REEF CHECK

ICRI

ICRAN
International Coral Reef Action Network

UNEP
United Nations Environment Programme

NOAA
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

GCRMN
Global Coral Reef Monitoring Network

REEFBASE

UCLA Institute of the Environment

REEF CHECK
1362 Hershey Hall Box 951496
Institute of the Environment
University of California at Los Angeles
Los Angeles, CA 90095-1496 USA
Tel: 310.794.4985 Fax: 310.825.0758
Rcheck@ucla.edu
www.ReefCheck.org

ISBN 0-9723051-0-6
90000>
9 780972 305105

THE GLOBAL CORAL REEF CRISIS

TRENDS AND SOLUTIONS

GREGOR HODGSON

JENNIFER LIEBELER

SCIENCE - EDUCATION - MANAGEMENT

5 YEARS OF REEF CHECK

COVER PHOTO BY

Coral Reef Adventure,
courtesy of MacGillivray Freeman Films

REPORT DESIGN BY

NanceNet

Daniele Fragniere Nance

Valerie Ensign

www.nancenet.com

ISBN # 0-9723051-0-6

Photo by Jeff Jeffords

THE GLOBAL CORAL REEF CRISIS TRENDS AND SOLUTIONS

BY

GREGOR HODGSON

JENNIFER LIEBELER

CONTRIBUTING AUTHORS

MOSHIRA HASSAN

GEORG HEISS

LENA MAUN

KELLY MCGEE

SEIJI NAKAYA

MICHAEL ROSS

CRAIG SHUMAN

DATA CHECKING

JENNIFER MIHALY

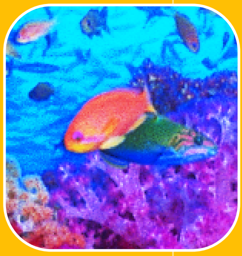
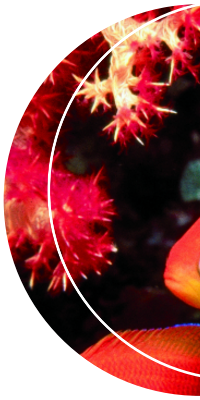


Table of Contents

Photo by Jeff Jeffords

PAGE	
4	LIST OF ABBREVIATIONS
5	FOREWARD
7	EXECUTIVE SUMMARY
9	CHAPTER 1 – ORIGINS OF THE CORAL REEF CRISIS
13	CHAPTER 2 – WHY REEF CHECK?
17	CHAPTER 3 – REEF CHECK METHODOLOGY
21	CHAPTER 4 – GLOBAL TRENDS IN CORAL REEF HEALTH
43	CHAPTER 5 – REGIONAL TRENDS IN CORAL REEF HEALTH
51	CHAPTER 6 – PUBLIC AWARENESS & EDUCATION
55	CHAPTER 7 – PARTNERSHIPS
61	CHAPTER 8 – MONITORING & MANAGING THE WORLD'S CORAL REEFS
64	APPENDIX – SUCCESS STORIES
75	REFERENCES
77	ACKNOWLEDGEMENTS



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.

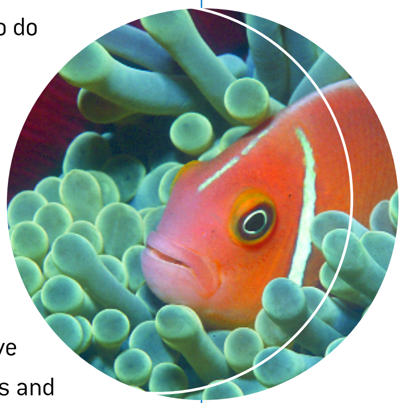
Nowhere is the problem of shifting baselines greater than for coral reefs. During my thirty-year career, I have watched every coral reef ecosystem I have studied change almost unrecognizably from the way it used to be. But when I try to explain these changes to younger scientists who were not there before 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 overfishing 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.

