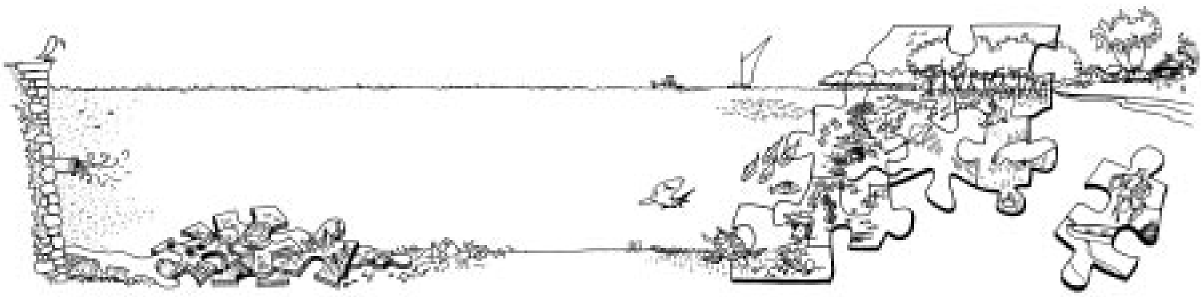
Coral Reefs, Mangroves and Seagrasses: A Sourcebook for Managers

Frank Talbot and Clive Wilkinson



with contributions from
Miguel Fortes and Peter Saenger

Case Studies from
Angel Alcala, Marlin Atkinson, Rolf Bak, Maya Borel Best, Barbara Brown, William Causey, Chou Loke Ming, Sue Clarke, Alasdair Edwards, Richard Grigg, Gregor Hodgson, Ove Hoegh-Guldberg, Terry Hughes, Cynthia Hunter, Catherine Isebor, Robert Johannes, Tim McClanahan, John McManus, John Ogden, Ross Robertson, Garry Russ, Bernard Salvat, Yacouba Sankare, A Sasekumar, Sam Snedaker and Suharsono.

and illustrations by
Christopher McLelland

ICRI
International Coral Reef Initiative

Australian Institute of Marine Science

GCRMN
Global Coral Reef Monitoring Network

IUCN
The World Conservation Union

CORDIO

WWF

Copies available from:

Science Communication
Australian Institute of Marine Science
PMB No. 3, Townsville Mail Centre
Townsville Q 4810. Australia
Fax: (07) 4771 6138
Email: bookshop@aims.gov.au

The National Library of Australia Cataloguing-in-Publication data:

Talbot, Frank, 1930- .
Coral reefs, mangroves and seagrasses : a sourcebook
for managers.

ISBN 0 642 32208 2.

1. Marine resources conservation. 2. Marine ecology. 3.
Marine resources - Management. I. Wilkinson, Clive R. II.
Australian Institute of Marine Science. III. Title.

577.7

CONTENTS

ACKNOWLEDGMENTS

We first conceived the idea for this book about 5 years ago, when there were few guidelines to management of tropical coastal areas, particularly coral reefs. Since then, some excellent books have been produced (see suggested reading) but often these are rather long. Sometimes they are very technical, using the language of science and management theory. We have written this book for the practising resource manager in developing countries, who may have limited training in science but is still required to manage complex ecosystems.

The basis for the book is a series of real case studies showing both the successes and failures in marine ecosystems and attempts to manage them. These case studies have been provided by experts from around the world (specifically acknowledged on the title page and after each contribution). We very much appreciate the valuable input of these authors and wish to thank them particularly for their generous contributions of time and pictures. As editors, we have had the challenging task of condensing and simplifying rigorous scientific work into a format suitable for our intended readership. We trust we have remained faithful to the essential themes of your studies. Thank you all.

Two people provided special contributions. Peter Saenger of Southern Cross University in Lismore, Australia, provided most of the input on mangrove forests and many of the photographs and Mike Fortes of the Marine Science Institute of the University of the Philippines in Manila guided us through the material on seagrass beds. Our special thanks to you.

This book is a contribution to the International Coral Reef Initiative (ICRI) and its operational programme, the Global Coral Reef Monitoring Network. We are particularly grateful for the financial support of partners of ICRI: the Department of State and National Oceanic and Atmospheric Administration (NOAA) of the government of the USA. The major financial support for coordination of the GCRMN has come principally through the help of Jamie Reaser, Peter Thomas, Brooks Yeager, and Adrienne Stefan of the Department of State, and Ned Cyr, Charles Ehler and Arthur Paterson of NOAA. Their support has been supplemented by generous contributions by the home institutions of Clive Wilkinson (Australian Institute of Marine Science – AIMS) and Frank Talbot (Graduate School of the Environmental, Macquarie University). WWF in Europe through Carel Drijver, IUCN in the USA via John Waugh and Jordan West, and the Great Barrier Reef Research Foundation through David Windsor, have contributed additional funds for production, as has the CORDIO project and Sida via Olof Linden. We thank these donors.

These financial contributions have enabled us to reduce the cost of this book for the target audience, coastal resource managers in developing countries.

We wish to thank the four co-sponsors of the GCRMN: the Intergovernmental Oceanographic Commission of UNESCO, with particular thanks to Ned Cyr and Patricio Bernal; the United Nations Environment Programme, via Agneta Nilsson; IUCN offices in the USA; and the World Bank, via Marea Hatziolos and Andy Hooten. The Global Secretariat of ICRI has also provided considerable support, especially Bernard Salvat, Francis Staub Genevieve Verbrugge, Olof Linden, Robert Jara and Ed Gomez.

The Director and staff of the Australian Institute of Marine Science have supported the production of this book and provided photographs. GBRMPA also assisted with photographs. Special mention goes to the staff of Science Communication: Liz Tynan, Steve Clarke and Wendy Ellery. Fiona Alongi assisted with the layout. Hugh Sweatman kindly read and commented on the manuscript.

Finally, thanks to Margaret Stoneman who helped us enormously with the editing, translating our messy text into the product you have before you, and to Chris McClelland who provided the inspirational cartoons – without them we would still be talking about how to get our messages across in print. Sue Talbot and Madeleine Nowak kept us sane and inspired us to continue, while Hoo'mi kept us amused.

1. INTRODUCTION

This book is written for resource managers and educators.

Its goal is to provide information and practical examples to help prevent further damage to coral reefs and other tropical coastal ecosystems.

Already 11% of all coral reefs have been damaged beyond recovery or totally destroyed. Another 16% were wrecked in 1998 by climate change related coral bleaching. Without effective management, another 30% of the world's reefs will become seriously depleted in the next 20 to 40 years - which is a very short time in human history. While this damage is occurring all over the world, the causes are mostly local – what is happening at each site.

This estimate excludes the 1998 coral bleaching caused by higher sea surface temperatures. This bleaching will add to the damage but the full extent is unknown. Most reef damage has been caused by human impacts, usually accidental or unintentional, and is often exaggerated by natural stresses. We now know enough to prevent most of this local damage.

More than 50% of the world's mangrove forests have been cleared without understanding the enormous value of these muddy coastal forests. Seagrass beds have had similar losses in many areas. Both these systems are rich nurseries for coastal fish and prawns, and both act to protect fragile shorelines from erosion.

Economists and managers have begun to measure the dollar value of these resources to coastal and marine fisheries, and to shoreline protection. They are finding that these values are surprisingly high; far higher than the money obtained by chopping down mangrove trees or pulling trawl nets through seagrass beds. It makes good economic sense to manage these coastal resources sustainably and this book will help managers do this.

We use real life situations to draw conclusions and give practical advice on the management of coral reefs, mangrove forests and seagrass beds. We outline where there have been real successes and failures, and provide methods for improved management of coastal resources, based on these case studies. Damaged habitats lose much of their economic value and often have bad impacts on other resources nearby.

The information in this book is drawn from the best available expertise of scientists and marine resource managers. Our aim is to highlight the dominant issues and suggest achievable solutions to what are sometimes complex situations. We have written the book for the resource manager in the field, who may be working without a lot of scientific support and literature. It is written in basic language and avoids technical terms where possible, because we realise that many managers use English as their second or third language.

It will also be useful to fishery managers, regional and town planners, tourist developers, marine park managers, traditional reef owners and others. We include useful references and we have concentrated on material that is available from international agencies like UNESCO, UNEP and IUCN. We particularly refer readers wanting more information to UNESCO's Coral Reef Management Handbook[1] and the IUCN's Guidelines for Marine Protected Areas[2] .

1 Edited by Richard Kenchington and Brydget Hudson.

2 Edited by Graeme Kelleher, 1999.

1 How to use this book to solve problems

This section will help you to identify problems, and where in this book you will find help and information.

The economic value of coastal environments

To help governments understand the importance of coastal environments and to make sound planning decisions, it is helpful for the manager to know the economic and other values of these systems. Those who make the final decisions on the fate of coral reefs, mangroves and seagrass beds may feel that other competing uses have a higher value, because they are more obviously money producing, but they are often wrong. Chapter A4, The Value of Tropical Coastal Resources, p.11, gives some of the real values of these important shallow water coastal systems. All values are in US dollars.

Human impacts

You may have a problem with a particular human impact (for example, sediment or sewage, or overfishing), or potential problems that come from coastal development. Most of the major human impacts are discussed in Section B, DAMAGE TO COASTAL ECOSYSTEMS AND HOW TO PREVENT IT, p.18; this section will refer you to other places in the text where impacts are discussed.

Discussions of your kind of habitat

You may have difficulty in the management of a particular kind of coral reef, mangrove forest, or seagrass area (for example, lagoonal mangroves or a fringing coral reef). Check through the case history studies in Section D, CASE STUDIES OF HUMAN IMPACTS ON COASTAL ECOSYSTEMS, p.94, to find an area similar to yours, which may provide insights into your problems.

Does your habitat really need management?

While your problem may be obvious, in many cases it is not clear whether an area really needs management. You may find help with methods to find this out in Chapter C15, Do Your Coastal Ecosystems Need Management?, p.73.

What kind of management is needed?

Different management strategies can be used, and some of these are given in the chapters in Section C, MANAGING COASTAL ECOSYSTEMS, p.48. The case histories in this section (Chapters C8-C14) give examples of successful and less successful management methods.

Creating Marine Protected Areas

Setting aside Marine Protected Areas (MPAs) is now an accepted way of protecting breeding fish and providing good habitats for tourism. Help on how to set up an MPA can be found in Chapter C16, p.77.

Integrated Coastal Management (ICM)

The best system being developed for the long-term sustainable management of coastal resources goes wider than the coast and includes the land and rivers which affect the coastal zone. It is called Integrated Coastal Management (ICM), or Integrated Coastal Zone Management (ICZM), or Integrated Coastal Area Management (ICAM). All refer to the same process. We use ICM, the shorter name, and the principles involved are in Chapter C17, Integrated Coastal Management for Sustainable Use, p.84. This is the most important development in coastal resources management; it urgently needs to be used widely.

Education and training

Education of stakeholders (those with interests or some involvement in the in the coastal zone) and the training for coastal managers is important. You will find a discussion of these in Chapter E26, Education and Training, p.153.

Pontoon, on Agincourt Reef, used by tourist operators
Photo: Ray Berkelmans ©GBRMPA

Measuring change: for better or for worse

To understand whether management (or the lack of it) is having an effect requires an understanding of change from year to year. Change is measured by various monitoring methods. These can tell you whether the system is in good health, is improving, or is getting worse. Simple but accurate monitoring methods are given in Chapter E27, Monitoring, p.157.

In some circumstances it may be possible to take active measures to aid recovery through restoration. The scope to do so varies. To learn more of these measures and what might be achievable, refer to Chapter E30, Restoration, p.175.

Legal issues

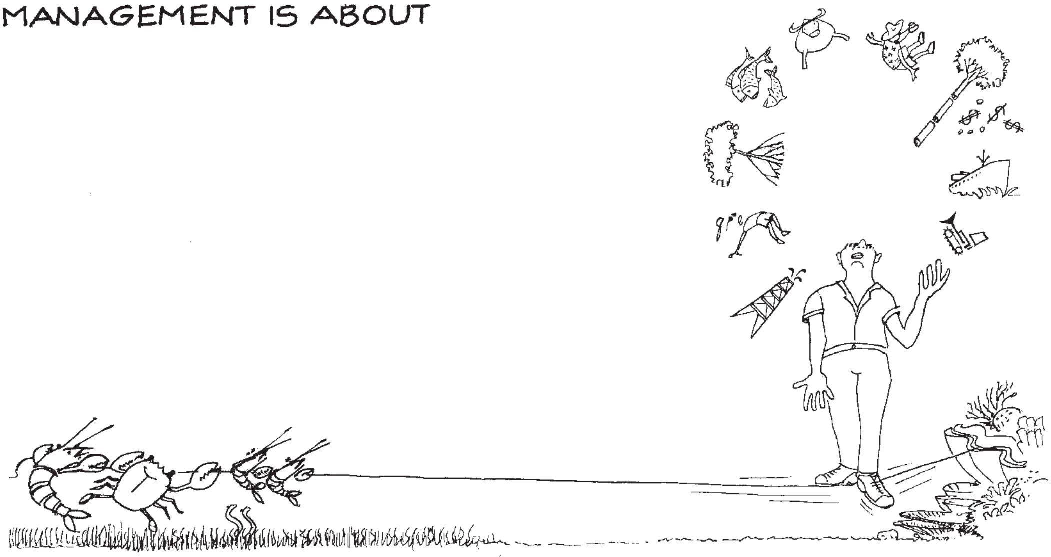
The law has an important role in the management of coastal resources. While it will not solve all problems of damage and conflict, it has an important role in the process. The most relevant aspects of the law and its role are discussed in Chapter E28, The Law and Coastal Management, p.167.

Tourism

Tourism has become a most important value of tropical coasts, particularly coral reef areas. The last section lists some of the tourist's needs in what is a very competitive market. See Chapter E29, The Potential of Tourism p.172.

A WHAT COASTAL MANAGEMENT IS ABOUT

CONTENTS



A2 Problems of management and planning

Most planning and management of coastal resources in the past has been sectoral (a term used to describe management for a single interest group). A single department may plan and manage one marine resource interest such as fishing, tourism, or harbours; or another may administer the control of sewage; or a third may give approval and permits for industrial pollution.

Competition between such departments is common, and there are always difficulties in limiting and defining the responsibilities of each. The result is often that several departments have some responsibility over the same coastal resource and this often produces conflicts. This makes it very difficult for a resource manager to do anything, particularly in working with the major users and getting their trust.

There is also a more serious problem. Each department (sector) has a job to do, but developments that are right for one sector may damage the resources for other sectors and work against the efforts of other departments. So one side may get profits from a development, but other sides may lose. For example, clearing mangroves for forestry or for waterfront housing will benefit some, but this will reduce the long-term value of fishing because a major nursery area for fish and prawns has been removed.

Often the winner is the resource user or the department that has most political power or money, and fishing communities are often the least powerful. The result may be confusion rather than good planning, with decisions not achieving the best economic and social benefits for the communities. Single sector management is a poor way to manage or plan.

There are different levels of control in each part of government for any particular area: planning for the future involves the national government (whole country); and shorter term or regional plans involve provincial or regional governments; and local authorities make decisions that affect the immediate villages, towns, cities. Somehow all levels need to work together.

Unfortunately higher levels of government often do not respect local authorities, which are in direct contact with the communities and know what is best for them. So, frequently, such plans result in overlapping responsibilities and in conflicts, rather than cooperation with sound management and planning.

A further complication is that a damaging impact (e.g. sediment from forest cutting, mining or agriculture upstream) may damage a fishery or a tourist coral reef but such an inland source is outside the control of coastal agencies or resource users.

A3 Seeking solutions?

3.1 Environmental Impact Assessment (EIA)

Most countries have developed legislation to assess the impact on the natural systems and on other users of a development before it takes place (environmental impact assessment legislation or EIA). Although this is important and may result in a softening of the impacts, much experience has shown that such legislation rarely works well, particularly when the environmental impact assessment is done by the company or government department that is doing the development. The impact assessment is difficult and may be too narrow in scope, or biased in favour of the development.

Often the EIA process may alert the developer to possible damaging problems and these may be reduced. Comments by other users and the public when the EIA is published or during a formal period for consultation, may also force the developer to reduce the impact. But often the assessment is poorly done and may only look at physical impact on the environment, while ignoring important issues such as the social impacts or the economic impacts. Many small proposals are also a problem because the Environmental Impact Assessment may show that one hotel and its pollutants will make little impact on a coral reef. But the combined effects of five hotels in the area could destroy the reef they all need.

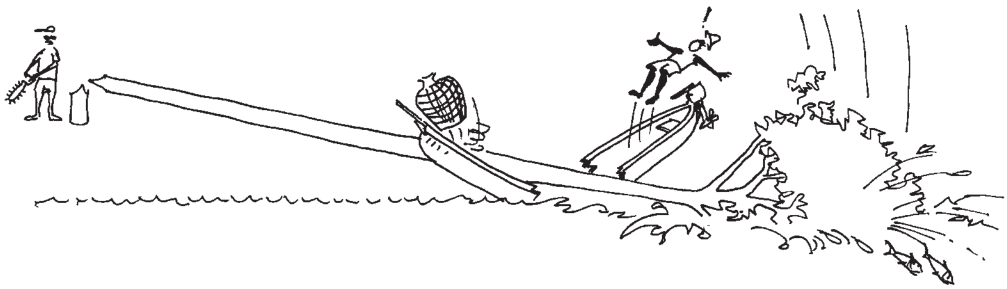
EIA rarely stops a development, even when the study of total costs and benefits to society shows that the costs are too high and that it should not go ahead. This is because the development has usually been planned, financed and often already given informal approval. Most developers have bought the land and drawn up the development plans, before they are required to do an EIA and it is then too late in the process. What is needed is a broad plan for the whole coastal region first, as shown below.

3.2 Integrated Coastal Management (ICM)

Although an EIA can be useful, we need broader methods that guarantee the best social and economic benefits to communities and users of coastal resources, and also consider activities in the catchment area. This means wider planning and much better discussion and cooperation between all users, controllers and planners of coastal areas. The need gets greater as coastal populations increase or development occurs, which multiplies the pressures on coastal and marine areas. Many coastal areas have been seriously damaged and have valuable resources lost due to poor management and planning.

Integrated Coastal Management (see chapter C17, p.84) is a method that considers the broader coastal zone. This is necessary because land and sea affect each other through rivers, estuaries and wetlands. Coastal resources of coral reefs, mangrove forests and seagrass beds protect the land from storm erosion. But agriculture, forestry, industry, mining, housing developments, and the building of dams, harbours and roads may have damaging impacts on these coastal resources. Bad land and river use damages estuaries, fills harbours with silt, pollutes fisheries, kills seagrass beds, destroys mangroves, converts coral reefs to algal reefs and degrades the local tourist economy. These changes (like removal of mangroves, coral reefs and seagrass beds) can increase erosion of coasts and islands (see case study on coral mining in D20, p.116).

Most systems on the coast are linked together, and planning, development and management must take this into account. Some form of Integrated Coastal Management is the only sensible solution. This is not a simple process, because the coast has many users who affect each other but, only by involving all interested groups will sound and lasting policies be developed.



BOX 1 TOURISM, FISHING AND LOGGING VALUES IN PALAWAN

Sediment from logging in Palawan, Philippines, caused rapid and severe damage to coral reefs in Bacuit Bay, and affected tourism and fisheries. A major economic study compared 10 years of logging with continuing tourism and fishing in the bay.

In a striking result, the values projected over 10 years show that "no-logging" will yield $41.6 million more than "logging". The reason is that tourism and fishing are badly affected if logging continues.

If there was no logging, tourism and fishing would yield $75.5 million over the 10 years. But when the forests are cut, heavy sediment flows result, and this revenue would drop to $21 million. Add to this only $12.9 million from forestry itself, and the losses are very large. The government's action was to ban logging and make a marine reserve.

From G. Hodgson & J. A. Dixon, 1988.

A4 The value of tropical coastal resources

4.1 *Increasing pressures on the coast*

The number of people living along tropical coasts is very large and increasing. The population of Southeast Asian countries was estimated to reach 375 million in the year 2000, with 224 million (60%) living on the coast. Populations are also increasing on many tropical islands in the Pacific and Indian oceans and the Caribbean Sea.

The pressures on tropical marine resources increase with the growing population and an understanding of the values of coral reefs, mangroves and seagrass beds is essential for the manager. This is particularly important when there are competing uses and where communities are trying to get the most sustainable, long-term value from their coastal resource. Government decision-makers usually think in terms of money (costs and benefits). Because political terms are short, politicians rarely think about the long term (10s to 100s of years) and non-money concepts like biodiversity, ecology and aesthetics are ignored. Yet long-term sustainability is vital for the community.

Managers are often asked to support their recommendations and decisions with economic values and informed arguments. These shallow marine resources have important values to be considered before development is considered, because the community may in fact lose and not gain money from a development in the long term.

4.2 *Products extracted directly*

It is easy to measure the values of products that can be extracted and sold (direct extractive use values), such as fish, molluscs, crustaceans and beche-de-mer for food; trochus; curio objects (corals, shells); live corals and fish for the aquarium trade; rock and sand for construction and cement manufacture; and mangrove wood for building or firewood.

Fisheries

The weight of fish on a coral reef can be very large but will vary from reef to reef. The weight of fish on Pacific reefs ranges from 12 to 237 tonnes per sq km. But the sustainable yearly catch is much less, ranging from below 1 tonne/sq km/yr to above 19 tonnes/sq km/yr.

5 tonnes/sq km/yr of fish is a reasonable sustainable average from most healthy, growing coral reefs. But research in Fiji suggests that yields up to 10 tonnes/sq km/yr are

sustainable. Fisheries scientists consider that Caribbean reefs (down to 30 m deep) may sustain a yearly harvest of 15 tonnes/sq km/yr if crustaceans and shellfish are included.

$$ To convert these weights, you need to multiply by the average value to the fisher families (either in prices obtained in the market or money needed to replace this food or income). If the value is $1 per kilogram – then 15 tonnes/sq km/yr means a value of $15,000 per sq km every year; if the value is $10 per kg, then it is $150,000 per sq km/yr.

If tuna or other oceanic species that feed along the edge of reefs (e.g. Spanish mackerel - *Scomberomoridae*) are included, the catch may be larger. Greater annual catches are also possible when schooling plankton feeders (fusiliers - *caesionids*) are also fished, as much of their food comes from the open ocean. The annual yield depends on total fishing time, the gear that fishers use, where they fish (e.g. off the edge of the reef) and what they fish for. Mangroves and seagrasses are also important in coastal fisheries and are often close to

Traditional fisheries provide a vital source of protein in tropical coastal countries

coral reefs. Fish, which shelter in the reef by day, may feed kilometres away in seagrass beds at night. Seagrass beds are highly productive and can produce more organic matter (for the same area) than Peruvian coastal areas with nutrient upwelling, which are some of the richest in the world. They yield food fish (particularly rabbitfish - *siganids*), and provide shelter for juvenile fishes and prawns, which later move to other habitats where they may be fished as adults. Juvenile fishes can also be harvested for cage culture. Seagrass beds may support hundreds of species of fish, e.g. 318 species were reported from beds in Thailand. They may support 5 times more fish than live on muddy bottoms.

Mangrove waterways are important fish habitats and may have high fish catch rates of between 1.3 and 8.8 kg per hour. The fish weight of the total catch is higher in more productive mangroves (measured by leaf fall and by carbon content of the sediments). Mangrove creeks are also important as nurseries for young fish and prawns, and some adults feed in mangrove forests at high tide. They also support large, edible crabs.

An area of 40,000 hectares of managed mangrove forest in western Malaysia supports a fishery worth $100 million or about $2,500 per ha per year. It produces a further $300 per ha from sustainably managed logging, yielding a combined total $280,000/sq km/yr from fishing and forestry.

$$ The dollar value of the catch from a mangrove fringed shoreline in the Gulf or Panama was $95,000 per km from shrimp, other crustaceans and fish, and in Malaysia the mangrove fishery was worth $250,000/sq km/yr.

Aquarium fish and living corals

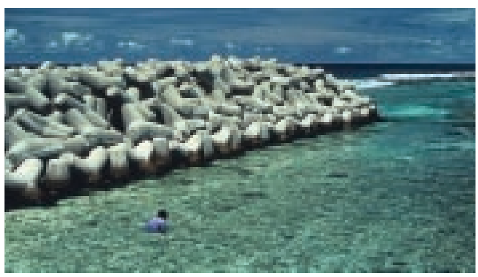
If managed correctly, collection of live fish and corals for aquariums can be sustainable and very profitable. This trade is now a multimillion dollar business but all fish should be collected in either traps or nets. These methods are slower than using cyanide but the fish live longer and other reef fish are not killed. Small and juvenile fish are left alive for the next time. Corals and aquarium fish are best collected from special areas that are leased or sold to the collector, who will have a direct interest to make sure there is no overharvesting. Also, only fast growing corals like staghorn species (*Acropora spp.*) should be sold. International trade in coral is restricted by CITES (see chapter E28 The Law and Coastal Resource Management, p.167) but some local trade may be permitted.

$$ The live aquarium fish trade is a major employer and has yielded over $1 million per year in Sri Lanka (see www.aquariumcouncil.org).

Sand and coral rock for lime and building

Coral reefs usually produce excess sand that is washed over the back by currents and waves. This sand flows off the reef into deep water, so some can be harvested carefully with little damage to the reef. Dredging should be conducted only in areas where currents flow away from the reef. Similarly, some rock can be harvested off the back of reefs but care should be taken not to lower the reef so that waves can cause erosion.

For long term sustainability, the amount of rock removed should not exceed the growth of the small to medium sized coral boulders. Or it may be better to take all the rock from one small reef, rather than take small amounts off many small reefs (see Maldives case study in D20, p.116, and Box 19, p.177).



Groynes replacing lost reef protection

$$ It cost $10 million per km to build walls to protect the main Maldives island because there had been too much mining of coral rock and sand from the reef, and reclaimed land had pushed the shoreline seaward.

Mangrove wood, bark and leaves

Mangroves have been cut for centuries for building timber, firewood, charcoal production and bark for tanning. For example, mangrove poles have been cut in Kenyan and Tanzanian estuaries for some 2,000 years and taken to Arabian countries. They are now being clear-felled for pulp and woodchips for making paper and the Japanese rayon industry. In Nicaragua, many young trees 10-12 years old are cut for poles. Mangroves can be harvested at a 20-30 year rotation time as a sustainable resource (e.g. in Malaysia, Thailand and Bangladesh). They can also be used for curio and cabinet timbers and for traditional medicines. Leaves are widely used to feed cattle and goats in India, Bangladesh, Pakistan, East Africa and the Middle East. The leaves of *Rhizophora mangle* increased milk yield in cattle.

$$ The 40,000 hectares of managed mangrove forest in Matang, West Malaysia yield $10 million in timber and charcoal and over $100 million in fish and prawns every year.

Seagrass beds

Seagrass beds have many other values apart from supporting fisheries. They provide a stable structure for the settlement of many larvae and provide food and shelter. They have high biological productivity and trap detritus and cycle nutrients, which also helps to stabilise shallow seabeds and protect the shoreline. Seagrasses are collected for compost, craftware and food.

$$ Half a hectare of seagrass has been valued at nearly $15,000 annually and seagrass prawn fisheries from Cairns Harbour in Australia yielded 178 tonnes per year, valued at $1 million.

Sustainability

Most economic assessment methods only consider short time scales when valuing resources (discount rates of 3 to 5 years). Fishes and corals can take a long time to replenish: tropical fisheries may take 5 years or more to recover from over-exploitation and coral reefs may take 20 years to recover from large-scale destruction. The growth of mangrove trees varies in different places but they can usually be harvested over a 20-30 year cycle.

All of these direct extractive values can be obtained continuously when the reefs, mangroves and seagrass beds are exploited carefully and sustainably but they lose their value if they are over-harvested. There is direct evidence that a number of these extractive values are declining rapidly in many places. If harvesting is reduced or stopped, they will usually recover.

4.3 Tourism and other direct uses

The largest non-extractive value is tourism, which is increasing rapidly. For example, the number of tourist visitors to Fiji increased by 10 times from 1976 to 1986. In Queensland, Australia, the Great Barrier Reef attracts over 2 million tourists annually and they spend over $1 billion.

Tourists are attracted to the beauty of corals and fishes, clear water and clean beaches for swimming, snorkelling and SCUBA-diving, relaxing, sun-bathing, sailing and walking. Coral reefs that are not overfished are major attractions when they have masses of colourful small fish, as well as big fishes like large grouper (gropers), sharks and manta rays. Overfished areas, beaches dirty with plastic and other garbage, and areas where sewage has reduced coral diversity or replaced corals with seaweeds, chase tourists away (see chapter E29 The Potential of Tourism, p.172).

Large old-growth mangrove forests, sometimes including nature trails on board walks, can also be used to attract tourists e.g. some have monkey populations. There are also important social and educational values of a well-managed coastal zone to the local community. School children can learn a lot about biology and the environment by visiting a mangrove forest.

BOX 2 THE VALUE OF TOURISM

Tourism is the best way of earning money from coral reefs and still conserving them. Look at some of these figures:

- $$ In 1990, Caribbean tourism earned $8.9 billion, and employed over 350,000 people.
- $$ Bonaire is a 288 sq km island in the Caribbean, 100 km north of Venezuela, with a population of about 10,000. The island is surrounded by a marine park from the shore to 60 m deep and the coral reefs in this park are visited by SCUBA divers. The economic activities (hotels, dive operators, restaurants, etc.) associated with Bonaire's coral reefs earn about $23 million annually. The cost of managing the park is under $1 million.
- $$ Australia's 2,000 km long Great Barrier Reef yields about $1 billion annually from tourism.

Reefs also create safe harbours for fishing and tourist boats, and mangrove channels are important, protected transport systems for small boats between villages in many parts of the world.

4.4 Hidden values

These values can only be measured when the asset is destroyed.

The main indirect use value is protection of coastlines, particularly fragile coral islands and muddy shores. Virtually all coastlines in the tropics are protected either by coral reefs, mangrove forests or seagrass beds. These systems often are interdependent; mangroves may protect coral reefs from silt and be protected themselves by the coral reefs from strong wave action.

Coral reefs protect coastal buildings and towns on low foreshores from very high seas (see 20.1, Coral mining, reef erosion and rehabilitation: The Maldives, p.116, and Box 19, p.177). Seagrass beds trap silt and protect mangroves and beaches from erosion. If they are removed, the damage bill and replacement costs can be huge. These potential losses should be considered when major constructions, sewage outfalls, port developments, dredged channels and forest clear-cutting or coastal agricultural developments are planned.

4.5 Non-use values

Finally, there are values that are difficult to measure, like high biodiversity, or unique fauna or flora. These may not have direct money value now but in the long-term they may be important as a source of medicines and valuable genes.

Dugong and calf. Photo: Ben Cropp © GBRMPA

Coral reefs, mangroves and seagrasses also support endangered species. For example turtles, dugongs and manatees all feed directly on seagrasses.

Coral reefs, mangrove forests and seagrass beds also have value as part of the global life support system and act as storehouses of carbon dioxide (CO_2). Mangroves may be able to absorb 2-4% of the current human increase of the greenhouse gas CO_2.

