, 98% of all reefs monitored worldwide had at least one butterfly fish. The mean abundance of butterfly fish in the Atlantic (0.2 ± 6.4 butterfly fish per 100 m^2) was significantly less ($p \leq 0.01$) than in the Indo-pacific (10.0 ± 10.0 fish per 100 m^2 reef) (Figures 4.8 and 4.9). This is believed to be a natural biological difference that defines reef fish

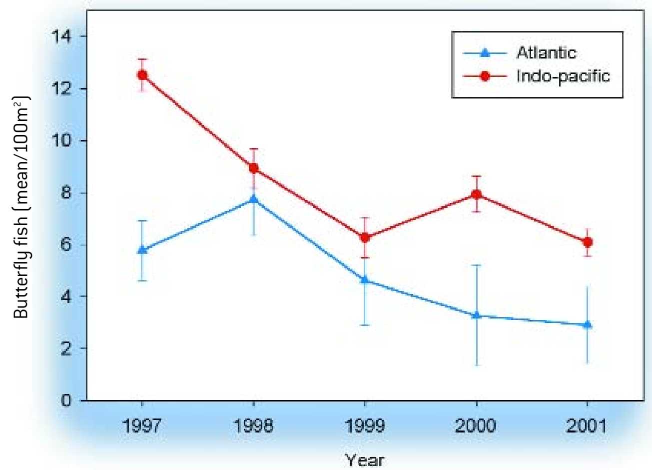
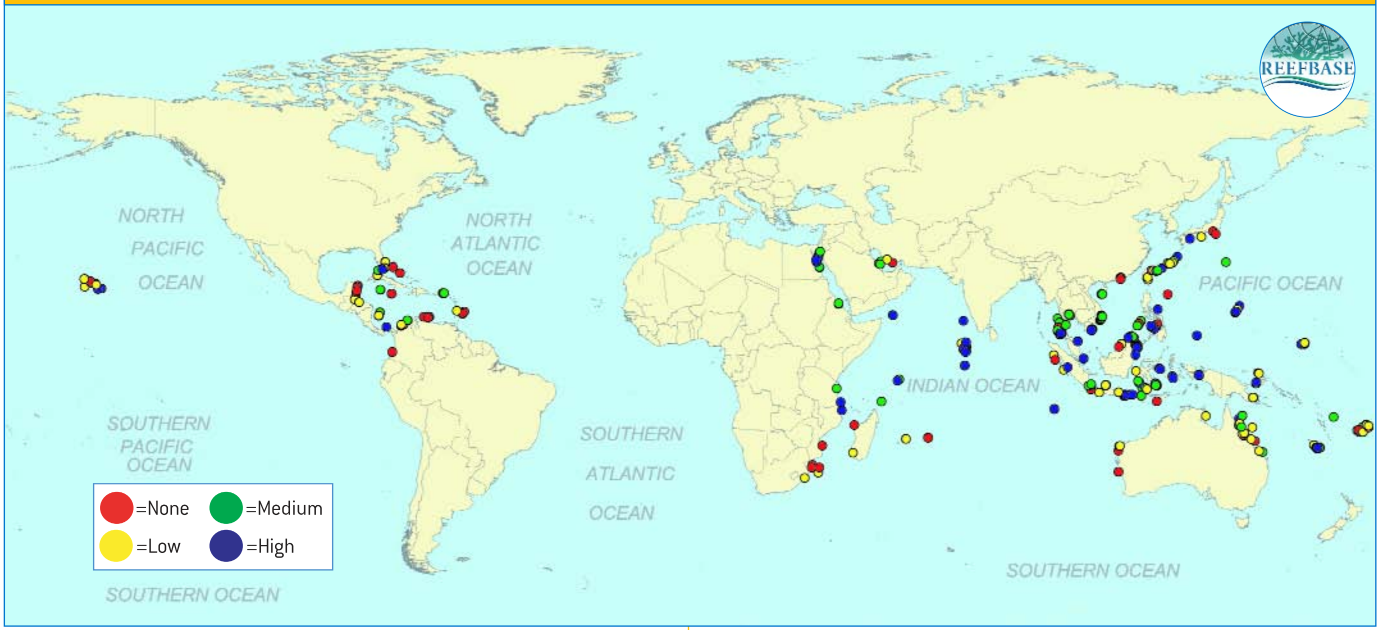


Figure 4.8: Mean abundance of butterfly fish per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

FIGURE 4.9: RELATIVE ABUNDANCE OF BUTTERFLY FISH (1997-2001). NONE = 0; LOW=1-16; MEDIUM= 17-44; HIGH>44



communities in the two oceans, and may be related to the fact that there is a ten times higher species diversity in the Pacific than in the Atlantic. This hypothesis is supported by multidimensional scaling analyses followed by the SIMPER test that indicated butterfly fish were responsible for 42% of the similarity among Indo-pacific sites (See Multivariate Analyses).

There was a significant decrease in the global mean number of butterfly fish in all oceans from 1997 (11.0 ± 10.6 per 100 m^2) to 2001 (5.7 ± 5.8 per 100 m^2 reef) ($p \leq 0.01$) (Figure 4.8). This decrease is primarily due to the decline in butterfly fish in the Indo-pacific. In 1997, the mean number of butterfly fish on an Indo-pacific reef was 12.5 ± 10.4 per 100 m^2. Five years later, the mean had decreased to half that number (6.1 ± 5.3). This significant decrease ($p \leq 0.01$) could be an indication of overfishing and destructive fishing methods.

Since 2000, Reef Check has been working with the Marine Aquarium Council to help test and establish a certification system to promote a sustainable marine ornamentals trade. The initial intensive surveys using the MAQTRAC method indicate that butterfly fish such as ***Chaetodon baronessa*** and ***C. octofasciatus*** have been severely overfished in two areas of the Philippines (Ochavillo et al., in prep). Additionally, Tissot and Hallacher (1999) demonstrated that aquarium collection significantly reduced the abundance of butterfly fish in Hawaii.

GROUPER

(Serranidae)

Grouper of any species with a length greater than 30 cm were selected to serve as an indicator for over fishing of all types. Grouper are some of the easiest fish for divers to spear because of their size and territorial habits. Grouper also aggregate during spawning, making them vulnerable to many forms of fishing. Grouper are fished using spears, nets, hook and line and various types of traps. Grouper larger than 30 cm are a very useful indicator of fishing pressure because they are one of the higher priced food fish and most easily fished out due to their reproductive traits. Grouper may take several years to reach sexual maturity and typically change sex. Fisheries that remove large individuals can easily wipe out all sexually mature fish and/or create a highly skewed sex ratio making reproduction unlikely (Sadovy, 1997).

In detailed multi-year studies of overfishing in locations including Jamaica, Australia and the Philippines, Serranidae initially show a decrease in mean size followed by local extinction (Craik, 1981; Munro, 1983; Koslow et al., 1988; Russ et al., 1989). When a new grouper fishery was opened on Boult Reef in the Great Barrier Reef, 25% of the grouper were removed in the first 14 days of fishing (Beinssen, 1988).

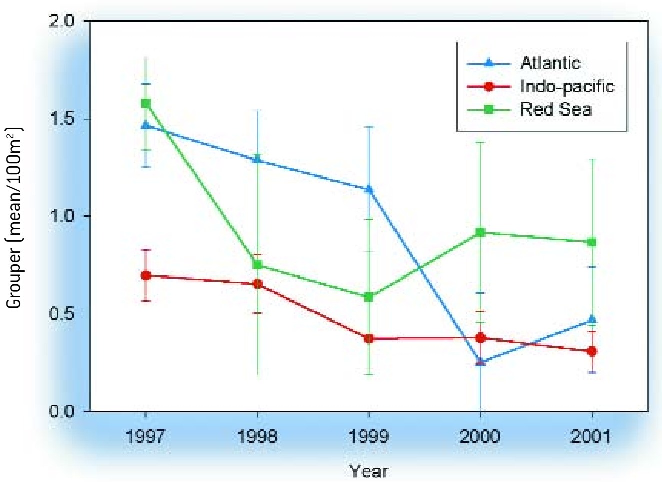


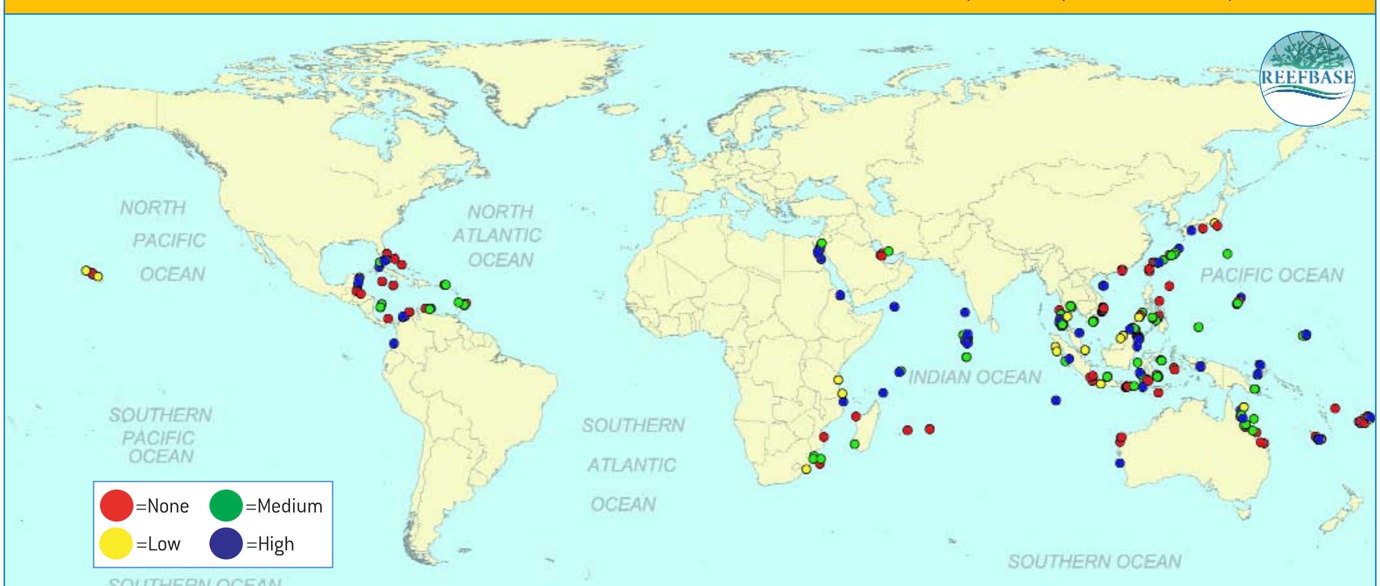
Figure 4.10: Mean abundance of grouper > 30 cm per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

Reef Check results indicate grouper have been fished out from most shallow reefs throughout the world (Figure 4.11). There were zero grouper larger than 30 cm recorded at 48% of 1,022 reefs surveyed during the period 1997 to 2001. In contrast, the highest numbers of grouper were found on Tennessee Reef in Florida in 1997. This reef is part of the Florida Keys National Marine Sanctuary and had an abundance of over 24 grouper per 100 m^2. Reefs surveyed in Ras Mohamed National Park in Egypt during 1997 and 2001 also had a high abundance, with a mean of over five grouper per 100 m^2.

The mean number of grouper found on Indo-pacific reefs during the period 1997 to 2001 was 0.54 $\pm$ 1.04. The mean number of grouper in the Red Sea during this period was 1.15 $\pm$ 1.3, while the mean number of grouper in the Indo-pacific (minus the Red Sea) was 0.45 $\pm$ 0.98 (Figure 4.10).

The mean number of grouper per 100 m^2 in the Indo-pacific decreased by a factor of two between 1997 and 2001 (Figure 4.10) from a mean of 0.69 $\pm$ 1.4 in 1997 to 0.31 $\pm$ 0.51 in 2001 ($p \leq 0.01$).

FIGURE 4.11: RELATIVE ABUNDANCE OF GROUPER > 30CM (1997-2001). NONE = 0; LOW=1; MEDIUM= 2-4; HIGH>4



Species	Location	Effects
Cepalopholis miniata, C. hemistiktos, Variola louti	Red Sea	About 30 to 300% increase in mean weight of species in un(der)fished relative to other areas (Roberts and Polunin 1993)
Serranids, mainly *Cephalopolis spp*.	Sumilon Island, Philippines	Average weight twice as large and density and biomass 3-30 times greater than controls (Russ 1985).
Plectropomus leopardus	Great Barrier Reef, Australia	Average lengths greater, and density higher on unfished than on fished reefs (Beinssen 1989, Craik 1981)
Epinephelus fulvus	Saba Marine Park, Belize	Unfished biomass, sizes and abundance greater in unfished than in fished zone (Polunin and Roberts 1993, Roberts 1995).
Epinephelus striatus	Marine Park, Bahamas	Eggs per area greater inside (due to greater parental sizes and abundance) than outside park (Sluka et al. 1997)
Serranids	Looe Key Reef, Florida, USA	Abundance increased after two years of protection from spearfishing (Bohnsack and Bannerot 1986)
Serranids, mainly young *Plectropomus leopardus*	New Caledonia	Significant increase of biomass and density in protected areas (Wantiez et al. 1997)

Table 4.2: Examples of the positive effects of Marine Protected Areas on grouper populations (Sadovy, 1999).

In the Atlantic region, grouper abundance (including Nassau grouper) declined from 1999 (1.13 grouper ± 3.2 per 100 m^2) to 2000 (0.25 ± 0.54 per 100 m^2). Although non-significant, this decline should be investigated in more detail.

Similar to the results of Sadovy (1999), the numbers of grouper counted by Reef Check were significantly higher inside than outside MPAs. Ferreira and Russ (1995), did not detect this trend.

Haemulidae

Haemulidae are represented in the Indo-pacific by sweetlips and grunts, and in the Atlantic region by margates and grunts. The 150 species of fish that make up this family were chosen as reef health indicators because they are a highly popular food fish in both oceans. Many species grow to a large size and thus are subject to all major forms of fishing. Some of the haemulids also have behavioral traits that make them particularly susceptible to spearfishing. In areas where spearfishing is common, many fish become "skittish" around divers. But haemulids such as ***Diagramma*** seem oblivious to past history and typically swim close to divers. Hence they tend to be the first to get shot out of a reef.

There was a mean of less than one haemulid per 100 m^2 in the Indo-pacific over the five-year period (Figure 4.12). In contrast to relative abundance of butterfly fish in each ocean, there were fifty times more haemulids in the Atlantic than in the Indo-pacific ($p \leq 0.01$)(Figure 4.13).

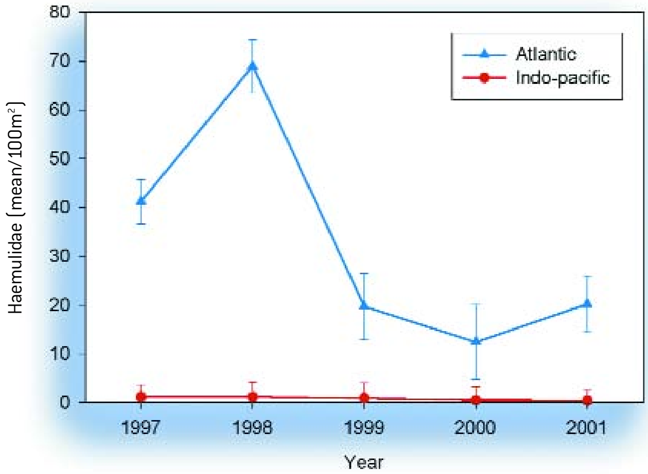


Figure 4.12: Mean abundance of Haemulidae per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

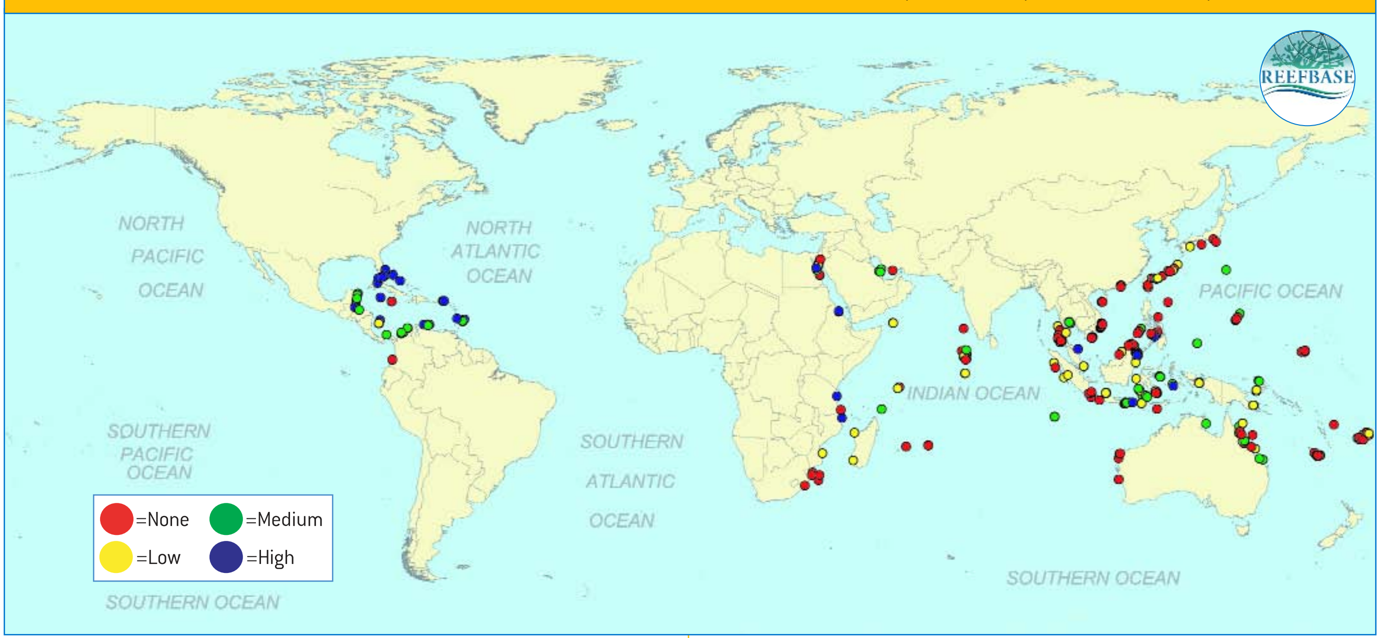
Consequently, two fundamental differences between reefs in the two oceans are the relative predominance of the family Haemulidae on Atlantic reefs and the predominance of the family Chaeodontidae on Indo-pacific reefs.

Between 1998 and 2001, there was a decrease in the number of Haemulidae in the Atlantic region. The mean density of Haemulidae decreased from 68.8 ± 142.6 per 100 m^2 to 20.1 ± 46.8 per 100 m^2 in 2001 ($p=0.08$). At least one haemulid was found on 98% of all reefs surveyed in the Atlantic region, with a record 797.5 fish per 100 m^2 found on Alligator Reef in Florida in 1998. This reef lies within the Florida Keys National Marine Sanctuary. When analyzed on an ocean wide basis, there was no significant difference in abundance of haemulids inside and outside of MPAs. Overall, 57% of all reefs surveyed in the Indo-pacific had zero Haemulidae, with the greatest number (25) seen on a reef in Ras Mohamed National Park in Egypt in 1997.

The number of Haemulidae was negatively correlated with increasing levels of blast fishing. The higher the level of perceived blast fishing, the lower the numbers of Haemulidae ($p=0.04$). In the Indo-pacific, the mean number of Haemulidae on reefs with no perceived blast fishing was 0.83 ± 2.2 per 100 m^2, whereas reefs with a high rating for blast fishing had a mean of 0.29 ± 0.73 fish per 100 m^2, however, this was not significant.

In detailed studies of reefs where overfishing has reached the ecosystem level, large Haemulidae are usually missing (Munro, 1983; Koslow et al., 1988). Reef Check results indicate that more than half the reefs have been fished so heavily that haemulids are missing. In the Atlantic, instead of seeing hundreds of grunts and margates, there are only a dozen per reef. The haemulid data clearly indicate that the level of overfishing has reached a damaging level.

Figure 4.13: Relative abundance of Haemulidae (1997-2001). None = 0; Low=1-2; Medium= 3-20; High>20



Parrotfish

(Scaridae)

Parrotfish were selected as an indicator of over fishing of various kinds. The 80-odd species of parrotfish play a critical role in the ecological balance of a coral reef because they are the largest herbivorous reef fish and they scrape large quantities of turf algae from the reef, ingesting live and dead coral, and creating sand in the process. Without parrotfish, algae would have an advantage in the competition for space with coral. The Indo-pacific bumphead parrot ***Bolbometapon muricatum*** is counted separately because it is a large, enigmatic, and easily identified schooling fish, and it feeds directly on live coral. Because of their wandering lifestyle, off-transect records are allowed for this species. Parrotfish are easily caught using nets, spears and traps. They form a significant part of the reef fish biomass. When reefs are subject to heavy fishing, the normal pattern is for predators to be fished out first, followed by the herbivores such as the parrotfish (Munro, 1983; Koslow et al., 1988).