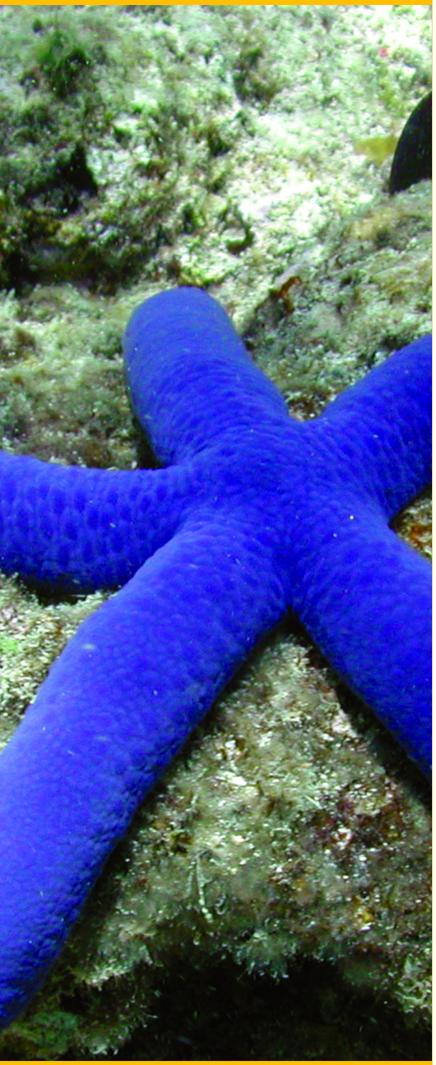
Last but not least, the volunteer program of Reef Check provides a valuable opportunity for divers and snorkelers to take a first step towards learning more about the threats to coral reefs and the importance of greater care and protection.

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



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.

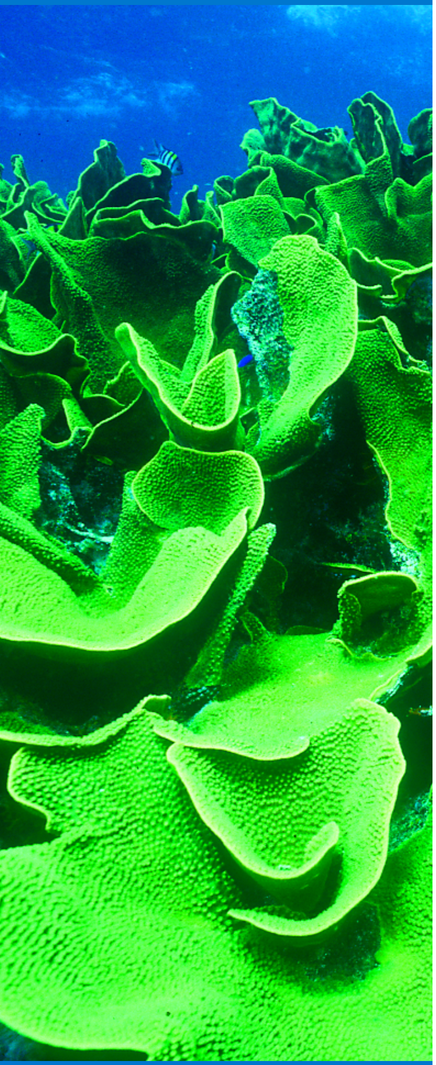
Reef Check also aims to design, test, and implement solutions to the problems facing coral reefs. As people learn more about coral reefs, they develop a sense of stewardship, and a desire to become involved in managing their local reefs.

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.