4.6 The need to consider all values

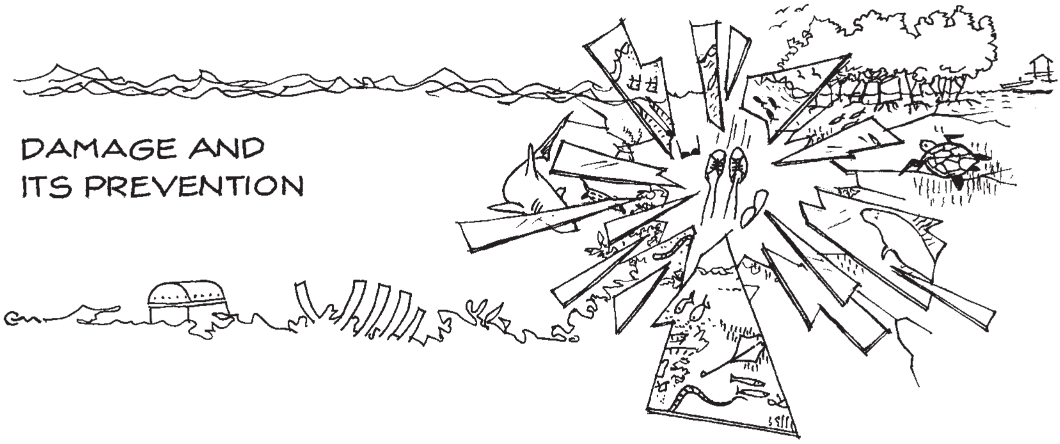
Coastal industries may compete with each other. For example, clear cutting of forests inland will release millions of tons of sediment that may damage coastal fisheries; or overfishing may result in more algal growth on coral reefs that make them unattractive for tourists.

Where new developments are planned on islands or along coasts, it is important that the values of development be carefully considered and weighed against the possible loss of other values. To make sure that a new development does not do more damage than it is worth, a broad analysis of all coastal values is needed. Sometimes, no development may be more valuable than replacing coastal resources but it is essential to have some dollar values to argue this. (See chapter A2 on Problems of Management and Planning, p.7, and chapter C17 on Integrated Coastal Management for Sustainable Use, p.84).

The price of paradise?
This tourist development in the Maldives used coral to build jetties and for reclamation. Then it had to replace natural reef protection with built barriers, using more coral.
A costly, destructive exercise and what is left for the tourists to see?

B DAMAGE TO COASTAL ECOSYSTEMS AND HOW TO PREVENT IT

CONTENTS



B5 Coral reefs

5.1 Stresses to coral reefs

The 3 major human stresses to coral reefs around the world are:

- sediment;
- inorganic and organic pollution; and
- overfishing.

There are other lesser threats caused by people, often only having local impacts such as:

- oil pollution;
- heavy metals and pesticides;
- engineering activities;
- destructive fishing (dynamite, cyanide);
- coral mining;
- physical damage from boat anchors; or
- uncontrolled tourism.

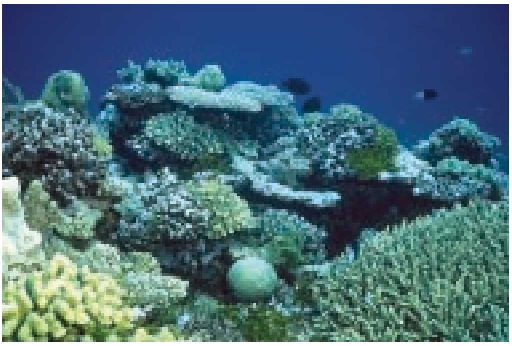
The other major stress that is caused indirectly by humans is through global climate change and the massive bleaching and mortality event of 1998 is an example of this (see Boxes 6 p.42 and 14 p.108). Unfortunately there is little a reef manager can do about this, so we will leave it out of this discussion.

There are also 'natural' stresses, which have caused damage to coral reefs for thousands of years and still do so. Very large population increases of crown-of-thorns starfish (*Acanthaster planci*) can destroy most of the corals on a reef in the Indo-Pacific. Heavy wave action from tropical storms may break more fragile corals, and large coral boulders break off in storms and smash across reefs due to wave surge. Heavy rainfall can result in too much fresh water pouring into bays and reefs near river mouths, which can cause coral death.

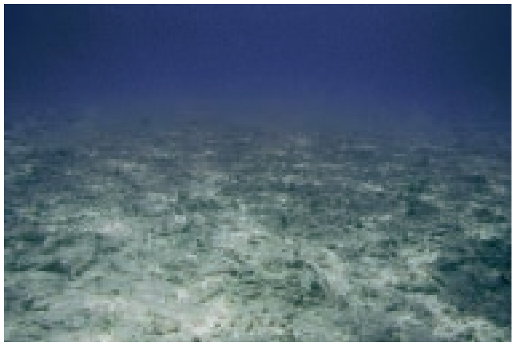
In this section, we describe how corals can be affected by various stresses and what can be done to prevent damage. In all management actions there must be monitoring, to make sure that the actions are put in place.

5.2 Sediment

Coral reefs do not grow very well where there is a lot of sediment, particularly near major rivers. Sediment reduces the light and smothers the corals and only a few species can withstand moderate sediment. Poor management will increase sediment runoff.



Clean healthy corals



Coral being buried and killed by sediment

Sediment consists of fine particles of soil (terrigenous material), particularly silicates, which remain suspended in the water much longer than larger particles. Fine sediments can be resuspended up from the bottom by strong winds and waves in water less than about 20 m deep. The larger particles can bury corals and kill them, because heavy sediments are difficult to remove. Sediments from the land also carry nutrients and fertilisers.

Coral reef sediments are calcium carbonate (calcareous) and make the water milky. They fall out onto the bottom of lagoons, bays and channels but can be resuspended into the water by waves, dredging and coral mining.

Where sediments come from and why

Sediment can damage coral reefs near large rivers and streams. It is caused by erosion resulting from:

- forestry, particularly clear-cutting of tropical forests;
- agriculture, especially ploughing between crops;
- raising of cattle and other animals, particularly over-grazing; and
- clearing of land for housing or industrial development.

Sediment also comes from:

- dredging of ports and boat marinas;
- clearing of mangrove forests (which trap sediments);
- bottom fish trawling; and
- cleaning of prawn and fishponds after harvest.

Symptoms and impacts

When sediment is present, the water is dirty brown to green, with low visibility. Damage is not obvious at first but sediment reduces the light energy available for photosynthesis by corals and reef algae. This also results in grazing animals (parrotfishes, sea-urchins) having less food. The growth rates of corals are slowed and many develop diseases (such as white- and black-band disease) because of the energy used for removing sediments. Corals may be attacked by animals boring through sediment piled around their bases, or be killed by being smothered in sediment.

Management action

It is essential to reduce the sediment that can flow onto coral reefs. This may mean controlling activities 10s to 100s of kilometres away (sometimes well outside the control of local governments or reef managers). Actions can be taken to reduce sediment.

Forestry: Clear-cutting of tropical forests should be reduced and, where possible, wide strips of forest left alongside all streams. Cleared forests lose 120 to 200 tons of soil per hectare every year but natural forests only lose about 2 tons or less per hectare. Recommend sustainable harvesting of trees (see Box 1 Tourism and logging values in Palawan, p.10, and management case study C11, p.62, where the Philippine government protected the reefs by restricting forestry).

Logging roads cause even more silt runoff than the tree clearing itself

Agriculture: Suggest ploughing only in dry seasons to reduce soil loss and sediment pollution. 'Green' sugar cane farming costs less in money and time and increases yields, because without burning the green trash on the ground keeps water in the soil. With replanting in drilled holes, annual soil loss drops from 70 to 500 tonnes per hectare (30 to 200 tons per acre) to less than 4 tonnes per hectare. Other erosion preventative techniques can also be used (e.g. terracing, crop selection).

Overgrazing by cattle: The large catchments are the greatest source of sediment and nutrient pollution on the Great Barrier Reef. Recommend reducing the number of animals and keeping enough grass on the land to prevent soil loss during wet seasons.

Development: Land clearing for development should be done in dry seasons, to prevent economic losses to reef tourism. Using simple bund walls and/or silt screens around developments will greatly reduce sediment runoff.

Mining: Contain all mining wastes in holding ponds and tailings dams to allow sediments to settle. Use these sediments later to fill the mining sites.

Dredging: Deposit dredge spoil well away from coral reefs.

Aquaculture: Use mud pumped out of ponds as landfill or to increase mangrove tree growth, otherwise it will pollute other ponds and reefs.

Fish trawling: Some countries have banned large trawlers within 3 miles of the coast to protect subsistence fishing and seagrass beds, and to reduce sediment disturbance (e.g. Indonesia).

5.3 Organic and inorganic pollution

Human, agricultural and industrial wastes contain organic compounds - proteins, sugars, starches, cellulose, fats and many bacteria. Marine bacteria break down organic pollution and increase inorganic pollution, which fertilises waters with excess nitrate, nitrite, ammonium and phosphate (and other minerals) and causes eutrophication - increased growth of algae. Sediment runoff also contains large concentrations of nitrogen and phosphorous.

Nutrient levels favour the growth of planktonic algae and large macroalgae, which would normally grow slowly in low nutrient waters. Where there is overfishing, the problem gets worse when grazing fish (like parrotfish and rabbitfish) are removed as these normally prevent the algae from overshadowing and replacing the corals.

Where and why

Pollution is very common around cities, towns and farms, because wastes often flow directly into rivers and the ocean. Pollution will increase as populations grow, unless good control and prevention are started.

Much pollution settles out onto the bottom and when strong winds blow over shallow areas (less than 20 m), nutrients trapped in the sediments are released back up into the water and may stimulate algal blooms. Primary and secondary treated sewage still contains much nitrate and phosphate. Only tertiary treated sewage is safe to release onto coral reefs (see case study 19.2 on Mamala Bay, Coral recovery after removing a sewage outfall: Hawaii, p.113).

Symptoms and impacts

The water looks green with much algal plankton (phytoplankton) which reduces light. Thick algal turf or large macroalgae cover the bottom and smother corals (see case study 18.2, The collapse of a coral reef: Jamaica, p.99).

Organic pollution increases many coral diseases and also it helps the growth of animal competitors, like filter-feeding sponges, polychaete worms, boring molluscs and ascidians which out-compete the corals. Many of these also bore into and weaken coral skeletons. (See case study 19.1 Damage and recovery: Kaneohe Bay, Hawaii, p.110).

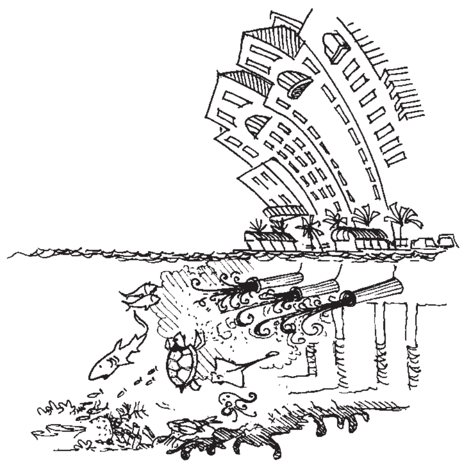
Bottom sediments in polluted areas are grey or black, because excess organic matter breaks down to hydrogen sulphide.

Management actions

Prevent sewage and agricultural pollution of coastal waters by:

- treating sewage to secondary or, preferably, tertiary standard;
- using the wastes as fertiliser for fields or forestry crops (particularly mangroves); or
- pumping the sewage into much deeper water.

Sewage: Treatment of sewage and industrial wastes is expensive for governments. Recommend that industries follow pollution control measures, particularly near coastal waterways. New industries should be 'encouraged' to treat their organic wastes.



Tourist resorts: To prevent damage to reefs and beaches, request that tourist operators treat sewage and wastes to tertiary level to remove nitrogen and phosphorous. Do not allow sewage (treated or untreated) to flow into lagoons but use it for agriculture, to water gardens or golf courses, or pump it into deep water. Reduce artificial fertiliser use on golf courses and lawns.

Forestry: Reduce clear felling of forests and land clearing. Ask Departments of Agriculture to develop programmes to reduce soil losses.

Agriculture: Ploughing of fields should be reduced during wet seasons. Request that wastes from chicken and pig farms and cattle feed lots are properly treated. Some industries can gain additional income by recycling the wastes or by producing other products e.g. stock food.

Aquaculture and fishing: Pond effluent should be used to fertilise forests, not pollute coral reefs. Trawlers should not be allowed to operate close to coral reefs.

5.4 Overfishing

Overfishing means smaller fish and fewer fish, especially if the juveniles are caught

Overfishing happens in most areas where populations expand and technologies increase. Overfishing removes both the breeding adults and small fish before they can grow, and so many fishermen turn to using very small mesh traps or dynamite.

Fish are important for the health of a coral reef and can also act as an indicator system. Without normal fish populations, reefs degrade (see case study of Jamaica, in D18, p.99).

Fish play the following important coral reef roles:

- feed on plankton (damselfish - pomacentrids, unicorn fish - acanthurids, fusiliers - caesionids);
- graze on algae growing on rocks (parrotfish - scarids, surgeonfish - acanthurids, rabbit fish - siganids);
- clean up corals and also feed on them (butterfly fish -chaetodontids);
- eat sea urchins and starfish (triggerfish - ballistids, pufferfish - tetrodontids);
- feed on other animals like sponges, worms, crabs, molluscs (snappers – lutjanids and lethrinids, angelfish - pomacanthids;
- feed on other fish (grouper - serranids, snappers); and
- scavenge on damaged or sick fish (some sharks).

Changes in the fish populations will affect reefs. For example, if algal grazers are trapped or speared, large algae may smother corals and stop new corals settling. Fishermen often have special techniques to catch triggerfish but if they are removed, sea urchins and some starfish can grow out of control, especially if algal grazing fish are also removed (see management case study C10, Overfishing and the Marine Protected Areas in East Africa, p.58). Sea urchins can erode corals and cause them to collapse (see case study 18.3, A reef under stress: Okinawa, p.102).

Where and why

Overfishing usually occurs when large populations have few opportunities for employment. People go fishing for food, and cash to buy food and consumer goods. Fishing pressure increases when land for farming decreases or becomes barren (see case study 18.1, The death of a coral reef: Bolinao, p.95).

Reefs off east Africa, across Asia, in some Pacific islands and in most of the Caribbean are overfished due to large human populations. Now large boats are fishing remote reefs of the Indo-Pacific using destructive methods (cyanide, muro ami and explosives).

Symptoms and impacts

Overfished reefs have few fish and these are small. Normal reefs should have thousands of fish, including large ones weighing over 100 kg (grouper and large wrasses). Tourists stay away from reefs with damaged coral and few fish.

The first fish removed with heavy line fishing are the groupers and snappers. Increased fishing, particularly spearfishing, leaves only small fish.

Abandoned fish traps, nets snared on corals, ropes and lines, and sometimes scars from blast and muro ami fishing (broken and flattened corals) or large areas of dead coral from cyanide fishing are good signs of overfishing.

Flattened corals - evidence of blast fishing

The fish in markets can be a good indicator of overfishing - when reef fish are very small, or there are only oceanic fish (tuna, flying fish) this is evidence for overfishing.

Management actions

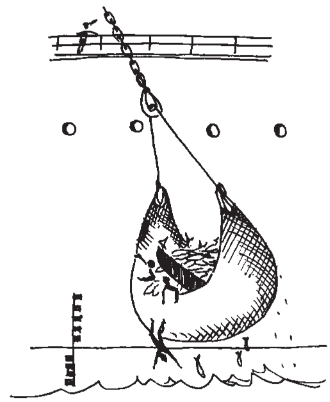
The best solution is to establish large Marine Protected Areas (MPAs) with about 25% of the reefs set aside as no fishing reserves and put strict control on damaging practices (see management case study C9 on Apo and Sumilon islands, p.53). Protected areas should coincide with tourist resorts, so that fishers can earn money carrying tourists.

MPAs use several methods to stop overfishing:

- restrict the number of fishermen;
- control mesh size of nets and traps, or prevent them being used;
- limit areas open to spearfishing; and
- stop taking of fish during the breeding season.

To be effective, these restrictions must be supported by the local population. Planning and management of MPAs should involve the local population, otherwise they will fail.

If possible, provide alternative forms of employment, either in tourism, industrial development, cooperative mariculture, or consider shifting fishing populations to areas where there is employment. All this requires good government coordination and the encouragement of economic expansion.



Watch for external predators

Box 3 Fishing on breeding aggregations

A number of important food fishes aggregate in large numbers to spawn at a few special sites on a coral reef. If fishermen learn the place and the times of these spawning aggregations, they can easily catch most of the breeding fish on that reef. Some snappers, triggerfish and groupers spawn this way.

Different methods of fishing have been used on spawning aggregations. Line fishermen often learn of these places. But destructive methods, like cyanide (for the live fish trade), dynamite, and spearfishing have also been used. Whatever method is used, this kind of fishing is very damaging because it targets the healthy breeding fish, and stocks may not recover for many years, if at all. The big losers are local fishermen who can lose an important part of their catch, and the catches of their children.

This is a key area for reef managers. By protecting these few small areas on a coral reef, a reef manger can protect the breeding populations of valuable food fish.

Message: *Find out where and when the breeding aggregations occur and try to protect these areas as Marine Protected Areas. Educate the local community on the need to protect the breeding populations, and look out for outside fishermen who may raid these areas during the breeding season.*

From Robert Johannes, Hobart.

5.5 Crown-of-thorns starfish and other predators

The crown-of-thorns starfish (COTS - *Acanthaster planci*) are the major natural predators of Indo-Pacific corals. They normally occur as very few, large individuals in reef lagoons. Recent population outbreaks or plagues have devastated whole reefs, with up to 90% mortality of corals. The starfish prefer branching corals, because they can hang on to them easier, whereas the large head corals (e.g. *Porites*) are often not affected, because the starfish are washed off by waves. These recent outbreaks may have been more frequent and damaging than before, and could threaten the ecology of some reefs.

Where and why

Crown-of-thorns plagues are more prevalent on reefs around large islands and continents, than on atolls. The starfish prefer calm water like lagoons and are rarely found where there are large waves or strong currents or in muddy water.

The following have been suggested causes for possible increases in plagues: more nutrient pollution from the land could increase the plankton food for crown-of-thorns larvae; overfishing of fish predators of juvenile starfish (e.g. snappers); or removal of large fish and giant triton predators of adult starfish.

Symptoms and impacts

Evidence of crown-of-thorns starfish is seen as clean, white areas of coral skeleton where the predators have eaten the coral polyps. During plagues, there are large areas of white or green-brown dead coral and the reef resembles a graveyard. Crown-of-thorns feeding scars are different from bleached or diseased corals. Starfish scars are circular and clean, with no diseased tissue around them. The scars can be anywhere on the coral; look near the scars for COTS hiding under corals or amongst staghorn branches.

Diseased corals have dead patches surrounded by a band of dying tissue and then there is live coral. Bleaching normally occurs on the tops of corals and there are often areas where corals are half bleached (less colour than normal). With severe bleaching, all the corals may be white but in big COTS plagues there are millions of the predators. Evidence of past outbreaks is difficult to find.

Management actions

Control of these predators is difficult or impossible. It is better to prevent the pollution and overfishing that may trigger the outbreaks. It may be necessary to kill crown-of-thorns starfish on reefs around tourist resorts and in national parks to protect valuable coral. But this is very time consuming and expensive. If this has to be done, the best method is to use large, mechanical syringes (the type used on cattle or sheep) to inject small volumes of the swimming pool chemical 'dry acid' into each starfish. Or else, collect them and allow them to die on land, because cutting them in half will not kill them. Protection of valuable tourist areas by killing the starfish may be necessary to maintain incomes from tourism.

Drupella

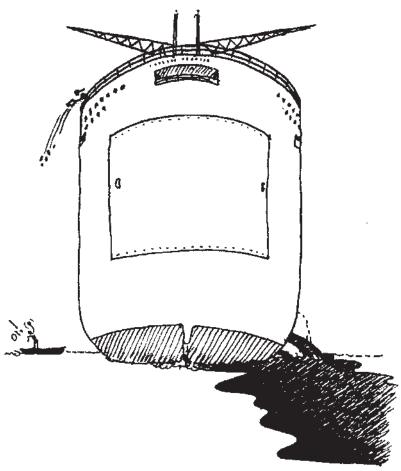
Drupella is a small shell (gastropod mollusc) that can occur in very large numbers amongst branching corals. *Drupella* have possibly increased because of overfishing of the mollusc predators, particularly some snapper species (*Lethrinids*). *Drupella* is too small for divers to collect in large numbers, so control is difficult.

Possibly the only thing a resource manager can do is reduce pollution and prevent overfishing.

5.6 Oil pollution

Oil pollution involves 2 impacts:

- immediate damage from large oil spills; and
- often subtle, long-term changes from slow leakage from oil wells, terminals and refineries (see case studies on Panama, 23.1, p.127; Aruba, 23.2, p.129).



Oil from spills, pumped bilges and spilt shipping fuel, can be driven by winds and tides over the water for days to weeks, before the lighter compounds evaporate and the oil becomes heavy and sinks. Floating oil and associated toxic compounds are most damaging during the first few days after the spill. Usually there is little damage to coral reefs, unless the oil settles out on fringing reefs and reef flats during low tides. Oil is particularly damaging to mangroves and seagrasses. There was little damage to reefs from oil spills during the Gulf Conflict in 1991 (see Box 4 Oil and the Gulf Conflict). The light and toxic compounds eventually evaporate, or winds and waves break up the oil.

Pollution of oil and chemicals, which may be in small amounts but continue for a long time (chronic pollution), is very damaging to corals and may cause slow death and poor recovery.

Where and why

Oil pollution is common around oil rigs, terminals, ports and shipping channels, particularly when ships dump their ballast water. This will increase unless governments and international agencies force stricter rules on oil and shipping industries.

Occasionally large oil spills occur when ships hit coral reefs or break up in storms, particularly old, rusty tankers because IMO (International Maritime Organisation) regulations are frequently ignored.

Symptoms and impacts

Obvious symptoms are slicks, the smell of oil and fuel and tar balls on beaches. There are no distinctive signs of oil damage underwater. Oil has little impact on the corals themselves, because it either floats and is carried away by the winds and tides, or it sinks into the sands. Corals can normally shed oil by producing mucus but toxic compounds can cause damage. Chronic oil pollution may cause a loss of, or slow, coral growth and stop reproduction.

The use of detergents and dispersants on oil spills near coral reefs is often more damaging than the oil itself. These compounds are usually toxic themselves and they may dissolve the oil into tiny droplets that settle out directly onto corals and other reef animals.

Box 4 Oil and the Gulf conflict

Corals in the Persian Gulf along the coast of Saudi Arabia survived the largest oil spill on record, with few visible effects up to 3.5 years after the Gulf Conflict.

The largest oil spill in the world occurred during the Gulf Conflict in 1991 when 6 to 8 million barrels of oil entered the sea in the northern Persian Gulf. In addition, more than 1 million barrels of oil were burned in the Kuwait oilfields. It was expected that all this oil would cause major damage to the coral reefs. Also, huge clouds of smoke from the burning oil reduced the sunlight, and lowered temperatures below normal. Researchers measured corals in permanent transects using video cameras in 1992, 1993 and 1994. Healthy corals covered 25% of the bottom when the transects were first measured, and then there was a small but steady increase in live coral cover over the next two years.

The conclusion was that Saudi Arabian coral reefs showed no detectable damage after the Gulf Conflict. But this environment is a harsh one for corals at any time, with very low temperatures in winter and the corals have developed in an area where there is probably some oil leaking all the time.

Message: *Oil usually floats over corals and rarely harms them directly. A manager needs to get good advice before using oil dispersants, which can do more damage than the oil. A good monitoring programme will help detect damage.*

From Helge Vogt.

Management actions

It is usually best to do nothing if oil spills near coral reefs but wait until the oil floats away and is broken up by the wind, unless booms can be deployed and oil removal is possible. Dispersants should not be used over reefs, because dispersed oil causes more damage. Very severe damage will occur if oil drifts into mangroves, therefore dispersants should be used (over deep water) to prevent the oil drifting inshore. Plans to deal with oil spills should be formed in advance, including methods like booms and skimmers to remove the oil.

Good computer simulation programmes can predict where oil spills will go, using simple information like wind direction and speed, tides and current patterns. These programmes can be set up for sensitive areas, like mangrove reserves or tourist beaches.

Chronic pollution from oil industries should be treated like other pollution, with all wastewaters either treated or impounded in holding ponds. Managers and governments can penalise shipping companies that spill oil and force them to pay fines under MARPOL (The International Convention of the Prevention of Pollution from Ships - see E28, The Law and Coastal Resource Management, p.167). Shipping companies are very careful in Australia because of recent heavy fines.

5.7 Heavy metals

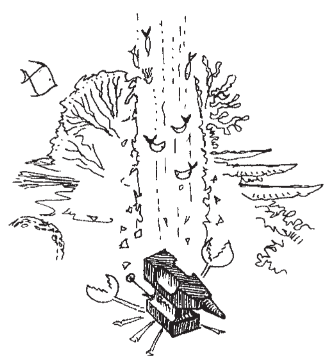
These are metals like lead, mercury, cadmium, copper, chromium and arsenic that pollute the ocean from industry, mining and the burning of fossil fuels.

Where and why

The major sources are cities, mining and industry e.g. most lead from car and truck fuel is washed out of the air and off streets and into the ocean. Most mercury pollution comes from liquids dumped by industry and gold mining. Heavy metal pollution increases with development, unless special measures are used to stop pollution.

Symptoms and impacts

There is no good information or examples of reefs damaged by heavy metals and some research work in Phuket, Thailand suggests that heavy metals may not be a large problem to corals. Usually other impacts (overfishing and sewage pollution) are more damaging. Heavy metals may accumulate in the food chain, especially in predatory fish, which can affect humans. Heavy metals can disrupt the normal reproduction of many animals.



Management actions

The control of heavy metal pollution is similar to other pollution: prevent polluting industries; treat sewage and industrial wastes; and build bund walls and holding ponds to prevent pollution from mining. Older pesticides with mercury and arsenic should be phased out in developing countries.

5.8 Pesticides and other complex molecules

These include pesticides: insecticides - DDT, heptachlor, aldrin, dieldrin, lindane, chlordane (chlorinated hydrocarbons), malathion, parathion (organophosphates), carbaryl (carbamates); herbicides - atrazine, paraquat (triazines), 2,4-D, 2,4,5-T (phenoxy compounds), trifluralin, diphenamid; and other pollutants such as PCBs (polychlorinated biphenyls) and dioxins. Compounds like DDT are used to control mosquitoes.

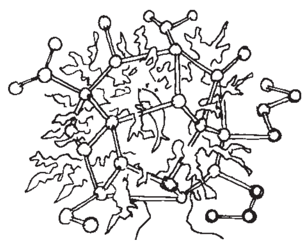
Where and why

Pesticides are essential for many cash crops that are susceptible to pests and weeds e.g. rice, cotton, corn, cocoa, coffee. However, pesticides are often used as 'insurance' against possible problems, so that only 0.1% or less hits the target pest. The rest ends up in the soil, rivers and the ocean. Pests are also developing resistance, so that greater concentrations of pesticides are then used (the 'pesticide treadmill').

Symptoms and impacts

There are no known effects on coral reefs. Many of these compounds remain in the water and sediments for many years (e.g. chlorinated hydrocarbons last up to 15 years). Sometimes accidents or deliberate spills by industry, e.g. dumping of PCBs, can cause massive fish kills.

Pesticides are designed to kill animals and plants; therefore these compounds will kill or disrupt the growth of animals and algae when released into coral reef waters. Chlorinated hydrocarbons, like DDT, accumulate in the food chain and can prevent seabirds from breeding by softening the eggs. Compounds like PCBs resemble hormones in animals and may disrupt breeding cycles of reef animals, particularly larger fish in polluted areas.



Management actions

Reduce the use of such pesticides and prevent them from flowing into waterways, the same as for all pollution. They can be chemically tested for and monitored but this is expensive. Reduce the dependence on pesticides by providing better education on how to control pests using natural methods (biological control). Dispose of old stocks of compounds safely (incineration) rather than dump them into rivers.

5.9 Tourism

Good tourism provides the best economic return from coral reefs for the least environmental impact - provided that it is well developed and managed. Coral reef tourism is probably the largest growing 'industry' in the world but polluted or overfished reefs attract few tourists.

Where and why

The best tourist destinations have clean beaches and coral reefs in clean water (see Box 16 Tourist checklist, p.144). The Red Sea, Southeast Asia, East Africa, the South Pacific, Australia and the Caribbean islands are the major tourist sites. Many tourist operators do not know how to use 'best practice' or they are after the 'quick buck', therefore sound government guidelines and control are needed.

Symptoms and impacts

There are 3 types of tourism impacts: development, operation and tourist activities. The building of resorts on soft soil slopes without attention to erosion can dump large amounts of sediment that can damage reefs for many years. Resorts are often built too close to the beach or on sand dunes that are liable to erosion by storm waves. They have also been built on landfill in shallow water and out on solid jetties. In some cases, boat channels or docks have been cut into reefs. Such developments may change current movements and cause increased erosion of beaches. Poor operations can also release pollution onto the reefs (see forms of pollution in 5.2, 5.3, 5.4, 5.8 above).

Poor operation of tourist resorts will result in sewage and garbage ending up in the water and over the reefs. Also overfishing near resorts will reduce the fish that tourists come to see. A live fish in the water is often worth 10 or 100 times more for divers and photographers than a fish on a plate.

Uncontrolled tourists (and local residents) often collect corals and shells, and damage corals through poor diving technique, carelessness or lack of knowledge. This can be prevented by educating the tourist, the tourist operators and the guides. Where tourists do fish, there should be strict limits on the places where fishing is allowed and how many fish can be taken. Catch-and-release fishing should be encouraged (this is becoming more popular).

Management actions

Provide good advice to owners and managers to improve the construction and operation of tourist resorts, including waste treatment. Resort managers can help with tourist education and by using well-trained dive and fishing boat operators.

5.10 Engineering practices, and sand and rock mining

Coral reefs are damaged by most modifications, such as:

- cutting and blasting channels through the reefs;
- building groynes, piers, wharves and rock walls;
- reclaiming land using solid fill;
- the construction phase of tourist resorts;
- dredging of marinas and harbours;
- building airports on coral reefs; and
- collection and dredging of sand and rock.

Where and why

These happen to increase living areas or protect structures from wind and wave action. More engineering is being used to modify the coastal environment as populations and tourism developments increase.

Symptoms and impacts

Dredging increases sediment pollution, erosion of beaches and reef flats, and results in the death of corals because of sediment build-up or changed current patterns. Careful engineering can avoid the most severe consequences e.g. through the use of Environmental Impact Assessments. Channels cut through the reef speed water flow on and off reef flats, and may result in sand loss from reef flats and beaches through the new passes.

Seawalls and groynes alter current patterns with sand building up in front and erosion behind (therefore more walls are constructed and so on). Dredging of sand and rock increases erosion of beaches and the collapse of buildings (see case study 20.1 on the Maldives, p.116).