In the Indo-pacific, 55% of all reefs surveyed were devoid of all parrotfish greater than 20 cm or bumphead parrotfish of any size

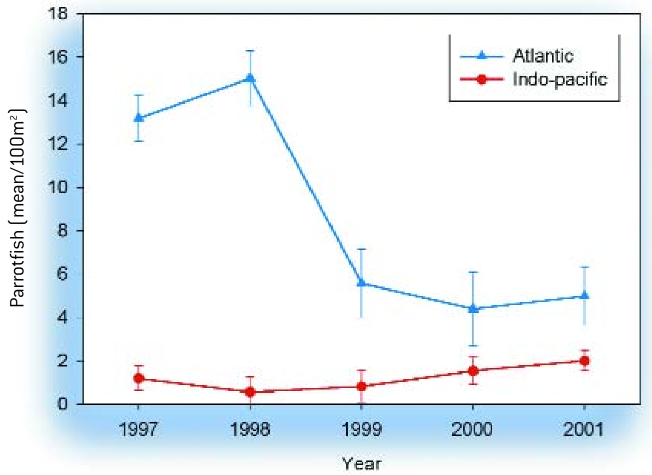
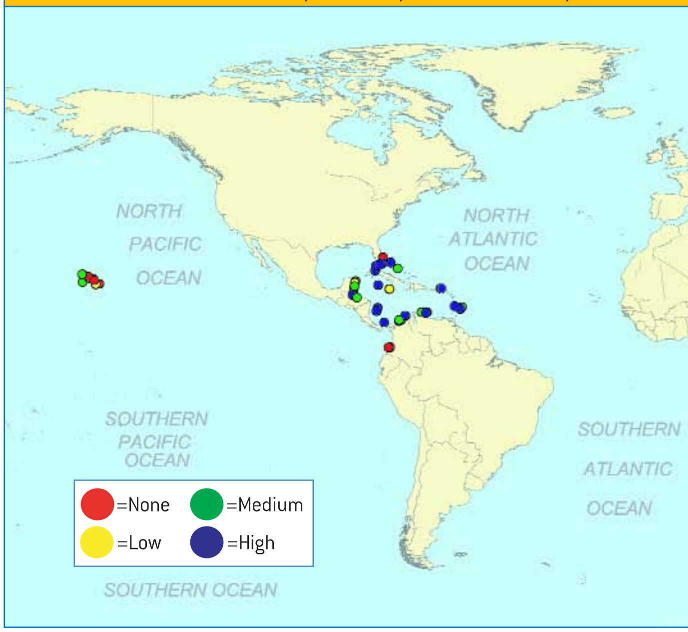


Figure 4.14: Mean abundance of Parrotfish > 20 cm and all bumphead parrofish per 100 m^2 (1997-2001) on Indo-pacific and Atlantic reefs.

Figure 4.15: Relative abundance of parrotfish (1997-2001). None = 0; Low=1; Medium= 2-4; High>4



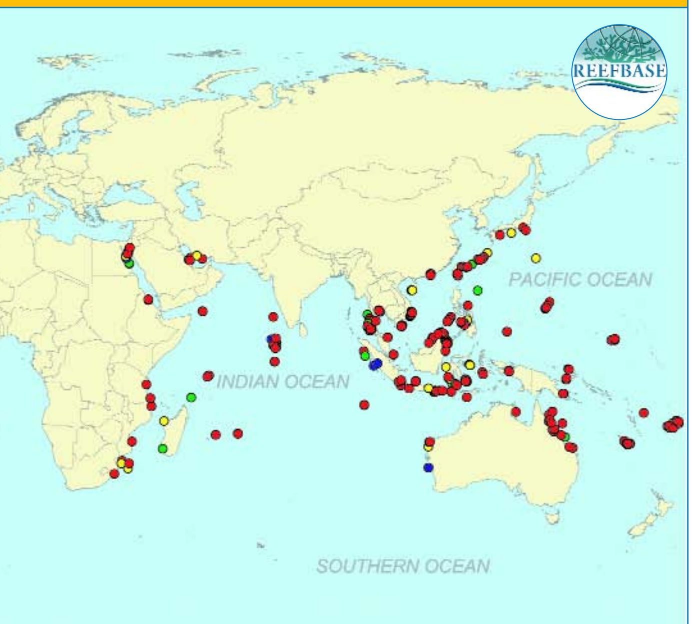
(hereafter defined as total parrotfish). Numbers of parrotfish in the Atlantic region ranged from four to six times higher than in the Indo-pacific – another defining difference between the two oceans (Figure 4.14). In addition, 96% of all reefs surveyed in the Atlantic region had at least one parrotfish > 20cm. (Figure 4.15).

Overall, total parrotfish in the Indo-pacific increased significantly ($p=0.01$) from 1997 to 2001 from 1.2 ± 2.5 per 100 m^2 to 2.0 ± 2.9 per 100 m^2 reef.

Parrotfish abundance in the Atlantic region decreased significantly over the same period from a high of 13.2 ± 24.0 per 100 m^2 in 1998 to a low of 5.1 ± 4.3 per 100 m^2 in 2001 ($p=0.05$). Despite this decrease, the density of parrotfish was greater inside MPAs (11.38 ± 21.7 per 100 m^2) than outside MPAs (5.5 ± 5.0 per 100 m^2), although this difference was not significant at the 95% confidence level.

In the Indo-pacific, the abundance of total parrotfish significantly decreased with higher ratings for blast fishing ($p \leq 0.01$). The mean number of total parrotfish was 1.6 ± 2.89 per 100 m^2 in the absence of any perceived blast fishing and dropped to 0.46 ± 1.2 per 100 m^2 where blast fishing was rated as high.

> 20cm and bumphead parrotfish of all sizes



Moray eels

(Muraenidae)

Moray eels were added to the Reef Check protocol in 2001 as another global indicator for fishing impacts. There are over 100 species ranging in length from a few centimeters to 2 m. While moray eels have a lot of small bones that make them difficult for people to eat, they are an easy spear fishing target for those in search of a meal because of their large size and territorial behavior. Each fish lives in a defined hole and is visible at close range. Morays are nocturnal predators. No moray eels were detected on 81% of the 302 reefs surveyed.

Snapper

(Lutjanidae)

Atlantic snapper were selected as a reef health indicator because of their importance as a food fish. Pacific snapper were then added to the protocol in 1999 to allow comparison between population levels in the two oceans. Snapper are medium to large-sized predators made up of over 100 species.

A total of 644 reefs were surveyed for snapper during the period 1997-2001. The mean number of snapper on an Atlantic reef (10.4 $\pm$ 23.2 per 100 m^2) was ten times higher than on an Indo-pacific reef (1.7 $\pm$ 5.2 per 100 m^2). This difference is largely due to the higher abundance of snapper found in 1997 and 1998 in the Atlantic (Figure 4.16) ($p=0.02$). In the Atlantic, 84% of all reefs surveyed had at least one snapper per reef. The abundance of snapper in the Atlantic declined from 15.5 $\pm$ 29.0 per 100 m^2 in 1997 to 3.5 $\pm$ 8.1 per 100 m^2 in 2001 ($p=0.10$). The greatest abundance of snapper, 169 per 100 m^2 reef, was recorded at Davis and Tennessee reefs in the Florida Keys National Marine Sanctuary in 1997 and 1998. No data are available from 1999-2001 from these reefs.

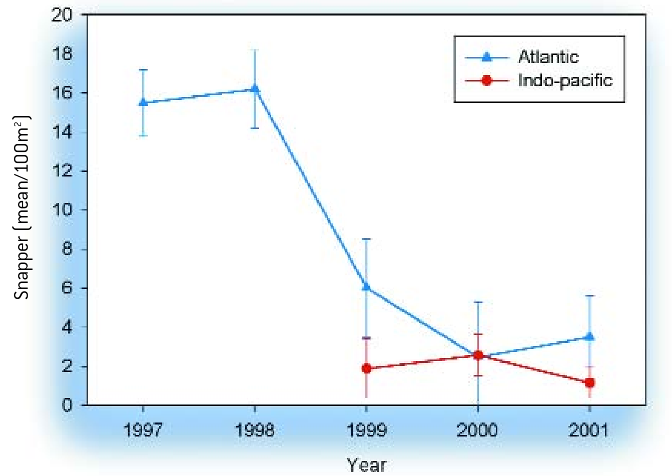


Figure 4.16: Mean abundance of snapper per 100 m^2 on Indo-pacific (1999-2001) and Atlantic reefs (1997-2001).

The numbers of snapper in the Indo-pacific did not change significantly between 1999 and 2001. However, there was a significant reduction between 2000 and 2001, the mean number of snapper per 100 m^2 reef dropped from 2.6 ± 7.8 to 1.1 ± 3.4. Snapper were not recorded on 45% of the 468 surveys conducted in the Indo-pacific.

In the Indo-pacific, more snapper were found on reefs inside MPAs (2.0 ± 6.2 per 100 m^2) than on reefs outside MPAs (1.2 ± 2.8 per 100 m^2) ($p=0.15$), although these differences were not significant. Biomass estimates made by Hawkins et al., (1999) at the Caribbean island of Bonaire showed a similar situation with 2.5 ± 0.7 kg inside the MPA and 1.1 ± 0.7 kg outside.

Multivariate Analyses

Six global indicators (butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index [% live coral/(recently killed coral + live coral]) were selected for ordination analysis. The MDS plot of the global indicators, averaged yearly by geographic region, is displayed in Figure 4.17. The Atlantic reef annual means are clearly separated from those of the Indo-pacific and Red Sea. The stress level of 0.03 corresponds to an excellent representation with no prospect of misinterpretation (Clarke and Warwick, 2001). ***Diadema*** and butterfly fish accounted for 44% and 30% of the similarity between Indo-pacific years, respectively. Haemulids and ***Diadema*** accounted for 42% and 24% of the similarity between Atlantic years, respectively. The mean dissimilarity of all pairwise coefficients between Indo-pacific and Atlantic regions was 34%. Of this, haemulids, ***Diadema***, and butterfly fish contributed 49%, 24% and 18% of the total value, respectively.

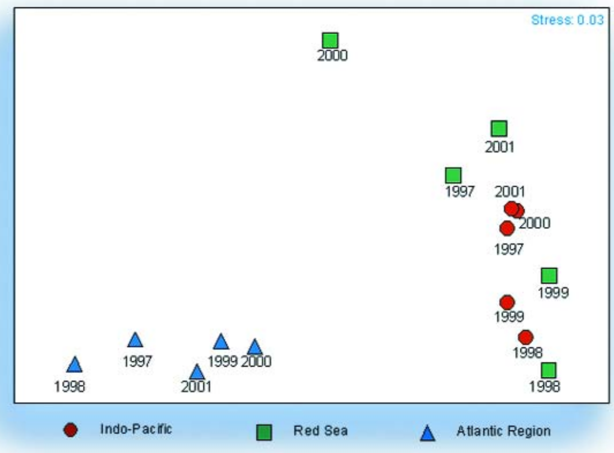


Figure 4.17: MDS plot of global indicators (butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index) averaged yearly by geographic region.

The mean of the global indicators in 2000 for the Red Sea reefs was quite different from all other yearly averages on the plot. The low average abundance of ***Diadema*** (1.9 per 100 m^2) accounted for approximately 40% of the dissimilarity with all other years in the Red Sea. The density of ***Diadema*** increased in 2001 and was not a major factor differentiating 2001 from other years.

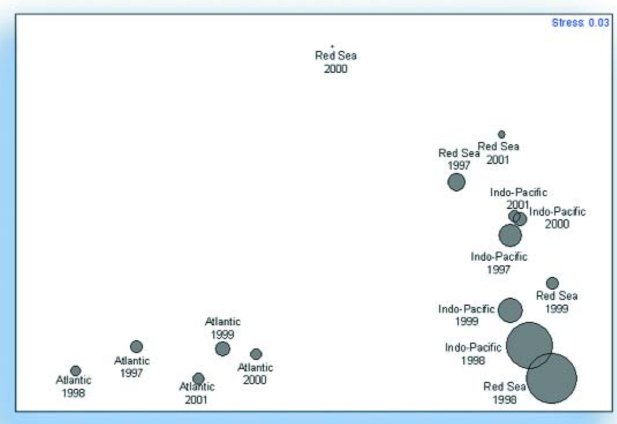


Figure 4.18: MDS plot of global indicators (butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index) averaged yearly by geographic region. Circles represent the relative density of ***Diadema***.

Figure 4.18 is a replicate MDS plot of Figure 4.17, however the relative abundance of ***Diadema*** is represented by the size of the circles on the ordination plot. It is apparent that the differential densities of ***Diadema*** in the Indo-pacific and Atlantic Regions may play an important role in the overall multivariate pattern. For example, in both the Red Sea and the Indo-pacific in 1998, a high abundance of ***Diadema*** (compared to other years) may have been important in placing these samples close to each other. The SIMPER routine was used to assess numerical values of these relationships, i.e. the effect of ***Diadema*** on both the mean similarity within distinct geographic regions and the dissimilarity between geographic regions. ***Diadema*** contributed 44%, 37%, and 24% to the similarity between years in the Indo-pacific, Red Sea, and Atlantic, respectively. ***Diadema*** contributed 24% to the dissimilarity between annual means in the Indo-pacific and Atlantic and 20% to the dissimilarity between Red Sea and Atlantic yearly averages.

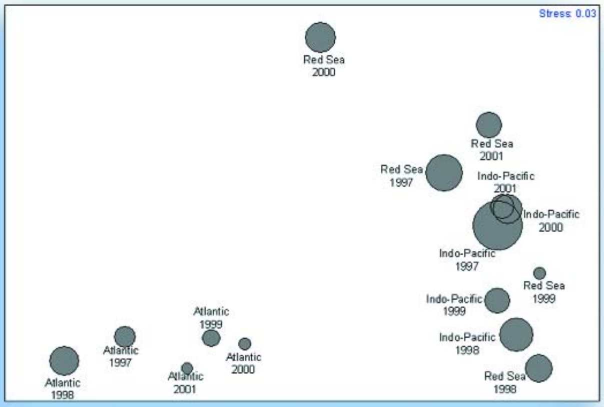


Figure 4.19: MDS plot of global indicators (butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index) averaged yearly by geographic region. Circles represent the relative density of butterfly fish.

The relative abundance of butterfly fish represented by the size of the circles on the ordination plot is shown in Figure 4.19, a replicate of Figure 4.17. The differential densities of butterfly fish in the Indo-pacific and Atlantic may play an important role in the overall multivariate pattern shown on the MDS. The contribution of butterfly fish was 30%, 31%, and 18% to the similarity between years in the Indo-pacific, Red Sea, and Atlantic, respectively. Additionally, butterfly fish contributed 18% to the dissimilarity between Indo-pacific and Atlantic and 19% to the dissimilarity between Red Sea and Atlantic yearly averages.

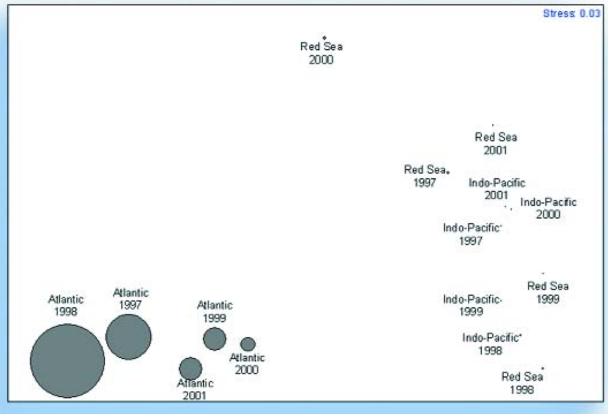


Figure 4.20: MDS plot of global indicators (butterfly fish, ***Diadema***, grouper, haemulids, lobster and live coral index) averaged yearly by geographic region. Circles represent the relative density of haemulidae.

Figure 4.20 is a replicate MDS plot of Figure 4.17 with the relative density of haemulids represented by the size of the circles on the ordination plot. The relatively high abundance of haemulids in the Atlantic compared to the other regions plays an important role in the overall multivariate pattern shown on the MDS. The contribution of haemulids was 9%, 10%, and 42% to the similarity between years in the Indo-pacific, Red Sea, and Atlantic, respectively. Additionally, haemulids contributed 50% to the dissimilarity between Indo-pacific and Atlantic annual means and 49% to the dissimilarity between Red Sea and Atlantic annual means.

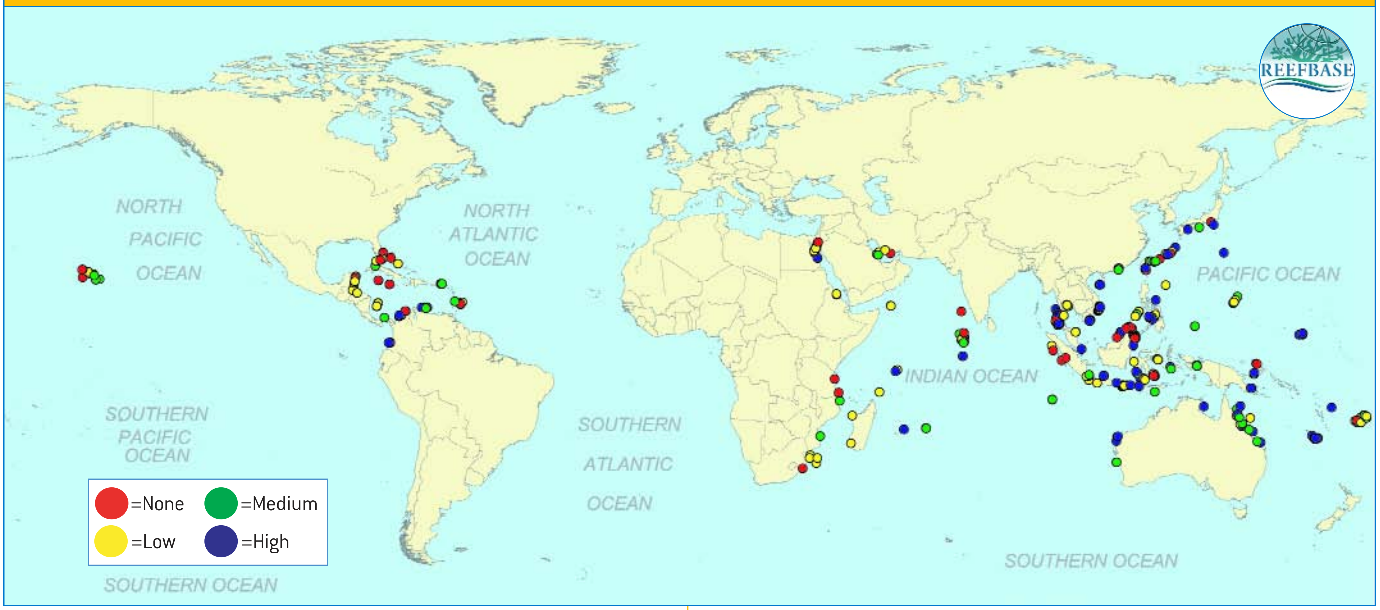
CORAL COVER

GLOBAL INDICATOR

Percent Hard Coral Cover.

The results of five years' monitoring show the percentage of the seabed covered by live coral at many of the world's best reefs is 32% (Figures 4.21 and 4.22). This number is important because previous characterization of reef health based on coral cover used very high percentages for good or excellent reefs e.g. (Gomez, 1981). Coral cover is greatly affected by the distribution of hard substratum on a reef as well as by the health of the corals living there. Out of over 1000 reefs monitored, only 34 had more than

Figure 4.21: Global relative percent hard coral cover (1997-2001).



70% hard coral cover and none had higher than 85% cover (Figure 4.21). Many of the healthiest reefs in the world have probably never had more than about 30% coral cover.

However, coral cover by itself may not be a very useful indicator of reef health unless permanent transects are resampled over time, or unless very large sample sizes are available such as in the above global analysis. Without permanent transects, it is possible that a subsequent sample of reef will hit a large patch of e.g. sand or rubble, biasing the results. The large number of samples provides evidence of a true 10% difference between the Atlantic and Indo-pacific reefs.

A more meaningful indicator of reef health is the ratio of live coral cover to total coral cover (hard coral index), where total coral cover is defined as live coral cover plus recently killed coral. In Figure 4.23 we see no significant change in the hard coral index between years in the Atlantic region.

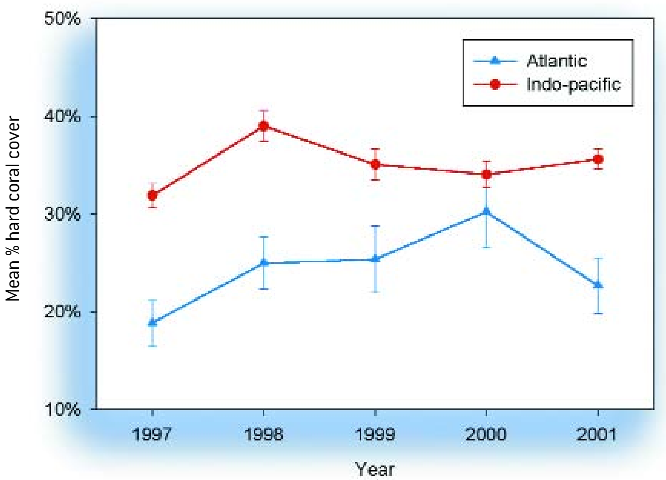


Figure 4.22: Mean percent coral cover (1997-2001) on Indo-pacific and Atlantic reefs.

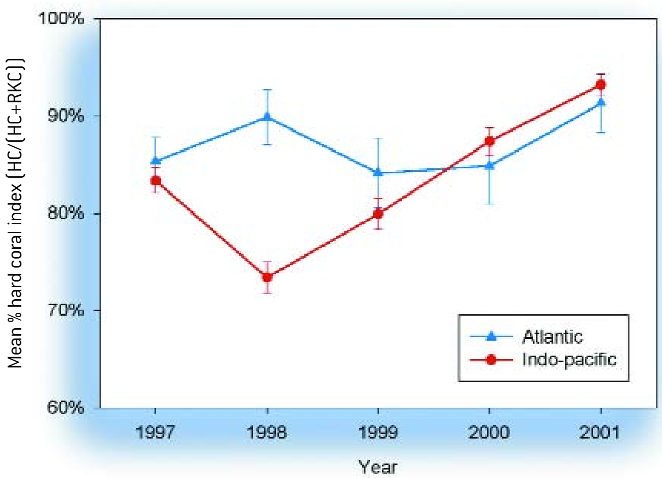


Figure 4.23: Mean percent hard coral index (hard coral/(hard coral + recently killed coral))(1997-2001) on Indo-pacific and Atlantic reefs.

However, the hard coral index drops significantly from 1997 to 1998 ($p \leq 0.01$) in the Indo-pacific as a result of the increase in recently killed coral cover in 1998, a consequence of the 1997-1998 bleaching event. The hard coral index increased significantly ($p \leq 0.01$) from 1998 to 2001, while at the same time the percentage of substrate classified as rock decreased. Figure 4.24 shows the relationship between recently killed coral cover and rock cover. This could be explained by the recently killed coral (RKC) category shifting into the rock category after one year. This is because the RKC category is defined only to include coral killed within the past year.