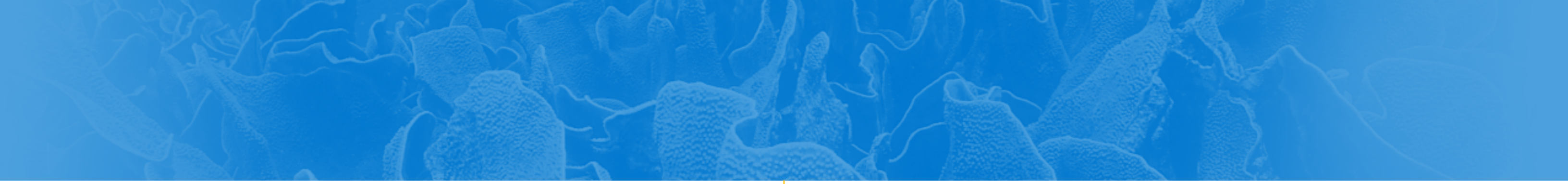
Jacques Cousteau went on to have an illustrious second career as an adventurer and natural historian. The Cousteau name is now synonymous with marine conservation, but this was not always the case.

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

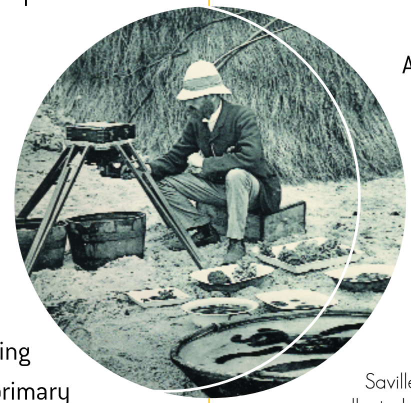
Most of the world's coral reefs are found in developing countries where human populations have typically doubled over the last 20 years. About 60% of these populations live within 100 km of the coast and depend on the reefs for a high proportion of their protein. Higher levels of local consumption and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

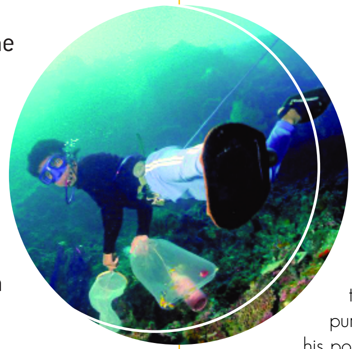
Since World War II, there has been a growing trade in reef fish and invertebrates for use in home aquaria. The marine aquarium and ornamental trade is now estimated at US $200 million per year as a result of improved husbandry techniques and an increase in the number and diversity of species. The Philippines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

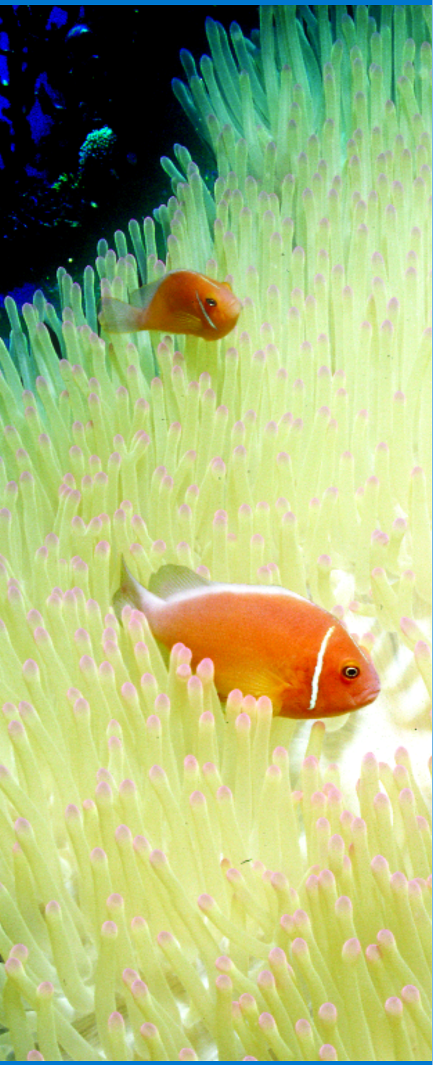
In addition to the various fishing methods described above, women and children are encouraged to forage on the reef flat at low tide, gleaning the reef for any tiny organism that can be added to the family stewpot. Women and children are also engaged in the collection and processing of reef animals for 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?



courtesy of Coral Reef Adventure, MacGillivray Freeman Films

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.

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.