Management actions

If there is careful consultation between engineers, reef scientists and managers before any modifications start, damage can be minimised. Problems and great expense can be avoided if reef scientists and managers are involved.

Box 5 Mining reefs in Jakarta Bay

Until recently there were many beautiful coral reefs and islands within Jakarta Bay, Indonesia. Now, about 5 of the reefs and islands have completely disappeared and some others are unrecognisable as coral reefs. The beauty of these reefs was described vividly by scientists early last century.

What happened?

Firstly, the reefs lie in one of the world's most polluted bays. Each day, the sewage, industrial and agricultural wastes of more than 10 million people in Jakarta and nearby towns enter into this shallow bay, creating conditions that are unsuited to coral growth.

Secondly, there has been massive land clearing for agriculture, industry and housing and the sediments have changed the bay into a muddy basin.

Thirdly, some of the reefs have been so extensively dredged for limestone and sand, that they have actually disappeared beneath the waves.

Two of the Jakarta Bay islands (Air Kecil, Ubi Kecil) disappeared in 1983. Dredging removed so much of the protecting coral and sand that they eroded and sank below the surface. In 1985, a third island (Ubi Besar) was close to total collapse, and 3 other islands have eroded markedly during the last 50 years. Now, all the reefs in the bay are severely damaged with coral cover less than 5% and very low coral diversity.

The pollution has completely changed the ecology of the bay, such that very few animals can live in the sediments and the fish and shellfish (cockle) industries that once flourished have been abandoned.

What is the future?

Even if the pollution could be cleaned up, there would not be much chance for recovery of many of these reefs, because the pollution buried in the sediments will take many years to break down and wash away. And some of the reefs have been taken away and can now be seen as the cement in the large buildings of Jakarta.

Message: *Sometimes it is necessary to admit that some reefs have been lost and just forget about them. But in this case there are many reefs nearby, so management is needed to save these.*

From Barbara Brown and Clive Wilkinson.

B6 Mangroves

6.1 Damage to mangroves

Mangroves are a valuable resource in the tropics, being used traditionally for timber and firewood, building materials and mine supports, fishing traps, charcoal and tannin production.

Mangrove channels are very valuable nursery areas for fish and prawns. At high tides, the mangrove forests are used as feeding areas by fish and other marine animals. Mangroves support a diversity of associated animal species, some of them endangered.

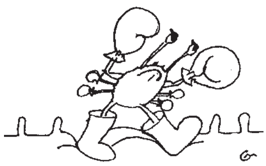
Mangrove areas are also cleared for fish and prawn ponds, salt production, industry and housing development, as well as port and airport construction. All of these remove trees and leave large bare patches within mangrove forests, or wide areas of salt tolerant grasses, stagnant ponds, changed water flows and compacted soil surfaces.

Controlled mangrove harvesting can provide resources continuously and be a sustainable industry. But if the harvesting of the trees is faster than the rate of reseeding and regrowth, or they are totally removed, then the following problems can occur:

- major losses of prawn and fish nursery areas and crab fisheries;
- increased erosion of the mangrove area and the land behind the mangroves with coastal damage (including prawn ponds);
- intrusion of salt water into farming land following this erosion;
- loss of sediment filtering and trapping by mangroves, resulting in more sediment flowing on to seagrass beds and coral reefs;
- exposure of acid sulphate soils and acid leaching;
- loss of old trees that provide seeds and propagules;
- loss of biodiversity of plants and associated animals;
- fire in areas where mangroves die or dry out; and
- gaps in the canopy cause higher death rates of newly settled young trees through increased light and evaporation.

6.2 The removal of mangrove forests

Most mangrove damage is caused by clearing with bulldozers, chainsaws, axes and machetes, and the most severe human impact is total removal of the mangrove forest. This is usually done for export wood chips, to make fish and prawn ponds, for port construction and channels, and for conversion of mangroves for other uses such as housing, industry, roads and grazing land.



Many village users make lesser impacts by cutting some mangroves for firewood, charcoal, poles, and bark for tannin and for medicinal purposes. In the Philippines mangroves are removed in forests and dug out to make 'miracle pools' that trap fish when the tide falls.

6.3 Water balance

If water flows into mangrove forests are changed the trees may die, become sick, grow more slowly or fail to reproduce. Mangroves that are cut off from the sea by roads, dykes or dam construction will soon die.

Reducing the flow of fresh water by building dams or diverting rivers will kill or damage most mangroves, because the salt concentration will increase, particularly affecting those species that do not like normal seawater. Higher than normal salt concentrations can also kill mangroves, particularly in wide shallow areas with restricted flow and high evaporation rates. Increasing flows of fresh water for long periods will kill or damage most mangroves.

The following human actions can change this water balance by:

- building channels for shipping;
- making earth bunds that can change or stop water flows;
- damming rivers; and
- increasing freshwater flooding from deforestation inland.

Mangroves may die, or become sickly and reduce growth and generation of seedlings, from such actions (see Box 18: Recognising stresses in mangroves, p.165).

6.4 Excessive silting

Silting and sediment flow increases where there is deforestation, poor agricultural practice, road building or city development. This mainly happens during heavy rains and monsoons, particularly when forest clearing increases the amount and speed of water flowing off the hillsides. Too much sediment can cover the aerial roots, or change the water balance (see above).

6.5 Acid sulphate soils

Mangrove soils often become extremely acid when waterlogged sediments which are high in sulphides (from the bacterial decay of past leaf litter, silt with organic material from leaves, wood, plankton and seaweeds) are exposed to the air or water with a high oxygen content. The result is sulphuric acid, which can stress or kill plants and animals in nearby waterways and transport heavy metals

6.6 Pollution

Many pollutants damage mangroves. Mangroves are reasonably resistant to increased nutrients (such as sewage), but pollutants from industry and pesticides can affect or kill mangroves and associated animals (see 21.2, Loss of lagoonal mangroves: Ivory Coast, p.122). Major oil spills have also killed large areas of mangroves and chronic oil spills may continue to stress them. In Panama, however, young mangroves are regrowing after a major spill in 1986 (see 23.1 on the oil spill at Bahia las Minas, Panama, p.127 and 23.3 on the oil industry and mangroves in Nigeria, p.131).

6.7 Natural impacts

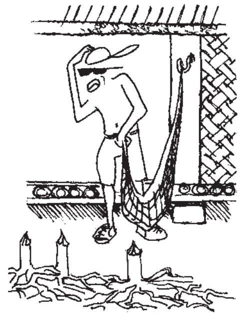
Natural stresses like drought, freshwater flooding (sometimes with heavy loads of sediment), erosion and bank collapse, lightning strikes and leaf eating insects (sometimes in huge numbers) damage mangroves. The trees are very resistant to wind and waves (small boats often shelter in mangrove creeks in storms) but really violent storms cause serious damage in more exposed mangrove areas. This damage will be increased if the mangroves are thinned, or there are gaps caused by prawn ponds or other constructions.

Recognising mangrove stress

Mangroves show many signs when they are stressed. Changes occur in their aerial roots, bark and growth rates, terminal shoots, leaf size and colour, flowers and fruit may be deformed (see Box 18, p.165).

6.8 Preventing decline and loss of value

Often decision-makers with little environmental and fisheries knowledge consider that mangroves are muddy, mosquito infested swamps that should be cleared and filled in. This does not recognise their true value as economically important coastal ecosystems (see chapter A4, The Value of Coastal Resources, p.11). Mangroves are also often cleared for prawn farms or fishponds, because the land does not belong to anybody or is government land.



The full economic value of mangroves should be measured before decision-makers consider removing them. These values include sustainable forestry, nursery areas for prawns crabs and fish, protection of coasts etc. These must be added to the estimated costs of providing coastal protection from storms, and the costs of compensation and employment to displaced fishers and villagers. Careful environmental and economic assessments should be made to prevent removal of mangroves that will result in larger problems in the future.

Planned changes to water and land in the catchment area need to be assessed for impacts downstream in the mangrove forests. These include coastal works like harbours, channels, estuarine land fills and causeways, and changes to river systems and estuaries by damming rivers, intensive agriculture, forest clearing, forest replanting and other earthworks (see C17 on Integrated Coastal Management, p.84).

Mangroves must be managed like an investment, where the interest earned is the sustained productivity of the trees and waterways - the long-term value to the community. Sustainable use of mangrove forests need:

- good forestry practice (understanding growth rates and wood production, how much can be removed annually, the rate of natural reseeding, etc.);
- full economic assessment of all mangrove values (fisheries, coastal protection, etc.);
- monitoring of the forests and other coastal areas to detect change or loss;
- education of all users and decision-makers; and
- inclusion of mangroves in Integrated Coastal Management.

B7 Seagrasses

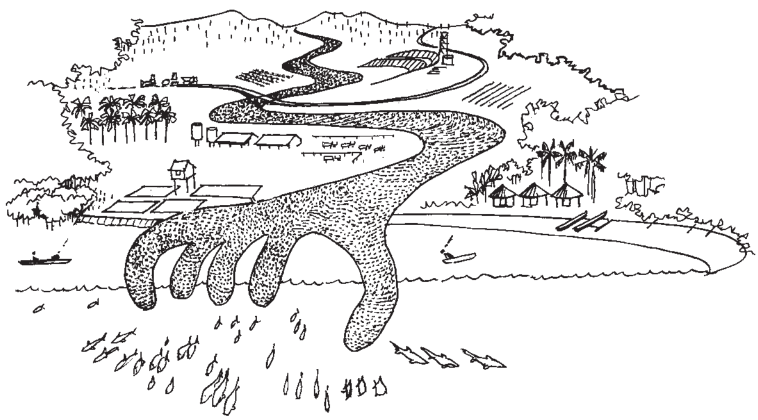
7.1 *Stresses to seagrasses*

Many things that damage coral reefs and mangroves also damage seagrasses. Losses can be attributed to natural biological and physical stresses but most recent losses are due to human activities, often because there is a lack of awareness in communities and governments on the value of these resources or the impact of human changes.

The decline of seagrasses is widespread in both temperate and tropical shallow waters. Some tropical examples are East Asia and Florida (see case study 25.1, p.139), and in temperate regions Cockburn Sound (Australia) and San Francisco Bay (California). Where seagrasses disappear the animals on the sea floor may be reduced by 70%, so both shelter and food are lost to fish and prawns.

7.2 *Sediment*

Heavy sediment flow in estuarine areas can bury seagrass plants. Suspended material flows down rivers and streams and can settle on seagrass beds. Much suspended material enters coastal waters because of unplanned coastal development and road works. Sediment in the water increases turbidity, which reduces the amount of light energy reaching seagrasses. Increased plankton growth due to excess nutrients carried by the sediments also increases turbidity and increases plants that grow on the seagrass leaves, fouling the seagrasses. Seagrasses will die if the water is too turbid, particularly those growing in deeper water. If they do not die, there will be reduced photosynthetic production and disease, and eventually a shrinking of the seagrass bed area. All this means less food and protection for fish and prawns.



Where sediments come from and why

Heavy sedimentation may occur when there has been extensive sub-tidal and inter-tidal land reclamation (Singapore), major agricultural cultivation (Philippines), or mining (Philippines, Thailand, Malaysia). Catchment area runoff includes sand, silt and clay caused by deforestation, slash and burn agriculture ('kaingin' in the Philippines), and industrial and urban development. Boat traffic and dredging for harbours and channels also increases sediment suspension.

7.3 Nutrient loading

The major long-term threat to seagrass beds around the world is from increased coastal nutrients. This is a particular problem in estuaries and bays with reduced tidal flushing. Nutrient loading (eutrophication) is caused by many factors:

- wastewaters which reach the coast from industrial, commercial and domestic activities;
- inadequate sewage treatment systems;
- boat discharges of human and fish wastes;
- stormwater drain runoff carrying organic waste and fertilisers;
- rivers coming from heavily fertilised agriculture; and
- from excess nutrients washed out of soils because of increased erosion from bad pastoral or agricultural practice.

Impacts

The direct impact of nutrients is more growth of plants that shade the seagrasses from light. This will reduce their health and all the commercial species that use seagrass beds for food and shelter. There are 3 main kinds of plants that compete with seagrasses for light:

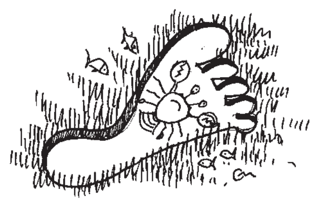
- free-floating plant plankton (diatoms and dinoflagellates) reduce light reaching the bottom;
- large algae which grow on the bottom and overshadow seagrasses; and
- small algae (epiphytes) that grow on seagrass leaves, prevent light reaching the leaves and weigh them down.

If seagrasses disappear from a bay or an estuary, which has happened in many tropical and temperate areas around the world, it indicates that something is going wrong. (See case study 25.1, Stress from water management and land-use practices: Florida Bay, p.139). Seagrasses are good indicators of overall ecosystem health.

7.4 Pollution

Other forms of pollution, such as heavy metals, pesticides and organic chemicals may also affect seagrasses. This is difficult to measure, because these pollutants may be masked by sewage and nutrients that enter with increased development. Little is known of the direct impacts but, presumably, these add to the stresses on seagrass beds. Pollution appears to interact with and increase a disease called 'wasting disease' that caused rapid die-off of eelgrass in the North Atlantic.

7.5 Physical disturbance



Blast fishing and other destructive fishing techniques are common in many parts of the tropics. Explosives create blowouts or grass-free depressions within the beds. For years after the blast, these blowout areas are continuously eroded by water movement. It may take 5 to 15 years for seagrasses to recolonise the blasted spot, and in some cases (e.g. inside the Belize barrier reef) they have not recovered after 40 years and may never recover.

Heavy boat traffic (near fish markets) also causes scouring of seagrass beds:

- through hauling boats across the shallows;
- through the propellers cutting the seagrasses;
- by anchors, ropes or chains; or
- by poles used for manoeuvring.

Managers consider that the grooves made by propellers cutting through Florida Bay seagrass beds will not regrow unless the scoured paths are filled.

7.6 Climate change

If sea temperatures rise by 1 degree or more and rainfall increases, the amount of water runoff will increase. This will lower salinity and add more nutrients, particularly in shallow seas and semi-enclosed waters. Increased land erosion will damage seagrasses and reduce their efficiency as nursery and breeding areas.

Sea level rise will be insignificant, compared with man-induced changes in the coastal environment. But increases in the number and severity of storms and wave surge, will cause increased shoreline erosion, inundation and changes in wetlands, and have severe impacts on seagrass beds.

Box 6 Global climate change and sea level rise

Human activities are changing the atmosphere and the world's climate. Burning of fossil fuels (oil and coal), clearing of forests, more industry and intense farming are all adding 'greenhouse' gases (carbon dioxide, methane, and nitrous oxide) into the air and warming the earth. The process is gradual and major effects may only be obvious in 20 to 30 years, but there are some effects already.

Greenhouse warming, global climate change and sea level rise are all getting a lot of publicity in the media, but there is little that a local environmental manager can do about it.

There will be 4 main effects of Global Climate Change:

- sea levels will rise;
- coral bleaching will probably increase;
- rainfall and weather patterns will change; and
- there may be large changes in currents and winds.

Another associated effect is: decreased ozone and more ultraviolet radiation (See Box 11).

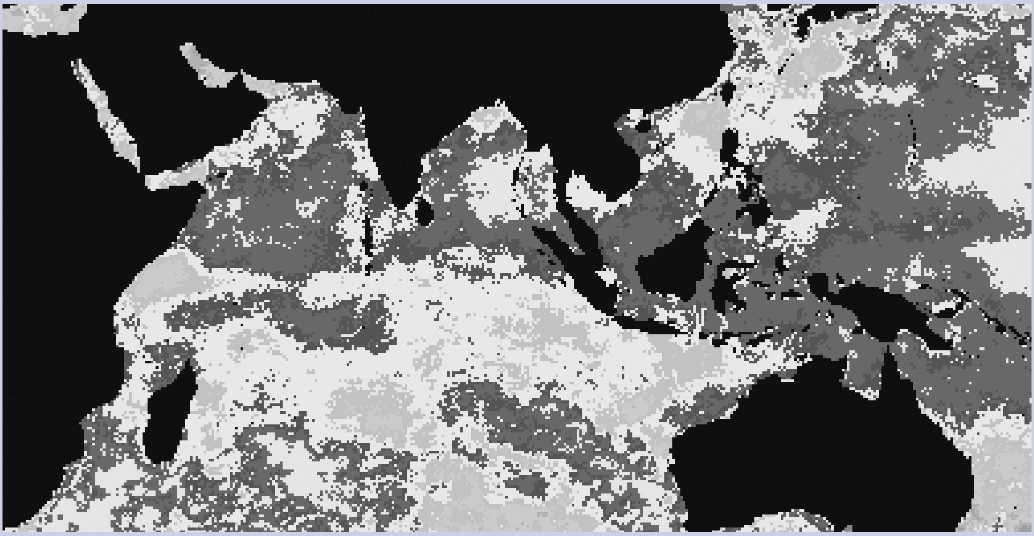
Sea level rise: Sea level is rising at about 5 cm every 10 years, which is less than the rate that coral reefs can grow upwards. A rise of 0.5 m in the next 100 years may not seem much, but people on many low lying sandy islands will have to move to higher islands or build expensive protective barriers.

Reef growth will keep up with sea level rise, but islands cannot accumulate new sand and rock fast enough to stay above the rising sea. A combination of storms and rising sea level will push seawater over low islands and contaminate the fresh water lens under the sands.

Agriculture will be reduced and underground drinking water will become too salty. Therefore, low lying countries should start planning for sea level rise now by not building near the shore, making plans to move towns away from the beach, and probably assisting people on some low lying islands move to higher islands or other countries. Building of sea walls will probably cause more damage by increasing beach erosion.

Coral bleaching: Increases in air, and particularly sea temperatures are causing more bleaching of corals. This is happening in all coral reef regions and is killing large areas of corals (see Box 14, p108).

Presumably, bleaching happened to corals thousands of years ago and they managed to recover, therefore it is likely that coral reefs will eventually be able to cope this time. However, recovery of healthy coral cover may take a long time and reefs in some tourist centres may become very unattractive. Recovery from severe bleaching will take 10 to 20 years at least.



Map showing sea surface temperatures in the Indian Ocean in January to June 1998. The 'hotspots', in darker shades, are on average 1 to 3°C above normal maximums for those 6 months.

Rainfall and weather changes: Rainfall will change in the tropics, with more rain in some areas, and less in others. Storm patterns will also change, and there may be more cyclonic storms, which will effect some coral reef areas not previously affected. It is also possible that the number and severity of El Niño, Southern Oscillation events will increase.

Current and wind changes: Climate changes cannot be predicted accurately enough to say if or where this will occur. It could be disastrous if there are major shifts in current patterns (people are suggesting that the Gulf Stream may stop warming Europe).

Message: *All the above effects are outside the control of the local manager. Direct stresses from large human populations will cause more damage than either climate change or sea level rise. The only prevention is to convince governments and people to burn less fossil fuel.*

Map of summary of satellite data from the US National Oceanic and Atmospheric Administration.

7.7 Non-sustainable development

In some developing countries, development means more exploitation of the environment and no conservation or protection. The latter are not seen as necessary or socially important, but rather as expensive and time-consuming options that either slow down or stop development.

Environmental goals, such as ecological sustainability, can appear to be in conflict with economic goals which are dominant. But this is a short-sighted attitude. Over-exploiting natural resources may yield some quick monetary gain but it is short lived, leaving no foundation for the future. To ignore or underrate environmental goals does not make sound economic sense. Ultimately, it is the environment which produces the resources on which the economy is built.

For long term sustainability and income growth, environmental and economic goals need to be considered together and kept in balance. Information and knowledge about the long term impacts of environmental damage cannot be ignored, if communities are to achieve their full economic potential.

7.8 Institutional problems

There is not enough knowledge and understanding of Integrated Coastal Management in the government and private institutions of most tropical developing countries. There are often overlapping responsibilities in different government departments, so that either no department takes responsibility, or there is conflict between different parts of government about who is in charge.

Traditional free-access fisheries, with more and more fishermen and better techniques, are not sustainable but no alternative has been developed that is acceptable to the users. Few governments have an overall policy on coastal development and management to guide government departments. There may also be no public support or inadequate implementation of existing laws that are designed to protect resources.

As long as seagrass beds are not considered as a vital part of the coasts and of less importance than coral reefs, they will continue to degrade rapidly and reduce the quality of other linked ecosystems, including coral reefs.

7.9 Some consequences of seagrass loss

Less vigorous growth and production by seagrasses, and major reductions in their area will result in serious changes to coastal ecosystems. There will be:

- less shelter for adult food fishery species;
- less shelter for developing young of important food species (prawns, fish), which are often harvested in other areas as adults;
- less food for important food species that feed on seagrasses directly;
- less shelter and food for molluscs, crustaceans and others that are eaten by commercial species; and
- loss of the function of seagrasses in stabilising sandy bottoms and slowing water movement, which will mean more coastal erosion.

Loss of seagrasses will have such major impacts on shallow coasts and estuaries that it may threaten the livelihood of local people who depend on coastal resources.

7.10 How can we stop seagrass decline?

It is important to identify the factors that damage seagrass beds and identify which are the most serious. Recommendations to prevent seagrass decline include:

- monitoring seagrasses to understand what is happening;
- banning or regulating coastal construction on or close to seagrass beds;
- improving wastewater treatment;
- controlling surface runoff and undertaking earthworks outside heavy rain seasons;
- preventing cutting of mangroves and foreshore use that increases erosion;
- banning the dumping of dredged material and industrial waste in and near seagrass beds;
- regulating boat traffic to prevent direct damage and erosion;
- reducing the use of fine meshed nets, trawling in shallow waters and blast fishing;
- monitoring and regulating fertiliser use, educating farmers to use it wisely;
- regulating seaweed, shellfish and fish harvesting;
- carefully assessing and regulating harbour and channel dredging; and
- restoring seagrass beds and continuing to develop expertise in this.

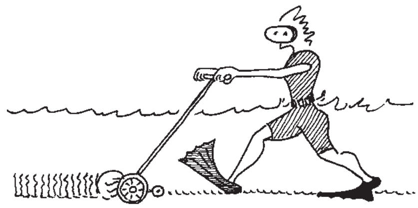
Cooperative agreements between countries and joint training for managers and users of coastal resources (including seagrasses), as well as improving public understanding, are important. Sound understanding of Integrated Coastal Management at the highest governmental level is essential to prevent these resources being steadily lost (see C17 Integrated Coastal Management, p.84).

7.11 What is being done?

We need to know more about the function and importance of seagrasses. Putting a real monetary value on seagrass beds (the 'goods and services' they provide), is essential.

$$ A value of over $30,000 per hectare was estimated for eelgrass beds in temperate Puget Sound and prawns from seagrasses within the harbour of tropical Cairns, on Australia's east coast, total 178 tonnes (valued at $1million) annually.

To determine the real values of seagrasses is difficult but figures show that seagrasses are very valuable. It is essential that they are not destroyed, for long-term sustainable coastal development.



Some countries are developing national plans, e.g. the Philippines, which has a National Seagrass Management Plan.

This plan, still to be implemented, has five major components:

- finding out where the seagrasses are (resource mapping and survey);
- learning about seagrasses (research and development);
- informing people about seagrasses (information dissemination, education, training and publication);
- developing laws and regulations for sustainable use and protection (policy and legislation);
- managing seagrasses so they are sustainable (environmental management).

The regrowing or rehabilitation of seagrass beds (see Section E, 30.3 on restoring seagrass beds p.181) was possible in Calancan Bay, Philippines (see Box 7, Transplanting seagrasses, p.47), where a mining company successfully replanted seagrass beds. Indonesia has incorporated policies to protect seagrasses and Singapore has protected seagrasses around the island of Pulau Semakau to protect coral reef productivity in the area. Thailand has provided funds to the Phuket Marine Station to protect reefs and seagrasses. Malaysia is also earmarking seagrass beds for protection.

The United Nations Environment Programme (UNEP) has a regional project in the Asia-Pacific region to assess the effects of river flows of sediment, nutrients and pollutants on seagrass beds, wetlands and coral reefs.

7.12 Artificial seagrasses

Artificial seagrasses may be a useful supplement to improve and rehabilitate very damaged areas and replace the nursery function of the beds. Artificial seagrasses have been used to investigate and monitor fish recruitment and changes in biomass. In the Singapore River, artificial seagrass increased fish and shrimp numbers and species within 3 months, and provided feeding areas for introduced seabass juveniles *(Lates calcarifer)*. At Cape Bolinao, Philippines, artificial seagrasses were used to improve the biodiversity and productivity of a degraded poor area. There were more fish species in the artificial seagrass than in natural seagrasses in the area.

Box 7 Transplanting seagrasses

Methods and techniques for transplanting and restoring seagrass beds have been developed over the past 10 years (see 30.3, p.181). Although the techniques have not completely restored a whole seagrass bed, there is one good example from Calancan Bay, Philippines. A causeway was built using copper mine tailings. The area nearby was planted with seagrasses and after 2 years, it changed from a bare mud area to a rich seagrass bed.

After 5 years, the transplants completely covered the bottom, and now have the same biomass and productivity as before the tailings were dumped, and fish species increased from 2 to 17 in 1989 to 22 to 34 in 1990. These beds are now the same as naturally grown seagrasses. In some places, transplanted seagrasses have grown slowly, probably because they were the wrong species for the habitat or the conditions were poor.

Where seagrasses have been destroyed by pollution or siltation, they cannot be restored until the damaging impacts have been stopped.

Message: *It is best not to allow destruction of a seagrass area but, if one is destroyed, the area can be restored. The problem is that it takes a lot of time and money.*

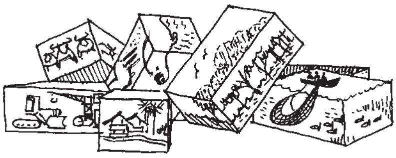
From Mike Fortes, Marine Science Institute, University of the Philippines.

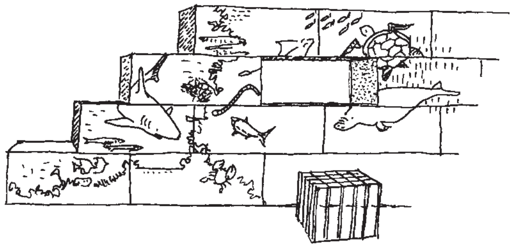
C MANAGING COASTAL ECOSYSTEMS

Ci Management case studies

CONTENTS

MANAGEMENT
CASE STUDIES





C8 Managing Australia's Great Barrier Reef

This is a special case study because it covers such a large area and management has been generally successful. There are many reasons why managing the Great Barrier Reef (GBR) has been different to managing other areas. These are:

- the GBR is a very large system (2,000 km long) with most reefs closely connected by currents which supply fresh larvae;
- many reefs of the GBR are remote from land (more than 30 km offshore);
- population density on the nearby coast is very low;
- fishing and other exploitation is moderate and there is no subsistence fishing;
- the economic status of the local population is relatively high;
- the local people have a high conservation ethic and strongly support the need for management;
- there is strong support from all levels of government and there are adequate funds for effective management; and
- there is a strong marine and social science community able to provide valuable data and support for management.

The Great Barrier Reef Marine Park (GBRMP) contains about 2,800 separate reefs along 2,000 km of coastline in an area of 350,000 sq km of broad continental shelf. It is by far the largest protected coastal area in the world being actively managed.

The GBRMP was set up by the Australian Government in 1975 after there had been an active public campaign to stop oil drilling and mining on the GBR. An Act of Parliament in 1975 established a single lead agency, the Great Barrier Reef Marine Park Authority (GBRMPA), with the task of planning and managing the GBR with a specific goal:

> "to provide for the protection, wise use, understanding and enjoyment of the Great Barrier Reef in perpetuity through the care and development of the Marine Park."

8.1 Full consultation

Management of the GBRMP was largely successful because of the above reasons and because the GBRMPA undertook extensive consultation with local populations, placing particular emphasis on talking to farmers, fishing groups (both recreational and commercial), the tourist industry, non-governmental organisations (NGOs) and the indigenous communities along the coast. All these people are represented on a special advisory body (Consultative Committee), which provides direct advice to the senior committee (The Authority). This is a four person committee with one each from the Australian Government, the State Government of Queensland, the broader community and the indigenous people.

Inter-government support is further helped by a Ministerial Council of two Ministers from the National and State governments, who meet once or twice each year to avoid disputes between governments. Within each part of the coast, there is a local advisory committee, which provides direct input into zoning of that part of the reef.

8.2 Multi-user zoning

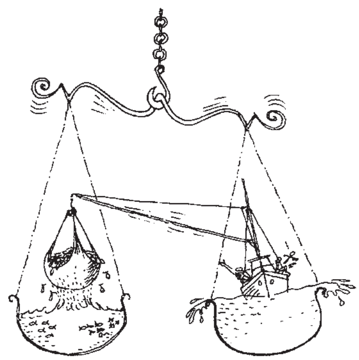
A special feature of the GBRMP, compared to other types of protected areas (e.g. National Parks), has been dividing the area into 7 different zones. These are to cater for all users and also to ensure that significant areas are conserved and protected.

The major direct activities being controlled are fishing, collecting and tourism.

The largest human threat to the areas surrounding the reefs is fishing by trawlers. In 1981, it was proposed that at least 10% of the sandy bottoms would be closed to fishing, now that figure is 15% to 30%.

There are 2 zones for the sandy bottoms around the 2,800 reefs:

- General Use Zone (in 80% of the area) - trawl fishing is permitted.
- Habitat Protection Zone and other categories (in the remaining 20%) - trawling is banned.



Balancing competing uses

On the reefs themselves there are 4 zones, permitting different intensities of use:

- ***Habitat Protection Zone*** (76% of reefs) - all fishing is allowed e.g. commercial and recreational fishing, including spearfishing, but trawling, some collection of animals and spearfishing with SCUBA are all banned.
- ***Conservation Park Zone*** (2% of reefs) - here commercial fishing, spearfishing and collection of animals are banned, while allowing recreational fishing.
- ***National Park Zone*** (21% of reefs) - accentuates protection of the reefs, by only allowing tourism but preventing all fishing and collecting. In some areas there is a Buffer Zone that allows for the catching of pelagic fish.
- ***Preservation Zone*** (1% of reefs) - this prevents entry by all people, except scientists doing research under very strict conditions.

Tourism is allowed in all zones, except the Preservation Zone. However, operators are allowed to place tourist pontoons on only 60% of all reefs, usually with only one structure on each reef.

All zones are protected by legislation and are intended to remain unchanged for 5 years, after which they can be renegotiated and rezoned for a similar period.

8.3 Catchment area pollution and management needs

Although most of the reefs are a long way offshore, sediment and nutrient pollution are two major threats to the inner reefs and to waters around the other reefs. The largest sources of sediment are from two major rivers that drain large areas of dry, cattle grazing lands. Heavy rains after drought result in major outflows of sediment into the GBR Lagoon, which damages inner and middle-shelf reefs. GBRMPA is attempting to involve farmers in reducing stocking rates to lower sediment runoff.