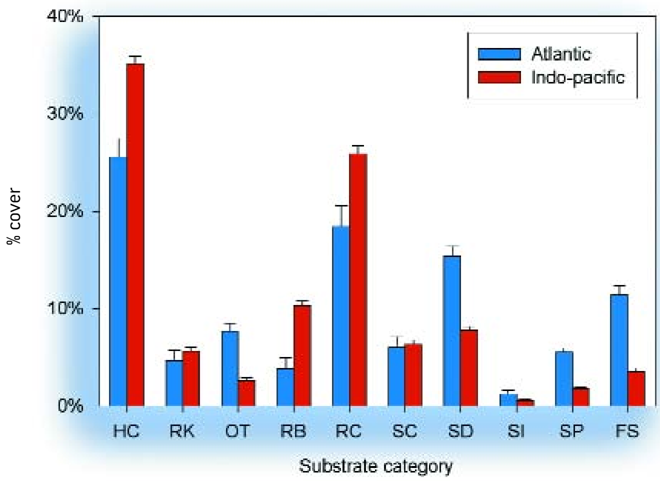


Figure 4.24: Mean percent cover of substrate categories in the Indo-pacific and Atlantic. HC= Hard coral; RK= Recently killed coral; OT= Other; RB= Rubble; RC= Rock; SC= Soft coral; SI= Silt; SP= Sponge; FS= Fleshy seaweed.

Globally, reefs are predominantly composed of hard coral, followed by rock (Figure 4.24). Indo-pacific reefs have a relatively higher proportion of hard coral and rock than Atlantic reefs. Indo-pacific reefs have approximately three times the amount of rubble than the Atlantic reefs. One explanation for some reefs would be that there are more than double the number of typhoons in the Pacific (mean 25) than there are hurricanes in the Atlantic each year (mean 9), and the mean wave height is higher (Pielke and Pielke, 1997). The average Atlantic reef has twice the percentage cover of sand as the average Indo-pacific reef. There was no significant difference in the percent cover of the "soft coral" category between the two oceans (NB: zooanthids are lumped into this category in the Atlantic).

Perceived impacts

The mean percent hard coral cover was related most closely to the perceived level of sewage pollution. Hard coral cover on reefs with no perceived sewage pollution (Figure 4.25) was 35 ± 18% whereas reefs with perceived heavy levels of sewage pollution had significantly lower hard coral cover, 28 ± 14% ($p=0.04$). In the Indo-pacific, the percentage of hard coral cover was significantly related to the perceived level of blast fishing. 99% of all perceived blast fishing occurred in SE Asia (Figure 4.26). Reefs rated as having no blast fishing had a mean hard coral cover of 35 ± 18%, whereas reefs rated as having a high level of blast fishing had a hard coral cover of 25 ± 19% ($p \leq 0.01$). Also in the Indo-

Figure 4.25: Human impact rating for sewage pollution (1997-2001).

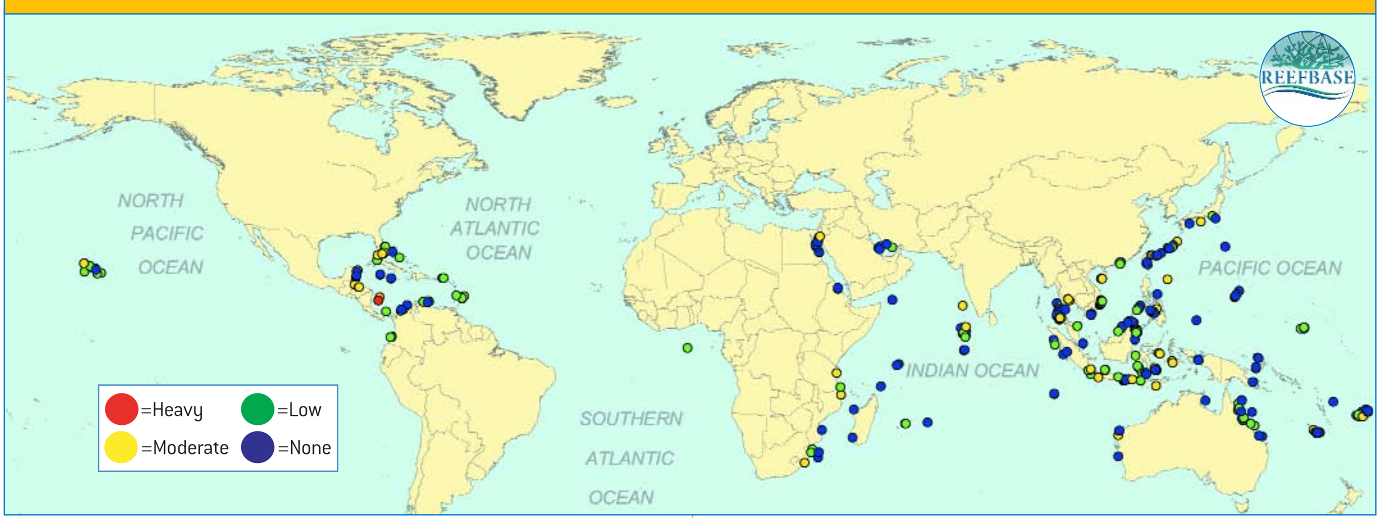
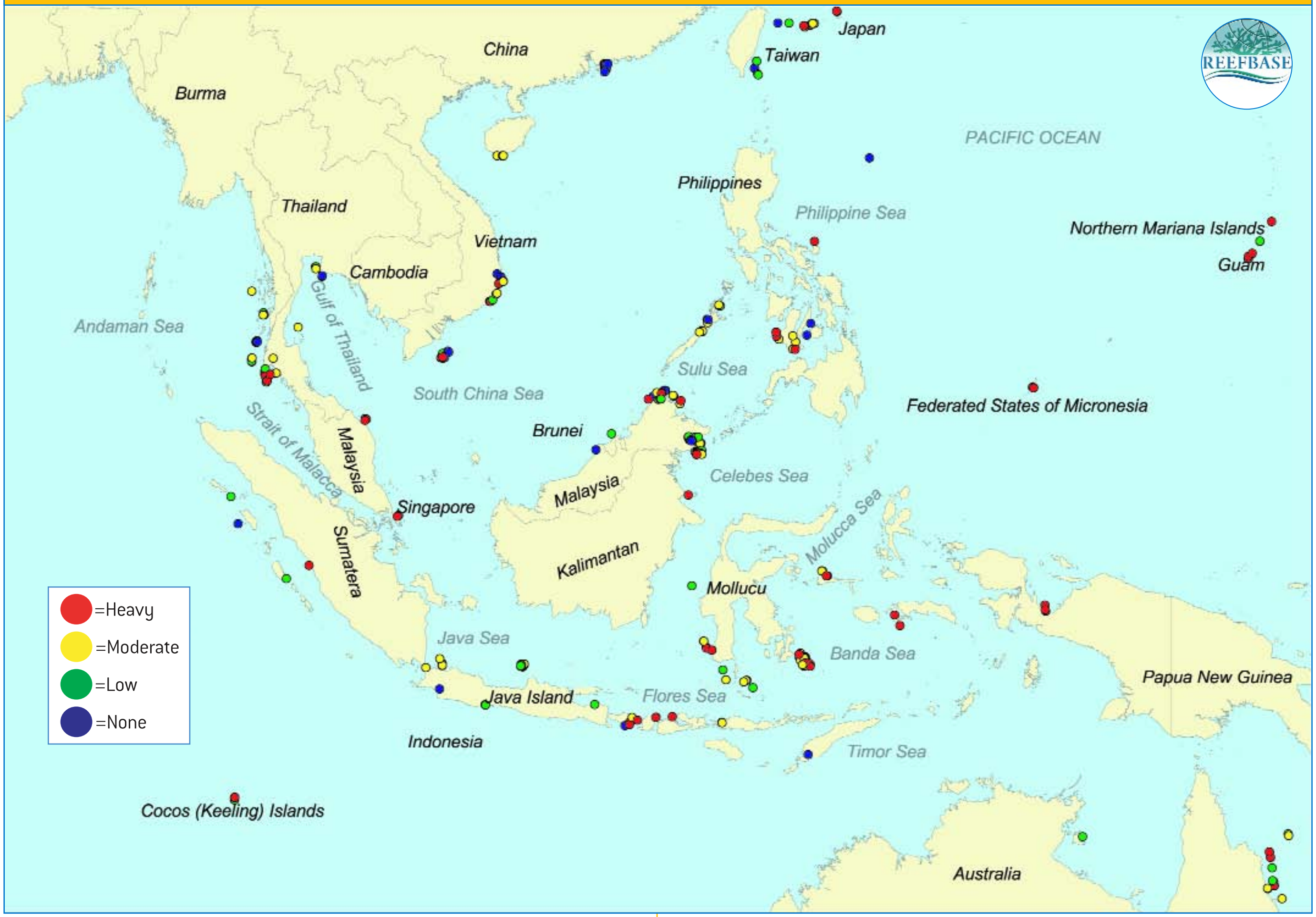


FIGURE 4.26: HUMAN IMPACT RATING FOR BLAST FISHING (1997-2001).



pacific, reefs rated with a high level of poison fishing had a significantly lower hard coral cover of 21 ± 19%, than reefs rated as having no poison fishing, 32 ± 18% ($p \leq 0.01$).

Worldwide, hard coral cover on reefs rated as having no anthropogenic impacts was significantly higher 39 ± 19%, than on reefs with a high rating for overall anthropogenic impacts (coral cover 23 ± 18%) ($p = 0.02$).

High ratings for sewage pollution, blast and poison fishing, and overall anthropogenic impact had the opposite effect on the percentage of dead coral. On reefs in the Indo-pacific without any perceived blast fishing, recently killed coral cover was 6 ± 11% of the total substrate. However, on reefs with heavy levels of perceived blast fishing, recently killed coral covered 11 ± 16% of the total substrate.

FLESHY (NUTRIENT INDICATOR) SEAWEED

Fleshy seaweed is a substratum category that was introduced to the Reef Check survey protocols in 1999 as a way to measure impacts of high nutrient inputs from sources such as fertilizer and sewage pollution. The types of seaweed in this category include the lettuce-like ***Ulva*** spp., slimy filamentous blue-green algae, and the fleshy green species such as the bubble-alga ***Dictyosphaeria cavernosa***. The fleshy seaweed category does not include natural seasonal reef flora such as ***Sargassum***.

Of the 670 reefs surveyed for fleshy seaweed, those rated with a high level of sewage pollution had a significantly higher abundance of fleshy seaweed ($p \leq 0.01$) (Figure 4.27). See Figure 4.25 for worldwide relative perceived levels of sewage pollution.

Reefs with no perceived level of sewage pollution had 3.8 ± 8.1% cover of fleshy seaweed, whereas reefs with a perceived heavy level of sewage pollution had a mean 13.1 ± 12.7% cover of fleshy seaweed.

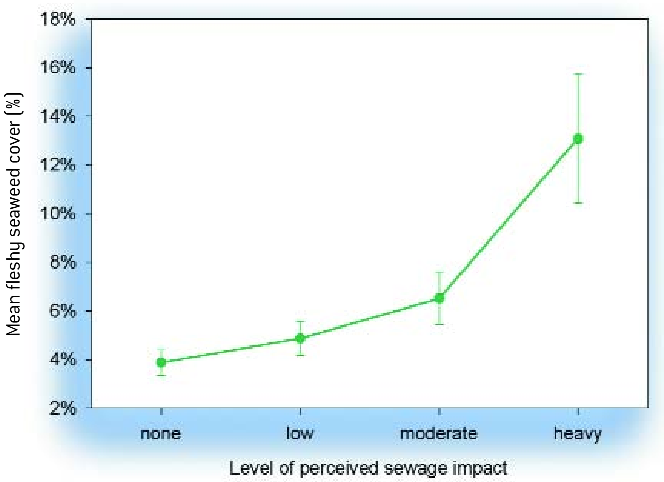


Figure 4.27: Mean fleshy seaweed cover versus level of human impact from sewage.

Marine Protected Areas

For the purposes of this analysis, protected areas are defined as any area that has some legal protection. In some MPAs, the laws do not exclude recreational fishing. Over half of all sites surveyed had some form of protection (Table 4.3).

Year	n	% Protected
1997	256	66%
1998	172	49%
1999	152	30%
2000	189	39%
2001	337	46%
Total	**1106**	**48%**

Table 4.3: Percentage of sites surveyed that had some form of legal protection.

Significantly higher numbers of five fish and one invertebrate indicator organism were found on reefs inside MPAs (Figures 4.28 and 4.29). These indicators include banded coral shrimp, grouper, haemulidae, lobster, parrotfish and bumphead parrotfish. This is a major improvement, over the 1997 results when there were no differences between reefs inside MPAs and those outside. This seems to indicate that management is becoming effective and MPAs are starting to work. However, the mean numbers are skewed by a few, very effective MPAs where high numbers of indicator organisms are found. For example, of the top 5% of sites that have the highest number of indicator organisms, 88% in the Atlantic and 76% in the Indo-pacific, are MPAs.

In the Soufriere Marine Management Area (SMMA), St. Lucia, higher numbers of indicator organisms were found inside the management area than outside. Additionally, fish populations outside SMMA have significantly increased over time (Roberts et al., 2001). According to the SMMA manager, Kai Wulf, the participation

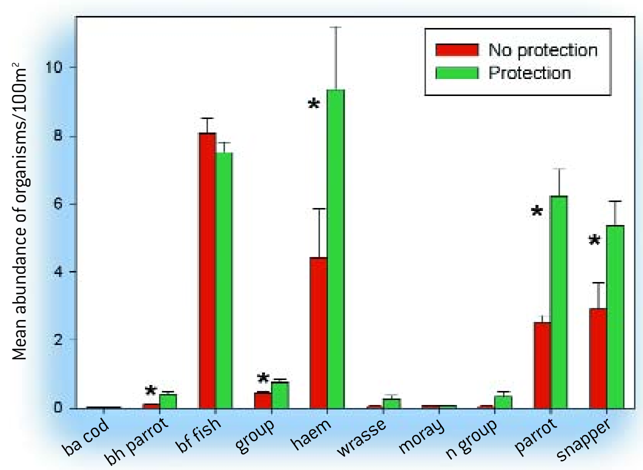


Figure 4.28: Five of ten fish indicator organisms had a significantly higher abundance inside MPAs than outside (bumphead parrot $p < 0.01$, grouper $p < 0.01$, haemulidae $p < 0.03$, parrotfish $p < 0.01$, snapper $p < 0.02$).

of local fishermen in the Reef Check Program helped foster community support and enforcement of no-take areas from the fishing community (pers. comm.)

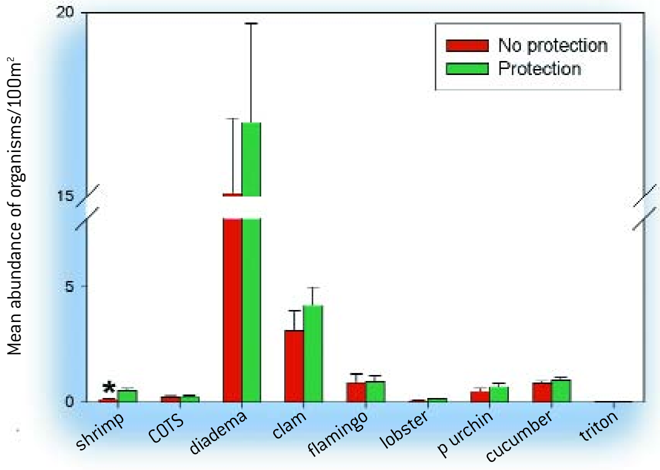


Figure 4.29: Only one of nine invertebrate indicators was significantly higher at MPA reefs (banded coral shrimp $p \leq 0.01$).

"Reef Check has been used to monitor the condition of the Apo Island Marine Sanctuary yearly since 1998. The ENSO caused widescale mortality of a major spatially dominant species, Galaxea fasicularis. Mortality of this one species has resulted in a significant drop in live coral cover, but has provided additional substrates for new coral recruitment. As Apo Island is well-managed, with little evidence of poaching and other human-induced impacts, it provides an interesting opportunity for long-term study of the response of a relatively pristine reef community to a major bleaching event. Such information in vital to broadening our understanding of long-term impacts of ENSO events, and the nature of reef recovery from such phenomena." -Dr. Laurie Raymundo, Silliman University, Philippines and Reef Check Philippines Coordinator

Perceived Threats to Coral Reefs

Worldwide, out of a possible maximum rating of 3 (for high impact), the mean rating of anthropogenic impacts on reefs was 1.5, halfway between zero impact (0) and high (3).

Over the five-year period the overall anthropogenic impact rating was significantly higher in the Atlantic region than in the Indo-pacific ($p \leq 0.01$) (Figure 4.30). The ratings for recreational diving impacts and sewage pollution impacts were significantly ($p \leq 0.01$) higher in the Atlantic region than in the Indo-pacific (Figure 4.31). There was no significant difference between regions for ratings of fishing pressure, harvest of invertebrates, collection of organisms for the aquarium trade, industrial pollution, or "other" impacts. However, the level of blast and poison fishing was significantly ($p \leq 0.01$) higher in the Indo-pacific than in the Atlantic region. The highest rating for poison fishing was reported in Northern Malaysia and the Philippines; a similar pattern was seen for blast fishing.

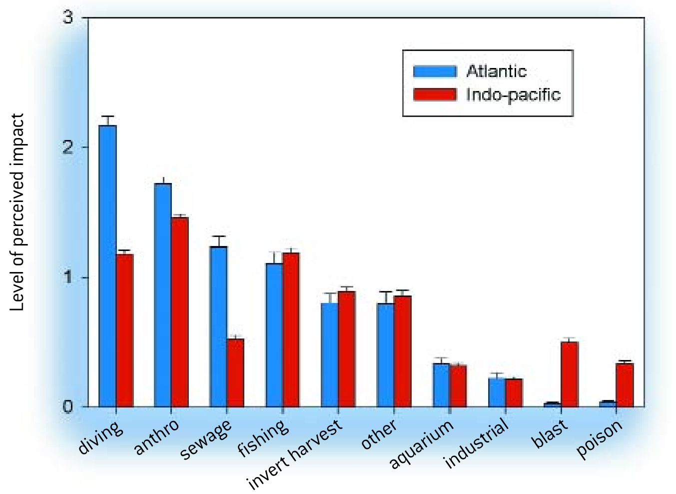
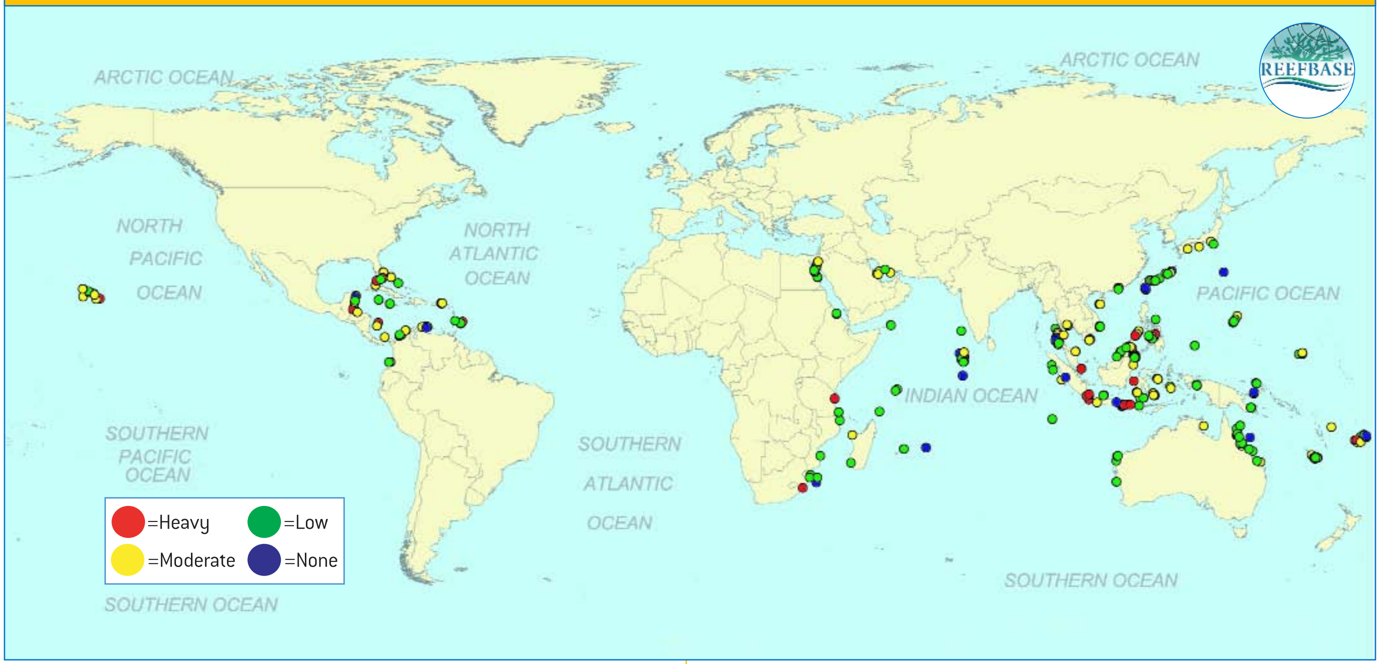


Figure 4.30: The mean level of perceived human impacts in the Atlantic and Indo-pacific 1997-2001.

FIGURE 4.31: RELATIVE OVERALL ANTHROPOGENIC IMPACT RATINGS (1997-2001).