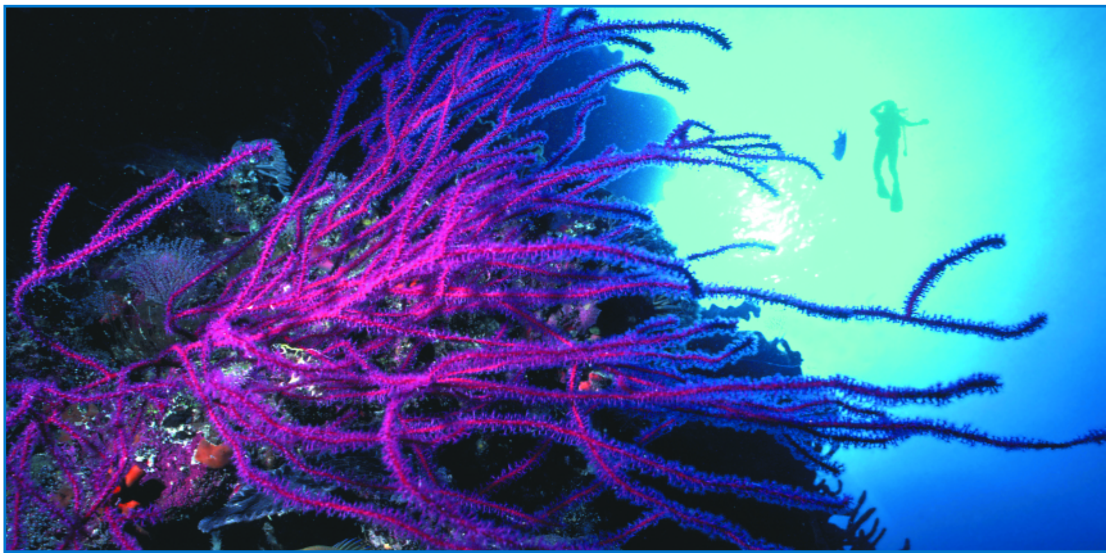
When Reef Check was conceived, the idea was to investigate the question of reef health on global and regional scales. Later, the vision was expanded to consider how to answer questions about reefs on a finer geographic scale, from one nation to one bay or even one reef. A 1999 paper, "Long-term monitoring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

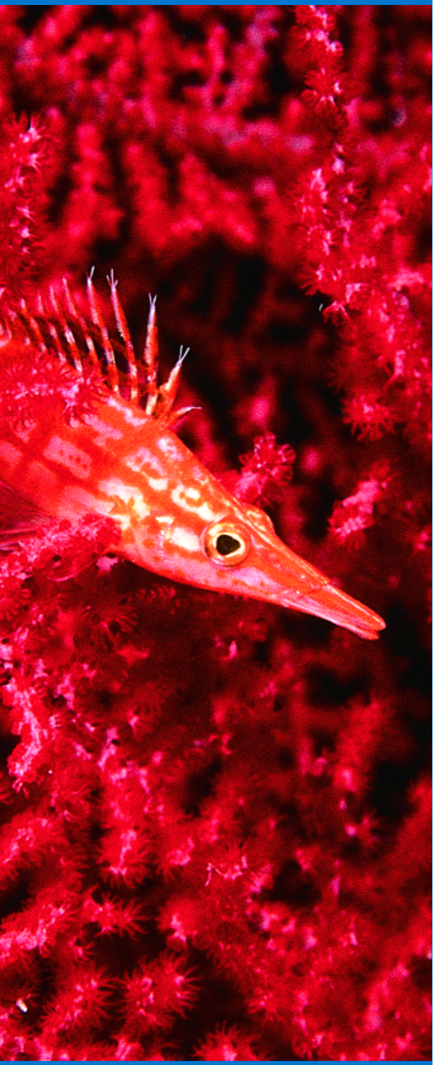
Photo by Jeff Jeffords



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).

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).



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

courtesy of Coral Reef Adventure, MacGillivray Freeman Films 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 spreadsheets, 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).