Sugar cane and banana farming are the second biggest source of sediment pollution. These are being markedly reduced through joint projects with the farmers, Departments of Agriculture and the reef managers. Many farmers, including those who are also keen fishermen on the reefs, have changed to green tillage of crops (leaving the trash on the ground as compost and not burning crops). This can reduce sediment runoff from cane fields by 20 to 100 times.

The major sources of nutrient pollution (nitrate and phosphate) on the GBR are from cattle grazing, cane and banana farming, domestic sewage and tourist activities, in that order. All tourist resorts and boats must install tertiary treatment of wastes or transfer wastewater to suitable sewerage plants on the mainland. Most cities and towns on the coast are installing secondary treatment plants. Cane and banana farmers are regulating their use of fertiliser and now leaving natural vegetation barriers around streams to minimise runoff loss. Controlling nutrient loss from over-grazed dry lands is a more difficult process.

8.4 Lead agency

Probably the most important success factor has been establishing the single lead agency, the GBR Marine Park Authority. GBRMPA is supported by an Australian Government Act, with a matching act passed by the State of Queensland. GBRMPA is responsible for planning and overall management of the GBR Marine Park (allocating reefs for the placement of tourist pontoons, setting the tourist carrying capacity of reefs, issuing permits for scientific research etc.). The State Department of the Environment is responsible for the day-to-day management and enforcement, through the use of rangers in the field.

GBRMPA has substantial government funding that is now supplemented by a day fee of $4 from all tourists visiting the reef. After completing zoning for the whole GBR, GBRMPA developed strategic plans for the next 5 years and 25 years. A widely representative group of 60 organisations took 3 years to map out strategic directions for the GBRMP to ensure: that the GBR remains a healthy, high biodiversity environment; that all activities in the area are sustainable; and that there is continued strong community education and support for management.

***Message**:*	*This is a special case but the lessons are clear: before attempting large area management, it is essential to have strong government, industry and community support; and it is essential to have a strong lead agency. It is also essential to have high capacity in planning, monitoring, education and enforcement, and to interact with and consult all the stakeholders.*

C9 Two management models for Philippine marine reserves

Sumilon and Apo islands: a lesson about the need for community support

9.1 Sumilon Reserve: A history of failed agreements

Sumilon Island (Lat. 9° 21' N., Long. 123° 23' E.) is 2 km from the southern tip of the large Philippine island of Cebu. The surrounding reef is only 0.5 sq km and about 100 fishers from two local towns (Santander and Oslob on Cebu) fish in the area using traditional gears - hook and line, gill nets, traps and spears.

Protection initiated

Sumilon Reserve was formed in 1974, to protect 25% of the reef, under an agreement between Silliman University and the Oslob Municipal Council. The people of Oslob and Santander were persuaded by biologists that the benefits of increased fish yields might be expected in 3-5 years. The fishers at first seemed unclear of the restriction but, by the late 1970s and early 1980s, there was a perception that the yields had increased.

Protection lost

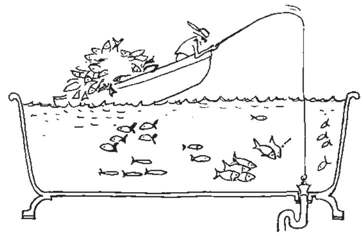
In early 1980, new mayors were elected to the two towns who did not support the reserve and in that year several serious fishing violations occurred. The University appealed to the national government and Sumilon Reserve was declared a nationally protected fish sanctuary and this order is still in place. The Governor of Cebu and the mayors of the two towns resented this, because Sumilon is part of Cebu and was being interfered with by a national government, and because a university from another island (Negros) was given control.

Fishermen began using the reserve again. In May 1984, there were threats against the caretaker of the reserve and he was removed for his own safety. Destructive fishing techniques (explosives, 'muro ami' drive net fishing) were used in the reserve. After over 9 years of protection, the reserve collapsed and the amount of fish in it declined significantly. A decline in fisheries yields in areas adjacent to the reserve suggested that fish had previously been leaving the reserve and were part of the catch in these areas - and that the reserve had been effective.

The development of the island

A hotel was planned for the island, then built, and an ad hoc decision was made to stop all fishing by the Santander and Oslob councils from the beginning of planning in 1987/88. On completion of the resort in January 1992, this protection was revoked for the non-reserve area and fishing began again. As before, the reserve was not effectively policed and there were again violations. A large fish corral was set up in the reserve and, although this was later dismantled, fish traps were commonly seen in the reserve during 1992-1994. Also it was rumoured that visitors were spearfishing with SCUBA gear in the reserve.

The tourist resort has now failed and is being sold.



This complex management history at Sumilon Island shows protection can result in significant increases in fish biomass that will increase nearby fisheries. Unregulated fishing in separate periods of 2 and 1.5 years eliminated fish biomass gains accumulated over 5 and 9 years of marine reserve protection. Slow, hard-won gains can be quickly lost.

Broken agreements

Sumilon Reserve was severely fished down in 1984 and 1992 because local fishers and municipal government ignored national law. An agreement was finally reached with the Oslob Municipality, to maintain the fish reserve and provide a guardhouse and caretaker, but fishing in the reserve continued in 1994. There was no active caretaker, although the construction of a guardhouse was completed in December 1995. The Oslob mayor and the caretaker maintain that line fishing is permitted in the reserve and this has continued up until at least late 1998. Such fishing is a clear violation of the national law, which has declared the area a 'no take' reserve.

Sumilon Reserve has been a management failure. Community support for the concept is still lacking 20 years after it was initiated.

Box 8 Value of cyanide fishing versus hook and line fishing

It may seem strange, but hook and line fishing is much more profitable than cyanide fishing if you measure it over 25 years. Economist Herman Caesar of the World Bank showed there will be a net loss to Indonesia of $46 million if cyanide fishing is allowed in Indonesia. This is mostly due to losses by not attracting tourists to damaged reefs without fish.

In spite of the approximately $500 million return from the fishing, the same reefs if fished sustainably with hook and line produce a net profit to Indonesia of $322 million more than cyanide fishing (costed over 25 years at a 10% discount rate).

9.2 Apo Reserve: Community support yields success

Apo Island (Lat. 9° 21' N., Long. 123° 16' E.) is a volcanic, mainland island surrounded by a coral reef of 1.06 sq km, approximately 5 km south of Negros Island and under the control of the municipality of Dauin on Negros. Unlike Sumilon, which was uninhabited, there are 500 permanent residents on the island.

Education and conservation

A programme of education and conservation by Silliman University in 1979 led to the idea of a marine sanctuary, and this was agreed to by Dauin municipality and the university in 1982. Protection of a 0.45 km strip of the coral reef (about 10% of that reef) began in that year. A community centre was constructed to assist in management of the reserve and this now serves as a meeting site.

Community support for a comprehensive marine conservation plan

In 1985, the Apo community endorsed a comprehensive marine reserve/sanctuary plan and the entire island was declared a marine reserve. The reserve included the sanctuary, where no anchoring, fishing or removal of anything was allowed, and the wider reserve area, where there was to be fishing only by traditional means.

The plan banned all destructive fishing methods within 500 m of the island. Scientific advice was provided by the university, a Marine Management Committee was set up, with mainly local residents, and enforcement was given to the Philippine Constabulary. Like Sumilon, studies at Apo showed that good protective management results in significant increases in fish biomass and there is evidence that local fish yields outside the area increase.

Two small tourist resorts have started on Apo island that cater to the middle range of the market This has meant that increased money is available to the community through accommodation, the supply of food, use of boats to ferry tourists around and the sale of curios. It was estimated in 1998 that the reserve contributes $500 per hectare per year into the local economy and also has made the island famous as an ecotourism site.

A success for the whole community

Apo Reserve has been very successful, with the community actively involved in the Marine Management Committee (now with its own building). Small tourist facilities have benefited the local economy and encouraged local craft industries. The sanctuary is now a well-known dive site, attracting "ecotourists" and creating pride in the community.

9.3 Conclusions

The Sumilon Reserve failed because the planning and the setting up of the reserve did not adequately involve the whole community. Silliman University's actions were thought to be selfish, and because they came from another island and another province, they were misunderstood. The benefits of increased fishing yield (and to a lesser extent tourism) are long term (3-5 years) and not understood by fishers, particularly when a politician seeking election promises to take the island and reserve from the (distant) university and give it back to the fishers themselves.

The management of the Apo reserve and sanctuary succeeded because local community support for the reserve concept was actively maintained, with original ideas and concepts evolving from the community, and implementation and maintenance achieved by them. Considerable community discussion led to the emergence of 'core groups' which formed the basis of the marine management committee. The residents themselves identified their needs and management problems, resulting in the concept of the reserve, with guidance from educators.

The marine management committee was involved in the drafting of the municipal ordinance to establish the reserve/sanctuary, for surveillance and collection of visitor fees and donations, and in the construction of the community education centre. This latter activity (planning, constructing and maintaining a marine education and community centre) was a critical factor in keeping up the enthusiasm of the residents.

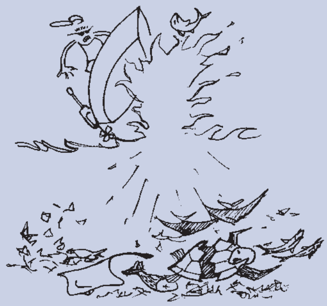
Message: *Protection of marine areas will not work unless there is active involvement and consultation with the local users, who then must have an active role in managing the resources.*

From Garry R. Russ, James Cook University, Australia and Angel C. Alcala, Philippines.

Box 9 Blast fishing destroys coral reefs

Since World War II, dynamite or blast fishing has become widespread and is now commonly used by many communities. As fishing pressures and populations increase, some fishermen feel that they are forced to use these more damaging methods to feed their families.

Blast fishing is a cheap and easy way to catch fish. But the explosion destroys the coral and kills many other fishes, particularly juveniles, in the blast area. Some fishermen have been killed using explosives, and others have lost fingers and hands.



Fish need shelter from larger predators, particularly at night, but explosives destroy both the coral that is their shelter and the food that fish eat, like small fishes and other invertebrates.

Where blast fishing is common, the reefs are flattened, coral shelter is reduced and the large breeding fish disappear. Then, only the small, quick-growing fish remain, so that the traditional fishermen do not catch enough fish to eat and even the blast fishermen get reduced catches.

This type of fishing should NOT BE PERMITTED. It is not sustainable, and destroys reefs that could produce fish on a continuous basis in the future. It is totally banned in most island and coastal countries with coral reefs but explosives are still used in remote areas where there is no control.

The best ways to combat blast fishing are to involve and educate the whole community, and to provide alternative employment for fishermen.

It is essential to educate fishermen, and their wives and children by showing them that the damage caused will prevent them and their children catching fish in the future and will not attract tourists.

Message: *It is essential that blast fishing be stopped because it causes severe damage to coral reefs. Probably the best way is to educate the community about the damages and losses caused and assist them in self management.*

C10 Overfishing and marine protected areas in East Africa

10.1 Economic and environmental benefits of marine parks

Marine parks and protected areas serve many purposes. This has been shown in East Africa, where marine parks set up by the Kenyan government have produced economic and environmental benefits. The reason for these parks was to attract foreign tourists and foreign exchange to help in Kenya's economic development.

The marine parks have rivalled many of East Africa's famous safari parks, as many visitors come to the beach to relax after watching animals on the dry plains. As well as bringing in money, the marine parks have shown how management can be used to increase fish stocks and improve the health of coral reefs.

10.2 Conflicts between tourism and fishing

There is almost a continuous fringing coral reef along the south coast of Kenya that protects the coral sand beaches from destructive monsoon waves and currents. These reefs support important fisheries and also have a high diversity of plants and animals. The calm lagoons behind the reefs are very important because most of the fishers are poor and only have small and unstable canoes or outriggers for fishing. These lagoons are also the areas used by tourists for swimming, coral viewing and other water sports.

All these uses of the lagoons create conflicts, particularly when the tourist wants to look at fish while fishermen want to catch them.

There are also conflicts between tourism that brings in export money, and the Fisheries Department which wants to increase fish catches to feed the increasing human population.

The number of fishers has increased steadily over the last few decades and fish catches now are quite low (1 to 4 kg per person per day), which suggests that the fishery is near the limit of exploitation. Therefore it has been essential to introduce some zoning of uses to reduce the conflict between attracting tourists and catching food.

There are clearly some limits for governments when they try resource developments that are incompatible and there are also limits to free-for-all development.

10.3 Impacts due to overfishing

Studies on the protected areas of Kenya show that heavily fished reefs develop many different problems. Fish predators control the populations of many invertebrates, like sea urchins, snails and starfish. If overfishing removes the fish predators, these invertebrates can increase to extremely large numbers, and this can be very destructive to corals and even fish populations.

Without predators destructive animals can flourish

Sea urchins damaging corals in East Africa

In Kenya, there may be 100 times more sea urchins on heavily fished reefs than in the marine parks. One sea urchin in particular, the rock-boring sea urchin *(Echinometra mathaei)*, has become dominant on these reefs and feeds on algae growing on the surface and also inside coral rock. This urchin can quickly erode the reef, flatten out the surface and remove the algal food that many herbivorous fishes need.

Fishing with large seine nets also damages coral. Therefore the direct and indirect effects of fishing is to reduce the cover of coral, removing the hiding places for fish, and their food. Many of these nearshore lagoons become unproductive and the only fish caught are ones that migrate into the lagoon from reefs further away.

10.4 Changes after setting up a marine park

The health of the reef

One coral reef near Mombasa, Kenya's largest city, was heavily used by both tourists and fishers until 1991. Then half of the reef was declared as a Marine National Park and over 100 fishers were excluded. Studies on coral, fish and sea urchins since the Park opened show that coral and fish abundance increased quickly in the first few years and sea urchin populations dropped in the spots where carnivorous fish increased.

A few areas dominated by large-bodied sea urchins *(Echinothrix diadema)* or with many good hiding places, did not experience a decrease in sea urchins or a very large increase in fish populations. When divers killed the sea urchins in some of these sites, both coral cover and some fish species increased. Therefore it may be necessary to do some restoration to achieve full reef recovery after reducing the fishing (see Box 15 Can damaged coral reefs be restored?, p.115).

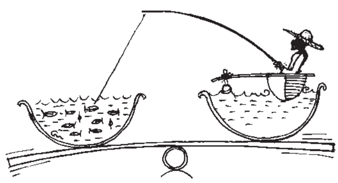
Fishing

The creation of the Mombasa Park protected area has had two opposing effects on fishing.

- On one hand, there was a marked increase in fish harvest close to the Park. Those fishers that remained caught 35% to 50% more fish near the Park than further away.
- On the other, the total fish catch went down by about 35%, because:
  - the total available fishing ground was reduced; and
  - many fishers who used to fish in and around the area stopped fishing, rather than being forced to compete in the reduced fishing areas.

But if the park had not been set up, the pre-park fishing levels would not have been sustained as the health of the reefs was already visibly declining. Furthermore, fishing is only one of the economic values of the reef. Once benefits from other uses such as tourism are taken into account, there was a net gain for the region.

One way of balancing competing uses while still optimising fishing potential may be to create smaller parks (~ 5 km^2). These may be able to protect fish stocks and produce more fish nearby to compensate for some overfishing in nearshore areas.



Protected areas should be carefully designed to protect fish stocks, large reproducing fish and species diversity, while still maintaining the fish catches required by developing countries with expanding populations.

Message:	*There are no magic solutions to our demand for marine resources, and setting limits and enforcing them may be the only way to sustain fish production at the present high levels. Marine parks are a proven way of producing both economic and environmental benefits.*

From Tim McClanahan, Wildlife Conservation Society, Coral Reef Conservation Project, Mombasa, Kenya.

Box 10 Monitoring and survey methods

Throughout this book we often refer to a manual* of monitoring and survey methods. This manual was developed jointly between 1984 and 1994 by marine scientists from five ASEAN countries: Indonesia, Malaysia, Philippines, Singapore and Thailand, in conjunction with the Australian Institute of Marine Science in Townsville.

The manual contains methods to assess coral reefs, mangrove forests, seagrass beds, soft sediment bottoms and tropical fisheries as well as guides for preparing monitoring programmes and databases.

The methods were specifically developed to be very basic and applicable in a range of ecosystems by people without extensive experience. For example, there are simple methods to assess the cover of coral over large areas then get better detail at chosen sites along line transects. There are also quadrat methods to count young corals and methods to count the numbers of settling larvae on ceramic tiles.

We have recommended the coral reef methods particularly, as they are in use throughout large areas of the Indo-Pacific and were recommended by the Global Coral Reef Monitoring Network, as well as forming the basis for the development of the Reef Check methods (www.ReefCheck.org).

*English, S., Wilkinson, C., Baker, V. (1997). Survey Manual for Tropical Marine Resources, 2nd Edition. Australian Institute of Marine Science, Townsville, 390pp.

C11 Partial management success in El Nido, Palawan

Some management success - but not complete

El Nido (Lat. 11°N., Long. 119°E.) is one of the best dive sites in the world for tourists and is already a large money earner for the local population and for the Philippines. The government has gone to considerable efforts to protect this valuable resource, but things are not going exactly to plan.

The forests of Palawan covered 92% of the island in 1968, but cover decreased to about 70% in 1980 and to 50% in 1987, because of timber logging and slash-and-burn agriculture. Large-scale logging of the forests commenced around El Nido in 1985 and immediately the increased sediment runoff into Bacuit Bay began smothering and killing the corals.

11.1 Reefs more valuable than forestry

A detailed ecological and economic study in 1988 of the relative values of coral reefs and extractive forestry in this Philippine island, showed that the reefs were more valuable than the forests. The reefs could provide more sustainable income from fishing and tourism than the income from removing the timber.

Following this study, both the provincial government of Palawan and the national Philippines government banned commercial logging, and the Department of Environment and Natural Resources strictly enforced bans on slash-and-burn agriculture. The area around El Nido, Bacuit Bay, is now a Marine Reserve, with a human population of 22,000.

Enforcement of both regulations has clearly worked as the old logged, and slash and burn areas have new cover of young trees and the reefs appear to have recovered well.

In spite of this encouraging news, at the end of 1996 market-sized fish and invertebrates had been markedly reduced by small-scale artisanal overfishing. Previously common organisms, such as giant clams (Tridacna) are now rare or very small, while lobster, trochus, green snails and edible holothurians are all gone. Once there were large fish (as large as 50 cm and more) including grouper, sweetlips, parrotfish, humphead wrasse etc., but now there are few, and these are small, even at the most remote dive spots.

The NGOs and government departments have had some difficulties working together at El Nido. Most importantly, there is no attempt to control fishing, other than trawling.

Many fishermen are recent immigrants, and have come to Palawan from neighbouring provinces, because there are few fish left back home. In El Nido they are experiencing serious difficulties catching enough fish, and they expect that the situation will deteriorate quickly. Dynamite fishing still occurs (two fishermen were blown up in one week) and there is some cyanide fishing.

There are two reasons for the rapid loss of fish stocks:

- growth of the population from 11,600 people in 1980 to 22,000 in 1995, has created a large demand for local fish; and
- ice is now available and an exporter sends 15-20 tonnes of iced fish per month to wealthy people in Manila. Much dried fish is also exported.

11.2 The need for integrated management

This case shows the difficulty of managing coral reefs and the need for an integrated management strategy (refer to A3, p.9, and C17, p.84 on Integrated Coastal Management). There were once many fish in the Marine Reserve of El Nido, which is relatively isolated (there is no road access most of the year), and has a low human population. But now the high-valued commercial fish and shellfish are virtually all gone. The corals so far remain in excellent condition, so that control of land use reducing silt can prevent damage to some marine resources.

Management controlled one problem, the source of sediment that was damaging the reefs, but did not stop overfishing. A reef without fish is like a city without people.

Message: *Management plans should seek to control all damaging activities on a coral reef. Excessive sediment flow onto the reefs was identified as a problem and controlled; but fishing, including blast fishing, was not controlled so now there are few fish left to attract tourists.*

From Gregor Hodgson, Institute of the Environment, University of California at Los Angeles, USA.

C12 Sustainable forestry of mangroves - Matang

There has been a sustainable forestry project on the west coast of Peninsular Malaysia for about 90 years. The Larut Matang area was originally declared a forestry reserve by the British colonial government at the start of the last century; it has been continued by the Malaysian Forestry Department with considerable success since independence.

12.1 Managing mangrove forestry sustainably

Of the 40,700 hectares in the area, 35,000 are clear felled on a regular rotation cycle to produce poles for scaffolding, building fish traps, housing and finally for conversion to charcoal. This leaves over 5,000 ha to maintain forest diversity and also protect a species of monkey that feeds on a variety of mangrove leaves. The forestry alone is worth over $10 million per year.

A staged thinning cycle

Plots in the forest are sold off to 55 charcoal contractors who are responsible for management. Their first task is to ensure that there is sufficient new settlement of mangrove trees, mostly *Rhizophora apiculata*, with lesser amounts of *Avicennia*, *Sonneratia* and *Bruguiera* species. With so many adult trees in the area, there is usually sufficient natural seed production to resettle the cleared areas but where this fails the farmer re-seeds the area with preferred species.

The first thinning is at around 17 years to produce long straight poles for building; a second thinning is done after about 22 years; and each forest plot is clear felled after 30 years to produce logs that are converted into charcoal for domestic cooking and roadside food stalls. This is a conservative management cycle, as scientists from nearby Universiti Sains Malaysia estimate that the minimum cycle could be about 25 years.

12.2 Fishing yields maintained at high levels

An even higher annual return, of $2,500 per ha, comes from the extensive fishery supported by this large mangrove area. The forests are the nursery area for a $100 million plus industry in fish, prawns, crabs and cockles collected either from within the forest creeks or the banks immediately offshore.

With a combined return of $2,800 per ha per year, this has been a very successful forestry and fishing project that is clearly sustainable. But there are limits. There is recent evidence of overfishing of mangrove related species and the fishery urgently needs management to ensure it remains sustainable.

Scattered plots the key to success

One of the key success features about Matang is that the plots are scattered throughout the total area, so that at any one time there are no large clear felled areas that would be subject to erosion. This is another feature in management of mangrove forests; they should be cut in strips perpendicular to the shore so that long lengths of the bank are not left exposed to erosion.

Message: *Mangrove forests can be managed sustainably and produce big returns, but the important lessons are to leave sufficient areas for seed production and to prevent shoreline erosion.*

From A. Sasekumar, University of Malaya and Clive Wilkinson.

C13 Replanting mangrove forests in Bangladesh

Bangladesh has a population of around 100 million and lies at the head of the Bay of Bengal to which the Ganges-Brahmaputra-Megna river system delivers 2 billion tons of sediment annually. It forms the world's largest estuarine, tide-dominated delta. About 80% of the land area of Bangladesh is formed of delta sediments, some as deep as 5 km. Averaged over the past twenty years, delta sediments have increased the land area of Bangladesh by 35 sq km per year. Cyclonic storms are funnelled into the Bay of Bengal every monsoon season, and have a devastating impact on the low Bengali coastline with a high death and damage toll. These major cyclones rework large amounts of the delta sediments each year.

What the mangroves were like

This rapidly changing coastline over the eastern two-thirds of Bangladesh does not support diverse mangrove vegetation. The much more stable Sundarbans area further to the west supports a rich mangrove forest forming the basis of an important forest industry. In addition, the extensive Sundarbans mangrove forests provide protection during cyclones to the western part of the coastline and, in order to extend this protection eastwards, a major mangrove planting programme was undertaken.

The success of mangrove plantings

So far over 120,000 ha have been planted with mangroves, predominantly of high quality timber species such as *Sonneratia apetala* (for timber), *Excoecaria* (for newsprint and matches) and *Avicennia marina* (for firewood).

Plantations were started by local village communities planting small seedlings supervised by the Forestry Department. Growth was rapid and within 7 years a thinning of the plantation was necessary. Within 14 years, the plantations can be harvested and a second rotation of mangroves planted in their place.

Mangrove nursery

The result is a self-repairing barrier to wave action

Although the plantation sites are initially unstable, the sediments are rapidly trapped, and the soil becomes more stable. Protection from cyclones rapidly follows. It is too early to assess the timber production value of the programme.

The plantations clearly accelerate the accretion of new land and they help to protect coastal agricultural land and villages from cyclonic storms and storm driven tidal surges. During one storm in 1990 in the Sitakunda area just north of Chittagong, about 25% of a 2 km seawall built of 2 tonne, steel reinforced concrete blocks was smashed and some concrete blocks were moved inland by up to 100m. In contrast, mangrove trees in a plantation just south of the seawall sustained damage to less than 1% of the trees and most of the damaged trees had recovered within 6 months. Nearby coastal areas that lacked seawall protection and were protected only by mangroves suffered no more damage during the storm than areas protected by the seawall. The mangroves survived relatively undamaged because they were flexible and, unlike the concrete wall, did not present a rigid barrier to the wave and current action. Equally important, the mangrove barrier is self-repairing.

The main objectives of the mangrove forest plantings were to increase coastal stability and protection and to provide timber resources. But these extensive plantations have also brought about coastal habitat enhancement. Spotted mangrove deer make substantial use of the plantations as do a range of other wildlife and aquatic fauna and flora.

Management actions needed

These plantations need forestry management. A number of insect pests have affected some of the plantations, causing some mortality and a decrease in wood quality. Increasing the species diversity of these plantations has been a management aim. This should improve the mangrove forest and also have ecological advantages.

What is happening now

This experience has shown that mangrove plantations can be established and managed successfully and that they have considerable potential value in stabilising coastal land and protecting it from storms and erosion. Mangrove plantations in certain areas may provide more long-term coastal protection than solid engineering structures, because they are flexible, and they may be more economical, because they are self-repairing.

***Message**:*	*Coastal managers should plan for inevitable change in rapidly changing environments rather than attempt to control or prevent the processes of change. Planting mangroves for harvesting is better than just trying to protect coastal mangrove forests.*

From Peter Saenger, Director, Centre for Coastal Management, Southern Cross University, Australia.

C14 Planning restoration of healthy coastal systems in Indonesia

The coastal area of SW Sulawesi comprises a mainland shore and a broad shelf 40 km wide with hundreds of islands and reefs (the Spermonde Archipelago), running north and south of Lat. 5°S. The islands have fringing coral reefs and there are also abundant coral patch reefs. Seagrass beds grow on the sandy bottom between the reefs, and mangroves used to be abundant along the coast. The shelf is in an area with the highest diversity of marine species in the world.

The coast is densely populated and Ujung Pandang, the capital of South Sulawesi, is the biggest city and most important port in eastern Indonesia. Land degradation inland is causing people to move towards the coast and there is 5% annual population growth in the region.

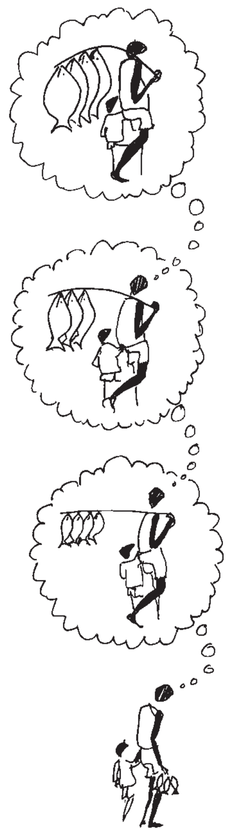
14.1 Why have an action plan for restoration?

The area was a highly productive shallow-water shelf and the most important fisheries province of Indonesia, with 90% of the catch being taken from a zone within 8 km from the shore. Fish and other marine animals are harvested from both the reefs and the open sea and fish, prawns and seaweeds are cultivated in brackish ponds (tambaks) along the shore.

Most fishermen still use traditional methods but technological and dynamite fishing, and also the use of coral for building material, are steadily reducing the harvest off the reefs. In addition, the removal of most of the mangroves has meant the loss of an important nursery area for small fish and crustaceans. Industry was growing at 14% a year until the recent turmoil.

Rivers are carrying human sewage and industrial waste into the sea, and agriculture is adding sediment and fertiliser nutrients. Road development, harbour works and dredging, and works in the drainage areas of rivers all add more damage to the land and to coastal systems.

Governments decided to act as the fishery could no longer sustain the production of food. An Action Plan was developed through cooperation between the Hasanuddin University in Ujung Pandang and specialists from universities and research institutes in Holland.



Remembering how it used to be

14.2 Defining the problem

The first step was to define the problem, the responsible agency and the probable causes of the problem.

The problem was the lack of sustainability of the fisheries. The problem was so great, and covered such a big area, that the only agency that could be considered to have responsibility and authority that could lead to solutions was the Council for Provincial Planning and Development (BAPPEDA).

BAPPEDA considered the problem to be due chiefly to the following:

- pollution from nutrients and sediment from agriculture; pollution from waste products and nutrients from households, industries and tambaks (aquaculture ponds);
- erosion of the coast due to reduced input of river sand because of river damming;
- decline of seagrass meadows because of all the above;
- destruction of coral reefs by dynamite fishing, harvesting of coral blocks and sediment overflow;
- decline of many reef organisms (fishes, crustaceans), as a result of the cutting of the mangrove forests and removing sheltering nursery grounds;
- overfishing; and
- the local population feeling they have no influence or responsibility for their resources, due to lack of support from authorities.

14.3 Developing an action plan

Definitions

A limited area was defined for the plan (due to limited funds, people and time). This was 70 km of coastline and 40 km off the coast, around the river Jeneberang, and off the city of Ujung Pandang. The plan was to be developed and implemented over about 10 years.

Objectives

The general management objective was: 'sustainable use of the coastal resources in SW Sulawesi'.

The broad objectives for management were to prevent or reverse the problems that were considered to be leading to a steady loss of production in the system (listed above).

Actions

The first effort was to make an inventory of possible actions that could be undertaken. These included:

- measures against erosion by agro-forestry, irrigation improvement, providing alternatives to destructive uses of the resources, improvement of better agricultural practices, and regulation of addition of manure;
- regulating waste products by improvement of sewerage, water purification, restriction of tambak (fish pond) culture and its waste products, and regulation of navigation;
- replanting of mangroves;
- control of fishing, by place, time and methods, and providing alternatives; and
- co-management, to give the people involved more control over their resources and involvement and influence with BAPPEDA, and a more secure living.

Limitations

In all such action plans, there are limitations that must be understood and taken into account if the action plan is to succeed. Understanding these helps in the setting up of the plan, and helps to set priorities. Limitations included:

- the realities of physical conditions like climate, water-movements, soil characteristics and conditions;
- socio-economic conditions like employment, capital input, production techniques, population growth, international competition;
- cultural conditions like the involvement of local populations and existing management strategies; and
- political conditions like the relationship between local politics and the national government in Jakarta.

14.4 Measuring changes resulting from the action plan

To put an action plan into place, it is necessary to see whether it is working and whether the desired improvements are taking place. Monitoring is needed to answer questions such as:

- Are the areas of mangroves increasing?
- Are the seagrass beds spreading?
- Are there more fish?
- Are the fish larger and have they reached breeding age?
- Is there less or more sewage entering the sea?
- Has the fertiliser use on the fields changed?
- Has the income per person increased or reduced?
- Is the plan being accepted and supported by the local people that it affects?

These are only a sample of areas where measurements are needed for this action plan. A set of measures must be developed for each plan that attempts to:

- change human behaviour;
- improve the environment;
- improve a yield or make certain it is sustainable; and
- develop new uses of natural resources.