Photos courtesy of:
Banded coral shrimp: Jeff Jeffords
Diadema: Gregor Hodgson
Triton: Fabrice Poiraud-Lambert
Butterfly fish: Niki Papakonstantinou
Grouper: Jack Randall
Haemulidae: Jack Randall
Parrotfish: Jack Randall
Moray eel: Niki Papakonstantinou
Snapper: Jack Randall
Above picture: Jeff Jeffords

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

INVERTEBRATES

INDO-PACIFIC INDICATORS

Crown-of-Thorns Starfish

(Acanthaster planci)

The Crown-of-Thorns starfish (COTS) was chosen as a Reef Check regional indicator for the Indo-pacific because it can have a major damaging effect on reef corals through predation during high-population years. In the 1970s, some scientists feared that COTS would destroy the Great Barrier Reef (Sap, 1999). The second reason that COTS was included is the controversy regarding the cause of COTS population explosions has yet to be resolved, and a number of scientists believe these episodes are linked to human activities (Birkeland, 1989). In particular, one hypothesis suggests increased runoff due to poor land use has led to eutrification that facilitates higher survival of COTS larvae and thus outbreaks. Another hypothesis holds that over harvesting of the triton, a predator of COTS, is to blame. On the Great Barrier Reef, it was estimated that 10,000 tritons were collected each year until the 1960s when they became rare (Sap, 1999). The evidence to date indicates COTS outbreaks occurred sporadically in many areas since the 1970s, however, a solid link to human activities has not been clearly established.

Of 884 reefs surveyed, only 22% of reefs had at least one crown-of-thorns starfish (COTS) (Figs. 5.1 and 5.2). The mean abundance of COTS was 0.23 ± 0.99 COTS per 100 m^2. The maximum number of COTS found on one reef was 35.5 per 100 m^2 on Kapikan Reef, Malaysia in September 1999, an abundance of COTS four times higher than recorded on any other reef. Several reefs in Malaysia in July 1997 and in Thailand in July 1998 reported 9.75 COTS per 100 m^2.

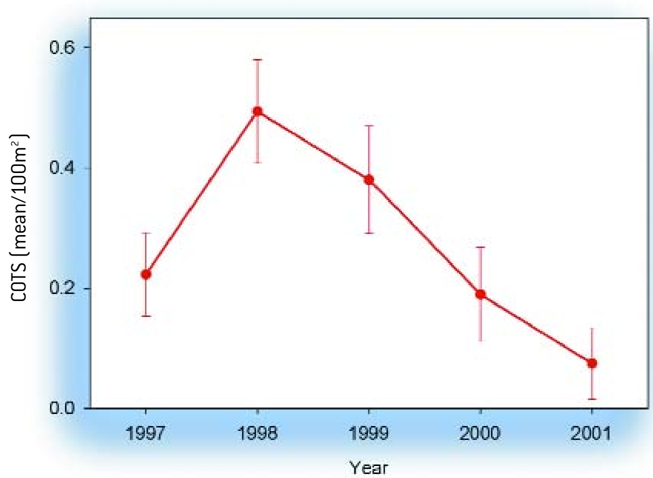
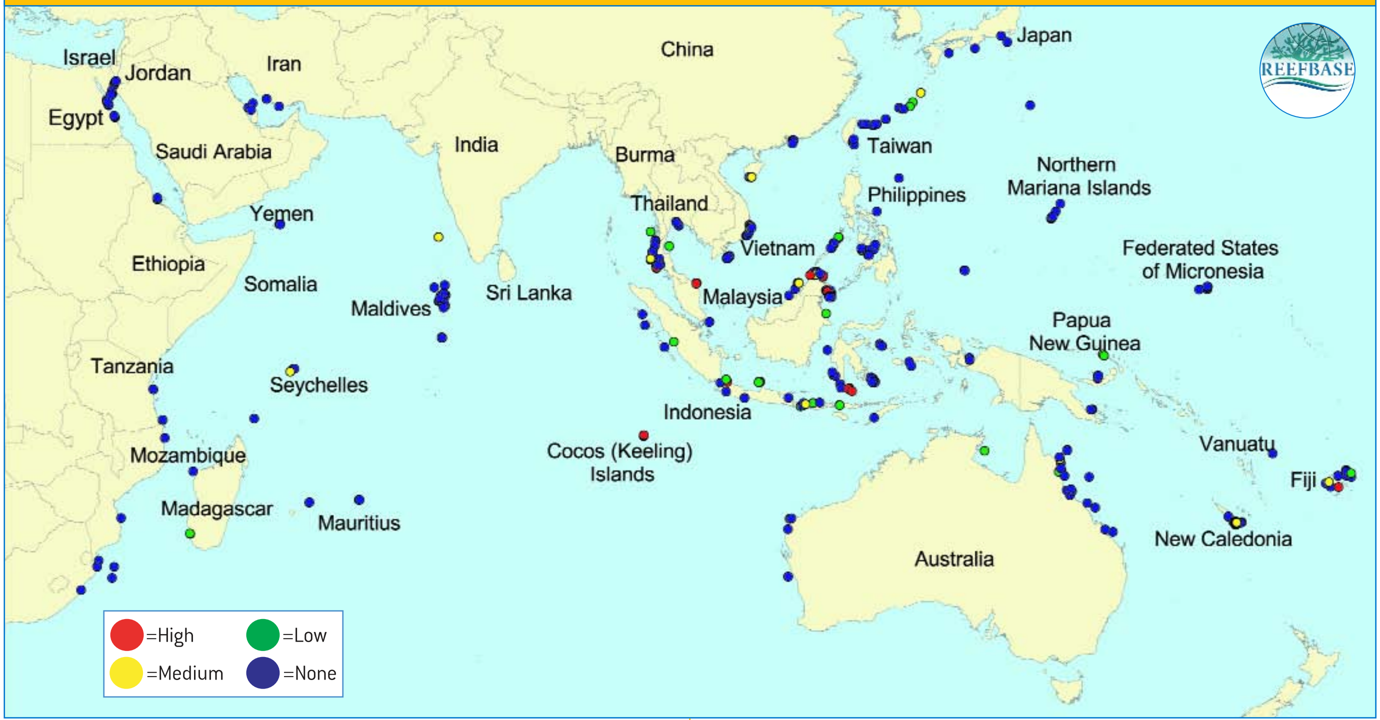


Figure 5.1: Mean abundance of COTS (crown-of-thorns-starfish) per 100 m^2 (1997-2001) on Indo-pacific reefs.

These densities can be compared to those recorded on the Great Barrier Reef as part of the Australian Institute of Marine Science (AIMS) long-term monitoring program. AIMS uses a manta tow survey where towed divers are asked to count COTS in a 10 m wide belt transect during a two-minute tow at 4 km/h. A COTS count of 0.22 per tow is classified by AIMS as an "incipient outbreak" while a count of >1 COTS

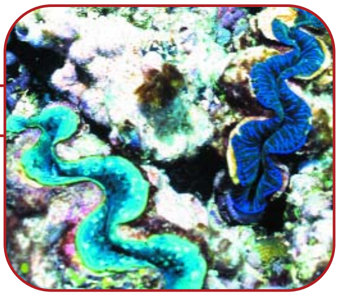
Figure 5.2: Relative abundance of COTS (1997-2001). None = 0; Low=1; Medium= 2-4; High>4



per tow is considered an "active outbreak." Using these numbers, the two classifications can be normalized to 100 m^2 for comparison with the Reef Check data. The results are 0.02 COTS per 100 m^2 as an incipient outbreak and > 0.08 COTS per 100 m^2 as an active outbreak. These numbers are far below those recorded during Reef Check and illustrate the difficulty of comparing results obtained using different methods. According to Ian Miller (per. comm.) Manta tow COTS counts are typically 10 - 35% of those recorded by swimming divers.

Giant Clam

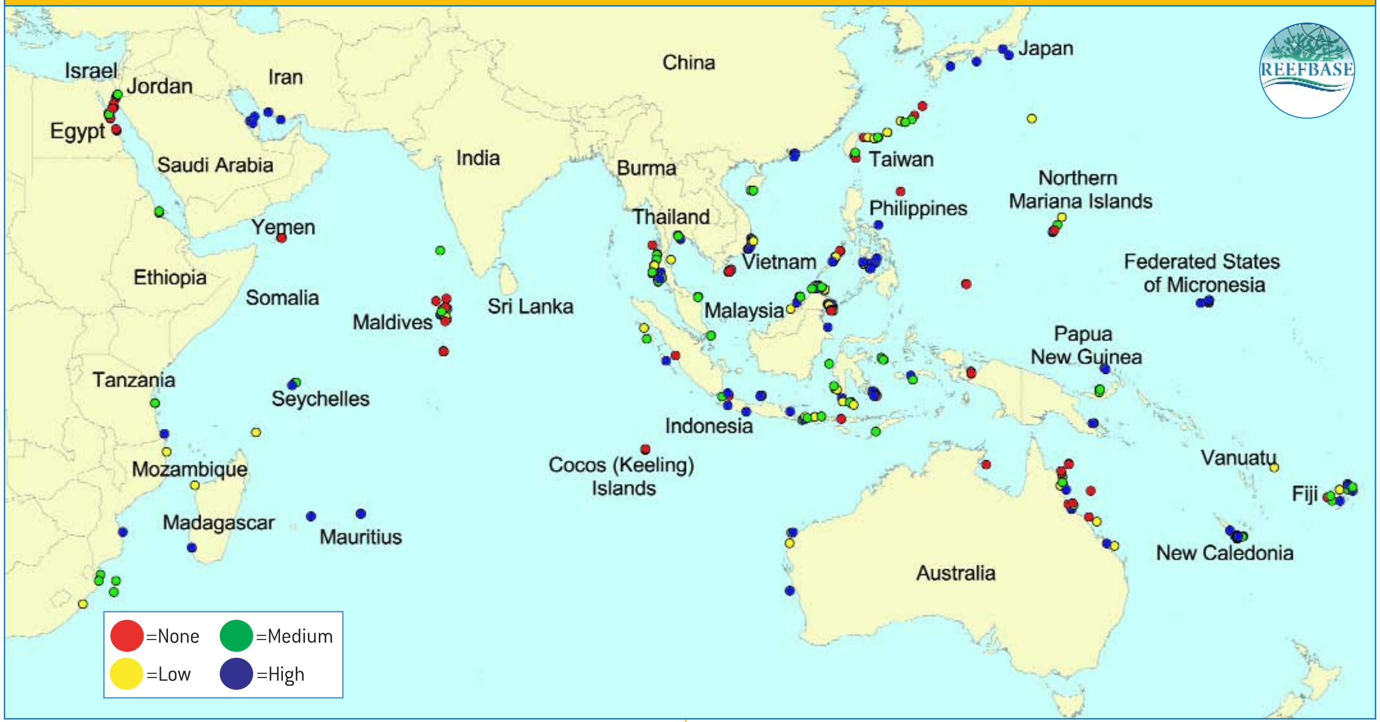
(Tridacna spp.)



Giant clams of the genus ***Tridacna*** were selected as Reef Check indicators because they have long been highly prized both as a food item, as a curio and more recently as an ornamental shellfish for aquarium keepers. There are several species of giant clam and all are included in the Reef Check protocol because all are the target of human predation. The largest clams ***T. gigas*** and ***T. derasa*** reach a maximum shell length of approximately 1.5 m and 0.5 m respectively. ***T. squamosa***, ***Hippopus hippopus***, and ***T. maxima*** may reach 30 - 40 cm, while the burrowing clam, ***T. crocea*** only reaches 15 cm in shell length. Now, large specimens are only seen in museums and in European churches where they often serve as holy water vessels. The long white adductor muscle of giant clams is consumed raw as a delicacy throughout East Asia and commands a wholesale price of $50 per kg of meat. ***Tridacna*** have now been farm raised commercially for over 20 years, and much of the trade in ornamentals is served by aquacultured clams - a true success story pioneered by Gerald Heslinga in Palau (Heslinga and Watson, 1985).

Of the 869 reefs monitored by Reef Check during the period 1997-2001, the mean number of giant clams found per 100 m^2 was 3.9 ± 19.1. However, there were no giant clams at 29% of all reefs (Fig. 5.3). The distribution of giant clams was very skewed, with a few sites showing high numbers of small (10 - 15 cm wide) specimens of ***Tridacna crucea***. This species lives imbedded in the

FIGURE 5.3: RELATIVE ABUNDANCE OF GIANT CLAMS (1997-2001). NONE = 0; LOW=1-3; MEDIUM= 4-11; HIGH>11



reef and so is more difficult to harvest. For example, four reefs had an abundance of giant clams greater than one per square meter, or over 400 clams per survey. Three of these sites were in Con Dao National Park, Vietnam, where collection of giant clams is illegal, but not strictly enforced. Another remote site in the Chagos Archipelago, which has no legal protection for giant clams, had 249.5 clams per 100 m^2.

A 1989 market survey carried out by Shang et al. (1989) of the University of Hawaii suggested a high demand for giant clams in Asia with a potential market of 240 tons per year in Taiwan alone. Based on interviews with importers they wrote:

"Because clam fishing is illegal (in Taiwan), the supply of giant clam adductor muscle in Taiwan has come from imports during the past few years. The main source of supply is Indonesia, Papua New Guinea, Australia and Fiji…at least 31 tons in 1987 and 40 tons in 1988 were estimated to have been giant clam adductor muscle. Preferred size is one kilogram per muscle, but in recent times, muscles of this size have been rare. Former clam boat owners indicated that species seem to be preferred in the following order: T.gigas, T. derasa, Hippopus hippopus, T. squamosa and T. crocea."

In contrast, the same study found that in Okinawa, the smaller ***T. crocea*** was the preferred clam for sashimi due to its tenderness, and commanded a price of $50 to $73 per kg.

Reef Check data show that during the time period 1999 to 2001, the number of giant clams inside MPAs was significantly higher than the number of clams outside MPAs ($p \leq 0.01$). This may indicate management is starting to show success for these species.

The abundance of giant clams was correlated with the level of aquarium fishing. Numbers of giant clams were higher (4.2 ± 21.4 per 100 m^2) in areas of no aquarium fishing than levels impacted by aquarium fishing (1.6 ± 3.9 per 100 m^2), however this was not statistically significant ($p=0.11$). A similar trend was seen in the levels of perceived impact from poison fishing.

Giant clam abundance was surveyed at Helen Reef, Palau by Weng et al., (2000) and one ***Tridacna gigas*** per ha was found.

Evidently, the huge clams collected during the late 19th century are a distant memory. The good news is that aquaculture works well. The challenges remain where the demand is far higher than supply. On most reefs, it is difficult to enforce a ban on collecting such an easily harvested food item. To achieve rehabilitation success on a large geographic scale, technical solutions to aquaculture problems for any species need to be accompanied by socioeconomic solutions as well. A good model is available for locally based management. Richard Chesher established strategically located giant-clam "rings" within traditionally managed MPAs in the 1980s at a time when large clams were almost gone. These have helped to restore the populations (Chesher, 1988).

Sea Cucumbers

(Thelenota ananas, Stichopus chloronotus)

Edible species of sea cucumbers were chosen as Indo-pacific reef health indicators because they are easily collected from shallow waters and have a high economic value. Sea cucumbers perform an important ecological function on the reef, digesting sand and compacting the sediments into pellets that aid in reef formation.

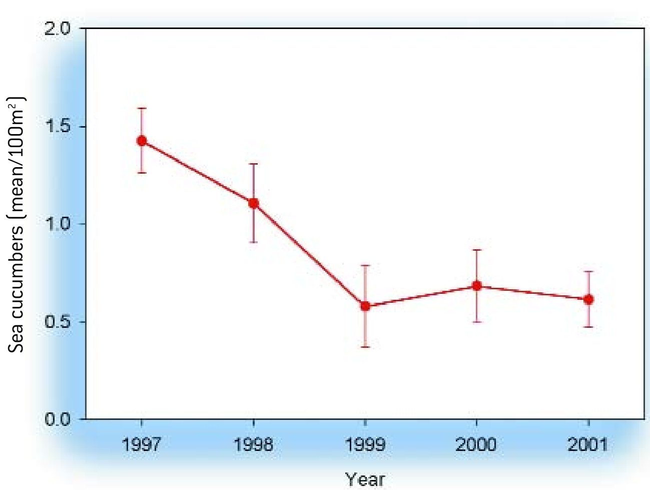


Figure 5.4: Mean abundance of sea cucumbers (*T. ananas* and *S. chloronotus*) per 100 m^2 (1997-2001) on Indo-pacific reefs.

As noted in Chapter 1, Saville-Kent (1893) reported on the fishery. In 1889, at Thursday Island (Australia) alone, there were 100 boats, 20 to 24 men per boat, harvesting 500 to 600 tons per month.

Half of the 874 reefs monitored for sea cucumbers were devoid of both species. The mean number of sea cucumbers per 100 m^2 significantly and steadily declined from a high of 1.4 ± 2.0 in 1997 to a low of 0.61 ± 2.1 in 2001 ($p \leq 0.01$). The highest abundance of edible sea cucumbers, 23.75 per 100 m^2, was recorded on a reef in Mauritius in 2001. A high density of 17.25 per 100 m^2 was found on Double Reef, Guam, USA in 1997 and again in 1998. However, by 1999, that number had declined to 4 per 100 m^2. By 2001, there were 3.25 per 100 m^2. Double Reef is not in a MPA and there are no regulations limiting the collection of sea cucumbers in that area. Rapid declines in nearby Rota were noted in an independent fisheries study (Trianni, 2002). There was no difference in the abundance of sea cucumbers found inside and outside protected areas.

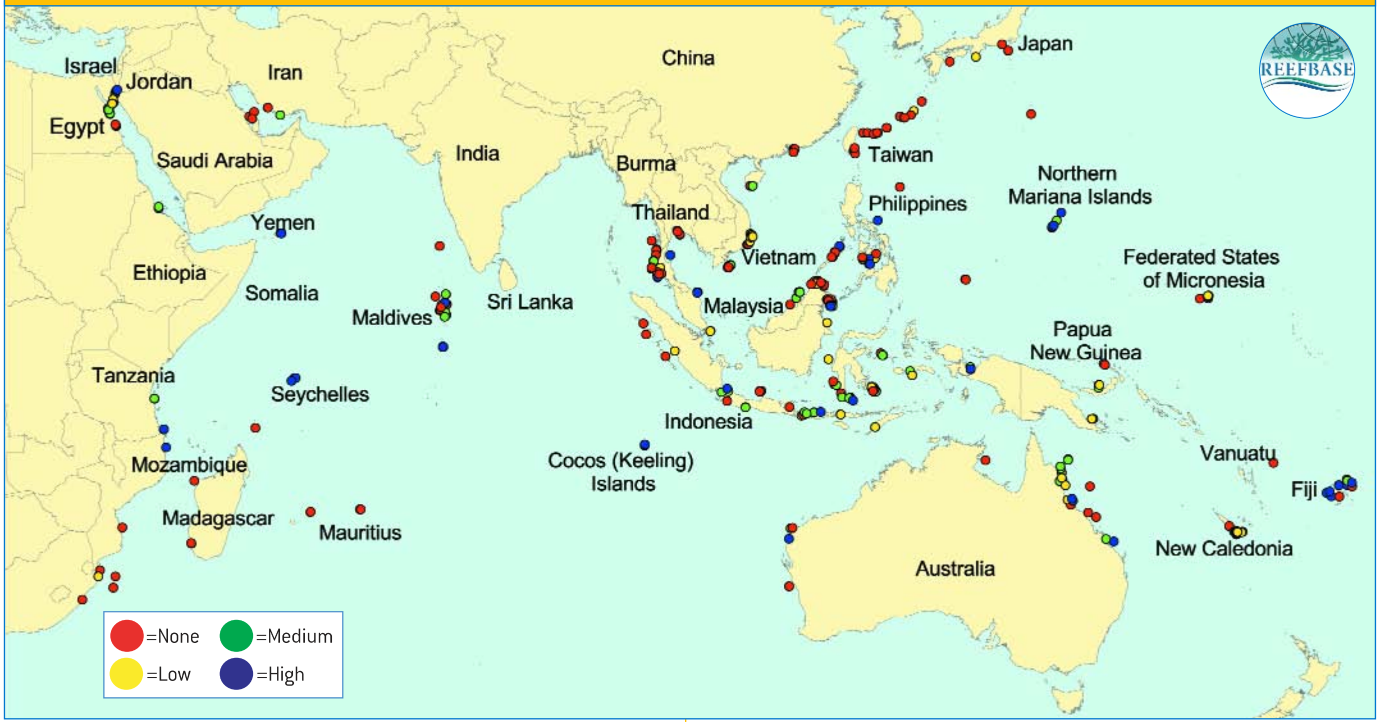
There were significantly more sea cucumbers found in areas where levels of harvest of invertebrates for food was rated as low (1.2 ± 2.9 per 100 m^2) compared to areas rated as high (0.71 ± 1.3 per 100 m^2) ($p = 0.03$).

Like other reef fishery targets, it appears that edible sea cucumbers are vulnerable to over-exploitation and Reef Check results indicate that most areas of the Indo-pacific have already been cleaned out.

These results are supported by studies reporting recent overfishing affecting the islands near Papua New Guinea. In previous years, edible sea cucumbers were found in localized densities of over 3,000/ha (equivalent to 30/100 m^2) in East New Britain, while recent surveys found densities less than 50/ha (0.5/100 m^2) (Adams et al., 1992; Lokani, 1992).

McElroy (1990) points out the general reduction in average price for sea cucumbers exported from Fiji and the Solomon Islands over the course of the 1980s, a result of the fishery

Figure 5.5: Relative abundance of sea cucumbers (1997-2001). None = 0; Low=1; Medium= 2-5; High>5



changing from a low-volume, high-value fishery to a high-volume, low-value fishery.

The trends seen in the Western Pacific are now being repeated in Africa. Beginning in 1990, the Madagascar export market for sea cucumber underwent rapid expansion, and in 1994, exports to Singapore and Hong Kong reached a peak of some 650 mt of sea cucumbers (Conand, 1998).

FISH

INDO-PACIFIC INDICATORS

Barramundi Cod

(Cromileptes altivelis)

The barramundi cod, also known as the humpback or panther grouper, is a fish in the family Serranidae. Its unique polka-dotted appearance cannot be mistaken for any other fish. Juveniles are high value aquarium fish, whereas adults fetch a high price in the Chinese live food fish market. Fish reach a maximum length of 70 cm and are widely distributed throughout the Western Pacific, but do not extend into the northern Indian Ocean or Red Sea.