Only this way can we recognise success or areas where further work needs to be done.

After 3 years study of the area, the teams created the action plan over 2 years, and the plan is expected to be put into action over a 10 year period. It is hoped that it will result in a healthy and productive coastal ecosystem on the Spermonde shelf of SW Sulawesi.

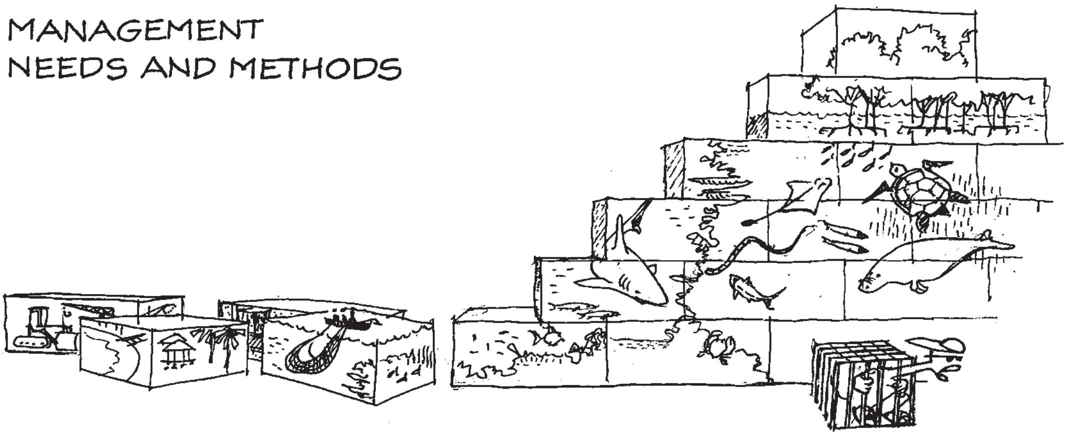
From Maya Borel Best, Natural History Museum, the Netherlands.

Developments like this can be used for cage culture - a productive, sustainable activity.
But they can also be misused as holding pens for the live reef fish trade, which is often based on the unsustainable, destructive practice of cyanide fishing.

Cii Management needs and methods

CONTENTS

MANAGEMENT
NEEDS AND METHODS



C15 Do your coastal ecosystems need management?

To determine whether your ecosystem needs management you should consider many factors.

15.1 Lessons about shallow tropical coastal systems

The case studies (D18 to D25) show that reefs, mangroves and seagrass beds are easily damaged. For example:

- Overfishing can seriously damage a rich fishery and can actually destroy a reef fish population if spawning aggregations are removed. This will reduce future incomes of local fishers.
- Coral reefs can also change to less productive reefs that are covered in large algae and nearby seagrass beds can die.
- Both coral reefs and seagrass beds can be killed by sediment, sewage and other pollutants from nearby or catchment area discharges.
- After mangroves are removed for firewood or building, there is often erosion of muddy shores.
- Unsustainable coral and sand removal can cause reefs to become rubble areas with no corals and few fish, or lower the protective barrier of the reef so that storm waves penetrate inland.

Many studies show that recovery, although possible, is neither common nor easy. Therefore the message is to prevent damage if possible, rather than rely on cleaning up the problem afterwards.

Marine habitats are often damaged by natural catastrophes but, if this happens, they almost always recover. If a coral reef is severely damaged by a cyclone, it will regrow from coral left living (old bases, broken loose pieces) and from settlement of young corals, and in 10-15 years can become a flourishing reef again.

However stresses from human impacts are often the real cause for permanent damage.

- Coral reefs, mangroves or seagrass beds may show little or no change under low, continuing environmental stress until there is some natural damage (like a cyclone). Then recovery may be slow or not happen at all because the human stresses are continuing.
- Sometimes ecosystems may be under steadily increasing stresses but appear quite normal. Then, when the stress reaches a breaking point, they collapse and do not recover until the stressing factors are removed.
- When there is change or damage, it is always easier to look for one damaging factor. But often several stresses work together without one being the major cause.

15.2 Interaction between shallow coastal systems

There are often interactions between the three tropical shallow water coastal systems, so that damage to one may affect the other. For example:

- Loss of mangroves may allow more sediment to reach reefs or seagrass beds and damage them.
- Many coral reef fishes leave the reefs at night to feed in the seagrass beds and good commercial fisheries will be lost or reduced if the seagrass beds are lost.
- Many reef fish live as juveniles in seagrass beds and in mangrove forests, so if these seagrasses or mangroves are reduced reef fish will also be reduced.

These are linkages we know about. There may be others we do not yet understand but we do know that damage to one coastal system will impact on others.

15.3 Long distance impact

The case studies show that often the damage comes from outside the area, where another group of owners or government agencies have control. But all human activities in the coastal zone will have an impact, usually negative. The most damaging impacts are major developments - mining, forestry or agriculture - on the land which result in inputs to coastal waters. Sewage with increased population, sediment from large urban developments, clear cutting of forests or harbour dredging, pollution from industry, and pesticides and nutrients from agriculture are some of the damaging consequences.

15.4 How to tell if management is needed

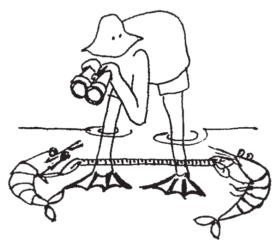
If management is not obviously needed, introducing management may cause more social problems than it solves. If you are doubtful, watch or monitor the system until you have reason to introduce controls.

The need for management may be obvious

Often those who use the resources of the reef, mangrove forests or seagrass beds can see that they are stressed by noting some of the following changes:

- Water may no longer be clear, but brownish and full of sediment (and it may be known where the sediment is coming from such as: new mines, careless development or poor agricultural practices).
- The water may be green from the growth of algae in the water (phytoplankton) due to sewage, detergents or fertilisers, or major blooms of red-coloured algae may occur and result in fish deaths (and harmful algal blooms poisoning human populations).
- Fewer fish may be caught in the area or they may be smaller.
- There may be loss of the most important fish species.
- Pollution from industry may cause fish kills.
- Corals may be dying or the coral cover may be much reduced.
- Mangrove trees may be dying or leaves discoloured, curling or falling off;
- There may be no new young trees growing.
- The seagrass bed may be getting smaller over the years or getting patchy.

Where change is not obvious, monitoring (observing, measuring and counting - see Chapter E27 Monitoring, p.157) over some time, such as a year or more, can help show whether changes are taking place, and whether the reef or ecosystem is getting worse or is improving.



15.5 Other reasons for management

There may be reasons for management other than evidence that the systems are changing for the worse, for example:

- an influx of new fishers or other resource users, that might overfish the resources in the future;
- a major increase in population close to the area;
- a polluting mine or industry is being developed; or
- land-use changes that could damage the shallow coastal systems (e.g. clear-felling, causing severe sediment flows, or massive new agriculture developments).

Even under-use of the resource may suggest that management is necessary to improve economic return for local people.

All management should be planned to cause improvements in the system with minimal and gradual changes to the activities of the human users. At all stages, the users should be informed, consulted and where possible involved in management.

Box 11 Less ozone and more UV radiation

Ozone (O_3, different from Oxygen O_2) in the upper atmosphere, plays an important role by absorbing ultraviolet radiation (UV). Otherwise the full UV level of radiation from the sun would disrupt life on earth by breaking DNA and killing exposed cells.

Chlorofluorocarbons (or CFCs) were used until recently in a lot of pressure pack sprays, refrigerators and air conditioners. Waste CFCs float into the upper atmosphere, where they break down to release free reactive chlorine, which breaks down ozone molecules.

As this ozone shield thins, the amount of UV radiation reaching the earth increases markedly, particularly in the higher latitudes and near the poles. This is causing damage to some plants, including plant plankton (phytoplankton) and animal larvae in the sea.

The 'Ozone Hole' will have less impact in the tropics and on coral reefs, because there has always been a lot of sunlight, including large amounts of UV. Animals and plants have developed mechanisms to cope with this high level of radiation by producing thicker skins or UV absorbing compounds. In addition, increases in the amount of UV radiation will be much less in the tropics.

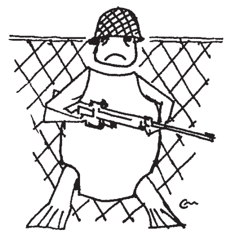
Message: *This is not an immediate problem for managers of tropical coastal resources.*

C16 Marine Protected Areas

16.1 A guide to Marine Protected Areas (MPAs)

Integrated Coastal Management or ICM (see next chapter, C17, p.84) is the best method to plan for the management of the whole coastal zone, which includes the watershed catchment area and all activities that occur on nearby land or sea or both, now and planned for the future. The declaration of Marine Protected Areas (MPAs) should be one part of the overall management plan for the coastal zone. MPAs are a good way to give effective management to particularly valuable areas, such as coral reefs, mangroves, fish and bird breeding grounds etc.

MPAs can be large or small. They can be established for a single purpose, or multiple purposes, or have zones for different uses. Therefore, they can be used by a nation or community to achieve many goals. They may be for long-term protection of sustainable local fishing, or to improve tourist facilities, or to protect a World Heritage site, or to maintain biological diversity, or any other purpose.



A Marine Protected Area has been defined as: 'Any area of inter-tidal or sub-tidal terrain, together with its overlying waters and associated flora, fauna, historical and cultural features, which has been reserved by legislation to protect part or all of the enclosed environment'. (IUCN, in Kelleher 1999). MPAs can provide for the primary goal of marine conservation and management, i.e. 'the protection, restoration, wise use, understanding and enjoyment of the marine heritage of the world in perpetuity.' Note that the IUCN goal covers both 'wise use'. (that is, uses that are ecologically sustainable and do not destroy the marine resource - and which are also good economic practice), as well as 'conservation and protection'.

MPAs are an important method to achieve sustainable fisheries. There is evidence that about 25% of the fishing area should be totally protected from fishing for good fisheries management. This area is needed to allow enough fish to grow to breeding size and produce the new larvae that will recruit new juveniles into the areas outside the MPA. A protected area is also essential to provide baseline information on what an unfished area should look like for management, and as a demonstration tool for the community to understand the fishery. Also, an MPA can be used to attract tourists, particularly SCUBA divers and snorkellers who observe the fish but do not take them.

16.2 How to select Marine Protected Areas

The mechanisms to select which part, and how much, of a marine area to put into an MPA are different from those used in selecting areas on the land. The reasons may be similar, such as:

- to maintain the ecosystem so that it will continue to support the animals and plants there;
- to ensure that use of species (such as fishing and gathering shellfish) is sustainable; or
- to preserve biodiversity.

But the difference is that water can flow in all directions, so habitats in the sea do not have clear boundaries and cannot be precisely defined.

Most species are not restricted to a specific site and many free-swimming animals have large habitat ranges. The larvae of bottom living species can be carried by water currents for hundreds of kilometres. Therefore, similar animals and plants can be found over a large geographic range, occurring wherever substrate and water quality are suitable. This has some disadvantages for management, because the source of larval recruits of some fishes may come from far away areas, often outside the boundaries of the country. But this has an advantage for biodiversity management, because reef species with wide-spreading larvae and wide distributions are less likely to go extinct (there are few recorded cases of marine extinction).

This is very different from the huge numbers of land species that have gone forever. Extinction is more likely for marine species that brood larvae or care for their young directly. But it is still difficult to say that a particular habitat is critical for endangered species. The big exceptions are those areas that are essential for marine mammals, sea turtles, sea birds and a few known endemic species.

Therefore, tropical marine conservation has concentrated more on:

- protecting areas with good examples of natural habitat, particularly areas to be visited by locals and tourists (or for World Heritage, if really outstanding);
- special protected areas for breeding birds, turtles and mammals; and
- habitats where important commercial or recreational species live or breed, and where conservation of stocks is necessary.

Following are some arguments for selecting particular areas to set up as MPAs:

- ***Biogeographic/biodiversity importance*** - whether the area either contains rare habitats or represents a good natural example of a special habitat in the world; or whether it contains unique or unusual geological features that should be protected.

- ***Ecological importance*** - whether the area is important for the maintenance of ecological processes or life-support systems e.g. source of larvae for downstream areas; or whether the area is a complete ecosystem, or if it can be combined with another protected area to form a complete system.
- ***Economic importance*** - whether it would make an economic contribution to traditional users if fishing or gathering were controlled to ensure that the area makes a maximum contribution of larvae or adults for surrounding areas; or whether it has particular value as a tourist diving and viewing area.
- ***Social importance*** - is the area valuable to local, national or international communities because of its heritage, historical, cultural, traditional, aesthetic, educational or recreational qualities?
- ***Scientific importance*** - is the area valuable for research and monitoring?
- ***International or National significance*** - could this area be listed on the World Heritage List or made a National Park of great value or declared as a Biosphere Reserve or considered as part of an international or national conservation agreement e.g. Biodiversity, Ramsar etc.?
- ***Practicality and feasibility*** - how isolated is the area from outside destructive forces? Will the local and regional people accept the area as an MPA and support its use for education, tourism or recreation? Can the area be managed to include some existing local uses that fit in with existing management regimes?

16.3 How to plan Marine Protected Areas

There are general principles for preparing management and zoning plans for MPAs of whatever size or function.

Objectives

It is important to set out very carefully the objectives in planning an MPA. These may be simple for a small and single purpose MPA, or there may be many different objectives for a large, multipurpose MPA. By the time the planning process is over, all the stakeholders (those involved or interested in the area) should understand and agree to the objectives of the MPA.

Forming a planning team

Planning MPAs is a multidisciplinary process that will require people with different skills and qualifications. The number of key participants should be few to work properly, therefore they should be the best people. Such a planning team will work most effectively if they understand the whole picture, and this will help the team concentrate on the key elements and not get bogged down in small details. Time should be spent educating the group, defining clear goals and discussing the key elements, problems, progress, and activities.

Different countries and economies will have different skills available for a team, but if possible, the expertise should include coastal zone planning, resource economics, ecology, sociology and environmental engineering. Government experts, university specialists, and consultants can help provide the needed expertise as the plan develops. A good manager of the planning team is important to coordinate activities and ensure good communications and consensus on decisions. Advice from a wider field of specialists (parks and tourism, pollution, fisheries, forestry) can also be sought as the work of the team develops.

Developing the plan

A 5 stage process can be used to prepare management or zoning plans:

1 *Initial Information gathering and preparation*: It is important to use available data and information to start the process. This should include literature on the area in government departments and perhaps in universities. It should also be remembered that there may be traditional owners or users who have very important, long-term information.

First, a simple description of the area should be made e.g. how big, what physical and biological resources are there, how are people using the resources. As with all planning; there will never be enough data, nor a perfect plan. Data will be gathered as planning proceeds and management is working. The planning process should continue even if you know that more information will be gathered later. Where it is possible and relevant, information should be sought on:

- coral, fish and other important animals;
- major currents and tide flows;
- commercial and recreational fisheries;
- traditional fisheries and gleaning;
- traditional rights and practices;
- mariculture and juvenile collection;
- shell, coral and aquarium collecting;
- endangered species (e.g. dugongs, turtles, etc.);
- bird or turtle breeding colonies;
- tourist activities, boating and resorts;
- SCUBA diving and spearfishing;
- research and education;
- adjacent land uses and catchment activities; and
- shipping and defence uses.

Also, to give some idea of what current changes are occurring or will occur, as much information as is available should be collected on trends, based on changes in past fisheries, future estimates of population, new hotels, diving tourists, etc.

2 *Public participation and consultation*: Before starting, the planning team should consult with users, interested groups and the public. They should be asked to comment on the accuracy and usefulness of the review literature and suggest what to put in the proposed plan, including different zones of use. It has been found that unless the majority of users and people in the area are involved in the process and support the MPA, it will fail (see case study C9 Two Management Models for Philippine Marine Reserves, p.53).

All forms of communication must be considered - print, maps, posters, talks, videos etc. and sent to all groups - local authorities, religious leaders, fishing cooperatives, schools, women's groups, etc. Special efforts must be made to communicate with peoples who do not use printed matter in their daily life. Extra time should be set aside for direct contact with affected peoples using methods that are familiar to them e.g. village or religious meetings. This contact is important, as many people may agree with proposals, but not speak out above those who protest vigorously.

The planning team must ensure that there are people ready to answer all questions and requests for information and be available to talk to meetings. People who are contacted should feel that their comments are important and will be considered by the planning team. This stage opens the first discussion with those who will have to live with the final results of the planning. It is vital that it is done well.

3 ***Preparation of the draft plan****:* From the above stage, the planning team will have received much information about how the stakeholders (those who are affected by or interested in the plan) have reacted. This information should be reflected in the Draft Plan. It may also show that further information, or better information, should be gathered at this stage. Planning should not be delayed until scientific surveys are completed, as this can severely slow the process. The Draft Plan should be as simple and clear as possible, and it should avoid unnecessary restrictions on human uses.

The Draft Plan should include papers, maps and photographs explaining the plan for the users and the general public (or their representatives). Specific goals and objectives should be defined for restrictions on the use of an area in the plan (e.g. stop fishing on spawning aggregations; or stopping destructive fishing), and, if there are multiple zones, the goals and objectives for each zone should be outlined.

4 ***Public participation or consultation****:* The team should ask the community, government and other users and parties, including NGOs and special interest groups, to review the Draft Plan, emphasising that the plan can be changed in response to community wishes. Similar emphasis should be made on direct communication so that all people are given the chance to state their concerns and suggestions as in 2 above. All comments by the community should be summarised by the planning team and communicated back to the people. This process may take several rounds, each time with a new draft, to ensure there is general acceptance of the final plan.

5 ***The final plan****:* The Final Plan, developed after considering the comments and information from users, interested parties, agencies and organisations, should be prepared with precise maps and descriptions of zones and limitations. The plan normally has then to be checked by government lawyers. The plans are submitted to government and the team should encourage the early approval of the plans through legislation, if this is needed.

16.4 Implementing the plan

Funding

No plan can be implemented without resources but there are ways to minimise the amount. Resources are essential because implementation[3] demands continuing education and communication with the users, as well as surveillance, enforcement and monitoring. No plan is perfect and, because conditions change, no plan lasts for more than a few years. Therefore, the plan will have to be renewed if conditions change or if parts are not working. The plan is almost certain to fail if there are no resources to implement it.

Training

The people who will implement the plan must be well trained. They must understand the objectives and the details of the plan, and also they should understand the people who are affected by the plan and what are their attitudes toward the plan. Careful and formal training of staff is necessary.

Public education and interpretation

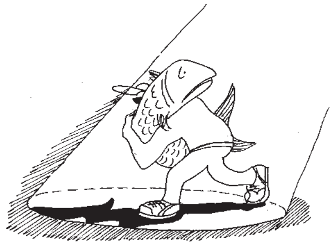
Public education may now be easier, because the people were involved in developing the plan, but education should still be carefully planned. The people who will be directly affected by the plan need to understand the reasons for the plan, so the objectives should be clearly communicated to them. This will mean regular meetings and discussions with town and village communities.

Surveillance and enforcement

The management authority will need to do some surveillance and enforcement to see how the area is being used and whether the MPA rules are being implemented. The community will always do the best monitoring and enforcement if they feel they have: ownership of the site and use of its resources, and will gain benefits because of the plan. However, if they do not feel the plan will help them, they will not accept the MPA and the rules to protect it, and will break them. This is why public education and interpretation is most important.

---

[3] See UNESCO's "Coral Reef Management Handbook" eds. Richard A. Kenchington and Brydget E.T. Hudson (1987) for more detail on implementation.



If every fisherman, tour guide operator or villager is watching out for those who break the MPA rules, surveillance and enforcement is cheaper and more effective. If the locals really police themselves, they will alert the authorities about outsiders who break the law or will deal with them themselves.

Monitoring

Monitoring is needed to see whether the plan is working. In Chapter E27 there are many simple monitoring methods, but which ones are used will depend on the expected outcomes of the plan. If one objective is to increase the abundance or size of fish, then the fishermen may help with the monitoring themselves, or the people who work in the markets can measure this. If the amount of coral cover on the bottom is expected to improve, then simple line intercept counts can be done once a year.

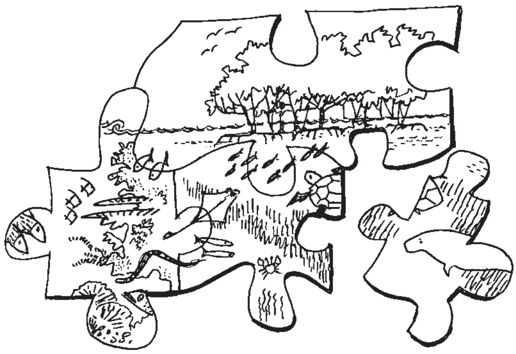
It would be wise to ask advice from specialists in sampling methods before planning a monitoring plan, or else the plan may have too much, or too little monitoring. All tropical marine systems change a bit every year with variations in the amount of recruitment etc., therefore monitoring will have to continue for a few years to show clear results of the MPA. But, without a monitoring programme in place, the manager has no idea whether the plan is working or not. Nor, more importantly, how to improve the plan and how to convince people who doubt the value of the MPA.

C17 Integrated coastal management for sustainable use

17.1 Problems of coastal management

Coastal areas are under more pressure, because increasing populations result in activities that damage coral reefs and other ecosystems e.g. more industry and housing development, agriculture, forestry, tourism, fishing etc. In addition, anything done in the catchment area or in another part of the coast will almost certainly impact on any coastal area.

The specific problems are:



- There are many different ecosystems (coral reefs, mangroves, seagrasses, estuaries, sandy shores) within the coastal zone, which all require different types of management.
- Each of these ecosystems provides a wide range of economic benefits to many different people but only some of these benefits are included in national economic analyses.
- Economic and social development of coastal resources is more varied than in other areas e.g. international tourism compared to subsistence fishing.
- Population density on the coasts is particularly high and is increasing, because disadvantaged people migrate to the coast when other resources are depleted. These people often lack political power and influence.
- Traditional legal, administrative, planning and management arrangements often serve individual sectors (e.g. fisheries), which can cause conflicts with other user groups.

[4] Much material for this Section comes from: *Burbridge P.R., Burbridge, V. & Clark, S. (1996) "Discussion Paper on Applicable Knowledge for The Pragmatic Development of Sustainable Coastal Resources Management Initiatives" prepared for UNESCO.*

- These traditional arrangements often treat the marine and terrestrial parts of the coastal zone as unconnected parts e.g. they do not consider that sediment coming down rivers damages coastal resources.
- Agencies serving different sectors rarely co-operate for integrated development, because they fear a loss of authority without gaining clear benefits.
- The gap between traditional and sectoral management of coastal development is growing. Traditional management developed by trial and error within small populations but increasing populations and economic development often bypass traditional management, particularly during strong economic development.
- Policy makers are often ill informed about the sustainable benefits of the coastal zone for local populations. These values include: food and income from fish, invertebrates and algae; building materials such as timber, rock and sand; medicinal and cultural products; and local economic opportunities in tourism, curios etc.

All these problems mean that new co-operative approaches must be tried.

17.2 What is Integrated Coastal Management (ICM)

Integrated Coastal Management (ICM) is a continuing process of involving all people and government agencies using, or managing, a coastal area in the planning and on-going management to minimise damage, and maintain and maximise long term economic and social benefits. ICM is a new process to create a co-operative environment that reduces or eliminates conflicts over resource use.

ICM is better for planning sustainable use than single sector management, because it asks decision makers to consider all possible interests (stakeholders), factors and problems in the area. ICM can also prevent future problems by keeping resource users informed about the goals and objectives of management. Starting ICM may be slow, because most existing political and administrative mechanisms are not set up for co-operative, multi-sectoral planning.

ICM is also called Integrated Coastal Area Management (ICAM) or Integrated Coastal Zone Management (ICZM). These are 3 names for the same thing - we use the shorter version ICM.

ICM co-operation means that coastal planning and management:

- involves all parts of the coast (usually the watersheds, the coast and out to deep water);
- integrates all management sectors, so that no single sector (e.g. fishing, agriculture, forestry, industrial development, tourist or town planning agencies) makes changes without considering the effect on others; and
- works within national, regional and local policies of development, investment, economics and cultural issues - and may affect them.

17.3 Basic principles of ICM

These are the golden rules for successful coastal management:

1 ***Equity*** - Planning and management should aim for the equitable use of coastal resources by many users and not for the exclusive use by one economic or cultural group.

2 ***Sustainability*** - Management should ensure that human use and development are sustainable so that:
- the resources maintain productivity;
- they continue to provide sustainable benefits to a wide group of users;
- they are not degraded beyond natural levels of recovery; and
- activities do not damage nearby systems.

3 ***Impact minimisation*** - Management should favour sustainable, non-destructive activities and reduce or eliminate destructive practices. Damaging developments should be placed to minimise impacts on the ecosystem, e.g. water flows should not be changed so that flooding, erosion or contamination of underground water is increased.

4 ***Involvement*** - Combined bottom-up and top-down approaches are preferable to ensure both the public and government support objectives and management plans.

5 ***Funding*** - Sufficient funds should be available for background studies to gather biological, physical, ecological, sociological, cultural and economic information about the area.

6 ***Patience*** - Sufficient time must be allowed for background studies, to develop community involvement and confidence, and to involve all levels of government in the planning process. At least 5 years (time and funds) should be allowed to see some results.

7 ***Communication*** - There must be good communication and information sharing between all stakeholders (users, communities, governments and managers).

17.4 Good practice in ICM

If ICM is going to work:
- a clearly defined area must be identified that is experiencing problems and needs management;
- the people and government must be convinced that management is needed and ICM is the best method;
- all users should know that management will provide advantages but will mean some compromises by the users in loss of or restricted access to resources;
- a lead agency must be identified and given enough authority to undertake ICM planning and implementation; and
- the local people must be involved in the process and given sufficient authority to do much of the local enforcement, in return for sustainable benefits.

17.5 How to implement successful ICM

Set achievable objectives progressively

All participants must realise that ICM is a continuous process of testing, improving and back and forth communication for 5 to 10 years and longer. Management should start with small, achievable objectives and gradually build up by trial and error to larger objectives. Projects should be designed to have several increasing stages e.g. each 3 to 5 years. The long term objective is to provide sustainable economic and social benefits to all users, without causing too much damage to coastal resources.

Identify the problems, determine the area

Before starting, all participants must understand that there are problems and identify the major issues for management. This happens when users recognise that resource use is unsustainable. This process should start at the local level, but may be lead by government or NGOs, and involves asking all stakeholders what are the major problems and what should be done to solve them. These problems and issues should be circulated to all for comment and revised as a priority list. This list forms the basis for management action.

It is essential to determine the area to be managed. If it is too small, then outside influences, such as pollution or overfishing nearby, will make management impossible. If the area is too large, it will be too complex and difficult to manage and enforce, so participants will become discouraged and management will fail. If possible, the area should include a complete ecosystem e.g. a group of islands with reefs, an estuary with mangroves. All stakeholders should be involved in setting the boundaries and these must be communicated widely.

The area should include all major human activities affecting the coast and ideally include the rivers and streams that impact on the coast. The area should also be one unit of control, containing one or several local governments that can work together for resource management.

Set goals and timetables co-operatively

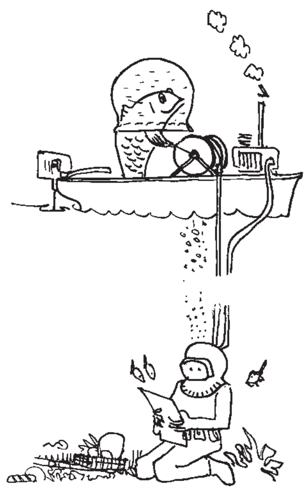
The project should have clear goals acceptable to all people involved. To do this, all the people must be involved in discussing and determining the goals, which should have a clear meaning to all e.g. improve fisheries, attract tourists, keep water clean and healthy. Sometimes international objectives, like maintaining biodiversity or protecting valuable ecosystems, may be included, but these are usually of secondary importance to user communities.

Gain integrated support for policies and plans

Integrated management means that there is both vertical and horizontal integration and support. Vertical - is when all levels of government (Local, State, and National) agree on the objectives and the mechanisms of management. Horizontal - means the different departments of each level of government work together to plan and implement resource management. Objectives and plans must be compatible with national and state policies, or there will be no government support. Likewise, support should be obtained from political parties, to avoid political conflicts and changes to plans if governments change.

A Lead Agency is essential to co-ordinate activities between different levels and government departments, so that some sectional interests do not dominate or are ignored. The Lead Agency should be given authority by the highest level of government (President, Prime Minister or Cabinet), otherwise inter-agency disputes will happen, but it may be guided by a inter-agency committee, which also contains representatives of user groups (see case study C8 p.49).

Local community leaders should be strongly involved at all stages of the ICM process e.g. government councillors, religious leaders, heads of fishing and women's co-operatives, teachers etc.



Ensure top-down and bottom-up involvement

Support for integrated management must come from user communities and government. The ICM process may start from the bottom (communities) in some countries, or from the top (governments), but both should be involved in planning and the eventual management.

Aim policies and goals at sustainability

All management plans should aim at ensuring that the resources are used sustainably. This means that practices damaging coral reef or mangrove resources beyond natural levels of recovery should be prohibited and that extraction of resources should be within the natural levels of replenishment.

All planned developments in the region e.g. tourism, industry, oil and gas development, should be considered by the ICM process to avoid disputes between different groups of people.

Do cost-benefit analyses

The economic and social benefits of new developments for the community should be compared against the costs and losses to the community and ecosystem. For example, developing tourism will bring more income and employment to the area but will mean that some populations may be moved and fishing effort may be reduced. Community acceptance of development will occur if there is understanding that there will be increased benefits.

Monitor and review

ICM projects should include a database that will continually gather data on the performance of planned activities. This will involve setting up a monitoring programme to assess critical goals of the project e.g. is erosion being reduced, are fish stocks increasing, is coral health better, are incomes increasing? The data from monitoring form the basis for regular reviews of the goals and objectives. These reviews should provide an early warning of unexpected effects and focus on improving the effectiveness of management.

17.6 What can go wrong with ICM

A manager should be aware of all the things that can go wrong and stop effective planning and management. Integrated Coastal Management can fail because of the following factors.

Poor information and understanding

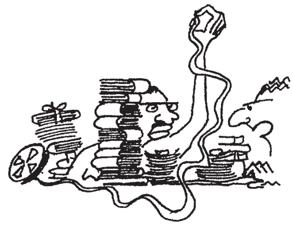
Conflict can occur when users and governments have poor information and understanding of all the benefits of coastal resources, and how human activities can damage these. A manager needs to integrate ecological, social and economic information in the early stages of planning. It is important to identify early: what information is needed to understand how the system works, what are the benefits and what natural and human impacts damage the resources. If the data are not available, the ICM process should not be stopped, because data may be available from similar coastal areas nearby. Often government departments, universities, colleges and NGOs have good information on the area that is not published.

Conflicts and poor co-operation between organisations

This happens when organisations and people have difficulty co-operating to manage the area because of cultural, social, religious, political and economic differences (e.g. strong top-down governments).

Things that can block or interfere with ICM are: a lack of government support; political changes in the government, and instability; confused legal definition of the coastal area (does it start at low or high water mark?); no understanding of the carrying capacity of the system; no control of what happens in upstream catchment areas (e.g. sediment from clearing of forests, pollution from industry).

Often different parts of government have responsibility for parts of the coastal zone and peoples, which leads to arguments over the laws and departments which have decision making power. Therefore, there may be conflicting decisions or no decisions at all.



Lost in red tape

No clear lead agency

If no agency is identified, government agencies and different levels of government (local, state and national) will dispute responsibility for the area. Sectoral planning (looking after only one resource or community e.g. fisheries and fishermen) is the old way of managing coastal areas but this can break down if other factors, resources and user communities are not involved (see Palawan case study C11 p.62, where forestry was controlled but not fishing).

Conflicts between users and managers

Conflicts may arise between different groups of people: over the definition of the problem and likely causes; or because they do not recognise that integrated management can bring advantages; or because groups will not compromise and reduce some rights or access to resources (e.g. between fishermen and tourist developers). Likewise, there will be conflicts: if participants have different goals and objectives; do not acknowledge the Lead Agency and cooperate with it; or are not prepared to participate in planning and help enforce management decisions.

Low budgets

ICM may fail if there is not enough money for planning, community consultation, education and communication (e.g. no sector or department will want to pay for it all). When funding stops and the government people leave, the local community may not continue the management, because they do not understand its benefits.

Few trained people

Integrated management can fail if there are not enough people employed or trained to do the planning and management, or if there is a lack of people with legal, social science or ecosystem science expertise in the planning teams.

No enforcement

Integrated management may break down when management agencies do not have enough power to control more powerful developers or groups, or if there are no rangers to control use. Enforcement is most effective if the local users are the front line of control over illegal or damaging practices (see case study C9, p.53).

Poor communication

ICM may stop or go in the wrong direction if there is poor communication between all the people involved because of different languages or social status.

Different standards

Often there are many different standards between agencies for planning and management. These may include permitted concentration levels of pollution, areas that can be used for tourism etc.

17.7 How to obtain local Participation in ICM

If local communities do not accept the need for coastal zone management and participate in planning, management and enforcement, then there is little chance of success.

1 ***Seek local involvement***: Planners should identify all potential stakeholders, including those who visit the area occasionally, inform them of management proposals and seek their advice and assistance.
2 ***Good communication***: Planners should ensure good communication and information sharing among community groups, managers, scientists and policy makers. Special communication methods should be used to help users understand the problems, management issues and possible solutions. The community may help by assembling information about traditional management practices and incorporating these, where possible, within ICM.
3 ***Support local decision-making mechanisms***: Existing local mechanisms (local community organisations, fishing cooperatives, religious groups) should be encouraged and strengthened to help community involvement. Where these are not present, care should be taken to ensure that any new mechanisms are acceptable to local communities. Training can be given to local leaders to improve capacity for self management.
4 ***Benefit local communities***: Management plans should ensure that local communities continue to gain access to existing resources and to new resources through gradual development e.g. of mariculture, tourism.
5 ***Community education and involvement***: Education of the principles behind ICM is essential for the community. Different education programmes, materials and equipment should be provided to communities e.g. school children, community leaders, senior citizens. Community-level monitoring is an important way for users to increase understanding of causes of resource degradation, and observe tangible benefits and project success.

Box 12 — What are sustainable activities on a coral reef?

Often the difference between sustainable and unsustainable activities is one of degree. Some fishing is fine, too much and it quickly gets destructive. These checklists give a quick guide to good and bad practice.

SUSTAINABLE

- Moderate fishing (subsistence, professional and recreational) that is low enough to allow recruitment of new young fish and replacement of breeding adults, even when poor years occur.
- Moderate removal of shellfish, coral, other marine animals and plants can be sustainable, if it does not change the reef over time.
- Well planned and regulated coastal human developments, including tourist hotels, which do not allow nutrients (sewage, fertiliser and industrial pollution), toxic chemicals and metals to flow into reef waters.
- Developments (domestic, tourist, industrial, port and road building) that prevent sediment flows onto a reefs.
- Farming and forestry activities inland which do not add sediment and nutrients to inshore reef waters.
- Tourist boating which does not smash corals by grounding and anchoring, but uses well made permanent moorings.
- Tourist diving and coral viewing where coral is not touched and broken, and fish not speared.
- Carefully managed reef-top walking by tourists that is limited to marked tracks.

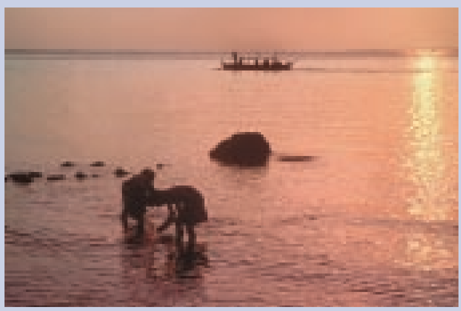
Low impact tourist operations

A sustainable approach to fishing

NON-SUSTAINABLE

- Too much mining of coral sand and rock that lowers the protective barrier and results in waves eroding the shoreline.
- Over-fishing that significantly reduces fish numbers, or removes the large breeding fish, or removes most of the grazers by traps and nets (this encourages algal growth).
- Fishing by destructive methods such as fish poisons (e.g. cyanide), explosives and muro-ami fishing (smashing rocks or poles down on corals to chase fish into nets).
- Spearfishing that removes sedentary fishes and changes fish behaviour so that tourist viewing is less enjoyable.
- Over-using shellfish and other reef organisms until they are 'mined' away.
- Poorly planned and unregulated coastal town and industry development that allows pollutants and sediment into the coastal waters.
- Inland farming and forestry that pours sediment and nutrients into streams and coastal waters.
- Tourist hotels and golf courses that do not control the flow of sediment, sewage, insecticides and fertiliser nutrients into coastal waters.
- Unregulated reef-top walking that smashes coral and damages large areas.
- SCUBA diving or snorkelling tourists who are not educated to protect corals and leave corals and shells. Untrained and unregulated, tourists will stand on and break corals and collect corals and shells.

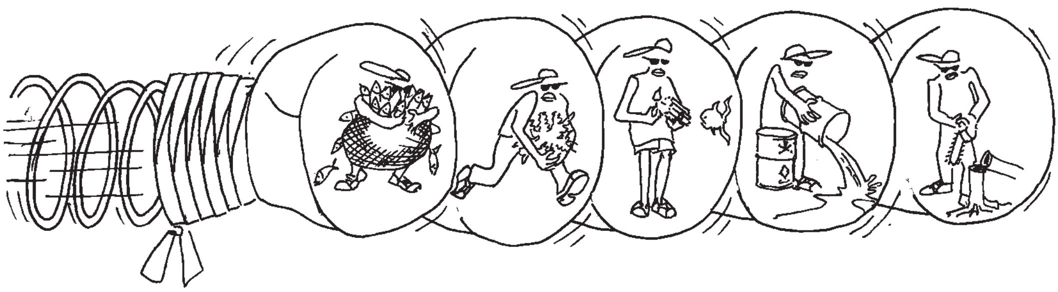
Development can be very damaging
Photo: Andrew Elliott ©GBRMPA



Constant gleaning eliminates species

D CASE STUDIES OF HUMAN IMPACTS ON COASTAL ECOSYSTEMS

CONTENTS



Classification of Case Studies

The cause of breakdown of a coral reef, a mangrove forest or a seagrass bed may sometimes be obvious. A single factor can be seen to cause the breakdown, such as silt from a dredging operation smothering a seagrass bed, or a causeway blocking normal water flow across a shallow mangrove area and killing the mangroves. But often there is no simple answer as different impacts reinforce each other. The following case histories are grouped under headings we think are the major reasons for breakdown. In some cases it is clear there is more than one impact (see D25). In the first four, overfishing played a role in reef destruction.

D18 Overfishing

18.1 The death of a coral reef: Bolinao

Population increase

The Bolinao reefs lie off northwestern Luzon, one of the largest Philippine islands. These are in the tropics (Lat. 16.5°N) with relatively high rainfall and mountains over 1,000 m nearby. Bolinao town has more than 50,000 people, with 20,000 depending on fishing directly or indirectly for a living. Within 25 years, there will be more than 100,000 people competing for the same resources, because pressures on the land are increasing and forcing many more to seek a living from the sea.

What the reefs were like

These are predominantly fringing reefs that extend down to about 20 to 30 m, with broad shallow flats behind these that contain numerous small patch reefs with many coral and fish species. There are extensive beds of seagrasses around these patches.

Up to 1980, both corals and fish were relatively abundant with more than 350 species of fish, sea turtles, crustaceans, molluscs and seaweeds ending up in the local market each year.

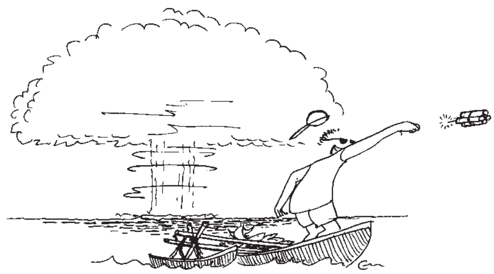
What it is like now

By 1986, more than 60% of coral patches on the reef flat and lagoon floor were dead and there was severe destruction of corals on the outer reef slopes. The reefs in the 1990s were producing only a small fraction of the fish catch of the 1970s, and coral cover on the other reefs had been markedly reduced.

What happened

Fishing pressures on these coral reefs are excessive, with a wide range of methods used, including many damaging ones. Before 1980, fishing pressures were high but coral cover was good. Then the government encouraged the use of large 'V' nets, hundreds of metres along each side, to force fish into a heart-shaped trap. Fish on the seagrass flats became as rare as those on the coral slopes.

At approximately the same time the fishermen expanded the poison fishing technique used to catch fish for the export aquarium trade. They started using sodium cyanide to stun fish for food. At the same time dynamite fishing became more common, mostly using dangerous homemade bombs. By 1988, divers could hear as many as 10 blasts per hour around Bolinao.



The reef became so severely degraded that the local military came under considerable pressure to stop blast fishing. One day, 5 people were found shot dead on a fishing boat containing homemade bombs. Following uproar and accusations, blast fishing first slowed but then began to rise again.

As excessive force was clearly inappropriate, a nationwide programme was used with television advertisements. Local teachers also spoke against blasting and local military commanders confiscated boats and put them on display. This whole programme helped reduce blasting rates by 90% in the late 1990s.

The scarcity of fish longer than 10 cm on the reef slope led spearfishers to use car tyre compressors to go deeper and fish longer from 1990. But they did not understand the dangers and many either died from 'the bends' (decompression sickness), or suffered paralysis.

Why did it happen?

As farm land around Bolinao and elsewhere could no longer be subdivided among expanding families, many turned to reef fishing as the only way to make a living in an area which has virtually no industry and other job possibilities. Overfishing damaged both the reefs and seagrass beds and severely depleted populations of fish and sea urchins.

At first, they used traditional methods but, as catches dropped, the fishermen turned to destructive methods. These have destroyed the coral cover and reduced the ability of the reef to sustain fish populations. The reefs are now virtually dead.

What are the chances of recovery?

These reefs could recover in 10-20 years if there was a major reduction in fishing pressure and some active management, such as establishing and enforcing marine protected areas. In a 6-year study around Bolinao in 1992, the University of the Philippines and the University of Rhode Island recommended that:

- there was a need to reduce population growth;
- alternative forms of livelihood should be developed, such as tourism, improved agriculture and mariculture;
- the number of people fishing the coral reefs should be reduced by half to be sustainable;
- blast and cyanide fishing and compressor diving should be banned; and
- a marine reserve system should be established.

Without all of these measures, the reefs are unlikely to recover and develop sustainable fisheries.

What is happening now?

A programme started in 1993 by the University of the Philippines and the Haribon Foundation has been working on community development and understanding. The programme includes alternative livelihood schemes and the implementation of marine reserves. An open-pit limestone mine for a cement factory was planned nearby and also a petrochemical plant may be built on very porous limestone soils. A big battle developed to stop the cement factory and succeeded. Big factories may provide some jobs but they also risk the survival of the reef as a sustainable resource for the people of Bolinao because of pollution and sediment.

Message: *Coastal resources cannot continue to provide food and other resources to ever increasing populations. In the end, the only control method must be reducing population pressures through population control and providing the people with means of obtaining a living other than by exploiting limited resources.*

From John McManus, Director, National Centre for Atlantic and Caribbean Reef Research, RSMAS, University of Florida.

Box 13 Cyanide and the live fish trade

"Coral reefs in Southeast Asia and a widening area beyond are being plundered and degraded in the quest for live reef fish to supply a lucrative market."

Cyanide was first used to catch aquarium fishes, because it stuns small fish and makes them easy to catch. But these fish usually do not live for more than a few weeks in aquariums. Now all the big aquarium trade importers only want fish caught in nets and traps.

Fishermen soon realised that they could catch larger fish this way and sell them for higher prices for the Asian restaurant trade. This trade now takes more than 25,000 tonnes per year of live reef fish out of Southeast Asia, the western Pacific and Indian Ocean. Using cyanide, fishermen catch many fish and make a quick, large profit - before they move to the next reef. Sometimes, local fishermen catch the fish, and hold them in cages to sell to middlemen, who ship them in large 'tankers' to Hong Kong. The middlemen make most of the profit.

Another method, is when large boats with many fishermen arrive and work around a reef catching all the fish they can get, even those in deep water at 20 or 30 m using SCUBA or hookah gear. This is a very damaging way to fish, as cyanide destroys reefs by killing coral, other invertebrates and all the juvenile fish. It may take a few days for the corals to die, but these fishermen do cause massive destruction to a reef. The biggest problem is that they remove the large breeding fish, especially if they target spawning aggregations (see Box 3, Fishing on breeding aggregations, p.26)

The demand for live fish is great, and expanding, and the fish farms of Southeast Asia only can provide a third of the demand. Fish farming needs to be improved with help from governments and donors, particularly for the most highly priced species, the groupers and humphead wrasses.

Most of all, reef destruction by cyanide must be stopped by banning the export and import of all cyanide caught fish. This is a very damaging, short term industry that yields less money than hook and line or other traditional fishing methods in the long-term. The live fish trade can be supplied by well managed fisheries using hook and line or trap methods, and with fish from farms, but these must increase production using modern breeding and catching methods.

***Message**:* *Cyanide fishing is very damaging to coral reefs, but there are large amounts of money being made in the short-term. Education is essential to push the message that cyanide fishing will destroy reef fishing for future generations. Aquaculture of fish is important to replace taking fish from the reefs.*

From Robert Johannes, Hobart.

18.2 The collapse of a coral reef: Jamaica

A coral fringed Caribbean island

Jamaica is a true tropical island (Lat.18°N.) in the central Caribbean. It is large (235 x 82 km) and mountainous, with its highest peak reaching over 2,200 m. It is an independent nation with a population of 2.6 million people. The island and surrounding reefs lie in clear tropical water. Fish are an important food, with most fishing being conducted with basic equipment.

What the reefs were like - rich reefs, full of fish

Most of the reefs lie close to the coast and were once considered the richest coral reefs in the Caribbean. They have also been the best studied And, in the late 1970s, there was a high diversity of corals, which covered 50-70% of the bottom (surveys made along 240 km of coastline).

What the reefs are like now - from coral to seaweeds

The reefs have lost almost all the rich living coral they had in the 1950s, 60s and 70s, because of a series of events. They are now dominated by large attached algae, which once were rare. These are now seaweed reefs along hundreds of kilometres. The weight of fish caught on the reefs has also dropped to one fifth of what it was in the 1960s and the fish being caught are much smaller than before.

What happened - human stress has added to nature's violence

Three events hit the Jamaican reefs in the 1980s and they collapsed. The first, Hurricane Allen, struck in 1980 and caused major damage to the large elkhorn and staghorn corals, and also tore up the gorgonians and sponges. Some algae grew on these bare surfaces but large populations of the black spined sea urchin *(Diadema antillarum)* grazed them down. Soon small corals started to settle from new larvae.

The second was in 1983, when a disease spread across the Caribbean and killed 99% of the black spined sea urchins. Thus, without grazing fish or sea urchins there was a spectacular growth of large algae (Sargassum, Lobophora and Dictyota), which were uncommon on the reefs before. The algae covered 90% of the reefs in about two years and young corals could not settle, smaller corals were overshadowed and only a few large solid corals were left *(Montastrea annularis).*

The third was another hurricane (Gilbert) in 1988, which damaged both the algae and most remaining corals. The algae grew back within weeks from the bases and remnants, but destroyed corals did not regrow. Coral cover had dropped down to only about 3% and the reefs have more than 90% cover of algae.

Coral reefs are often severely damaged by tropical cyclonic storms but they usually regrow in 10 to 20 years from broken pieces, as well as receiving new recruitment of juveniles. But these reefs were already under large human stress before the cyclonic storms. Overfishing had removed almost all the fish that ate algae, as well as the predators of the algal grazing sea urchins. The large urchin populations had no predators and almost no competition for food from fish. There was enough nutrient pollution coming off the land (farming, untreated sewage) to ensure rapid growth of algae.

Why it has happened - overuse of reefs

Overfishing was the reason why these rich coral reefs collapsed. Fishing pressure was 2 to 3 times what the reef fish populations could sustain. Fishing first removed the large predatory fishes - sharks, snappers, jacks and groupers. The sea urchin predators were greatly reduced (triggerfish, porgies and toadfish). The remaining grazing fishes (parrotfish and surgeonfish) were removed either in fine-mesh fish traps or by spearfishing. Now, virtually no fish reach normal breeding size.

The reefs would have recovered from the natural impacts of storms and disease, but the overfishing and some pollution combined to kill off these coral reefs, because the algae took over the bottom and smothered everything.

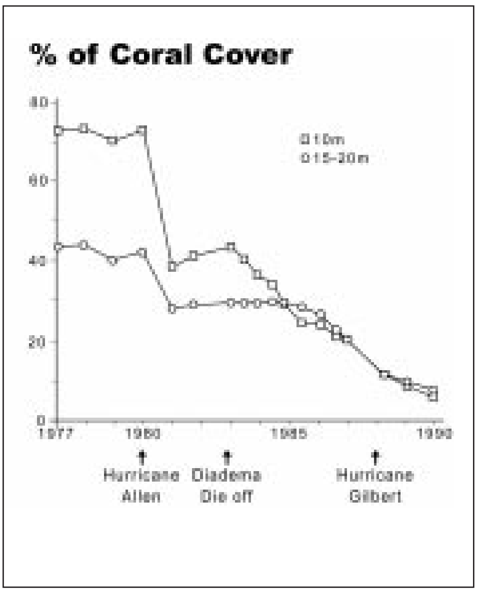


Figure 1 Coral cover on Jamaica's reefs

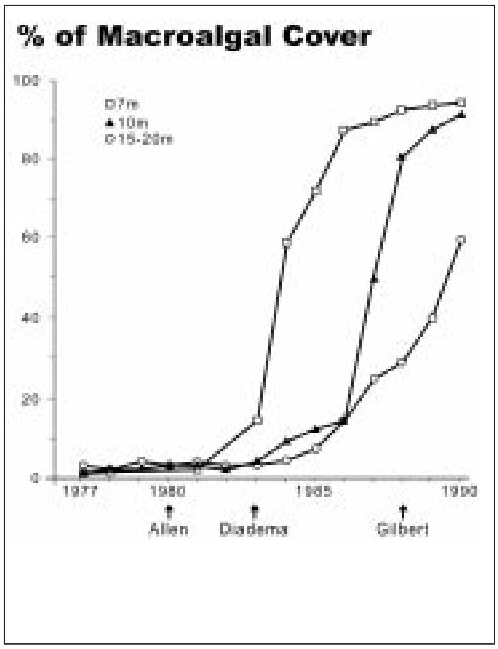
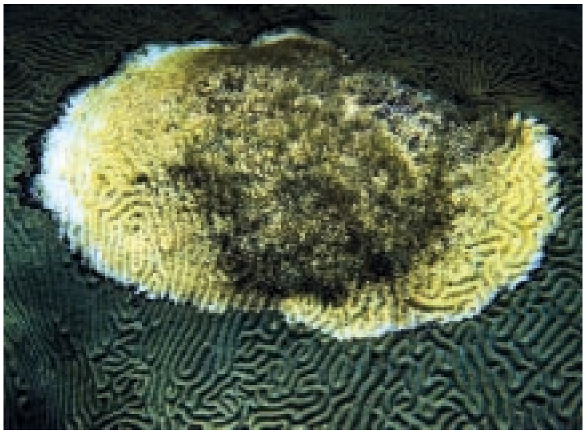


Figure 2 Algal cover on those reefs

The reefs will not recover without management action

The reefs are unlikely to recover because heavy fishing pressure is removing the algal grazers. Fish are being reduced to below spawning size over wide areas of the Caribbean and new fish recruitment must become reduced.

Human impact through overfishing has allowed the algae to out-compete the corals. Some corals are starting to settle now but recovery is very slow.



Diseased coral is on the increase in the Caribbean - coastal stresses may be involved

Possible management actions

The only way for these reefs to recover will be to reduce fishing pressure and land pollution. It would be helpful to set up marine protected areas where fish can grow and breed, and hopefully the corals will regenerate. These areas would allow adult fish to move out into the fished areas and increase yields for fishermen.

Message:	*The reason for the decline of coral reefs is often complex and may involve several factors. Here it was storms that caused the major damage but the real problem was overfishing.*

From Terence Hughes, James Cook University, Australia.

18.3 A reef under stress: Okinawa

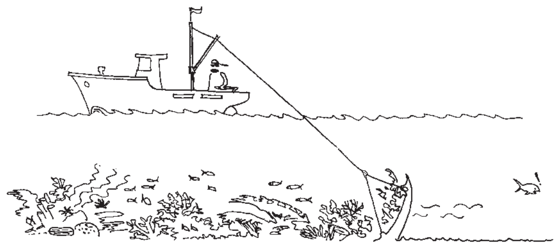
Damaged by fishing, and also by sewage and other pressures

The Japanese island of Okinawa (Lat. 26° to 27°N.) is the largest of the southern Ryukyu Islands. Coral reefs have flourished there because the warm north-flowing Kuroshio current flows around these islands, providing suitable temperatures for reef growth. The current brings fish, coral and other animal larvae from coral reefs to the south. The whole island was surrounded by a well-developed fringing reef.

The reefs originally had very high numbers of coral species and had a high percentage of coral cover. On the nearby Kerima Islands, there are still extensive fringing reefs, with some small platform or patch reefs.

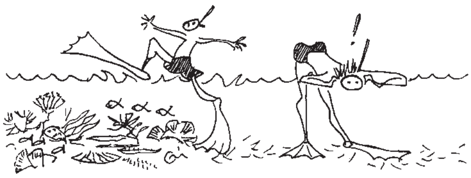
Badly damaged reefs

Most of the reefs around Okinawa look as though a bulldozer has flattened them.



Except for a small area on the northwest corner, where a clean water current sweeps by the island, the percentage of the bottom covered by coral is either zero or less than 5%. The water is cloudy and green from suspended sediment and algal plankton; and only a thin mat or lawn of turf algae covers the coral rock base.

The dead coral rock also has the appearance of being carved with an ice cream scoop. The surface is pitted with numerous round depressions caused by the grazing activities of millions of sea urchins *(Echinometra mathaei)*. These hide during the day in the cracks and crevices of the reef but come out at night and thoroughly graze the lawn of algae, scraping down the coral rock surface. This grazing removes any new coral recruits and also undermines the few remaining corals, so that they collapse and break up.



The one remaining area of coral reef is invaded daily by another 'plague'. Literally thousands of novice divers line up to enter the water on their first dive. There is much evidence of their activities with the few remaining corals having many broken branches.

What happened to the reefs

The reefs were used extensively in the past for food and curios and fishing has been so heavy that there are few fish to be seen on Okinawa reefs now. The fish that occur on the Kerima islands are also being threatened by continued active fishing. Spearfishing is a common activity, often with SCUBA gear (this practice has now been banned in most of the world).

1.25 million people live on the island and most wastes are dumped untreated into the sea. This has resulted in a high level of nutrients in the shallow waters and reef flats around the islands. The wastes of the small to medium size industries on Okinawa are also added to this. Heavy loads of red clay sediment wash off the land during development and from farming. These run directly into the sea, because most of the rivers and streams have been lined with concrete to ensure a rapid runoff of water.

Recently, large areas of the island have been converted into golf courses to attract golfing tourists from the rest of Japan. These courses are heavily fertilised and treated with pesticides, with the excess flowing onto the reefs. Another major impact has been through major engineering developments on the coast. Virtually the entire coastline has been ‘protected' with concrete walls, and many ports and groynes have been constructed using tetrapods - massive concrete blocks with four projecting arms.

Damage by many factors

Two major human impacts working together have caused the collapse of the reefs:

- There has been massive overfishing of virtually all fish. This includes the natural predators of the sea urchins (triggerfish, pufferfish, snappers and bream); and those fish that are grazers (parrotfishes, surgeonfishes). Fishing has been conducted with lines, nets, traps and, recently, by spearfishing.
- The increased levels of pollution by nutrients from sewage, industry and farming have stressed the corals and provided ideal conditions for the growth of algae (both bottom growing algae and free planktonic algae in the water).

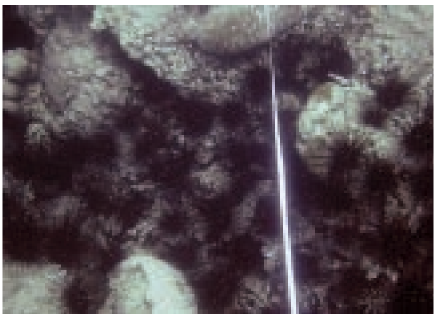
During the war, Okinawa suffered considerable damage and the island stresses increased when special efforts were made to reconstruct Okinawa after the end of the war in 1946. The reefs, although stressed, continued to grow until a second, and possibly unrelated, impact hit them. A massive infestation by the crown-of-thorns starfish *(Acanthaster planci)* hit the island in 1972 and wiped out large areas of corals. Although an enormous and expensive effort was undertaken to remove the starfish, the starfish continued eating corals until almost all of the reefs were bare.

After this impact, the reefs should have recovered with new corals arriving, like all the reefs on the smaller islands around Okinawa. But the reefs did not recover, although there are plenty of corals nearby to provide new larvae. The reason that corals do not grow now is that any new juvenile corals are rapidly eaten down by the large populations of sea urchins that graze every night. Thus, there is no new growth of coral rock (calcification) but instead there is considerable erosion of rock by the urchins and other eroding organisms.

Economic losses

This means that the reefs around Okinawa are gradually, but surely, disappearing and this may increase the need for more concrete walls and groynes. In addition, the reefs themselves are no longer the rich source of coral reef fish they once were. To allow the reefs to grow back may be a cheaper alternative in the long term. This will keep Okinawa a popular destination for tourists escaping the cooler regions. Tourists wishing to dive or snorkel to see coral reefs must either pass through Okinawa to the Kerima Group, or continue further south to Ishigaki Island, or leave Japanese territory.

The chances for recovery?



Invading sea urchins inhibit coral recovery

The chances for recovery are very low if current activities continue.

With the coral almost gone and the reef converted to one dominated by algae and sea urchins, coral larvae have little chance of surviving at present and fish cannot return because of heavy fishing pressure and no coral reef shelter.

Need for management

Conservation does not have a high priority in Japan. There were no management guidelines to prevent these impacts and the principal stresses on the reef still continue. Management is needed to improve the reefs. It would involve:

- declaring large marine areas of the island as reserves with no fishing;
- reducing pollution by treating sewage and lowering runoff from the agricultural fields; and
- preventing the construction of more walls, groynes and ports.

Message: *Overfishing is the major problem on these reefs compounded by pollution and shoreline destruction. A major programme is necessary to reverse all these damaging impacts.*

From Chou Loke Ming, National University of Singapore and Clive Wilkinson.

18.4 Compounding problems: Pulau Seribu and Jakarta Bay, Indonesia

A problem of overfishing, city pollution and natural disasters

Jakarta Bay on the Indonesian Island of Java had many coral islands and surrounding reefs (see Box 5 Mining reefs in Jakarta Bay, p.34). These reefs were mapped in 1874 and described as being spectacularly beautiful in 1928, so there is a good historical baseline.

Stretching out 80 km north of Jakarta is a line of islands known as the Pulau Seribu, or Thousand Islands. Jakarta (Lat. 6°S.) is the capital of Indonesia, with a population that has increased from 1 million 30 years ago, to more than 10 million today and is still growing.

The city is on the southern end of the bay and all the pollution from the port and city flows into shallow coastal waters. This shallow water also receives much sediment because of considerable excavation of building materials (sand, coral shingle and rock) and agricultural activities.

Coral shingle and rock mined for many uses

What the coral reefs were like

The reefs in the Bay and Pulau Seribu were once described as spectacular, with many species and high percentage cover of coral. In 1979, the inner (southern) reefs of Pulau Seribu (Pulau Pari group) had particularly high diversity and cover on sheltered sides of islands. Even in 1985, the reefs further north in Pulau Seribu had similar high coral diversity and moderate cover.

What the reefs are like today

Reef surveys between 1985 and 1992 showed that many reefs further north in the Pulau Seribu chain maintained high coral diversity and moderate cover of coral up to 40%. But some reefs had surprisingly low coral cover. The southern reefs had coral cover values of 20-30%. Much of the low coral cover was initially due to a crown-of-thorns outbreak (see Section B 5.5, p.27.) in the 1970s and a severe coral bleaching episode in 1983 (see Box 14, p.108). But coral recovery has been prevented by heavy dynamite fishing over a 10 year period and other human impacts. The wide variations in coral cover on reefs far away from Jakarta occurred because guards on privately owned islands and tourist resort islands chased fishermen away, whereas other reefs had many dynamite scars.

Results from surveys in 1995 are even more alarming, with coral cover down to below 10% on some islands. It appears that many of the corals had been eaten by a new low level outbreak of the crown-of-thorns starfish in 1994/95.

Many of the islands now have tourist resorts, that were built with little planning or understanding of the consequences. This has considerably damaged some reefs, because corals were used for building and channels were dredged through the reef and walls, jetties and helicopter landing stages were constructed that changed current patterns, resulting in serious erosion of reef flats and islands.

Catches of fish from Pulau Seribu reefs have declined markedly recently such that fishermen are now turning to other fishing methods. In the early 1980s, 200 fishermen on the islands caught 1,200 tons of fish per year by small-scale muro ami. In 1992, catches were less that 200 tons. Some families have switched to other livelihoods such as growing seaweeds (*Eucheuma*).

What has happened?

The major stresses are overfishing and pollution from Jakarta and the tourist resorts on many of the islands. Fishing pressures have continued to increase including the use of destructive methods like muro ami, explosives and poisons. There has also been over harvesting of giant clams (*Tridacna*), the collection of aquarium fishes and invertebrates, and continued mining of coral, even though the Pulau Seribu chain has been designated as a Marine Protected Area (MPA).

Pollution from Jakarta Bay and the coast is already reaching the inner reefs and apparently creeping out to the middle reefs of the chain. In addition, few of the many tourist resorts have sewage treatment systems, so that nutrient rich waste water flows directly onto the reef flats, causing coral death and disease.

What are the chances of recovery?