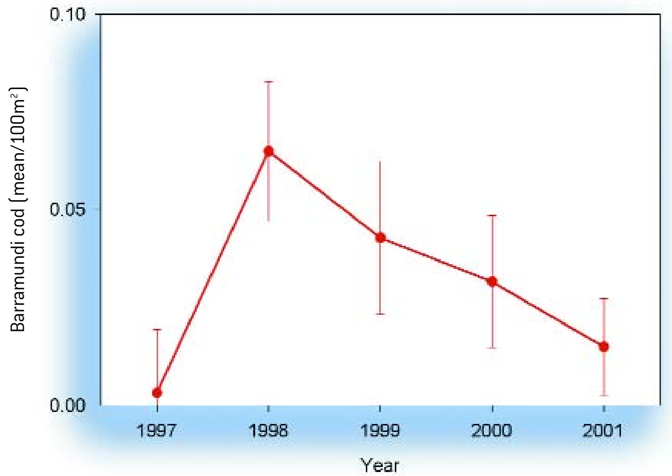


Figure 5.6: Mean abundance of barramundi cod per 100 m^2 (1997-2001) on Indo-pacific reefs.

Of the 773 reefs surveyed for barramundi cod, 95% reported zero fish and only ten sites had more than one fish per reef. The mean number of barramundi cod per reef over the five-year period was 0.03 ± 0.20 per 100 m^2 reef. Due to the typically low numbers found, the spike seen in 1998 (Figure 5.6) is primarily due to 12 fish per reef recorded at an MPA in the Sunda Islands, Indonesia.

Bumphead Parrotfish

(Bolbometopon muricatum)

The bumphead parrotfish is one of the largest members of the family Scaridae reaching 130 cm in length and up to 50 kg in weight. Due to its large size and schooling behavior, it is vulnerable to spear, net, poison and blast fishing. It is widely distributed throughout the western Pacific, Indian Ocean and Red Sea.

In the Indo-pacific, the mean number of bumphead parrotfish per reef during the period 1997-2001 was 0.25 ± 1.5 per 100 m^2. Of the 793 reefs surveyed for bumphead parrotfish in the Indo-pacific, 89% were devoid of bumphead parrotfish. The area with the highest abundance of bumphead parrotfish was the Karimun Java MPA in the Sunda Islands, just north of Java where fishing is illegal. On Cemara Kecil reef, 12 parrotfish per 100 m^2 were seen during a survey conducted in July 2000. When Reef Check teams returned one year later in July 2001, the number of bumphead parrotfish had increased to 27 per 100m^2.

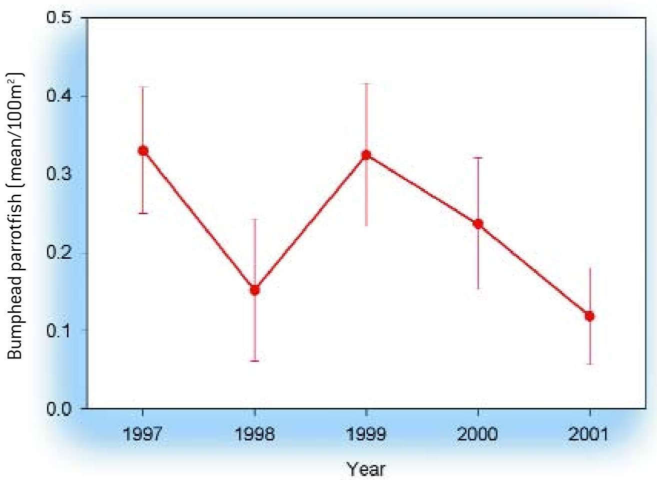


Figure 5.7: Mean abundance of bumphead parrotfish per 100 m^2 (1997-2001) on Indo-pacific reefs.

Humphead wrasse

(Chelinus undulatus)

The humphead wrasse is the most desirable and high-priced fish in the live fish trade. One large fish can be sold retail for as much as $10,000 (Lau and Parry-Jones, 1999). This labrid is widely distributed throughout the western Pacific, Indian Ocean and Red Sea and may reach 230 cm in length and 200 kg. The humphead is a predator and feeds on other fish, shellfish, urchins and crown-of-thorns starfish.

During the period 1997-2001, 88% of the 859 reefs surveyed were devoid of all humphead wrasse. The numbers of fish were consistently low across time (Figure 5.8). The peak seen in 1998 is due to three surveys that recorded relatively high numbers of humphead wrasse. In September 1998, 41 humphead wrasse per 100 m^2 were recorded during a survey done in Apo Marine Reserve, southeast of Negros, Philippines. A survey done one year later in 1999 sighted only three humphead wrasse. Surveys of the same transect in 2000 and 2001 found no humphead wrasse. Two surveys conducted in a National Park southeast of Honshu, on Togahama reef and Igaya-Katanzaki reef in July 1998 found 12-13 humphead wrasse per 100 m^2. Surveys along the same transect in 2001 reported zero humphead wrasse.

The average number of humphead wrasse per reef during the entire period was 0.14 ± 1.6 per 100 m^2. However, of the 465 humphead wrasse counted during the five-year period, 269 of those were found on the aforementioned three reefs. Since 1998, no more than five humphead wrasse have been reported on any one Reef Check survey of an Indo-pacific reef.

During the period 1997-2001, the mean number of humphead

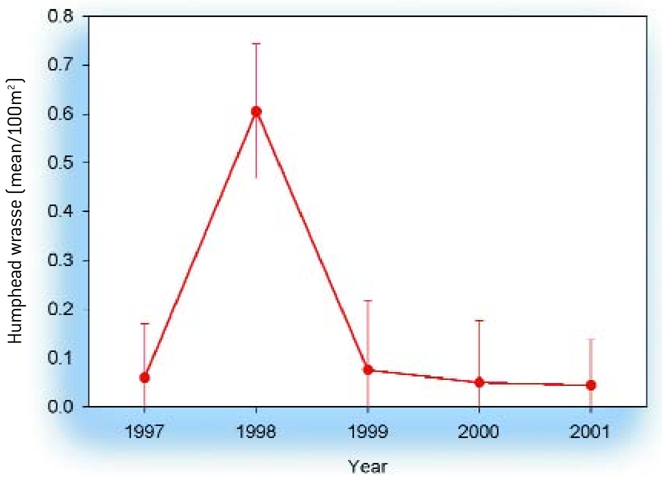


Figure 5.8: Mean abundance of humphead wrasse per 100 m^2 (1997-2001) on Indo-pacific reefs.

wrasse recorded from surveys of MPAs was 0.25 $\pm$ 2.4 per 100 m^2, whereas the mean number outside MPAs was 0.05 $\pm$ 0.22 per 100 m^2.

These findings may be due to the high value of this fish in the live food fish trade and the expanding range of long distance fishing vessels to even the most remote reefs. This species currently sells for about US $100 per kg in Hong Kong. To supply this market, diving fishermen throughout the region use sodium cyanide to stun and capture live humpheads (Johannes and Riepen, 1995).

On reefs where there was no perceived blast fishing, the numbers of humphead wrasse (0.19 $\pm$ 1.9 per 100 m^2) were twenty times higher than on the reefs with any level of blast fishing (0.02 $\pm$ 0.10 per 100 m^2) but this difference was not significant ($p=0.18$).

A similar relationship was seen between the abundance of humphead wrasse and the perceived level of poison fishing. On reefs without any perceived poison fishing, there was a mean of 0.18 $\pm$ 1.9 per 100 m^2, whereas on reefs with any perceived level of poison fishing, the number of humpheads dropped to 0.04 $\pm$ 0.14 per 100 m^2. There were no correlations between the numbers of humphead wrasse and other impacts.

Steve Oakley and colleagues have carried out very large, detailed surveys of humphead wrasse on reefs in Sarawak, Malaysia, covering hundreds of kilometers of reef front (for details see **http://tracc.org.my/**). In a survey of 44 km of heavily fished reefs, only 0.00007 fish per 100 m^2 were observed. They found only two sites in Sarawak where viable populations of fish remained, (Pulau Sipadan, 75 fish and Pulau Layang Layang, 350 fish), however, the populations were skewed indicating few young fish were joining the populations. On reefs protected for ecotourism diving operations, 0.075 fish per 100 m^2 were counted, three orders of magnitude higher than unprotected reefs.

A 1998 survey by Yeeting et al. (2001) in Bua Province, Fiji found four humphead wrasse in an area of 9.75 km^2.

The humphead wrasse is listed as "vulnerable" by the International Union for the Conservation of Nature (IUCN). This species requires urgent conservation action if it is to survive.

FISH

ATLANTIC REGIONAL INDICATORS

NASSAU GROUPER

(Epinephelus striatus)

Nassau grouper are top-level predators that can grow up to 1.2 m long and weigh up to 25 kg. Like other grouper, they grow slowly, mature late, and form seasonal spawning aggregations. These life history characteristics, combined with a high value as a food fish, have led to severe overfishing throughout the Caribbean.

Of 162 reefs surveyed for Nassau grouper, 82% were totally missing this species (Figure 5.9). Only eight reefs had more than one fish. Of the 106 total fish counted during five years of monitoring, 76 were found on two reefs in San Andres World Heritage Site in Colombia. Spearfishing is prohibited on both reefs.

A review of Nassau grouper status by Sadovy et al. (1999) indicated that there were 12 fish per ha in Bermuda in the 1950s, decreasing dramatically to the 1990s.

FIGURE 5.9: RELATIVE ABUNDANCE OF NASSAU GROUPERS

(1997-2001). NONE= 0; LOW=1; MEDIUM= 2; HIGH>2

GORGONIANS AND FLAMINGO TONGUE

(Cyphoma gibbosum)

In the Atlantic, vast areas of shallow reef are colonized by a mix of gorgonians and hard corals. While such communities exist in the Indo-pacific, they are not as common. Given that hard coral cover has been declining over the past 15 years in the Caribbean, a gorgonian category was added to Reef Check protocols in 1998. The flamingo tongue was added as an indicator of curio collecting. Sufficient sample sizes have not yet been obtained in the region to draw any conclusions about the data. However, preliminary results indicate that flamingo tongue and gorgonia abundances fluctuate proportionally, an expected result given the dependence of the flamingo tongue on sea fans, particularly ***Gorgonia flabellum*** and ***G. ventalina***, as a food source (Figure 5.10).

The highest numbers of flamingo tongue, 16.5 per 100 m^2, were found in 2001 in the British Virgin Islands on Pelican and Spyglass Reefs, within a National Park.

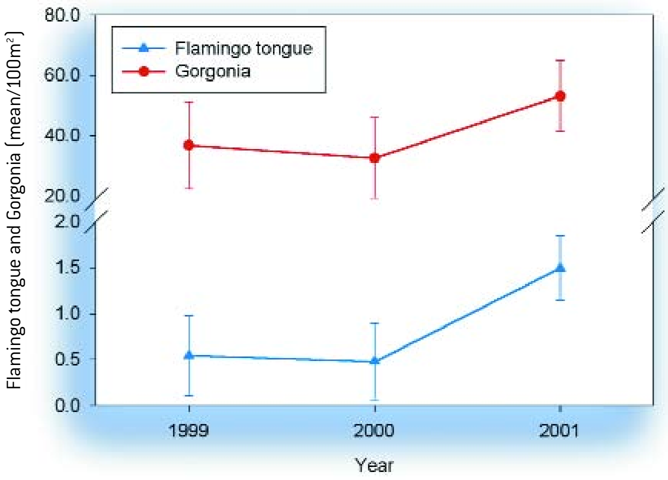


Figure 5.10: Mean abundance of flamingo tongues and ***gorgonia*** per 100 m^2 (1999-2001) on Atlantic reefs.

Photos courtesy of:
Crown of thorns: Jeff Jeffords
Giant Clam: Brian Bielmann for the Crossing, Quiksilver International
Sea cucumber: Gregor Hodgson
Barramundi cod: Ken Leonard
Bumphead parrotfish: Steve Turek
Humphead wrasse: Niki Papakonstantinou
Nassau Grouper: Jack Randall
Gorgonia with flamingo toungue: Claudine T. Bartels

Chapter 6 PUBLIC AWARENESS & EDUCATION

Photo by Jeff Jeffords

A major focus of this report so far was to present the results of five years of coral reef monitoring covered in Chapters Four and Five.

An important aspect of Reef Check is raising public awareness about coral reefs and educating stakeholders about how to monitor and manage reefs from the grassroots level. This chapter is a summary of how Reef Check is implementing the education components.

Reef Check began as a scientific method of tracking global changes in coral reef health, but it quickly developed into an international environmental organization with the broader goals of educating the public about the coral reef crisis, as well as providing training on how to implement solutions.

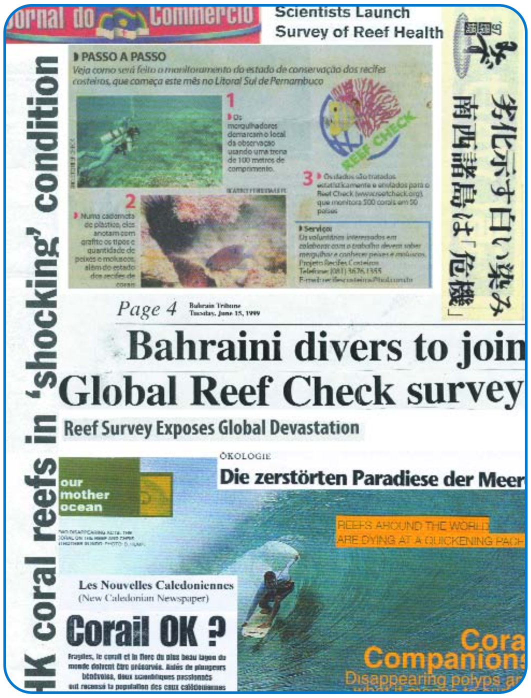
Reef Check is the only program to define and measure reef health using a standard method on a global scale. Reef Check achieves its goals through scientific research and a public education program, training workshops, presentations at scientific and management meetings, annual events such as press conferences, an international Dive In, and dive expeditions including the Quiksilver Crossing, television and film productions. Each of the education components of Reef Check is discussed below. The target groups are the general public, end-users, politicians and managers, and scientists.

Public Awareness Activities

Prior to 1997, coral reefs were rarely featured in the international press. The successful completion and analysis of the 1997 survey revealed a global coral reef crisis that required immediate attention. Consequently, a press conference was held in Hong Kong to quickly publicize the results to governments and international organizations. The first press release on October 16, 1997 stated, "The preliminary results from about 230 sites are being released today because they reveal such a clear pattern of global damage to coral reefs, particularly due to overfishing and destructive fishing." National coordinators in several countries held simultaneous local press events to publicize their results.

"In Bahrain, Reef Check provided the only time series data on the condition of local coral reefs. It was the only measurement available for the unprecedented coral bleaching event in 1998."
– K. Roger Uwate, Ph.D.

This approach successfully attracted a high level of media attention. The results from the first Reef Check survey were featured in most major print media, radio and television around the world in dozens of languages. Media coverage was given by all of the major international television networks including BBC, CNBC and CNN, as well as national networks such as RTK (Japan), CTV (China), NBC (USA), and GBF (Germany). Print media coverage was extensive, and often front-page, in dozens of languages with major stories in publications such as USA Today, The Independent



Media coverage from around the world.

(London), Le Figaro (France), and Sydney Morning Herald (Australia). Since 1997, the global media coverage of Reef Check and the coral reef crisis have expanded. Many other influential publications such as Reefs at Risk (Bryant et al., 1998) have supported the initial results of Reef Check.

Reef Check training programs provide guidance on how to publicize results and activities on the community and local level. As a result, many teams have been very successful in generating media coverage of their activities, ultimately generating public support and funding.

In addition to providing material to the media, Reef Check has sought corporate partners, such as Quiksilver and MacGillivray Freeman Films, in an effort to get the message out to the general public. Reef Check is partnering with other organizations to help produce two public service announcements that focus on the "shifting baseline" problem and the coral reef crisis. These campaigns will direct interested people to the Reef Check website for further information on how to help reefs or to become a member of Reef Check.

Education of End Users

Reef Check provides training workshops and materials to end users, people who are either members of Reef Check teams, or stakeholders. This year, with funding from US AID, Reef Check will be setting up an interactive website that will allow teams to compare their results with previous results from their reef and other locations.

A major goal is to establish regional training centers in the major coral reef regions. Since 2000, a Regional Training Center was established in Phuket, Thailand to serve SE Asia (see page 54). Centers in the Caribbean and East Africa are next in line. Dozens of training workshops have been carried out over the past five years at the national and regional levels throughout the world. These workshops provide training in the Reef Check protocol as well as other more taxonomically detailed protocols as desired by the trainees.

Ideally, after attending a training, the participants would return to their home areas and set up long-term reef monitoring programs. To facilitate this, Reef Check provides seed money for new teams. In addition, the training includes a component on fundraising. Volunteer coordinators donate their valuable time and energies to monitoring and management efforts. In order to ensure that efforts continue in perpetuity, funding is necessary to establish a paid coordinator in each country.

From Left: Thailand RC scientist Niphon Phongsuan, RC Vietnam coordinator Vo Si Tuan, RC Philippines coordinator Laurie Raymundo, RC Indonesia coordinator Abigail Moore, RC Program Manager Jennifer Liebeler, RC Thailand coordinator Pinya Sarasas.

As part of some of the workshops, additional training components have been provided on coral reef and related ecosystem management. This year, a rapid assessment protocol for socioeconomic monitoring is being designed with NOAA and will become a standard part of the Reef Check training course.

Science As Education

One objective of Reef Check is to carry out scientific research on the basic and applied questions affecting reef health, and to publish these results in scientific journals in order to disseminate information to the scientific community (Hodgson, 2000; 2001). In addition, as a major partner of the Global Coral Reef Monitoring Network (GCRMN), Reef Check supplies metadata to regional databases and for use in periodic GCRMN status reports, the most recent being "Status of Coral Reefs of the World: 2000" (Wilkinson, 2000).

A wide array of key scientific questions has arisen during the course of the research. These range across various fields from biology, to education, to socio-economics and include:

- What is the natural population range for indicator organisms in the absence of human predation and other anthropogenic impacts?
- What sample size is "adequate" for long-term monitoring of individual reefs in different areas?
- What are the best indicators for overall reef health?
- What is the best formula to test whether a trainee has learned the methods?
- How to motivate people to act once they have the knowledge about an environmental problem?

Graduate students at several universities are studying these questions.

Reef Check has also provided advice to numerous countries on how to establish long-term monitoring programs. Very detailed and expensive monitoring programs are not feasible in developing countries without large external funding inputs. Neither Reef Check nor any other organization will be able to pay for all the monitoring work that should be done globally to track reef health. Therefore at some point, local private or governmental groups will have to take on this role. The only possible mechanism to sustain a large program is to run it on a volunteer basis. Therefore, a sensible approach for most countries is to start with a modest community-based program, achieve sustainability, and then expand their programs to include more detailed monitoring.

An example of how raising public awareness and providing education to stakeholders can to lead to effective management can be seen at the Gilutongan Marine Sanctuary. The 15-hectare Gilutongan MPA has become one of the most popular diving sites in the Cebu area since being formally established in 1998. In 1999, Reef Check methods were integrated into the monitoring activities for selected MPAs that directly involved the training and participation of local community members. These participants have now seen and realized first-hand the impressive results of protecting their reefs and are helping to enforce protection.

As a result, coral and fish life have improved dramatically since 1999 and the reef is now home to many large target species of fish, such as "jacks" and groupers, that are rarely seen on unprotected reefs in the area. To help support protection, user fees were introduced for divers and snorkelers visiting the sanctuary. These fees, averaging about US $1 per diver, now generate about US $20,000 per year for the local community, which uses the funds to support operation of the sanctuary as well as other related activities identified by the community. In addition to this "direct" source of new community income, an "indirect" source of income was introduced by helping to organize the local fishermen into a cooperative that helps to enforce the sanctuary rules while also serving as vendors to the visiting tourists.

Raising public awareness and educating stakeholders will continue to be a major priority for Reef Check. New ways of getting the word out are continually being sought, and this depends on establishing partnerships.

Reef Check runs education programs for all age groups. Here a preschooler from Los Angeles, California gets her first look at a starfish. Photo by Jennifer Liebeler.

Reef Check Regional Training Center, Phuket Marine Biological Center

The Reef Check Southeast Asian Regional Training Center has been in operation at the Phuket Marine Biological Center (PMBC) since early 2001. Funded by a grant from the US Agency for International Development, East Asia Pacific Environment Initiative, the center hosted its first group of international trainees in June 2001. Participants in this workshop included representatives from Indonesia, Cambodia, China, Vietnam and Thailand. Dive shop operators from Thailand, Indonesia, and Malaysia also attended, along with volunteers from England, Canada, and the USA.

Sporting their new "Reef Check Thailand" caps, workshop participants gather in front of the R/V Chakrathong Thongya, about to embark on a 3- day mission to survey the reefs in Thon Sai Bay. Photo by Jennifer Liebeler.

During this first workshop, PMBC senior scientist, Dr. Hansa Chansang, Thai RC coordinator Pinya Sarasas, and RC Thailand scientist Niphon Phongsuwan, received awards from RC Program Manager Jennifer Liebeler for their dedication and work in setting up the regional training center.

Subsequent training programs have followed the model tested during this first training. Workshop participants spend two days in the classroom, where they learn the basics of Reef Check methodology and organism identification. On the second day, each participant presents a short discussion about coral reef ecology and conservation in their country or region. Following the classroom sessions, participants spend three days in the field, conducting Reef Check surveys on snorkel and SCUBA. This time is used to discuss training techniques and identify and correct any knowledge deficiencies. At the end of the five day training program, participants who have mastered the techniques are certified as Reef Check trainers and are required to train at least five people in their home regions and conduct at least ten Reef Check surveys over the course of the next year. This method has proved very effective in expanding Reef Check monitoring, education, and management programs in Southeast Asia.

In Thailand itself, national level training has also been carried out at PMBC and the number of Thai surveys has increased ten fold, a direct result of the training workshops held at PMBC.

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

REEF CHECK IS DEFINED BY ITS PARTNERSHIPS WITH GOVERNMENT AGENCIES, THE PRIVATE SECTOR AND NON-PROFIT GROUPS. THIS DIVERSITY OF PARTNERSHIPS IS THE STRENGTH OF THE PROGRAM AND CAN ALSO BE A WEAKNESS.

Government Partnerships

At the international level, Reef Check partners with the International Coral Reef Initiative (ICRI) , an umbrella organization for coral reef activities that provides a forum for groups and nations interested in coral reef issues. The current ICRI Secretariat is shared by Sweden and the Philippines. Within ICRI there is the GCRMN, led by Clive Wilkinson and funded by several governments, the United Nations International Oceanographic Commission and NGOs.

In 1998, the GCRMN chose the Reef Check protocol to serve as its community-based monitoring program. The present arrangement for collaboration is that GCRMN collects metadata, publishes status reports on global reef health, and networks with governments to try to set up coral reef monitoring initiatives.

From the perspective of GCRMN, the role of Reef Check is to:

1. organize regional training centers and run regular training programs in all aspects of coral reef monitoring and management;
2. facilitate the establishment of a global network of community-based monitoring teams;
3. support and assist the collection, management and storage of coral reef monitoring data using the standardized Reef Check method, and
4. analyze and report on the monitoring results.

By linking the two programs under ICRI, a complementary partnership was formed. In practice, this means that the network of national coordinators is shared, and all GCRMN training starts with Reef Check methods and proceeds to more detailed methods of use to highly trained government technical teams. In the future, each coral reef country will have a large number of Reef Check sites, monitored by local residents as well as other stakeholders, with smaller numbers of sites monitored in more taxonomic detail by government teams. The Reef Check network thus acts as an "early warning" system.

Reef Check also has partnerships with international organizations such as UNEP Regional Seas (Caribbean, East Africa and SE Asia), PERSGA, SACEP, UNESCO, World Bank, and UNDP to name a few. In general, these organizations respond to requests from countries for assistance in setting up coral reef monitoring training workshops and provide the funding to allow Reef Check to facilitate the activities using local trainers.

NGO Partnerships

Several existing bilateral coastal management projects and numerous national government agencies and NGOs have incorporated Reef Check into their monitoring and management work. This institutionalization of Reef Check has occurred with the help of the US Agency for International Development, NOAA/NOS, US Peace Corps and numerous non-governmental organizations such as Worldwide Fund for Nature (WWF), the Coral Reef Alliance (CORAL), Coral Cay, Reefkeeper, CANARI, Frontier and many others.

A specific example of such an alliance is a partnership created with the Marine Aquarium Council (MAC) to carry out the basic science and monitoring needed to manage the aquarium trade in a sustainable manner. MAC is an international, not-for-profit organization that brings marine aquarium animal collectors, exporters, importers and retailers together with aquarium keepers, public aquariums, conservation organizations and government agencies. MAC's mission is to conserve coral reefs and other marine ecosystems by creating standards and educating and certifying those engaged in the collection and care of ornamental marine life (**www.aquariumcouncil.org**).

MAC has stepped in to provide a form of self-regulation within the industry to prevent the regulatory challenges that might arise should severe restrictions force the aquarium trade underground. Using the rational behind the "green" certification within the timber industry, MAC expects to use the certification process to create a sustainable industry by providing consumers with the option of buying a certified fish. The goal is that over a period of several years, certified companies will supply higher quality fish that will dominate the market and the demand for certified fish will prevent the sale of cheaper, uncertified fish.

Through its programs, MAC is working to raise public awareness about the industry's role in conservation and establish independent standards and certification of "best practices". By providing objective and accurate data on the marine ornamental trade and ensuring the health and quality of marine life through responsible collection, handling, and transportation practices, MAC hopes to ensure quality and sustainability in the aquarium industry.

In order to test how MAC certified collectors are affecting the sustainability of coral reefs and associated organisms, Reef Check has reviewed information on aquarium trade organisms, collection levels, and source areas and drafted both a set of monitoring protocols and a list of organisms to be used in the monitoring program. Two workshops have been held to review the monitoring methods and species included in the preliminary stages of the certification and monitoring. The workshops in Jakarta, Indonesia (April 2001) and in Honolulu, Hawaii (July 2001) resulted in The Marine Aquarium Trade Coral Reef Monitoring Protocol and species list (MAQTRAC). MAQTRAC was field tested in the Maldives and Indonesia during summer 2001 and is currently being implemented in Indonesia, the Philippines, and Fiji to establish a series of management plans for reefs subject to aquarium trade collections.

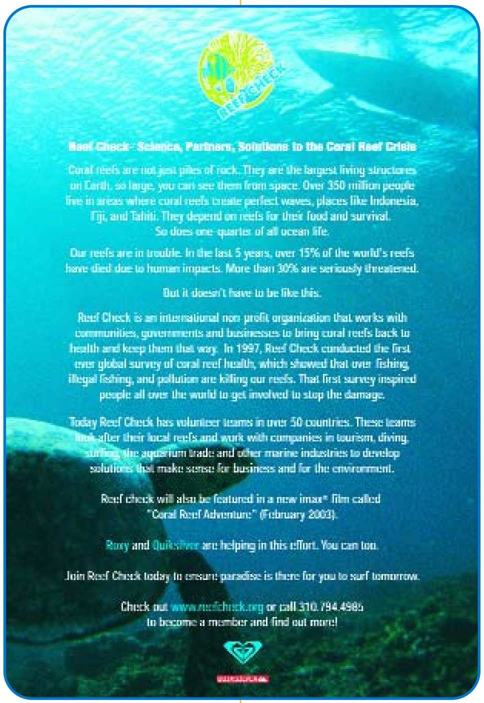
Aquarium fishermen collect using nets. Photo courtesy of Lynn Funkhouser.

Corporate Partnerships

Recently, Reef Check has established the first in a series of strategic partnerships with the private sector. The advantage of these collaborations is the potential for co-marketing.

Quiksilver, a leading clothing and surf brand, and MacGillivray Freeman Films (MFF), the innovative producer of IMAX films, have joined forces with Reef Check to form a powerful coalition. These marketing and film innovators are sending an urgent message to their audiences to preserve and restore the world's coral reefs as well as the overall wellness of our ocean planet. Through a series of Reef Check supported special events, promotions, and educational programs, these corporations are maximizing their combined reach to convey the need to protect the health of the planet with a simple marketing slogan, "***How Good Is This?***" In essence, coral reefs and the life and beauty they support are worth saving.

Quiksilver's continuing desire and commitment to give back to the communities that have hosted the surfing culture has resulted in a company-wide initiative named "The Crossing". "The Crossing" is the circumnavigation by a 72-foot exploratory vessel, ***Indies Trader***, to find remote surf spots. By providing a berth for a Reef Check scientist on several legs of this trip, Quiksilver has established a floating research station. The vessel has allowed the company and researchers to access previously unreachable reefs, as well as an audience that may have never thought about what is beneath the surf (See Box "In Search of Pristine Reefs"). Quiksilver has also designed a line of limited edition t-shirts to promote Reef Check to its customers, supporting coral reef conservation amongst a younger and more diverse audience. MFF succeeds in transporting its audience underwater in their newest IMAX film, ***The Coral Reef Adventure***. Following release in 2003, the Quiksilver Crossing and Reef Check will be highlighted on the IMAX screen. This film is one of the best available mechanisms to deliver a coral reef conservation message to the general public. Reef Check's message will also be distributed in the form of educational materials that will be placed in museums and schools across North America. Reef Check helped to develop a museum research guide, a teacher's guide, a family fun guide and interactive website material as one of the primary scientific contributors.



This postcard is being distributed worldwide as part of a partnership between Reef Check, Quiksilver, and MacGillivray Freeman Films and provides an example of how co-marketing can be used to help get the message out.
Image by Dianne Young.

In Search of "Pristine" Reefs
The Reef Check/Quiksilver Partnership

By Craig Shuman

The Indies Trader anchored off-shore a remote island. The Trader has made an excellent platform for Reef Check scientists to survey remote reefs. Photo courtesy of Jeff Hornbaker, for The Crossing, Quiksilver International.

A fundamental problem facing coral reef managers is determining the ecological goals of management. What balance of species and abundances should the well-managed reef have? Ideally, nearby pristine reefs that have not been influenced by humans could be used as a model. Unfortunately, pristine reefs are rare, and recent work suggests that humans have had a much greater impact on diverse marine systems for far longer than had previously been believed (Jackson et al. 2001).

Despite the long history of human exploitation of coral reefs, there may exist isolated pockets that have been spared from most human impacts giving a glimpse of what "once may have been."

If they exist, these "near-pristine" reefs must be few in number, small in size, isolated from anthropogenic activities and thus, difficult to identify. If an attempt were made to mount a standard scientific expedition to find such reefs, the risks and costs would be enormous. An alternative would be to find a "ship of convenience" on which to hitch a ride, much like the ***Indies Trader***.

After leaving Papua New Guinea in 1999, the ***Indies Trader*** crisscrossed the South Pacific and surveys were carried out at numerous remote reefs. During this time, Reef Check scientists began to truly understand the far-reaching effects of human impacts, a realization that would become increasingly clear through the voyage. In Fiji, for example, a series of seemingly non-impacted reefs were surveyed under the assumption that their distance from population centers would result in high overall species densities. However, only one of these reefs was found to contain high densities of fish and invertebrate indicators.

The summer of 2001 was spent throughout the Indian Ocean and continued to provide information on the extent of coral recovery from the catastrophic 1998 bleaching event (thought to be caused by a coinciding El Niño event), effectiveness of management activities employed by different countries, and the location of remote "pristine" reefs.

The living corals were found to face some surprising threats. For example, the widespread forest fires on the island of Sumatra in Indonesia may have resulted in a large-scale coral die off as a result of increased sedimentation and an algal bloom induced by nutrient enrichment. Reefs in the Maldives experienced extensive bleaching, which has been linked to the elevated seawater temperatures observed in the area. Overall, reefs in Indonesia and the Maldives had similar live coral cover while those in Madagascar were spared the effects of the 1998 El Niño. Surprisingly, the remote reefs located in Chagos and the Seychelles displayed higher hard coral cover despite being in the region that was influenced by elevated seawater temperatures. Densities of fish and invertebrates tended to show a more consistent pattern. Remote reefs in Chagos and the Seychelles exhibited the highest density of almost all fish and invertebrate indicators.

The high mobility of this research platform has also allowed comparisons over broad geographic areas to help determine what factors may be responsible for the ecological trends detected by the surveys. Although uninhabited, the reefs in Chagos were not as free from human impacts as would have initially been expected, and in this case, being remote may have increased the extent of exploitation. The absence of infrastructure to ensure fishing activities were sustainable or in accordance with local regulations allowed large-scale commercial dory fishing operations to harvest live grouper at alarming rates. Consequently, observed grouper densities were relatively low, while densities of other indicators, such as giant clams, were extremely high. A series of reefs in the Seychelles provided an example of how the fine balance between remoteness and enforcement may be the most effective way to protect coral reef resources. The high abundance of most indicator organisms observed on these reefs was most likely due to the protection afforded to them by the small local population residing on the nearby islands. With a total population of 25, the inhabitants exerted minimal pressure on reef resources for subsistence while being able to alert government authorities to the presence of illegal commercial fishing operations.

Since the inception of the "The Crossing" in 1999, 117 reefs have been surveyed by eleven different marine biologists. This voyage has been and will continue to provide Reef Check scientists the opportunity to scour the globe in search of "pristine" reefs. Once identified, these reefs can be revisited by scientists for research purposes. In addition, identification of such reefs can lead to protection from long-range commercial fishing fleets that are concurrently searching the globe to exploit marine resources. In addition to providing valuable scientific data, the presence of Reef Check scientists onboard "The Crossing" has greatly extended the education and awareness of coral reefs. Many of the world's leading surfers have participated in Reef Checks during the voyage and have now become spokespersons for the conservation and awareness of threats to coral reefs.

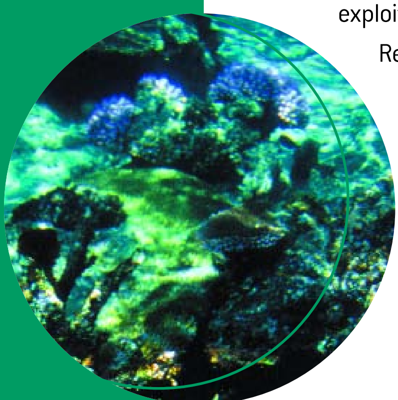


Photo courtesy of Brian Bielmann for The Crossing, Quiksilver International.

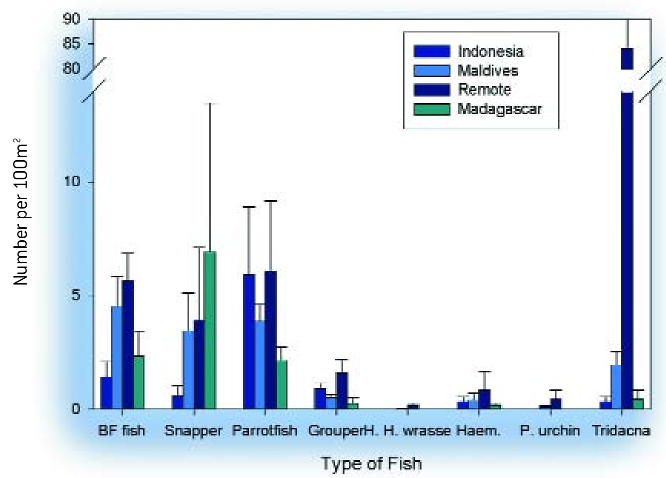


Figure 7.1: Abundance of RC indicators.

Quiksilver has recently announced the extension of "The Crossing" for an additional five years to complete a circumnavigation. Due to the unique scientific opportunities available during such a voyage, Quiksilver will continue to provide a berth to a Reef Check scientist for the duration of the journey. This distinctive marriage between private sector corporate resources and science, combined with the thirst for exploration, will continue to help marine scientists answer the important question: What are the characteristics of a well-managed reef?

For more information regarding "The Crossing" go to:
www.quiksilver.com. "The Crossing"

Photo courtesy of Don King for The Crossing, Quiksilver International.

Chapter 8 MONITORING & MANAGING THE WORLD'S

courtesy of Coral Reef Adventure, MacGillivray Freeman Films

A review of the first five years of Reef Check indicates that a program based on coral reef education, monitoring, and management works well. Participation in Reef Check is often the first step towards sustainable management of reefs. Yet many challenges still remain. In this concluding chapter, the goals of Reef Check will be revisited and progress evaluated.

The fundamental goal of Reef Check is to reverse the coral reef crisis and to facilitate the rehabilitation of reefs worldwide. The ingredients required for success include:

- International cooperation to unite regional and global efforts
- A national government legal framework for reef management in every coral reef country
- Increased public understanding and support for management initiatives
- Partnerships among governments, private sector, academia and NGOs to carry out monitoring and management programs
- Funding and trained personnel willing to carry out the work

Some 350 million people depend directly upon coral reefs on a daily basis for food and other resources. Unfortunately, most of these people and their reefs are located in developing countries that have a relatively small voice on the global political stage. Even in developed countries with large coral reef resources, such as France and the United States, most citizens are not aware of these assets, let alone realize that their reefs are facing a crisis.

Ultimately, solving the coral reef crisis will require a global environmental campaign to raise public awareness, similar to those that have focused attention on the plight of the rainforests, tigers, panda bears and whales. Only when everyday people throughout the world become aware of the coral reef crisis and why it may affect them personally, will it be possible to successfully garner the political and economic support needed to implement government management programs.

International programs alone cannot solve the coral reef crisis because they lack the legal mandate to manage resources within countries. Strong national coral reef initiatives are required to form the framework for reef management at the local level. Both ICRI and GCRMN can, and have been addressing these needs through meetings and workshops, but far more work is needed to push national governments to set up reef management groups. The Philippines has developed a set of laws that give control of coastal reefs to local governments, thus resolving the "tragedy of the commons" situation by allowing the establishment of municipal MPAs and fishing grounds. The US Coral Reef Task Force may provide a useful model for a national government inter-agency management group specifically formed to address coral reef issues.

Reef Check has been contributing to the above tasks in the following four areas: monitoring and reef science, education and training, public awareness, and management.

Monitoring and Reef Science

Anyone who has flown over the Caribbean or Micronesia can attest to the size of the problem facing those wishing to implement a country or region-wide monitoring and management program for coral reefs. Even from an airplane, the reefs appear endless. The reality is that there are a large number of coral reefs spread over an immense area. Attempting to monitor even a small fraction of the world's reefs is a huge challenge.

To meet this challenge, it is necessary to revisit the rationale for monitoring in the first place and answer the following questions. What types of data and/or information are really needed? Who needs them? Is a standard method really needed at this scale?

A sensible approach is to establish a broad brush, inexpensive, and rapid method so that the maximum number of sample sites can be monitored to gain a geographically widespread dataset from a given country. As the technical teams gain more skills and funding, they can expand their monitoring through addition of indicators or more taxonomic specificity as needed. With this basic "early warning system" design, if a problem is detected, a more highly trained scientific team can be dispatched to investigate in detail.

Sadly, what has often occurred is that funds are spent only on intensive, detailed protocols such that the costs are high and only a few sites can be monitored for a short time. Allowing scientists to control the design of a monitoring program in the absence of input from managers and stakeholders is not wise.

Attempts to cross compare Reef Check data with, for example, the AIMS monitoring program COTS numbers or the ***Diadema*** results from early surveys in the Caribbean are problematic due to issues with timing and scale. Density estimates based on different scales of sampling often are not comparable. If there is a good reason to want to track changes at a national, regional or global level, then a standard sampling method is required.

A summary evaluation of Reef Check monitoring is given below.

Successes	Challenges
1. Global network established 2. Standard field methods 3. Results useful for both science and managers 4. Multiple languages	1. Add new countries 2. Find and implement sustainability mechanisms 3. Increase sample size within each country 4. Provide training on analysis and interpretation 5. Create interactive website 6. Turn-key training 7. Repeatability

Table 8.1: Successes and future challenges for Reef Check monitoring.

On the success side, the worldwide network is well established and standard field methods have been distributed in many languages. The results of the monitoring have been disseminated to the general public via the media and to scientists through scientific publications.

On the challenge side, there is a need to expand into new countries, particularly in Africa, Central America and South Asia, and to increase the sample size of sites within each country. Finding sustainable funding mechanisms is a major constraint on the program. New training modules are needed for rapid socioeconomic assessment (currently being developed), data analysis and interpretation. An interactive website to be produced this year will provide a new level of data analysis and support for teams in the field. In general, all training and monitoring should be "turn-key" i.e. should be standardized and replicable.

Education and Training

There is a fundamental need to give communities a complete set of tools and training so that they can monitor and manage their own reefs. Progress towards making Reef Check available through existing coastal management and coral reef programs has been rapid, but far more work is needed to expand the network and provide the training needed to use the tools.

"Many of our members have been involved in the Reef Check/CAFNEC community based coral reef monitoring project and found it educational and rewarding. We have learned a great deal about marine ecology and applied it directly to the reefs we visit. The education and practice of observation and monitoring have ensured that we now see far more of what is there than before the training and education. We have become more alert to and considerate of the reef and take greater care in diving." - Nautilus Scuba Club, Cairns, Australia

Guidelines on necessary additions of spatial and temporal replicates for long-term monitoring are available (Hodgson and Stepath, 1999). Temporal replication is especially important for monitoring mobile fish populations. The second step is to make use of existing projects and programs to spread Reef Check to communities around the world.

Successes	Challenges
1. Regional training workshops 2. Support from international and national groups 3. Brazil kids education center	1. Find and implement sustainability mechanisms 2. Create video training material 3. Develop K-12 education materials 4. Create interactive website 5. Turn-key training

Table 8.2: Successes and future challenges for Reef Check education and training.

Public Awareness

The public awareness campaign has been highly effective despite limited resources. The initial monitoring was a "first" and so was of interest to the press. The global crisis and the bleaching event were news stories that were covered by major news media. The current partnerships with Quiksilver and MacGillivray Freeman Films are just starting to inject major funding and expertise into the public awareness campaign. Educational materials are also being developed as part of this campaign.

In addition, major celebrities have volunteered time and energy to help with the public awareness campaign. There are also many other potential collaborations that can be developed with corporations.

Successes	Challenges
1. Media coverage of crises 2. Partnerships starting 3. Coral Reef Adventure 4. The Crossing	1. Find a high profile spokesperson for reefs 2. Develop more corporate partners in relevant industries 3. Documentary of Reef Check

Table 8.3 Successes and future challenges for Reef Check public awareness.

In conclusion, one of the most important results of the first five years of monitoring is the demonstration that MPAs in developing countries are starting to work. This provides a glimmer of hope that it is still possible to stop the coral reef crisis and allow coral reefs to recover and flourish.

Reef Check in Europe

by Georg Heiss, RC Europe

Reef Check activities in Europe started in the International Year of the Reef (1997) in Germany, France, Switzerland, and the UK, and were primarily aimed at raising public awareness among Europeans regarding the threats to coral reefs worldwide. Scientists from several European countries organized Reef Check surveys in the Red Sea and the Indian Ocean. They found support from research institutions, corporate sponsors and the diving industry in Europe, and also from authorities and the tourism sector in the countries where surveys were conducted.

Reef Check Europe was founded in 2000 to expand education and public relations activities in Europe. Field activities are primarily focused in the Red Sea. However, scientists from Europe, in conjunction with local groups, also carried out Reef Check surveys in the Comoro Islands, La Réunion, Maldives, Mauritius, Myanmar, Thailand, Seychelles, and the Philippines. A dedicated website (**www.reefcheck.de**) was set up, and in 2001 Reef Check was founded as a non-for-profit organization under German law. The long-term goal of Reef Check Europe is to unite together marine scientists and sport divers, as well as funding agencies and the tourism industry, both from European and coral reef countries, in a sustainable effort to continue and expand Reef Check surveys and accompanying public awareness campaigns.