These reefs should recover from low levels of infrequent damage but the chances of recovery from such regular human disturbance are extremely low. Natural impacts, such as crown-of-thorns starfish outbreaks and coral bleaching, reduce the chance of recovery.

Pulau Pari reef is an example of slow recovery. In 1981, there was severe bleaching (see Box 14 Coral bleaching, below) of corals on the shallow reef flats and slopes of the sheltered southern side. About 80-90% of corals died on the reef flat, because of higher water temperatures, long hours of sunshine and low sea levels during that El Niño year, when coral bleaching also occurred in many other areas of Indonesia. Recovery on Pulau Pari has been patchy since then.

For the first 4 years, few corals grew back and some parts recovered to near normal, whereas other areas have shown little recovery. Now the new corals consist of only a few species, mostly *Porites*, that tolerate severe conditions of temperature and exposure to air. The diverse *Acropora* coral community has not come back and it is probable that pollution from Jakarta, Pari Island and also the large number of ships using the channel nearby have contributed to the lack of recovery.

What is being done?

The Indonesian Government has declared large parts of Pulau Seribu as a Marine Protected Area. While this is sound policy, there are not enough resources to prepare an effective MPA management plan and enforce the regulations. Tourist resorts continue to be developed with little regulation and pollution from Jakarta is continuing to spread towards the outer reefs. This pollution is often seen as blooms of phytoplankton, particularly dinoflagellates, over the reefs. Such blooms indicate the potential for toxic algal blooms, which adds another concern for management. Much of the dynamite fishing has been controlled but other damaging fishing practices have continued and the reefs continue to show damage.

Future outlook for the reefs and management needs

The future for the inner reefs does not seem good. This may also be the case for the outer reefs, if the current levels of human and natural stresses continue to pressure these reefs. If they are to recover urgent and effective management to reduce overfishing and to curb the pollution from the resorts is needed. Without this the reefs will not recover when hit by natural disturbances. With good management, the diversity and quantity of corals on the reef will increase and a richer fishery can be sustained.

Message: *The damage to these reefs is from a mix of human and natural factors. Recovery will be slow unless the human damage is reduced, particularly overfishing, sewage pollution and engineering changes to the islands.*

From Dr Barbara Brown, University, Newcastle-upon-Tyne, United Kingdom and Dr Suharsono, LIPI, Indonesia.

Box 14 Coral bleaching

Bleaching occurs when corals lose their colour and turn white, and now it is becoming more common. The coral either throws out the little brightly coloured algae that live in its tissues (symbiotic algae or zooxanthellae) or the algae lose their chlorophyll pigments.

It can happen when corals are stressed, such as pollution or rapid changes in salinity, light or temperature, but most bleaching is due to temperature rises of just a few degrees above normal.

Bleaching appears to be worse in corals that are already stressed, either by pollution or sediments. The zooxanthellae that live in all reef-building corals are essential for coral life, because they provide most of the carbon energy and help the corals lay down calcium carbonate skeleton. So loss of them slows coral growth, stops reproduction or can result in coral death.

Since 1979, there have been five major mass-bleaching events with about 60 separate incidents, which covered thousands of square kilometres of coral reef. Strong bleaching and death of corals occurred in islands of the Pacific such as Samoa, the Cook Islands, and French Polynesia. This usually coincides with El Niño, Southern Oscillation years, when warm water (called the 'Pacific warm pool') moves south and east and reaches these islands.

Corals on the Great Barrier Reef bleached in 1998; white fully bleached; mauve half bleached.

The severe bleaching in 1998 suggests that this is getting worse. Massive bleaching was reported in the Indian Ocean, when a warm pool of water moved over the Maldives into the Seychelles, Sri Lanka and India. There was also bleaching in East Africa, the Middle East and Asia. Bleaching is also increasing in the Caribbean.

Big questions face scientists and managers. Has coral bleaching really increased since the 1980s, or are more people looking and it is better reported? If bleaching is increasing, it is probably due to the global climate change and could get worse (See Box 6).

But all corals do not react the same way. Some coral species do not bleach when others are completely white. Some species recover after a short period of bleaching, while mortality may be as high as 95% in others.

- Will this cause changes in the species composition on coral reefs?
- How long will it take reefs to recover?
- How much does bleaching slow coral growth rates and reproduction? and
- How will this affect coral reefs in the future? These are now major questions for coral reef scientists.

There are also big questions for reef managers.

- Will bleaching increase in future?
- What impacts will bleaching have on reef fisheries?
- Will recovery be rapid enough to prevent large economic losses for operators and communities that depend on tourist incomes?

***Message**:* *There is nothing that a reef manager can do about coral bleaching, except request that communities and governments decrease their use of fossil fuels. Keeping coral reefs clean of pollution and sediments will probably reduce bleaching or speed up coral recovery afterwards. It is essential that reef managers assist communities by explaining what is happening.*

From Ove Hoegh-Guldberg, University of Queensland, Australia.

D19 Sewage and sediment

Dumping of raw or partly treated sewage into tropical seas causes damage. Coral reefs normally live in clear water with low nutrients (low nitrogen and phosphorous). Addition of nutrients will encourage the growth of algae and filter feeding animals rather than corals.

Seagrasses are also damaged by too many nutrients (e.g. sewage or fertilisers) washing off the land. Light necessary for growth of seagrass leaves is reduced by too much plankton in the water; also many small algae grow on the leaves, reduce light to them, weigh them down and cause disease. In the following case, both silt and algae killed a huge coral area in Kaneohe Bay.

19.1 Damage and recovery: Kaneohe Bay, Hawaii

Damage from sewage and silt is reversed

This is a 3-stage story of reversals: increasing damage up to 1978; partial recovery to mid 1980s; and then more damage.

Kaneohe Bay (Lat. 21.5° N.) is the largest bay in the Hawaiian Islands (13.5 km by 4.5 km). It is on the northeast side of Oahu, facing the trade winds and has a barrier coral reef protecting the mouth of the bay and 60 patch reefs inside. There are two natural channels to the ocean at each end and a 17 m deep ship-channel was dredged along the length of the bay. The mean depth, however, is about 8 m and the average time it takes for clean water to enter the bay is about 13 days and slightly longer in the southern bay.

The 100 sq km catchment area for the bay receives about 140-240 cm of rainfall per year. But occasional storms can pour about 2 million cubic metres of water per day into the bay. This happened in 1965 and 1987, when the whole bay was covered with a 1 m freshwater layer that killed shallow corals in the south and central parts. The volume in these freshwater floods has increased, because many streams have been covered in concrete and water runs off more rapidly because houses, roads and parking lots cover the land that was once covered in forest.

Population growth

The traditional land use with small taro patches has changed to large scale farming of pineapple, sugarcane, rice, cattle, horses and goats. The population around the bay increased from 5,400 to 67,000 people in the past 50 years, with many new housing developments, shopping centres and roads. Nearly 60% of the shoreline has been modified by seawalls, harbours, dredging and filling for fishponds. A US Navy base was built at the entrance to the bay and removed 15 million cubic metres of reef for landfill and to allow seaplanes to land. They cut the channel through the reef.

Stage 1: What the bay was like and how it changed

Up to the 1960s, the Bay had clean water with the northern coral reefs being the best developed. They included most of the coral species and other bottom animals found in the Hawaiian Islands, as well as a rich fish populations. They were called 'coral gardens'.

But by the 1970s, the water in the southern end became a dirty, green colour from increased plankton due to sewage and sediment increases. Populations of sponges, tunicates, colonial zooanthids, polychaetes and motile gastropods all increased, particularly the filter feeders, and the detritus and mud eaters.

This southern part of the bay now had only 6 species of coral reef fishes, while the cleaner northern bay still had 40 species. Large fleshy algae became abundant on the reef slopes and reef tops. The green bubble alga *(Dictyosphaeria cavernosa)* smothered and replaced corals on the central reefs and species of the green alga Ulva dominated the southern reefs.

In the late 1960s, fishermen changed to gill nets and surround nets and increased the fish catch by 4 times. But by the early 1980s, catches began dropping and have continued to drop.

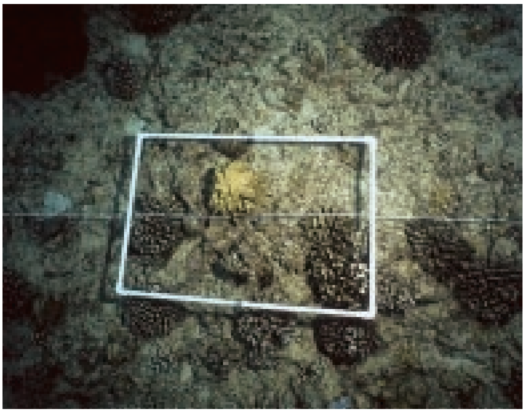
What caused the change

The output of sewage from the town and the Naval Base increased from 4,000 to 20,000 cubic metres per day, when the population grew between 1960 and 1970. These added nutrients caused the growth of phytoplankton and bottom algae. The increase in sediment from farming and development added more stress to the corals and reduced water visibility.

Half the shoreline was also modified by seawalls, harbours and fishponds. Surface reefs were dredged, land was reclaimed for the naval base and the ship channel was dredged. These disturbances combined to cause changes but the primary problem was sewage and sediment.

Stage 2: Removal of sewage and the recovery of Kaneohe Bay

In 1977-78, the sewage was diverted away from the southern bay and into a deep ocean outfall beyond the bay entrance. Within 2 weeks, the plankton blooms and the bottom filter and detritus feeders started dying. After one year, populations of sponges, tunicates, zooanthids and polychaete worms were down by 80% in the southern bay and by 35% over the whole bay.



Monitoring progress of coral regrowth

Improvement continued and after 10 years, the chlorophyll (from phytoplankton) was down 40%, the water was clearer, coral cover had doubled and algae on many reefs had reduced. The water was still getting clearer as nutrients in the southern bay sediments washed out to sea. The Kaneohe Bay coral lagoon showed real recovery and coral cover increased. The improvements should have continued, with only the major freshwater floods threatening the coral reefs.

Stage 3: Decline again in Kaneohe Bay

The coral cover increased to an average of about 50% on the better reefs by 1983, with the cover of fleshy algae around 1%. Since then there has been a steady decline in coral cover, while the cover of algae is increasing (up to 10% in many places). The reasons for the decline in the corals and increases in algae are because: nutrients from about 3,000 septic tanks continue to flow into the bay; there are now many more boats in the bay which release sewage and other pollution; and the sediments still have trapped nutrients and heavy metals which are gradually being released. Thus, it appears that these reefs will continue to come under stress from the developments on the land and may never fully recover to the 'coral garden' state that was there before 1960.

What management action is needed?

Houses in rural areas of the central and northern areas are steadily being connected to the sewerage system, which should further improve water quality (see case study 19.2 below). A Kaneohe Bay Master Plan is being developed, which should help control fishing, land and shoreline development, water quality and urban and rural runoff.

Message: *A mix of problems caused reef decline but when the sewage and sediment were reduced there was recovery. This was short lived because continued human population growth added more nutrient pollution. All sources of nutrients entering this enclosed bay must be minimised to solve ongoing pollution problems.*

From Marlin Atkinson and Cynthia Hunter, Hawaii Institute of Marine Biology.

19.2 Coral recovery after removing a sewage outfall: Hawaii

Severe damage to a coral reef from a sewage outfall in Mamala Bay and recovery after its removal to deep water.

Mamala Bay is a shallow coastal bay 30 km long, in front of Honolulu City and on the leeward side of the Hawaiian island of Oahu (Lat. 21°N, 157°W.). Honolulu has about 1 million people and has nearly doubled in population since 1959.

What was it like?

Before 1955, there were good coral reefs throughout the Bay but that year a sewage outfall was built discharging directly onto the reef.

In 1975, Rick Grigg started a study which showed that the outfall had a strong impact over an area 2 km to the east and 4km to the west of the outfall. Corals were either absent or very reduced in abundance.

The bottom within 1 km of the outfall became covered in half-metre high mounds formed by the tube-building polychaete worm, *Chaetopterus*. The green alga, Ulva, was common and the sea urchin *Echinothrix diadema* was abundant, eroding and excavating corals along the affected 6 km strip. But about 6 km from the outfall at 10 m depth, healthy, living corals covered about 70% of the bottom.

Sewage outfall in Mamala Bay

In 1978 the outfall was moved into deeper water (70 m) and extended 2.9 km offshore. The sewage was also treated to an advanced primary level. After this, the Chaetopterus mounds disappeared within a year, leaving behind a flat, highly eroded limestone bottom, virtually barren of corals.

Steady improvement over fifteen years

Although there was no obvious recovery in 1978, corals and other animals gradually came back to the area during the next 15 years. By 1993 coral cover had increased to between 10-25%. There were more corals on uneven areas and less on flat areas. Recovery in all areas was slowed down by large hurricanes in 1982 and 1992.

How did it happen and will it recover fully?

The sewage outfall was the major influence on the coral reef before 1977 and had destroyed most corals in shallow water (12 m) with *Chaetopterus* mounds replacing them. The coral cover of the bottom before the outfall must have been around 60 or 70%, because this is what is found at distances well away from the outfall.

After the outfall was moved to deeper water, coral recovery has been slow and the hurricanes have destroyed some newly settled corals. But recovery is happening and mature reefs are likely to come back with large corals and a high percentage coral cover. At the present rate it may take 50 years to get complete recovery. No management actions are needed.

***Message*:** *This is a direct example of the damage caused by sewage pollution; and the reversal when the sewage is turned off – a 'good news' story..*

From Rick Grigg, Department of Oceanography of the University of Hawaii, USA.

Box 15 Can damaged coral reefs be restored?

Can managers help restore coral reefs? Can local communities help by reducing fishing or by reducing pests? If so, how long will it take for reefs to recover? Can restoration be speeded up? Is the cost of restoration worth the uncertain benefits?

Recent studies show that managers can solve some problems and be confident about the results of management. Corals are often smothered by large algae that increase because of nutrient pollution, or the removal of fishes and urchins (herbivores). So if communities, dive clubs, and fishermen can remove large algae with wire brushes, coral will grow back and reef health will be restored.

The reef manager should monitor the corals for the long-term effects of wire brushing, determine how often brushing is needed, and analyse the costs and benefits. The benefits of scrubbing, however, will be reduced if over-fishing continues to remove the herbivores or pollution is not reduced. The algae will just grow back and continuous brushing will be needed to keep the reefs clean, therefore restoration should be used along with other management methods.

In Kenya in the early 1990s, heavily fished reefs became infested with sea urchins, because the predators, particularly the red-lined triggerfish, were fished out (there were 10 to 20 fishermen per sq km). Sea urchins became so abundant that they grazed all algae to such low levels that the other fish and small invertebrates that fed on or lived in the algae were reduced. Therefore, the large populations of sea urchins caused a big reduction in the reef fisheries. Managers tried to restore the infested reefs by removing the sea urchins. The fishermen were kept out of one area before and after reducing the sea urchins. In the other area, fishing continued as usual:

- Where no fishing was allowed, there was an increase in parrotfish and other fish as well as coral abundance;
- Where fishing continued, the algae and seagrass grew over the bottom and only small wrasses and damselfishes increased. Coral cover was reduced on the over-fished reefs, because of algal growth.

***Message*:** *There are no quick fixes to restoring coral reefs. But sometimes restoration, combined with control of fishing and pollution, may be the only way to permanently restore degraded reefs. If the community can be involved, this will reduce costs and they will help in the long term management of the reef.*

From Tim McClanahan, The Wildlife Conservation Society, Kenya.

D20 Mining

20.1 Coral mining, reef erosion and rehabilitation: The Maldives

Tourism on beautiful coral reefs

Islands of the Republic of the Maldives span the equator (between Lat. 7°N. and 1°S.) in the central Indian Ocean. There are 26 low-lying coral atolls and 1,300 islands, with about 300 inhabited and a population of about 238,000. Many of the Maldives coral reefs have spectacular coral cover, which has made them very attractive for divers and snorkellers and tourism has become the major source of income. Tuna fishing has also been important to the economy but many people still rely on the reefs for subsistence fishing.

Coral mining


Coral blocks used for building

Coral boulders are a traditional building material in the Maldives and are removed with crowbars from shallow reef flat areas (down to 1-2 m). Massive "boulder" corals are preferred. They are traditionally left in the open for the rain and sun to clean the rock of living parts and leach out salt. The boulders are then broken up manually into irregular pieces and incorporated into walls, originally with lime cement but now with imported cement.

Generally mining reduces the reef flats to unconsolidated coral rubble and sand with little shelter for fish and invertebrates and, with usually less than 3% coral cover, low productivity and poor chances of recovery. In the first half of this century, with a population of around 75,000 spread over 200 or so islands, coral mining was probably sustainable, being on a relatively modest scale to supply coral rock for building walls.

A rapid growth rate of population from both natural increase and immigration since the mid-1960s, together with a strong development of tourism and infrastructure, led to a rapidly rising demand for housing. The demand for coral rock for construction rocketed, particularly in the central atolls near the capital Male. In the mid-1980s it was estimated that at the rate coral was being mined, all shallow submersible flats in the North Male atoll would be exhausted of coral by 2014.

Population pressure has been particularly intense on the island capital of Male itself, where about 25% of the nation live on a 2 sq km island. This rapid growth has also led to an acute shortage of land for housing, schools, power plants, hospitals, etc. In an attempt to remedy this some land has been "reclaimed" from the sea, increasing the size of Male from 110 to 185 ha. (See Box 19 Reefs as breakwaters: the cost of replacement, p.177)

Coral reefs may not recover after mining

Natural recovery of areas that have been mined seems to be very slow and is almost non-existent where mining has been particularly intense (no recovery after 25 years). This is primarily because:

- the mined areas offer little shelter to grazers such as fish which clean surfaces for settlement of corals and other invertebrates; and
- the mobile degraded surface leads to mechanical abrasion and smothering of most corals that do succeed in settling.

Management and human help in recovery

The government of the Maldives took measures to limit coral mining and in particular banned the mining of reefs that protected inhabited islands. Substitutes were needed, and hollow concrete blocks were considered, but these need carefully controlled conditions to be strong enough. Solving these management issues was much more difficult than expected because there were strong social, cultural and economic implications.

The feasibility of restoring the reefs was also tested. Where corals have been removed from the top of small flat platform reefs (faros) in the Male atoll they have not recovered. They lack silt-free, stable, grazed surfaces for coral settlement. Also the lack of structure and shelter for grazers after mining prevented fish and other grazers living and using the degraded reef flats.

Four sets of artificial reef structures were tried on the reef flats. Within one year fish populations on all the concrete artificial structures were restored to levels the same or greater than those on healthy, unmined reef flats. Coral recruitment was also high, with up to 31 corals per sq m after the first year, with fast growth giving substantial coral cover after 3.5 years. Only on the cheapest structures (chain link fencing anchored to the reef by paving slabs) was recovery poor.

Because there was no shortage of coral larvae reaching the artificial structures, actually transplanting corals to speed up the process was found not to be cost-effective, and would make no difference in 5-10 years.

But restoration has a high cost

While the experiments were a success, the cost of the artificial structures was high, at US $ 40-310 per sq m. While a good part of the cost was in the large paving slabs needed to anchor the structures to withstand storms and other anchoring methods could perhaps be found, it is clear that such approaches could only be cost-effective on reefs protecting valuable land (see Box 19, p.177).

From Alasdair Edwards, Barbara Brown and Sue Clarke of the University of Newcastle, UK.

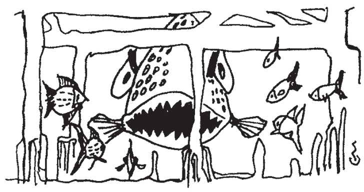
D21 Forestry

21.1 Unsustainable mangrove use: Nicaragua

Over-harvesting threatens a rich mangrove resource and its associated fisheries

Mangroves on the Pacific Coast of Nicaragua in Central America are an important resource in the subsistence life-styles of local villagers. Mangroves provide wood, and minimise storm damage from hurricanes on coasts like the Heroes y Martires de Veracruz region. The mangroves also provide a rich fishing habitat for local villagers, where they gill net for mullet, cast-net for shrimps and dig for shellfish. Local mangrove deer populations are also hunted.

The mangroves act as nursery grounds for lagoon and near-shore fisheries, especially mangrove dependent shrimps (*Penaeus, Trachypenaeus*) and fishes (*Micropogon, Mugil, Centropomus* and *Lutjanus*).



The mangrove waterways are the only means of communication and transport between villages and towns, and many small boats carry people and produce (including mangrove poles), because there are few roads in this part of Nicaragua.

Mangrove losses

Luxuriant mangroves up to 25m high fringe all of the waterways and include *Rhizophora racemosa, R. harrisonii and R. mangle,* with occasional large trees of *Avicennia germinans.* More inland, there are salt flats (known as 'salinas'), which are bare but fringed by the locally endemic mangrove *Avicennia bicolor. Laguncularia racemosa* and *Concarpus erectus* bushes are found on sandy areas.

Around Heroes y Martires de Veracruz, the mangroves are still in reasonable condition but show signs of over-use including loss of large trees and patches of over-cutting. Around Corinto harbour and around Las Penitas, there is intensive pole cutting and poles are seen being carried in many small boats. While the mangroves are still reasonably healthy, there are clear signs of over-harvesting. If this continues the mangrove forests will degrade rapidly and the communities will lose valuable fishing and timber resources.

What is happening

The collection of poles, firewood and commercial collection of bark for tanning, are the major uses of mangroves. Pole cutting for building and firewood from *Rhizophora mangle*

and *R. harrisoni* is very intense and most poles are relatively straight, 2-4m long with a diameter of 5-10 cm, showing that the prime targets are young trees, about 10-15 years old. The bark is removed by pounding the poles and not used. The other species are not used much, although *Avicennia germinans* is used as firewood in the dry season.
Bark is removed from large (over 10m) Rhizophora trees as large sheets and sold to local tanneries. Many large dead debarked trees are seen but they are not cut down for firewood, because they become hard and dry if too large.

Removing bark from mangrove trees

These two local uses are in clear conflict and lead to inefficiencies. One user cuts young trees for poles, which prevents the trees growing large enough for the bark collectors. It is also inefficient, because the bark from the poles is wasted, while the dead trees left standing after bark collection dry out and are too hard to cut down. Because both groups target different tree sizes, over-exploitation is the end result.

What chances for recovery

Clear signs of over-exploitation are obvious, although the mangroves are still in reasonable condition. The mangrove forests will recover if they are well managed and all the mangrove users are involved.

Management actions needed

Two approaches are suggested:

- Establish some permanent plots where there is no harvesting, in consultation with local residents. These plots can then be used to measure 'mean annual increments' of standing timber to how much timber can be cut sustainably.
- Make lists of forest product harvesting with help from the local residents, to estimate harvest rates for all areas. (The density of standing debarked trees should be estimated, as well as measuring tree regrowth after pole removal).

With these data, it will be possible to assess the value of the harvest. More efficient use of forest products should be investigated, including:

- using the bark from poles;
- collecting firewood from the debarked larger trees;
- better extraction of tannins from bark;
- alternative sources of tannins; and
- finding alternative sources of firewood.

What is happening now

The staff of the Science Faculty, University of Leon, now have a small field station in the region and have started a collaborative, broad-ranging mangrove research programme with the local communities. They have technical assistance from CATIE (the Centro Agronomico Tropical de Investigacion y Ensenanza), funded by the IUCN Regional Wetlands Programme.

This study will determine what rates of harvesting are sustainable, what rotation times should be used and what effects continued mangrove harvesting will have, particularly on the fisheries and shoreline protection.

This information is important for management plans. Finding the right balance between harvesting the mangroves and preserving good fishery habitats can be valuable and sustainable (see management case study C12 on Matang p.64)

Mangrove forests can be sustainable resources, if carefully managed

From Peter Saenger, Director, Centre for Coastal Management at the Southern Cross University, Australia.

21.2 Loss of lagoonal mangroves: Ivory Coast

Over-harvesting, plus pollution and canals put mangrove forests at risk

The West African country of Ivory Coast (Cote d'Ivoire) (Lat. 6°N.), has a population of around 15 million, and borders the Gulf of Guinea between Liberia to the west and Ghana to the east. It has a coastline length of 540 km and an annual rainfall between 1,000-2,000 mm punctuated by two dry periods.

As a result of past sea level and climatic changes, most of the mangrove vegetation is confined to semi-enclosed coastal lagoons or embayments, generally with little tidal exchange and limited (and strongly seasonal) freshwater input. Mangroves are found in the extensive coastal lagoon system including in the lagoons Aby, Ebrie, Grand Lahou and Fresco. Over 50% of the country's population also lives close to the coastal lagoons with the result that mangrove habitats are encroached on for towns, roads, ports and airports and are also heavily exploited by an urban population (mainly for wood). They are subjected to the wastes from those urban centres.

What the mangroves were like

Well-developed mangrove communities were once found in all of the coastal lagoons. For example, around Fresco, particularly the lagoon Ngi, four mangrove zones were readily distinguishable, including:

- a tree zone of Avicennia germinans 15-18 m high;
- a tree zone of Rhizophora racemosa 8-10 m high;
- a shrub zone of Dalbergia ecastaphyllum 4 m high (mixed with Hibiscus tiliaceus, Drepanocarpus lunatus and Acrostichum aureum); and
- a grassland zone of Paspalum vaginatum 0.8 m high.

Similar formations occurred throughout the coastal lagoon system.

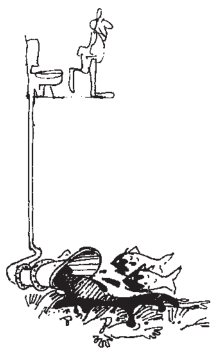
What the mangroves are like now

The extent of these lagoonal mangroves has been much reduced (with the best estimates now at 15,000 hectares) and several species, which could be expected to occur, are no longer found (including the trees *Rhizophora mangle, R. harrisoni* and *Laguncularia racemosa).* Mangrove remnants attaining heights of around 20m are found only around Abata to Mossou, around Grand Bassam and Fresco.

What happened

The development of large towns with many industries caused some major changes to the mangrove vegetation. Around the capital, Abidjan, industrial pollution has adversely affected the coastal lagoons (e.g. Laguna Ebrie) and their associated mangroves, leading to the disappearance of mangroves in many areas. The decline in water quality has been magnified by sand mining from the coastal lagoon system, while the effects on the mangroves have been increased by the intense cutting of the red mangrove (*Rhizophora racemosa*) for firewood used for cooking and the smoking of fish.

Almost all of the mangrove forests of the Ivory Coast lagoons have been damaged through changing water flows, primarily due to the building of the canal de Vridi, which provides permanent access for the port of Abidjan. This 2.7 km long canal, completed in 1950, cuts directly through the coastal dunes system and provides an opening to the lagoons that did not previously exist, while the old mouth at Grand Bassam is now generally sanded up. Not only has this changed the tidal circulation within the entire lagoonal system but it has also altered salinity patterns drastically. These changes have been further compounded by the construction of 6 dams on the rivers flowing into the coastal lagoon systems.



Sewage treatment is very limited throughout the country and raw sewage is discharged into the coastal lagoons and the rivers flowing into them. For example, it is estimated that 186 cubic metres of untreated sewage flows into Ebrie lagoon from Abidjan each day. Because of this pollution and limited tidal exchange of the lagoons, eutrophication is widespread. In the lower salinity areas of the rivers, water hyacinth, *Eichhornia crassipes,* is a major problem and it is flushed into the lagoonal system, decaying and reducing concentrations of oxygen during the wet season.

What are the chances of recovery

To restore the lagoonal mangrove systems, three separate initiatives need to be undertaken, followed by a fourth active programme:

- woodcutting of mangroves needs to be controlled and regulated, at least in some areas of the lagoons;
- pollution inputs to the lagoons need to be reduced either by treatment facilities, or by deep ocean discharges;
- the destruction of mangrove areas for other land uses needs to be drastically reduced; and
- active replanting programmes need to be undertaken in those areas where restoration is feasible.

If these four measures are well done, the lagoons will recover and their values will be restored.

What is happening now

With the establishment of a Direction de l'Environment within the Ministere de l'Environment et de Tourisme, studies into the degradation of the lagoons are in progress. However, there are no specific measures for mangrove protection although a small mangrove reserve has been established at Les isles Ehotiles in Aby Lagoon. A deep ocean outfall has been under construction since 1992, which will divert some of Abidjan's sewage from the lagoonal system directly to the Gulf of Guinea.

Recently the Global Environment Facility (GEF) established a programme to improve coastal water quality along the entire Gulf of Guinea coast to preserve biodiversity. This project, called the "Gulf of Guinea Large Marine Ecosystem Project", aims at: the prevention and control of land-based sources of industrial and urban pollution. The project also seeks novel ways to achieve this and one of the first steps has been to establish a pilot project to use mangroves as a productive wetland to produce wood, while reducing the effects of sewage.

Mangroves and their creeks are important fish nurseries and forestry resources

A second GEF project has recently commenced to use biological control to eradicate water hyacinth from the rivers and lagoons of Ivory Coast. While this is an important step forward, management of the catchment to regulate all inputs into the coastal lagoon systems is necessary, or the water hyacinth problem will occur again. If sewage treatment using mangroves proves to be as successful as pilot studies indicate, then a permanent improvement of the coastal lagoons is within sight.

From Yacouba Sankare and Peter Saenger, Director, Centre for Coastal Management at the Southern Cross University, Australia.

D22 Introduced species

22.1 Problems with introduced mangrove palm: Gulf of Guinea

Invasion by an introduced species

The Gulf of Guinea lies in the tropical part of the Atlantic coast of Africa and is the most densely settled coastal region of the continent. It has a hot and humid climate that has allowed the luxuriant development of mangrove forests in the deltas of the big rivers. The mangroves on the Volta, Niger, Cross, Wouri and Ogooee have extensive tracts of mangroves that form the basis of the lifestyle of the coastal villagers (see case study 21.2, p.122).

Mangrove palm introduced and spread

The mangrove palm, *Nypa fruticans,* is known from ancient fossils from the area (25 million years before the present) but died out. The palm was re-introduced into Nigeria from the Singapore Botanic Gardens into Calabar in 1906 and Oron in 1912. The species then spread slowly through the Niger, Imo, Bonny and Cross Rivers. Its spread seems to have accelerated over the past few years and it has now reached the Wouri estuary in Cameroon, where it is spread by local villagers who use it for thatching. Some palms have also been found at the mouth of the Volta River in Ghana, perhaps also planted by villagers.

What is happening

Nypa is common in mangroves in the high rainfall areas of Southeast Asia and often forms pure stands along low salinity rivers. Its introduction into the Niger delta with its high rainfall has allowed the species to establish and spread and it is now found in all the high rainfall deltas of the Gulf of Guinea. It occurs in very dense stands and prevents the regeneration of native mangrove species. As other mangroves, such as Rhizophora, are cut for firewood, Nypa gradually replaces the native species.

More significantly, Nypa forms dense fringes along the river edges but, because this species has neither proproots, nor butresses nor upright aerial roots to hold the muddy banks together, the Nypa dominated river banks are more susceptible to erosion and slumping during high river flows than banks edged with other mangroves.