Reef Check Europe represents the Reef Check organization at scientific conferences and public events. The organization also works together with other coral reef NGOs and serves as a regional coordinator of the global Reef Check network, which brings together interested volunteers and scientists, and offers assistance in setting up of Reef Check surveys and training workshops.

Divers wave before descending underwater to survey the reefs of the Soufriere Marine Management Area in St. Lucia.
Photo by Gregor Hodgson

Barbados

Barbados is the easternmost island in the Caribbean, located south of St. Lucia and just east of St. Vincent. The island covers 430 sq km (166 sq mi) and is the second most densely populated island in the world with over 250,000 people who depend on the island's coastal resources, primarily for tourism. In the geological past, Barbados was comprised of two islands that merged later into one. Today, Barbados is a low island featuring numerous beautiful white sand beaches. Along the North coast, coral and sandstone cliffs rise straight out of the sea for several hundred feet.

RC coordinator Andre Miller explains to a new volunteer how to use a PVC pipe to measure distances underwater. Photo courtesy of RC Barbados.

RC Barbados has been active since it was kicked off by the Coral Court Hotel Team of Barbados Marine Trust in 1997. Since then, it has become part of the Barbados Coastal Management Unit's coral monitoring program and has established solid partnerships with other organizations such as Mauby Divers, and PADI project AWARE. These various groups have come together to work hard on achieving their common goal – to ensure that Barbados' coral reefs are healthy and sustainable. Other local hotels such as Casuarina, Royal Pavilion/Glitter Bay, and Treasure Beach have also become involved with helping to protect Barbados' coastal ecosystem through joint beach cleanups and community education efforts.

Last Earth Day (2001), RC Barbados, led by Loreto Duffy Meyers and Renata Goodridge, together with their partner organizations, surveyed four sites on the west coast and Carlisle Bay. They were overwhelmed with volunteers who were eager to participate in the event. Results from these surveys showed a general improvement in reef health since 1997.

The mean percentage of dead coral cover decreased from 31 ± 17 % to 0.2 ± 0.07%. There was no significant change over time in the hard coral cover, which averaged 16 ± 9% across all years. Abundance of almost all indicator organisms increased from 1997 to 2001, with the notable exception of ***Diadema*** and parrotfish. The mean number of ***Diadema*** per 100 m^2 reef decreased from 103 ± 136 in 1997 to 7.25 ± 12.5 in 2001 and the mean number of parrotfish decreased from 5.25 ± 6.2 per 100 m^2 reef in 1997 to 1.75 ± 1.76 per 100 m^2 reef in 2001.

Overall, the twelve reefs in Barbados surveyed by Reef Check were primarily composed of sand (17.9 ± 3.0%) followed by hard coral (16.9 ± 2.6%).

Brazil

One of our newest teams, Reef Check Brazil, was started in 2001 by Dr. Beatrice Padovani Ferreira, Departamento de Oceanografia, Universidade Federal de Pernambuco in Recife. In the past year, Beatrice has recruited 65 volunteers, including divers, students, researchers, fishermen, and members of the local community. The group's activities have included surveys in five different reefs of Tamandaré in the Coral Coast MPA. A team of land-based volunteers has also joined Reef Check and has been running beach cleanups. During Earth Day 2001, the group removed 15 bags of garbage from a local beach.

RC Brazil has received funding from PROBIO, a division of the Brazilian Ministry of Environment, to monitor the 3,000 km of reef along the Northeastern coast. Four pilot locations have been selected: Abrolhos Reef, Fernando de Noronha Archipelago, the Coral Coast MPA and the Maracajaú Reefs. Monitoring has started in the southernmost of the four sites, the Abrolhos complex, which has the largest and most diverse coral formations in the area, including seven endemic species of coral. The Abrolhos complex has been part of a marine park since 1983 and is a popular tourist destination. In addition to surveying the reefs and collecting valuable data, Beatrice and her colleagues have built a remarkable Reef Check team by recruiting local dive operators, park rangers, and environmental managers from around the area.

Another exciting project founded by RC Brazil is the Reef Check Center for Kids, a project helping to educate Brazilian children about coral reef biology and solutions to the impacts threatening Brazil's coral reefs. During 2001, with funds from the Boticario Foundation, the Center pioneered an environmental education program that educated 600 school children about ornamental fish, which are over-fished in the region.

Beatrice and her team would like to thank the Brazilian Institute of Environment, Aratur turismo and all the volunteers who have been helping them. RC Brazil has also received support from the Project Coastal Reefs, an integrated coastal management project executed by the Federal University of Pernambuco, Center of Research and Fishing Extension of the Northeast, Ibama, Foundation Sea Mammals and Interamerican Development Bank.

Cocos Keeling Islands

Cocos (Keeling) is a remote coral atoll made up of 27 islands surrounding a central turquoise-colored lagoon. These reefs are some of the most remote in the world, situated in the Indian Ocean 2,950 km northwest of Perth, Australia and 900 km southwest of Christmas Island.

> Through my investigations of many different types of reef monitoringTechniques, I have found that Reef Check provides a statistically viable survey technique that is not too complex and can be undertaken by non-scientists and involves all reef lovers. It is fun to dive our reefs and search for all the indicator organisms while conducting our surveys."
> – Robert (Greenie) Thorn, Parks Australia

The 27 islands are formed on two small, isolated mid-oceanic atolls. One solitary island 24 km to the north of the main atoll is North Keeling, now known as Pulu Keeling National Park. A population of only 600 Malay and 100 government servants from Australia inhabits two of the 27 islands. The 26 islands that make up the southern atoll cover a total landmass of just 14 km^2. The islands have been a focus of coral atoll research since Charles Darwin visited in April 1836. On his voyage home after a three-year journey aboard the ***HMS Beagle***, Darwin stayed on Cocos for ten days and recorded evidence to support his theory of coral atoll formation.

Robert (Greenie) Thorn has been the volunteer Reef Check coordinator on Cocos since it started in 1997. Greenie is a horticulturalist and conservationist who works for Parks Australia. With the help of volunteer Wendy Murray, Greenie organizes a yearly Clean Up Australia Day with activities on land and underwater around Cocos and assist the Cocos school with environmental activities such as surveying fish nursery areas and leading discussions on endangered species. Additional Reef Check activities in Cocos include working with various clubs, private businesses and other government and non-government agencies to install mooring buoys around the islands for commercial dive operations. The program has installed 23 public moorings at nine locations around Cocos. During Reef Check surveys, only four incidences of coral damage from anchors were observed on all reefs, an indication that the mooring program has been effective.

Reef Check teams have been conducting yearly surveys of Cabbage Patch reef since 1997. Numbers of organisms have remained consistent over time. The site has been devoid of snapper, barramundi cod, bumphead parrotfish and lobster for five years. Historically, Indonesians fished the area. However, giant clams are abundant and have been found each year, with a mean of 16.0 ± 12.9 per 100 m^2 reef. Similarly, sea cucumbers have been found each year, with a mean of 5.8 ± 6.9 per 100 m^2 reef.

Commonwealth of the Northern Mariana Islands (Saipan and Rota)

The Commonwealth of the Northern Mariana Islands (CNMI) is a chain of 15 islands, with most of the population centered on Saipan, Rota, and Tinian. All islands have well-developed fringing reefs, and feature 254 species of hard coral. The reefs are affected by sedimentation and nutrient enrichment in coastal waters and net fishermen walking on shallow reefs. In 1999, the Rota high school marine science club, led by teacher Lisa Skilag and then University of Guam marine scientist Dr. Sandra Romano, conducted the first Reef Check surveys in CNMI, off Teteto beach. The group used Reef Check to help educate the students about their local resources and what they could do to help conserve and protect coral reefs. The next year the Reef Check program expanded to Saipan where Peter Houck, marine biologist with the Division of Environmental Quality, and John Starmer, Costal Resources Management, led surveys at Obyan beach. The program has continued to grow to include volunteers from the Northern Marianas Divers Association (NMDA).

In 2001, in conjunction with the GCRMN/MAREPAC coordinators meeting, Reef Check Saipan hosted an international Reef Check training. Led by RC Program Manager Jennifer Liebeler and RC Saipan Coordinator John Starmer, the training involved 22 participants, including government officials and scientists from Chuuk (FSM), Kosrae (FSM), Pohnpei (FSM), the Republic of the Marshall Islands, Guam, Palau, Rota (CNMI) and Saipan (CNMI). Also attending the training were thirteen volunteers from the NMDA. The participants from NMDA have since received training materials translated into Japanese, courtesy of RC Japan, and are training Japanese visitors in Reef Check methods with support from several dive shops in Saipan, including Blue Horizon Divers, Coral Diver, Squall Divers, Big Dog Divers, and Sea Shore Diving. As a result of the training, Reef Check teams are now being set up in Chuuk (Federated States of Micronesia) and the Republic of the Marshall Islands.

The Northern Marianas Divers Association, with members from local dive shops, joined by Carol Emmarois and Francis Matsutaro, from PICRC, pose after a successful Reef Check training at Obyan Beach in Saipan. Photo by Jennifer Liebeler.

Cuba

Cuba, with approximately 2400 miles of almost continuous reef, has some of the best reefs in the Caribbean. However, due in part to sewage, oil-related pollution, and mining and industrial discharges, Cuba's reefs and reef fisheries are deteriorating. RC Cuba and their extensive volunteer network are doing their part to save Cuba's reefs. RC Cuba coordinator Susel Castellanos Iglesias and her team conducted a local workshop in the summer of 2001 in the Rincon de Guanabo area.

> "Our group has found Reef Check to be a good methodology to involve all shore communities in the conservation of Cuba's coral reefs." - Susel Castellanos Iglesias, RC Cuba coordinator

The trainees were from Flora Y Fauna, a management center responsible for protecting habitat in Cuba and the Sibarimar Dive Club. RC Cuba has been successfully involving coastal communities in coral reef conservation. This is no easy task; RC Cuba members often conduct surveys without the use of a boat, and swim up to one kilometer to some of their survey sites. The team's hard work has also contributed to conservation efforts around Latin America. Thanks to Susel and volunteers Mario González Martín, Enrique Genes Dueñas, and Mario Oscar Alvarez, the Reef Check training material is now available in Spanish.

Egypt
by Dr. Moshira Hassan

Reef Check got off to a spectacular start in the Red Sea during the International Year of the Reef, 1997. Started mainly as a public awareness campaign, the Egyptian and European (German) team jointly used Reef Check to promote active reef conservation within the tourist sector in both regions. Since then, the program has achieved this goal and grown to include a much larger aim and more sites have been added since then.

During the summer of 1997, over forty sites were surveyed throughout the Egyptian Red Sea, involving more than 200 tourist volunteers from Egypt and foreign countries. This impressive start was achieved through coordinated efforts between dive shops and scientists. Two scientists, Moshira Hassan and Gert Woerheide, coordinated the surveys and recruited 13 scientists from Australia, Germany, Egypt, Netherlands, and the UK to travel to Egypt for a period of two to three weeks each. This merging of science and the tourism industry proved to be the perfect way to increase public awareness.

Reef Check groups in Egypt and Germany also involved the media and corporate sponsors to enlarge the reach of the conservation message. German and Swiss TV documented a number of the surveys and broadcasted films on Reef Check in the Red Sea throughout Europe. Articles have been featured in a number of politically based, as well as environmentally based, magazines in the Middle East and in Europe. Corporate sponsorship included reduced rates for flights from a number of airlines, free accommodation through local hotels, donated T-shirts, underwater writing slates, certificates of participation, and other Reef Check materials from local businesses. Together, these groups are working to preserve the corals of the Red Sea while supporting sustainable businesses. Dive centers and hotels continue to be added to the list of sponsors.

Since 1997, Reef Check has become a permanent and supported part of the European diving community, as well as the local Egyptian tourism industry. Moshira Hassan and Georg Heiss continued to coordinate Reef Check in the Red Sea after its spectacular beginning.

Reef Check has also been adopted as a standard survey protocol by a number of scientific groups in Egypt during 2002. For example, Dr. Mohammed Kotb, at the University of Ismailia, has used Reef Check to train rangers of the Egyptian Environmental Affairs Agency as well as the Park Authority in Egypt, who will continue to survey the reefs under his direct supervision. There are also plans to train students at the Suez Canal University in Ismailia and at the American University in Cairo in the Reef Check survey methods and to incorporate Reef Check in the syllabi of marine biology courses.

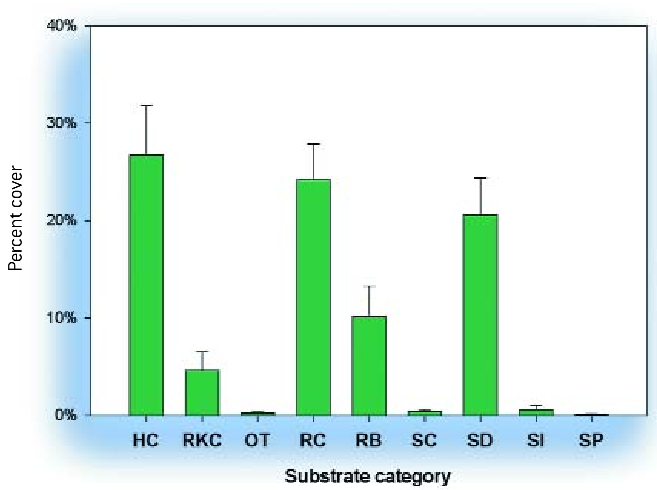
In general, Reef Check surveys have found the reefs in Egypt to be in much better condition than expected, especially in the regions of Sharm el Sheikh, Hurghada and Safaga, considering the high diving pressure and construction activities. The management efforts of the National Parks and NGOs appear to be actively helping to preserve and protect the reefs. For example, the installation of mooring buoys has resulted in less broken corals at areas where anchoring was damaging the reefs.

Reef Check in other areas of the Red Sea

Reef Check has also extended its reach in the Red Sea. Surveys of the region include Eritrea, Israel, Saudi Arabia and Yemen. Two new coordinators have recently been recruited: Malek Abdal-Aziz in Yemen and Dr. Nabil Mohammed in Djibouti. Both are extremely enthusiastic and will continue to expand Reef Check effort in their countries in 2002.

Hawaii

The island of Kauai in the Hawaiian Islands was the site of the world's first volunteer Reef Check survey on June 14th, 1997.



Hawaii substrate results

Dave Raney (right), RC coordinator explains Reef Check methodology to Jeff Kuwabara (left), Hanauma Bay education coordinator, and another volunteer during a training in Waikiki. Photo by Jennifer Liebeler

Organized by former Hawaii Coordinator Carl Stepath, team scientists included Jim Maragos, Alan Friedlander, Rick Grigg and Cindy Hunter. The first survey was held in conjunction with the CleanOceans '97 conference, organized by Robert Kennedy Jr., senior attorney for the Natural Resources Defense Council. Since that time, Reef Check Hawaii has been growing steadily.

After receiving funding from US NOAA and the State of Hawaii Coastal Zone Management Program, Reef Check Hawaii has expanded under the guidance of RC Coordinator Dave Raney and many others, and now includes all the major Hawaiian Islands. Activities on Oahu include bi-monthly surveys of reefs around the island and educational activities held in conjunction with the Waikiki Aquarium.

The threshold for having a sufficient number of surveys to assess individual islands and reefs has recently been reached. Taken together, the results show that the Hawaiian reefs surveyed have live coral cover ($26.7 \pm 2.1\%$) just below the Indo-pacific regional average and recently killed coral is relatively low ($4.5 \pm 7.7\%$). The highest hard coral cover recorded was 42%, from a survey done in 2001 at Palauea Beach in Maui.

Indonesia

The world's largest archipelago, Indonesia consists of more than 30,000 islands and is located at the center of the world's coral reef diversity with some 75,000 km^2 of reefs, approximately one-eighth of the world's total.

Reef Check Indonesia began in 1997, and since that time, Reef Check Indonesia has had a hugely successful partnership with the WWF Wallacea Program based in Bali. With funding from the Macarthur Foundation and from the USAID East Asia Pacific Environment Initiative, a network of training centers has been developed in 13 islands around Indonesia. A series of training events has taken place with dozens of trainees from the private sector, fisheries department, and other NGOs. To facilitate training of local community members, training materials and indicator organism underwater identification cards were translated into Bahasa Indonesia.

Since 1997, over 270 volunteers have been trained in Reef Check methods and educated about coral reef conservation and management. Reef Check training workshops and surveys have been conducted in 14 of 29 provinces: Sumatra Barat, Lampung, Jakarta, Banten, Jawa Barat, Jawa Tengah, Jawa Timur, Bali, Nusa Tenggara Barat, Nusa Tenggara Timur, Kalimantan Timur, Sulawesi Utara, Sulawesi Selatan, and Sulawesi Tenggara.

Reef Check team proudly displays their banners.

The data collected have been used to compile comprehensive reports in Bahasa Indonesia, which were circulated at the highest levels of Indonesian government. In fact, one Minister participated directly in a RC survey. RC Indonesia is planning to increase the number of Reef Check locations to an additional ten provinces and gain more volunteers in 2002 in preparation for the establishment of the Reef Check Indonesia Center in Bali, 2003.

With the help of Operation Wallacea, Reef Check is being used to help monitor and manage the Wakatobi Marine Park in the Tukang Besi Islands. These islands are an area of rich biological diversity and provide livelihoods for thousands of coastal people. In 2000, Reef Check was used to survey a range of 19 reefs across the archipelago and baseline assessments of coral reefs were conducted concentrating on benthic condition, reef fish families and invertebrate indicators of stress as designed by the Reef Check program. In the 2001 season Operation Wallacea teams again took part in Reef Check and visited a total of 37 sites during the survey period June – October.

Reef Check Indonesia has been very successful in using the media to educate Indonesians about threats to coral reefs and what Reef Check is doing to protect corals. Reef Check has been publicized by SCTV, Bali Sun, TVRI Lampung, Indosair Jakarta Post, Nusa Newspaper, Radio News 68H, Paradise FM, Top FM, Pinguin FM, and other local radio stations and newspapers in Indonesia.

Perhaps the most rewarding media effort came when Reef Check/WWF helped Nugie, a popular singer, write his hit song 'Hingga ke Terumbu Karang' (Up To the Reef), which promotes coral reef conservation and relates the impacts of poorly planned development on land to the impacts on downstream coral reefs. Nugie sang his song at Bali Hardrock Café Hotel to help celebrate "Ocean Day" on June 14th 2001. Attendees from the Bali "Kids club" sang along and learned about their reefs. The song was spotlighted on MTV Asia and has helped raise awareness and knowledge among the younger generation.

"If I were a fish". Artist and contest winner: Angela K. Winna, St. Yoseph's elementary school.

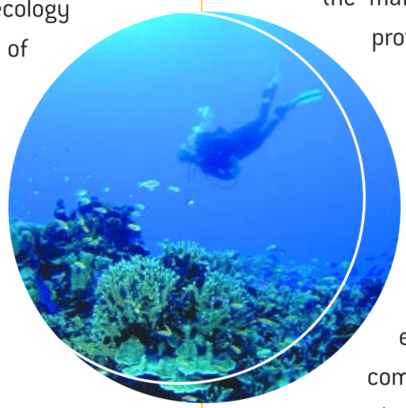
In another successful educational program, Reef Check and Friends of the Reef, an NGO dedicated to coral reef conservation, held a drawing competition among elementary school children in Bali. The children were taught about coral reef ecology and conservation and asked to draw pictures of themselves as fish. Hundreds of beautiful drawings were sent by talented children and have included one winning entry is shown here. Reef Check has used these wonderful works of art on promotional materials in Indonesia and elsewhere to raise awareness about coral reef conservation.

Kosrae

Kosrae is one of the jewels of the Federated States of Micronesia, a tiny (43 square mile) and mountainous island in the Central Tropical Pacific just five degrees north of the equator. Due to its unique location, the island has some of the most diverse and healthiest corals in the world. The local fringing reef has provided sustenance to the islanders for centuries and as a result, the Kosraeans are very committed to the protection and continued good health of their reefs.

Katrina Adams at Kosrae Village Resort established Reef Check Kosrae in 1999. She recruited volunteer sport divers who were visiting the region and willing to donate their vacation time to a worthwhile cause. Over the past five years, Katrina and Kosrae Village have continued to host RC Kosrae and have teamed up with the Kosrae State Fisheries and Marine Resources and the Kosrae Conservation and Safety Organization to expand conservation projects on the island.

Early efforts by RC Kosrae have grown to include an annual month-long training for all 9th grade students on the island in reef ecology and monitoring techniques. This program, run in collaboration with the Marine Resources Department, also teaches the students to analyze the data gathered, thereby strengthening their math skills. Marine Resources has also added a monthly monitoring session that is carried out by local volunteers and staff year-round. The collaboration between RC Kosrae and the Kosrae State Department of Fisheries and Marine Resources works well, with RC Kosrae and Kosrae Village providing the manpower and equipment and Marine Resources providing direction and supervising data collection.



A diver descends onto a pristine and highly diverse coral reef community to find an appropriate area to set up permanent transect line for future monitoring surveys. Photo courtesy of Reef Check Kosrae.

Other conservation projects on Kosrae include the Kosrae Reef Protection Project, which was established in 1996 and has since involved the community in the installation of 56 mooring buoys around the island at the most popular dive and fishing spots. The buoys protect the reefs by providing anchorage to anyone using the ocean: fishermen, divers, swimmers and snorkelers. These mooring buoys also serve as permanent markers for the 20 coral monitoring sites established by RC Kosrae over the past three years.

Results of surveys conducted on these buoys reveal the highest hard coral cover of any Kosrae survey. The mean hard coral cover was 57.0 % ± 58%, with a range from 28 to 78% hard coral cover. Dead coral cover was consistently low on all reefs, a mean of 2 % ± 2 %. The consistently high hard coral cover is likely due to the relatively low levels of anthropogenic impacts on the reef and the location of Kosrae, south of the typhoon track. Reef Check surveys have also been used to track damage to corals from anchors. Incidence of damage to corals at the monitoring buoys fell from an average of 1.2 broken corals per reef in 2000 to 0.36 broken corals per reef in 2001, an indication that the mooring buoys are effective in preventing anchor damage.

"The Reef Check protocol makes coral monitoring and reef preservation accessible to the community. Since the advent of the coral monitoring project on Kosrae we have seen a tremendous increase in awareness amongst the Kosraean community. We plan to continue building our programs to develop community based marine protected areas and other conservation projects. "– Katrina Adams, Reef Check Kosrae

The abundance of indicator organisms is also relatively high. Kosraean reefs had an average of 4.01 ± 4.2 parrotfish per 100 m^2 reef, four times the regional average, with a maximum of 16.5 parrotfish per 100 m^2 reef. On Kosrae, 64% of reefs surveyed contained at least one parrotfish. Grouper were also relatively abundant, with 69% of all reefs surveyed recording at least one grouper, and with an mean of 1.05 ± 1.04 grouper per 100 m^2 recorded, about double the average for the Indo-pacific region. Similarly, snapper were relatively abundant, with at least one snapper found on 73% of all reefs, with an average on all reefs of 3.65 ± 2.39 snapper per 100 m^2.

Sea cucumbers were relatively rare, with a mean of 0.25 ± 0.26 sea cucumbers per 100 m^2 reef, and 82% of all reefs reporting zero sea cucumbers. Although sea cucumbers are not eaten in Kosrae, they have been collected for export sales in the past. This practice is currently banned, however it remains to be seen if the cucumber population will rebound.

Reef Check Cebu (Philippines)

BY MIKE ROSS, REEF CHECK COORDINATOR

The island province of Cebu is centrally located in the Philippine archipelago. The fringing coral reefs of Cebu, together with those of the adjacent island provinces of Bohol and Negros, are noted for their high biodiversity and sheer beauty. Once a major magnet to divers from around the world, these reefs have lost their attraction in recent years due to the decline in coral quality and marine life as a result of overfishing, poison fishing, and blast fishing.

Mike and Nora Ross, who coordinate Reef Check operations through their dive shop, Tropical Island Adventures (**www.cebu-dive.com**) established Reef Check Cebu in 1998. Today, Reef Check is successfully addressing the problems facing Cebu's reefs by involving key stakeholders, including local resorts, dive operators, dive instructors, and other concerned divers in monitoring and management projects. RC Cebu has been instrumental in mobilizing the active support and resources of key stakeholders within the dive and resort community.

The local fishermen and coastal community members of Cebu often do not directly benefit from many popular reef uses, such as recreational diving and tourism and view these activities as impinging upon their fishing grounds. As a result, many of these individuals have negative attitudes towards recreational divers, tourism and related reef conservation activities. Dive-based tourism, which is a major attraction in the Cebu area, is often viewed as a luxury sport operated by "outsiders" providing local communities limited economic benefits or sources of livelihood. Most reef surveys and studies have also historically been conducted by outside scientists and managers who use the resulting data either offsite or to regulate fishing. There is often little communication between managers and locals, leading to distrust and disinterest.

To help overcome this lack of community involvement Reef Check Cebu sponsors free or highly discounted PADI scuba certification courses and Reef Check training to selected community members. These community members become directly involved in Reef Check surveys and conservation activities after successfully completing their training courses. In addition, introductory PADI "Discover SCUBA Diving" courses have been provided to key decision makers, such as local mayors and a vice-governor, to further educate them about their underwater resources.

In the process, Reef Check Cebu is proud to have helped to develop several "champions" of reef surveys and conservation from the nearby island communities. Examples of these "Reef Check Champions" include "Nong Tuti" Menguito and "Jun" Ochea, who was selected to participant in Reef Check trainers' training held in Phuket, Thailand in November 2001 (See "Reef Check Champions").

Although Cebu is surrounded by coral reefs; the public and private schools of the area offer very little formal education on reef ecology and awareness. This lack of general awareness is reflected in the common name for corals in the Cebu dialect, ***bato sa dagat***, a term literally translated as "sea rocks". Many local residents simply do not know that corals are sensitive, living animals. Reef Check Cebu, assisted by local partners, has developed and is conducting simple yet exciting educational programs on reef ecology and conservation. These reef awareness and education programs have proved particularly popular with young students from the coastal communities of Mactan and Olango Islands.

The Cebu International School (CIS) has expanded this program to include various PADI scuba certification courses, orientation on the Reef Check program, and community-based management of MPAs. This on-going program proved equally interesting to the parents, many of whom are influential business leaders and resort owners in the area.

An increasing number of success stories and local "Reef Check Champions" are providing renewed inspiration for improving reef conservation in the Cebu area and beyond through the Reef Check program.

Recently, Mike and Nora founded the Coastal Dynamics Foundation to further support their Reef Check and reef conservation activities. The foundation directly involves a growing cross-section of concerned local individuals and Reef Check teams. In recognition of innovative efforts to help establish and monitor marine protected areas (MPAs) using the Reef Check program, the foundation has been awarded two grants by the PADI Foundation. A larger project funded by the US National Oceanic and Atmospheric Administration (NOAA) will help introduce socio-economic assessment approaches. A primary focus of these project activities will be the islands of Mactan and Olango, which may represent some of the most accessible, high diversity reefs in the world due to their proximity to Cebu City, the second largest urban area in the Philippines.

Reef Check Champions
by Mike Ross

Jun Ochea is a unique individual who has worked with RC Cebu (Philippines) for five years and now serves as lead boat operator, dive guide and all around great guy. Jun is from Olango Island from a community called Talima. Talima is infamous for being a home base to ***pala-ut***, or long-distance fishermen who, as a result of the degraded/depleted conditions of their own reefs, venture each year all over the Philippines. Paid by their catch (which is determined by whatever the trips "sponsor" has ordered, such as marine aquarium species, dried sea cucumbers, shells and the like) they dive these outer reefs for months, either free diving or using improvised "hookah" compressors consisting of an old paint compressor and typically a beer keg as a reserve tank. This is highly dangerous work, which claims many young lives each year and pillages many reefs. For more information on Olango and this type of fishing, please visit **www.oneocean.org**.

Jun has become a well-qualified Reef Checker, and has participated in a dozen surveys and presented the results at the recent Reef Check regional training in Phuket, Thailand. As a former fisherman, Jun has been able to communicate with other fishermen on his island and to educate them on the importance of reef conservation efforts.

Nong Tuti Menguito

The Gilutongan Marine Sanctuary is very effectively managed and monitored by a Reef Check Champion" – Nong Tuti Menguito. Following his PADI diver training, Nong Tutu was trained in Reef Check methods and has actively lead the survey and data analysis teams for the last four years, using dive equipment and support services provided through Reef Check Cebu. Highlighting his unique character and accomplishments, Nong Tuti was recently featured in a Reader's Digest article. His beloved sanctuary has now become a popular site for other communities and scientists to visit, study and learn more about this exciting success story and new model for conserving reefs and enhancing economic benefits to local communities by using Reef Check.

Tonga
by Seiji Nakaya

The Kingdom of Tonga is located approximately two-thirds of the way from Hawaii to New Zealand. The 171 islands that make up Tonga stretch 1000 km from Minerva Reef in the south to the island of Niuafo'ou in the north and spread over 700,000 square kilometers of the South Pacific.

The first Reef Check survey in Tonga was conducted in January 2002 on the northern reef of Pangaimotu Island, about 4km northeast of Tongan Capital, Nuku'alofa by a team from the Department of the Environment (DoE). The team is a perfect example of the international cooperation that often surrounds Reef Check. The team was led by Asipeli Palaki, marine conservation officer with the DoE and Seiji Nakaya, an advisor for marine park management from the Japan International Cooperation Agency who had previously led Reef Check surveys in Japan. Other DoE staff and US Peace Corps volunteers joined the leaders. Preliminary results show the reefs were relatively healthy, with no obvious signs of damage from anchors, sedimentation, or dynamite fishing. Although the density of fish was relatively low, the average hard coral cover was 40.5%. This is about 10% above the regional Indo-pacific average.

The reef surrounding Pangaimotu Island is one of five MPAs in Tonga. Although it has been in existence since the 1970's, it is the closest to the capital and the most heavily visited. Unfortunately, due to budget shortfalls, enforcement is lacking and fishing is common throughout the no-take MPAs. DoE has now drafted a management plan of the MPAs and is about to start implementation of the management. Reef Check will be an important part of the monitoring and awareness components of the management plan.

Reef Check in the Virgin Islands
by Lena Maun, Reef Check Assistant Program Manager

In May 2002, Reef Check led its first public education monitoring expedition to St John, in the US Virgin Islands. Ten participants ranging in age from 17 to 65 joined Reef Check staff members and UCLA graduate students, Lena Maun and Craig Shuman on the trip to the Eastern Caribbean. The proximity of St. John to the continental United States, beautiful beaches, coral reefs and a distinct culture attract over one million tourists annually. Although the island is two-thirds US National Park (including Park protected waters), the island's marine system is affected by anthropogenic impacts from both land (sedimentation) and sea (fishing and dive impacts). Because St. John and the other surrounding US and British Virgin Islands depend on tourism for the majority of their local economies, however, there is an incentive to protect the natural resources.

The Reef Check expedition team, made up of people from the United States and United Kingdom, spent ten days in the field learning about coral reef ecology and monitoring, and human impacts on the Virgin Island's marine system. The trip was organized through the University of California's University Research Expeditions Program (UREP) and served as a successful test of implementing such trips as a regular feature of Reef Check. The group worked with local Reef Check coordinators, scientists from the Virgin Islands National Park (VINPS), the University of the Virgin Islands (UVI) and the Division of Fish and Wildlife, local dive shop owners from both the US and British Virgin Islands, and local US and British NGO's to develop a plan to integrate Reef Check into the larger coral reef management and eco-tourism picture. Reef Check and other programs that provide the public with a way to learn about natural resources in a low impact manner will help provide sustainable eco-tourism options to areas such as the Virgin Islands.

Adams, T.J.H, J. Leqata, P. Ramohia, M. Amos, and P. Lokani. 1992. Pilot survey of the status of trochus and beche-de-mer resources in the Western Province of the Solomon Islands with options for management June/July 1992 IFRP UNPUBLISHED COUNTRY REPORT, South Pacific Commission. Inshore Fisheries Research Project assisting the Solomon Islands Government Fisheries Division.

Adams, T. and P. Dalzell. 1993. Pacific Island Lobster Fisheries: Bonanza or Bankruptcy? Fisheries Newsletter of the South Pacific Commission Fisheries Programme - Number 67 (October-December 1993), pages 28-33. Inshore Fisheries Research Project South Pacific Commission New Caledonia.

Beinssen, K. 1988. Boult reef revisited. Reeflections 21: 8-9.

Beinssen, K. 1989. Results of the Boult Reef replenishment area study. Report to the Great Barrier Reef Marine Park Authority, Townsville, Australia.

Birkeland, C. 1989. The Faustian Traits of the Crown-of-thorns Starfish. American Scientist 77: 155-63.

Bohnsack, J.A. and S.P. Bannerot. 1986. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. NOAA Technical Report NMFS. 41:15.

Bryant, D., L. Burke, J. McManus, and M. Spalding. 1998. Reefs at Risk: a map-based indicator of potential threats to the worlds coral reefs. World Resources Institute, Washington, DC.

Carson, R. 1950. The Sea Around Us. Oxford University Press, New York, USA.

Chesher, R. 1988. Report to Great Barrier Reef Marine Park Authority. World Wide Web electronic publication.
http://www.omnicom.com.au/charonia/report88.htm.

Clarke, K.R. and R.M. Warwick. 2001. Change in Marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E. Plymouth, UK.

Conand, C. 1998. Overexploitation in the present sea cucumber fisheries and perspectives in mariculture. In: R. Mooi and M. Telford (eds.) Echinoderms: San Francisco, Balkema: 449–454.

Cousteau, J.Y. 1964. The Living Sea. Harper & Row, New York, USA.

Craik, G.J.S. 1981. Recreational fishing on the Great Barrier Reef. Proc. 4th Int. Coral Reef Symp., Manila. 1: 47-52.

Reece, E. and M.P. Crosby. 1996. A Manual for Monitoring Coral Reefs with Indicator Species: Butterflyfishes as Indicators of Change on Indo Pacific Reefs. Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration, Silver Spring, MD. 45 pp.

Darwin, C. 1851. The Structure and Distribution of Coral Reefs. California Library Reprint Series Edition (1976) University of California Press, Berkeley and Los Angeles, California, USA.

Ebert, T.A. and R.F. Ford. 1986. Population ecology and fishery potential of the spiny lobster ***Panulirus penicillatus*** at Enewetak Atoll, Marshall Islands. Bull. Mar. Sci. 38 (1): 56-57.

Edmunds, P.J. and R.C. Carpenter. 2001. Recovery of ***Diadema antillarum*** reduces microalgae cover and increases abundance of juvenile corals on a Caribbean reef. Proc. Nalt. Acad. Sci. 98:9 5067-71.

Evans, C.R. and A.J. Evans. 1996. A practical field technique for the assessment of spiny lobster resources of tropical islands. Fisheries Research. 1996. 26(1-2): 149-69.

FAO. 2002. FAO STAT. World Wide Web electronic publication.
http://apps.fao.org/fishery/fprod1-e.htm

Ferreira, B.P. and Russ, G.R. 1995. Population structure of the coral trout, ***Plectropomus leopardus*** on fished and unfished reefs off Townsville, central Great Barrier Reef, Australia. Fishery Bulletin 93: 629-642.

Ginsburg, R.N. 1993. Global aspects of coral reefs; Health, Hazards and History. Case Histories, Miami: University of Miami. 385 pp.

Gomez, E., A. Alcala, et al. 1981. Status of Philippine coral reefs - 1981. Proceedings of the 4th International Coral Reef Symposium, Manila.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley, New York.

Grignard, J.C., P. Flammang, DJW Lane, and M. Jangoux. 1996. Distribution and abundance of the echinoid ***Diadema setosum*** (echindermata) on sediment-stressed coral reefs in Singapore. Asian Marine Biology 13 (0): 123-32.

Harris, M. 1999. Lament for an Ocean. McClelland and Stewart Inc, New York.

Hawkins, J.P., C.M. Roberts, T. Van't Hof, K. De Meyer, J. Tatalos, and C. Aldam. 1999. Effects of Recreational SCUBA diving on Caribbean Coral and Fish Communities. Cons. Bio. 13 (4): 888-97.

Heslinga, G.A. and T.C. Watson. 1985. Recent Advances in Giant Clam Mariculture. Proceedings of the Fifth International Coral Reef Congress. 5: 531-537.

Hodgson, G. 1999. A global assessment of human effects on coral reefs. Mar. Pollut. Bull. 38: 345-355

Hodgson, G. 2000. Coral Reef Monitoring and Management Using Reef Check. Integrated Coastal Zone Management. 1(1): 169-176.

Hodgson, G. 2001. Reef Check: The first step in community-based management. Bull. Mar. Sci. 69(2): 861-868.

Hodgson, G. and J.A. Dixon. 2000. El Nido Revisited: Ecotourism, Logging and Fisheries Cesar, H. (Ed.) In: Collected Essays on the Economics of Coral Reefs, CORDIO, Kalmar University, Kalmar, Sweden.

Hodgson, G. and C.M. Stepath. 1999. Using Reef Check for long-term coral reef monitoring in Hawaii. p. 173-184. In: Maragos JE, Grober-Dunsmore R (eds). Proceedings of the Hawaii Coral Reef Monitoring Workshop, June 8-11, 1998. Department of Land and Natural Resources and East-West Center for Development, Honolulu, HI, USA. 334 pages.

Hughes, T.P. 1994. Catastrophes, Phase Shifts, and Large-Scale Degradation of a Caribbean Coral Reef. Science 265: 1547-1551.

Hughes, T.P., D.C. Reed, and M.J. Boyle. 1987. Herbivory on coral reefs:

community structure following mass mortalities of sea-urchins. J. Exp. Mar. Biol. Ecol. 113: 39-59.

Jackson, J.B.C. 1997. Reefs since Columbus. Proc 8th Int. Coral Reef Symp. 1: 97-106.

Jackson, J.B.C, et al. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science. 293: 629-637.

Johannes, R.E. and M. Riepen. 1995. Environmental, economic, and social implications of the Live Reef Fish trade In Asia and the Western Pacific. Report to the south Pacific Commission and The Nature Conservancy, Honolulu, 81p.

Koslow, J.A., F. Hanley, and R. Wicklund. 1988. Effects of fishing on reef fish communities at Pedro Bank and Port Royal cays, Jamaica. Mar. Ecol. Prog. Ser. 43: 201-212.

Lau, P.P.F and R. Parry-Jones. 1999. The Hong Kong Trade in Live Reef Fish For Food. TRAFFIC East Asia and World Wide Fund For Nature Hong Kong, Hong Kong.

Lessios, H.A. 1995. ***Diadema antillarum*** 10 years after mass mortality: still rare, despite help from a competitor. Proc. R. Soc. Lond. 259: 331-337.

Lokani, P. 1992. Survey of Commercial Sea-cucumbers (Beche-de-mer) in the West New Britain Province, Papua New Guinea. PNG Department of Fisheries and Marine Resources.

Ludwig, D. R. Hilborn and C. Walters. 1993. Uncertainty, resource exploitation and conservation: Lessons from history. Science. 260: 17 and 36.

McElroy, S. 1990. Beche-de-mer species of commercial value - an update. South Pacific Commission Beche-de-mer Information Bulletin (2) 2-7.

Miller, M.W, and C.L. Gerstner. Reefs of an uninhabited Caribbean Island: Fishes, benthic habitat, and opportunities to discern reef fishery impact. Biological Conservation. 2002 106 (1): 37-44.

Munro, J.L. 1983. Caribbean Coral Reef Fishery Resources. ICLARM Stud. Rev. 7:1-276.

Ogden, J.C. and R.C. Carpenter. 1987. Species profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (South Florida)--Long spined Black Sea Urchin. U.S. Fish and Wildlife Service Biol. Rep. 82(11.77) pp 17.

Pielke, R.A. Jr. and R.A. Pielke, Sr. 1997. Hurricanes- their nature and impacts on society. Wiley, New York. 279pp.

Prescott, J. 1980. Report on the South Pacific Commission lobster project in Solomon Islands. SPC Report 205/80, Noumea, New Caledonia.

Roberts, C.M. 1995. Effects of fishing on the ecosystem structure of coral reefs. Cons. Bio. 9: 988-995.

Roberts, C.M., et al. 2001. Effects of Marine Reserves on Adjacent Fisheries. Science. 294: 1920-1023.

Russ, G. 1985. Effects of protective management on coral reef fishes in the central Philippines. Proc. 5th Int. Coral Reef Congr. 4: 219-224.

Russ, G. and A.C. Alcala. 1989. Effects of intense fishing pressure on an assemblage of coral reef fishes. Mar. Ecol. Prog. Ser. 56: 13-27.

Sadovy, Y. 1997. Problems of sustainability in grouper fisheries. Proc. Fourth Asian Fisheries Forum, China Ocean Press, Beijing, pp. 321-324.

Sadovy, Y. 1999. The case of the disappearing grouper: ***Epinephelus striatus***, the Nassau grouper, in the Caribbean and western Atlantic. Proc. Gulf Carib. Fish. Inst. 45: 5-22

Sadovy, Y. and A. M. Eklund. 1999. Synopsis of biological information on ***Epinephelus striatus*** (Bloch, 1972), the Nassau grouper, and ***E. itajara*** (Lichtenstein, 1822) the jewfish. U. S., Dep. Commer., NOAA Tech. Rep. NMFS 146, and FAO Fisheries Synopsis 157, 65 p.

Sap, J. 1999. What is natural? Oxford University Press, New York. 275 p.

Saville-Kent, W. 1893. The Great Barrier Reef of Australia: Its Products and Potentialities. W.H. Allen and Co. London.

Shang, Y.C., C. Tisdell, P.S. Leung. 1989. Report on a market survey of giant clam products in selected countries. Center for Tropical and Subtropical Aquaculture - Publication #107. University of Hawaii, Honolulu, HI.

Sluka R., M. Chiappone, K.M. Sullivan, and R. Wright. 1997. The benefits of a marine fishery reserve for Nassau grouper (***Epinephelus striatus***) in the central Bahamas. Proceedings of the 8th International Coral Reef Symposium, Panama. 2: 1961-1964.

Spalding, M.D., C. Ravilious, and E.P. Green. UNEP-WCMC World Atlas of Coral Reefs. University of California Press, Berkeley, California, USA.

Tissot, B.N. and L.E. Hallacher. 1999. Impacts of aquarium collectors on coral reef fishes in Kona, Hawai'i. Report for Division of Aquatic Resources, State Of Hawaii.

Trianni, M.S. 2002. SPC Beche-de-mer Information Bulletin #16. Summary of data collected from the sea cucumber fishery on Rota, Commonwealth of the Northern Mariana Islands. World Wide Web electronic publication. http://www.spc.org.nc/coastfish/News/BDM/16/BDM16.htm

Vo, S.T. and G. Hodgson. 1997. Coral reefs of Vietnam: Recruitment limitation and physical forcing. In: H.A. Lessios (ed) Proc. 8th Int'l Coral Reef Symposium. pp. 477-281.

Wantiez, L., et al. 1997. Effects of marine reserves on coral reef fish communities from five islands in New Caledonia. Coral Reefs. 16:215-224.

Weng, K. and M. Guilbeaux (eds.). 2000. Marine Resources of Helen Reef in the Year 2000. Community Conservation Network, Honolulu, Hawaii. Page 6.

Wilkinson, Clive (ed.). 2000. Status of Coral Reefs of the World: 2000. Australian Institute of Marine Science, Townsville, Australia.

Yeeting, B.M., P. Labrosse, and T.J.H Adams. 2001. The Live Reef Food Fish of Bua Province, Fiji Islands: A first assessment of the stock potential and guidelines for a management policy. Secretariat of the Pacific Community, NOUMEA. New Caledonia. (February).

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Photo by Jeff Jeffords

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