Nypa is now too widespread to be removed easily from the mangroves of the Gulf of Guinea. The cost of removing it would be much too high and it is now permanent. The damage caused by its spread could be reduced if there was regionally coordinated action to reduce the amount of Nypa and prevent it spreading further. But in all the countries with Nypa (Ghana, Nigeria, Cameroon) there is no legislation to control the management, use or protection of mangroves.

What is happening now?

Because of the lack of government action, the only control being attempted is by non-government organisations (NGOs). These groups are educating villagers about Nypa and the problems of its spread. At the same time, they are encouraging villagers to use existing Nypa palms for thatching and alcohol production in an attempt to remove it faster than it is able to regenerate. Elsewhere, there are small-scale projects removing Nypa and replanting with the local mangrove trees.

Message: *There are around 70 mangrove species in the world and introductions can be dangerous to the environment. Any accidental introductions should be taken extremely seriously and they should be removed when they are first seen.*

From Peter Saenger, Director, Centre for Coastal Management at the Southern Cross University, Australia.

D23 Oil and oil mining

23.1 The oil spill at Bahia las Minas: Panama

The effects of a massive oil spill on mangroves, seagrasses and corals

The spill occurred in the Republic of Panama at a refinery in the Bahia Las Minas, a bay just east of the Caribbean entrance of the Panama Canal (Lat. 9°24′ N, Long. 79°52′ W). The coast is heavily indented, with major mangrove stands, though these have been affected by solid causeways built between the islands, changed water flow and heated water from electricity generation. The bay itself has numerous small islets and two large islands. The spill, 38.3 million litres (240,000 barrels), leaked from a ruptured storage tank into the sea and was held in the area for six days by onshore winds.

The area of pollution included a biological reserve and marine research laboratory on Punta Galeta Reef, run by the Smithsonian Tropical Research Institute, where information on the area had been previously gathered and recorded by scientists. This allowed for an unusual before-and-after study to be undertaken, with the aim of showing both the immediate and long-term effects of the oil spill.

What the area was like before the spill

The land has been changing over many years with drainage of swamps, the cutting of forests, excavation, dredging and landfill. In spite of this, there were large areas of mature stands of mangroves, platforms with fringing reefs and large areas of seagrass beds. Reefs sampled before the spill had corals covering between 15-27% of the reef surface in shallow water (less than 3 m) and 17-38% at a depth of 3-6 m.

What happened to the coral reefs, mangroves and seagrass beds

The oil reached the coral reefs 12 days after the spill and accumulated along the seaward edge of the reef for over a week due to seasonal low tides. This is the area of most coral growth and there was mass mortality of corals, sea urchins and other invertebrates. The area stank of rotting animals.

Three months after the oil spill, the corals showed extensive effects, many having died or showed damage. Coral cover of the bottom had been reduced by 76% in shallow water under 3 m and by 56 % in water from 3-6 m in depth. Corals on non-oiled reefs over the same time period showed no change. Oiled corals that lived showed reduced rate of growth, increased number of injuries and slower recovery from injury. Rapid re-growth of algae has increased their abundance in reefs previously occupied mainly by corals and soft corals (*zoanthids*).

Many mature mangrove trees died after the spill over a large areas (75 hectares). Some of the seedlings were not killed and over the next three years the bare areas became densely covered in seedlings, in spite of the fact that a substantial amount of oil is still present in the mud. It will take many decades for a mature mangrove forest to develop and there is some indication that the growth rate of shoots may be affected. Some, but not all, of the attached fauna and flora on mangrove roots were badly affected by the oil. For example, a dominant mussel on roots *(Mytilopsis sallei)* was absent three years after the spill and the barnacle *(Balanus improvisus)* was still reduced in abundance. Mangrove sediments still contain substantial quantities of oil and will continue to be a source of chronic contamination.

While the seagrass beds below low tide may have been affected by the oil, there was no measurable difference a year later. While some changes in the organisms on and under the seagrasses were measured, there were no catastrophic changes.

How can management help?

There is little that management can do except see that:

- oil transfer and storage equipment are regularly maintained and checked to prevent spills;
- that containment lagoons or areas around tanks and pipes are adequate;
- that recovery systems are in place and kept up-to-date; and
- that chronic minor spillage which could affect recovery is prevented.

(see case study 23.2, p.129 on the Aruba refinery)

From B.D. Keller & J.B.C. Jackson[5] .

[5] Keller, B.D. & Jackson, J.B.C. (1991). *Long-term Assessment of the Oil Spill at Bahia Las Minas, Panama: Interim Report*, Vols1 & 2. US Department of the Interior, Minerals Management Service, New Orleans.

23.2 Long-term effects of an oil refinery on coral reefs: Aruba

The subtle effects of continuous, slight oil pollution

Aruba is a Caribbean Island about 27 km north of the coast of South America and 12° North of the Equator. The Island is 300 km long by 90 km wide. Aruba is an independent nation state, which has increased in population over the past 10 years from 65,000 to over 80,000. Tourism and an oil refinery drive the economy. The coral reefs are becoming an increasingly important tourist attraction.

What the reefs are like

The coral reefs are fringing reefs close to the shore, stretching along the southwestern coast of the island. They are well-developed, with very uniform coral communities and species composition, and consist of large branched colonies of coral *(Acropora)* in shallow water down to 2 m. At around 4 m, there are abundant massive and heavy columnar colonies (Montastraea). Deeper than 8 m there is a mixture of species.

Effects of the oil refinery and terminal on the reefs

Environmental damage from oil refinery worsened by its location. Photo: Rolf Bak

The oil refinery was built in 1923 on the southeastern tip of the island, where the almost continuous current flows to the northwest past the refinery and then over most of the reefs. Shallow water corals in front of the refinery are mostly dead or broken, with almost no live corals nearby and 25% or less coral cover as far as 10 km down the coast. In deeper water (5 m) both the coral cover and the structural complexity are very reduced, and sometimes there are no live corals.

In contrast, there is a normal reef with 50 to 60% coral cover on the other side of the refinery. The cover of live corals and their diversity slowly increases further down current away from the oil refinery, until it is almost normal about 9 km away from the refinery. The number of new juvenile corals is 10 times less near the refinery than in other areas. All the affected areas have dead coral stumps and fragments, indicating there was once very rich coral growth.

Why did it happen?

There are two distinct effects of the refinery:

- physical damage nearby due to construction and ship movements, with nothing but rubble; and
- the pollution of the reefs along the direction of the current (showed by dead coral skeletons still standing upright).

The reefs in front of the refinery have been physically battered by ongoing construction and ship activity, and most corals are smashed in this area. The downstream changes seem to be due to pollution carried by the current away from the refinery. Coral cover is reduced downstream, diversity is low and there are very few new juveniles. The effects are visible as far away as 15 km in shallow and 10 km in deeper water.

What are the chances of recovery?

Even if the physical damage around the refinery could be stopped, it seems unlikely that the corals in front could recover, because gradual pollution from the refinery continues. This refinery is considered to be well managed and spills are apparently kept to a minimum. But the local people say that spills and leakages of hydrocarbon, dispersants and wastewater do occur. This steady leakage of pollutants continues to destroy the corals downstream in a slow and almost invisible way. Because oil pollution takes a long time to show up, local scientists expect that this slow degradation will continue and damage will get worse further along the reef. Therefore the reefs downstream of the refinery are unlikely to recover until the pollution is stopped.

What can be done?

There appear to be only two solutions: close the refinery, as it was built in the wrong place; or clean up its operations significantly. Special attention should also be placed on ensuring that all the other activities, like towns and tourists resorts, are not adding to the problem with more pollution.

From Rolf Bak, Carmabi Foundation, Netherlands Antilles and Netherlands Institute of Sea Research, Netherlands.

23.3 The oil industry and mangroves: Nigeria

The Niger River delta dominates the 835 km long Nigerian coast on the Gulf of Guinea in tropical West Africa. The delta has high rainfall and very humid conditions and the river has washed sediments down to form a delta, with outer sandy barrier islands, an inland freshwater flood plain and extensive brackish mangrove forests between them.

What the mangroves were like

The delta mangroves cover approximately 700,000 ha and are the largest, continuous mangrove area in Africa. Early accounts describe these 'endless walls of mangroves', largely dominated by *Rhizophora racemosa* reaching heights of 20 m, although 10-12 m is more common. Other significant tree species are *Avicennia germinans, Rhizophora mangle* and *R. harrisonii*. The timber resources of these mangrove forests are over 280 million cubic metres.

What happened to the mangroves

The coastal people of the Niger delta are dependent on local resources, with fishing a major activity. Now numerous pressures are changing the delta mangroves, particularly habitat loss, coastal erosion, pollution, cutting mangroves for firewood and collecting mangrove bark for tanning. The pressures of the local people have damaged some mangrove areas but the discovery of oil in the mid-1950s has caused major impacts.

Nigeria currently produces about 1.6 million barrels per day from more than 4,000 oil wells in the Niger Delta and the nearby coastal areas; and 23 of the 62 large oilfields occur in the Niger Delta mangroves. There are 7 oil terminals in the delta (at Bonny, Brass, Qua Iboe, Forcados, Escravos, Pennington and Warrie) and 3 refineries (Port Harcourt, Warrie and Kaduna). There are also 8,000 km of seismic lines (20-30 m wide) and oil pipelines crossing the mangroves. Oil spills are common and random water analyses showed oil concentrations in 1980 between 10.4 and 64.9 parts per million (ppm). Therefore most surface waters are contaminated and not drinkable, which has forced some local people to leave.

Between 1970 and 1982 there were 1,581 oil spills, of 2 billion barrels of oil. In July 1970, the Bonu II oil well had a blowout, which caused widespread loss of leaves and killed all trees in the most polluted areas. Other major spills were the Elf Obagi 21 blowout in 1972 and the Texaco blowout, and the Agip Oyakama pipeline rupture in 1980. These accidents killed mangrove seedlings and trees, reduced productivity of plant plankton and larger water plants, and damaged the food chains of fishes.

In January 1980 the Funiwa oil blowout released 200,000 barrels of oil about 5 km offshore which flowed back into the mangroves. The oil was trapped in the delta and spread by the tides, affecting the villages of Fishtown, Sengana, Kulanma and Otua Island. Most mangroves became leafless after 6 months and, after 14 months, 23,000 ha of mangroves were affected, with 338 ha totally killed; 90% of the damage occurred within 5 km of the river mouth.

Oil spills can devastate mangroves

Mangroves are affected by impacts other than oil spills and slow leaks.

Gas flares that burn off waste hydrocarbons create lots of heat (Shell's IMO-1 flare station) and damage the mangroves around for 150 m. Mangrove growth outside this area is reduced and productivity lowered due to increased soil temperatures.

The seismic lines allow seawater to flow into the brackish and freshwater swamp areas, causing widespread tree death. Massive destruction of approximately 20,000 ha around the Tsekelewu Oil Field in the Niger Delta was seen using aerial photographs. The destruction was caused by higher salinity water coming in from the sea because of seismic exploration. Salt concentration normally decrease away from the sea but suddenly increased at the saline/freshwater mixing zone. Here the seismic lines caused the greatest damage, including the death of all *Avicennia germinans* trees.

What are the chances of recovery?

Because the mangroves in the Niger Delta cover a large area, the damage caused by the oil industry is affecting only some parts and would be reversible. To reduce future threats to these mangroves will require the following:

- reduce oil spills and other damaging activities;
- improve clean-up capacity;
- improve techniques for mangrove rehabilitation; and
- establish more effective surveillance and management.

Management actions needed

The National Institute of Oceanography and Marine Resources has recommended that mangrove forest reserves be established to replace trees cut by coastal people. It has also suggested that the price of gas should be cheaper for coastal communities to reduce the use of mangroves for domestic cooking. In addition, the oil industry needs to improve its operations.

What is happening now

All 11 oil producing companies established the Clean Nigeria Association (CNA) in 1981, as a non-profit cooperative to increase their ability to respond to major crude oil spillages and to back-up each company's clean-up capability. However, this has not been adequate and oil is still leaking. The oil industry has set aside funds to study the ecology and restoration of delta plants and animals.

The Federal Environmental Protection Agency was established in 1988 to protect the environment, and restore and preserve the ecosystems of Nigeria. More recently, a National Coastal Management Authority was proposed within the EPA to regulate and manage all coastal resources. But no mangrove protection has occurred, although the Cross River National Park, east of the Niger Delta, contains some mangroves. There is also a 25,000 ha mangrove forest reserve in the delta but it is not patrolled.

The Global Environment Facility (GEF) has established an intergovernmental programme to improve water quality along the entire Gulf of Guinea coast to preserve biodiversity. This 'Gulf of Guinea Large Marine Ecosystem Project' aims to prevent and control land-based sources of industrial and urban pollution and seeks new ways to achieve this. A priority for Nigeria will be to identify which mangrove areas should be rehabilitated.

From Catherine Isebor from the National Institute of Oceanography and Marine Resources, Lagos, Nigeria and Peter Saenger, Director, Centre for Coastal Management at the Southern Cross University, Australia.

D24 Construction, building and dredging

24.1 The costs of rapid wealth: the reefs of Singapore

The Singapore reefs are near the Equator (Lat. 1°9' N, Long. 103°50' E). They lie between the Indian Ocean and the South China Sea or Java Sea and in a narrow passage that is particularly important for shipping. These reefs receive influences (and larvae) from both the Indian Ocean and the Java Sea.

The types of coral reef

The reefs are typical small platforms, some with coral cays, sitting in approximately 20 m of water. There are some deeper trenches up to 60 m further offshore.

What has happened

The land area of Singapore has been increased by more than 10% in the past 35 years and another 5% will be added in the next few years. This has occurred through massive land 'reclamation' along the southern coastline, using sediment dredged from the coastal shelf and sand imported from nearby countries. However, much of the fine sediment remains suspended in the water after the dredging or from leakage out of the landfill. This has resulted in a big reduction in water visibility and the sediments are continually being stirred up by the massive amount of shipping that passes through the Port of Singapore. There is also dumping of sediment dredged from deepening the shipping lanes.

Sediment damages corals directly by settling on them and also by reducing the amount of light energy that the corals receive. The increasing loads of sediment have resulted in decreased coral reef growth - once the reefs grew below 10 m depth but corals occur now in only 5 m or less.

Some of the inner islands (Pulau Sakra and P. Bukam) were converted for industrial use e.g. oil refineries, ports etc. with large scale building of rock walls and dredging of shipping channels. These islands no longer have coral reefs.

The eastern half of one of the larger islands (Pulau Semakau) has been enclosed by bund walls for use as a garbage dump. For the next 50 years, Singapore's solid wastes will be dumped here and then covered to make a larger island. Unfortunately, toxic waste and fine sediments will leach out from the dump, thereby polluting the adjacent reefs, unless proper controls are implemented.

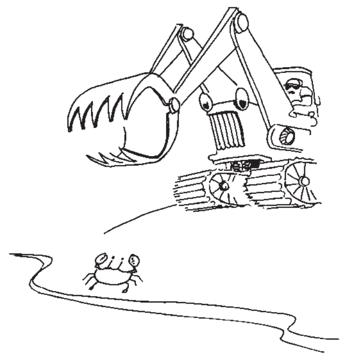
Fishing activity has decreased on these reefs as the fishermen can earn more money in industry or by assisting in the port. However, a few years ago there was much collecting of live corals, other invertebrates and fish off the reefs for the local aquarium trade. There are strong efforts to control this collection.

What it is like now

The only reefs in relatively good condition are those in the far south (e.g. Raffles Lighthouse) and those controlled by the military.

On most other reefs, live corals only extend down to about 5 m, with dead coral on the slopes down to 10 m. Corals growing in shallow water appear healthy and are very diverse, which indicates that if the water cleared up, they would grow much deeper.

Why has this happened?



The priorities for the government and people of Singapore have been to increase economic activity as fast as possible but many aspects of the environment have been sacrificed. This is now changing rapidly, as the economy is one of the strongest in the world. The government is actively trying to improve the environmental quality of the island and adjacent waters.

What are the chances for recovery?

Much recent attention has been focused on the reefs in the press. A major exercise was conducted by the Singapore Institute of Biology, Singapore Underwater Federation and the Singapore Yacht Club, when they trained 150 divers to monitor coral reefs using transect tapes.

Recently an attempt was made to transplant corals to another site from a reef that was being filled in. There was a lot of publicity about success but when scientists from the National University of Singapore conducted proper monitoring, they showed very low survival rates. These scientists have undertaken extensive coral reef studies elsewhere in Asia and are able to advise governments on how to manage reefs.

The numbers of Singapore people who go SCUBA diving have increased dramatically in the region but many divers must travel to nearby Malaysia or other regions to ‘see' coral reefs in clear water.

Management actions

There are current plans before the government to include 4 reef areas as Marine Protected Areas. These have been incorporated into the country's Green Plan but exist as paper parks without the formation of a management agency or plans.

What is happening now?

The Singapore Government has the goal of cleaning up the environment and has connected all Singapore houses to sewage treatment systems. Industrial wastes must be treated on site before being discharged into the sewerage system. Therefore much less pollution is now coming off the land.

The Singapore River and Kallang Basin were particularly polluted and unfit for marine life. The government started cleaning up the rivers in 1977 and now much marine life has returned to the river and harbour and the water is cleaner. However, similar management emphasis has not yet been put on the coral reefs.

***Message**: Singapore is a country that progressed rapidly from developing to wealthy status. A consequence of development is that the flourishing coral reefs have been steadily degraded. Can Singapore use its wealth to reverse some of the damage?*

From Chou Loke Ming, National University of Singapore and Clive Wilkinson.

24.2 Coral reef impact and recovery after harbour dredging: Thailand

What the reefs were like

On the sheltered south-east corner of Phuket island, on Thailand's west coast, intertidal coral reefs stretch out from the shore for up to 200 m. They may be exposed to the air for 4 hours at low spring tides and are extensively gleaned by villagers searching for fish, shellfish and octopus. The coral-covered reef slope drops away for 3 m and ends in soft sediments. There is high seasonal rainfall (300 mm per month in the wet season) and fine sediments (chiefly clay minerals kaolinite and illite) are washed into the sea. This results in turbid water (with solids as high as 40 mg per litre), with visibility of less than 1 m. The reefs in the area are dominated by massive boulder corals (*Porites, Goniastrea, Platygyra* and *Favites*) with some *Acropora* and *Pocillopora* at the reef edge. The coral species present are very tolerant to sediment.

Dredging

In 1986-87 dredging to build a deep-water channel and port continued for 9 months. The sediments were placed behind a bund wall but very fine particles escaped and accumulated on the reef flat. Sediment from the main dredging activities also reached the reef because onshore winds carried the dumped material back from offshore dumping sites. Frequently the pipes that carried the sediments from the dredge to the fill site broke and leaked. Suspended sediment concentrations were many times natural levels (as high as 286 mg per litre) at the reef edge.

Plumes of sediment from dredging
Photo: D. Shanahan ©GBRMPA

What happened to the corals

Reefs at the site were monitored for 6 years before dredging and also at a reference site 800 m away. The dredging had a major effect on coral cover and species diversity at the dredge site, but not at the site 800 m away. The living coral cover of the dominant massive coral *(Porites lutea)* declined by 25% at the end of dredging and other massive corals also showed a marked decline in abundance. The sediment from dredging also coincided with exceptionally low tides, due to normal seasonal depression in mean sea level in December-May and even lower tides than the previous five years (due to an El Niño event). Sediment became 'baked' on the upper, exposed surface of the corals as the sun dried them. In spite of being very sediment resistant, the corals could not shed the sediment when submerged and the 'baked' areas died.

Recovery

A year after the dredging ceased (July 1988), coral recovery at the site was well under way, with *Porites lutea* growing rapidly back to its former abundance. The massive corals died on their upper surfaces but often the sides that were underwater remained alive. Mean sea level was also higher in 1988. Corals rapidly grew from their living sides to cover the dead upper surfaces.

Conclusion: The story in brief

- Increased sediment from dredging caused major coral damage and reduced coral cover on intertidal reef flats.
- Human interference was compounded by natural factors; with unusually low water levels, sediment settling on the corals and strong sun baking the sediment hard.
- Engineering difficulties delayed dredging to the worst time of year, when the tides were lowest.
- Return to normal water quality resulted in rapid regeneration of the corals on the reefs. The corals were sediment tolerant and fast growing species and were only partially damaged. Higher water levels than usual helped re-growth.

Message: *Sediments do cause a lot of damage to corals but, if the sediment pollution can be stopped, corals can recover rapidly, particularly if there are sediment resistant species there.*

From Barbara Brown, Marine Sciences and Coastal Management, University of Newcastle, UK.

D25 Multiple effects

Often many human impacts are the cause of damage to shallow water habitats, sometimes also added to by natural impacts.

25.1 Stress from water management and land-use practices: Florida Bay

In 1992, Florida Bay was on the verge of collapsing, largely due to major man-made changes in the flow of freshwater into the Greater Everglades estuary which flows into the Bay. It soon became evident that the continued problems of Florida Bay, in turn, threatened the USA's only living barrier coral reef. It put at risk marine environments of great biological and economic significance.

Florida Bay is a large (250 x 80 km) shallow bay with hundreds of mangrove covered islands. Its vast seagrass beds and hard-bottom habitats make it a critical link in an enormous ecosystem. This system stretches from a chain of inland lakes, through the vast Everglades estuary and coastal mangrove forests, then across the Bay and through the coral keys (islands) to its fringing coral reefs.

What happened

The clearest signal that the ecosystem was on the edge of collapse came when the seagrass beds suffered a massive die-back in 1987. But this was only one of a series of symptoms signaling that water quality had declined including: major losses of corals; and occasional blooms of bottom and plankton algae - one resulting in a destructive 'red tide'.

Changes in the quality, quantity, timing and spread of fresh water entering the bay through the Everglades were major reasons for the problems in Florida Bay. Water quality around the Florida Keys was worsened further by nutrients from sewage disposal systems (even some open sewage pits). Stormwater runoff, containing heavy metals, fertilisers, insecticides and other pollutants, added to the damage.

Other factors degrading the water are nutrients from house boats; poor flushing of canals and embayments; build-up of organic debris along the shoreline; sedimentation; lack of hurricanes; and environmental changes associated with global climate change and sea level rise.

Why did it happen

There have been major landscape changes in south Florida and on the coral keys (islands) along the Bay. One of the biggest was a project in the 1940s to drain the fresh water marshes and provide irrigation from a massive system of canals. 2,240 km of canals were dug by the US Army Corps of Engineers.

This opened the door for extensive urban and agricultural growth. With a massive 50% reduction in wetlands area, the timing and flow of water was altered throughout the South Florida ecosystem. In addition, Lake Okeechobee near the headwaters of the system was being polluted with agricultural runoff and the coastal estuaries were damaged with excessive freshwater during storm events. Other problems came from the introduction of harmful exotic plants.

Before efforts were made to drain the South Florida wetlands, the landscape had three key qualities:

- it was extremely flat, with no more than a 6.1 m drop in elevation over the 160 km between Lake Okeechobee and Florida Bay;
- the landscape had varied flora, fauna and habitats; and
- most importantly, the landscape was determined by the rainfall pattern, it was a dynamic water storage system, with a shallow, widely spread flow.

Vast areas of marshland were drained for agriculture
Photo: Andrew Elliott ©GBRMPA

This has now changed.

Massive reshaping of the land and a very substantial increase in population, with associated agriculture, urban development and other human activities, is now putting the entire South Florida ecosystem in peril.

The collective consequences of these human impacts have affected all living things in the region - plants, animals and people. From the headwaters through the Florida Keys to the coral reef, the natural system is under great strain.

The changes now threaten the wellbeing of South Florida's multibillion dollar tourism, agricultural, trade and fishing industries, which are the economic backbone of the region and the state. To ensure the long term economic viability of these industries, massive amounts now have to be spent to correct the environmental errors of the past.

By the late 1980s the Florida Keys coastal and coral reef ecosystem was suffering:

- deteriorating water quality throughout the region,
- a major seagrass die-off,
- significant loss of living coral cover on reefs,
- declining reef fish populations,
- the die-off of the long-spined urchin,
- the spread of coral diseases, and
- the impacts of coral bleaching.

To this was added another threat: oil drilling off the Florida Keys.

Commercial and recreational users, environmentalists, scientists and resource managers all agreed that the greatest threat to the natural resources and the economy of the Keys was the deterioration in water quality.

What has been done

The US Congress stepped in and passed a new law, the Florida Keys National Marine Sanctuary and Protection Act (FKNMS Act), signed by President Bush in 1990. The Act designated 9,600 sq km (2,800 square nautical miles) of coastal waters off the Florida Keys as the Florida Keys National Marine Sanctuary.

Rich reef life the Sanctuary protects
Photo: Susan Scherner for the Florida Keys National Marine Sanctuary

There was instant prohibition of any oil drilling, including mineral and hydrocarbon leasing, exploration, development or production within the Sanctuary. The legislation also prohibited the operation of tank vessels (ships) more than 50 m long in an internationally recognised "Area to Be Avoided" within the Sanctuary.

The FKNMS Act called for the US Secretary of Commerce to consult with appropriate federal, state and local government authorities, and with a Sanctuary Advisory Council (SAC). The objective was to develop a comprehensive management plan and implement regulations to achieve protection and preservation of living and other resources of the Florida Keys marine environment.

Much of the Sanctuary (65%) is in State waters and there are also overlaps in responsibility between State and Federal agencies over areas in and near the Sanctuary, so it was imperative that planning was an inter/intra-agency effort. With many and diverse users of the area's resources, it was equally important that the public have a strong role in developing the total management plan.

The SAC consists of members of various user groups; local, state and federal agencies; scientists; educators; environmental groups; and private citizens. During planning, numerous public workshops were held to get input from knowledgeable individuals on a wide range of topics that could be implemented in the management of the Sanctuary.

The Final Management Plan was developed over six years by the Department of Commerce's Office of National Marine Sanctuaries in NOAA (National Oceanic and Atmospheric Administration). It contained 10 Action Plans (covering channel/reef marking, education, enforcement, mooring buoys, research, regulation, submerged cultural resources, volunteers, water quality and zoning) to manage the Sanctuary.

The two Action Plans that attracted the most public attention during the development of the management plan were:

1 ***The Water Quality Action Plan*** – developed to restore the water quality in the Florida Keys and to reverse the degradation that had taken place. This action plan identified the sources of the water quality problems and the technical and infrastructural solutions that are available.

2 ***The Marine Zoning Plan*** – developed in the Marine Sanctuary to assist in the protection of the biological diversity of the marine environment in the Keys. Five separate zone types have been established to reduce user conflicts and lessen the concentrated impact to marine organisms on heavily used reefs. Those five zone types are:
   - Wildlife Management Areas;
   - Ecological Reserves;
   - Sanctuary Preservation Areas;
   - Special Use Areas (Research-Only); and
   - Existing Management Areas.

Three of the zone types in the Marine Zoning Plan are 'no-take' areas and establishing the 23 separate Marine Reserves was the most controversial part of the whole management planning process. Commercial and recreational fishermen lobbied politicians vigorously against the location and extent of the reserves.

Management challenge

The Florida Keys comprises one of the USA's most biologically diverse environments, surrounded by one of the country's most diverse socio-economic settings. The attraction of the living coral reefs and the need to conserve its rich marine life may seem simple. Yet it is the complexity of this unique marine environment and the activities of its many users that challenges managers. They must find a balance between protection and continued use. It is a major challenge but a community so closely linked to the environment has to find a workable and sustainable balance between the environment and the economy.

The completion of the final management plan for the Sanctuary addresses that challenge. At times the debate was long and intense, but solutions were found and compromises were made. Many local people joined in the process and helped to ensure a common sense approach. People have begun to understand how easily coastal systems can be damaged and are now supporting the Final Management Plan. This is one of the many steps that have to be taken toward sustainability.

From John Ogden, Director of the Florida Institute of Oceanography and
Billy D. Causey, Superintendent, Florida Keys National Marine Sanctuary (NOAA).

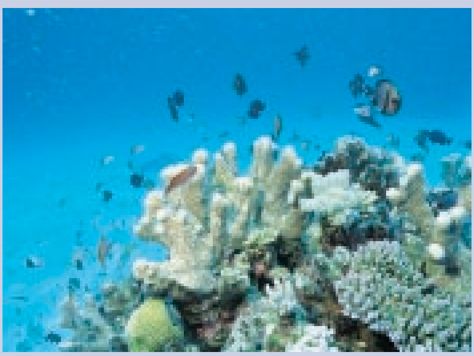
Box 16 Tourist checklist

Positive

- ❑ calm and peaceful country
- ❑ safe streets
- ❑ hotel rooms are safe
- ❑ tap water is clean and safe
- ❑ food is safe to eat
- ❑ no nasty diseases e.g. Malaria
- ❑ no garbage on streets & beaches
- ❑ seawater is clean
- ❑ no garbage floating around
- ❑ corals are healthy, not broken
- ❑ many fishes and some big ones
- ❑ good fresh seafood
- ❑ exotic food and fresh fruit
- ❑ exciting local cultures
- ❑ local artwork and curios
- ❑ chance to learn something new
- ❑ 'ecotourism' experiences
- ❑ good value for money

Negative

- ❑ reports of war or terrorism
- ❑ tourists report burglaries & mugging
- ❑ thefts from hotel rooms
- ❑ stories of sickness
- ❑ dangerous driving in region
- ❑ smells of sewage, open drains
- ❑ dirty beaches, litter on seafloor
- ❑ corals dull, water dirty
- ❑ few fish, scared fish
- ❑ mostly rocks or broken corals
- ❑ no fish to be seen, or only little ones
- ❑ same food as at home
- ❑ no exotic foods or fruits
- ❑ nothing to do at night
- ❑ curios all imported and plastic
- ❑ only television for entertainment
- ❑ hotel and trip expenses too high
- ❑ no education on environment or culture



Tourists like to see views like this
Photo: Steve Parish ©Steve Parish Publishing Pty Ltd.

Who would pay to look at this?

25.2 Steady coral loss from multiple human impacts: the Tiuhura reefs, Moorea

Human pressure and natural events change a reef over 35 years

The Tiuhura reefs are on the north west coast of Moorea, the sister island of Tahiti in French Polynesia (Lat. 17°30′ S, Long. 149°55′ W). The island is volcanic with mountains rising to 1,200 m in the centre and is surrounded by a narrow coastal belt where most of the 10,000 people live. The main economic activity is tourism and most of the hotels, for about 1,000 tourists, are on the northern side.

Fringing coral reefs

The island is surrounded by a lagoon, beyond which is a fringing reef, partly emerging at low tide. A channel 7 m deep separates the fringing reef from the main barrier reef, which extends out about 1 km from the shore. The barrier reef consists of many small patch reefs that join to form a continuous barrier on the outer edge facing the sea.

The Tiuhura reefs are typical of the central Pacific with a low diversity of reef animals, especially corals, because of wide isolation across Pacific. But in spite of having few species, the reef used to have high coral cover and an abundance of fish. The outer slope is still well covered in corals down to a sandy plain at 30 to 40 m depth, before the final slope that goes down thousands of metres. Large waves from the trade winds drive clean oceanic water over the fore reef and into the lagoon. This mixes with water coming from the west in the channel before emptying back into the ocean through the pass, the main break in the reef.

Moorea is one of the best-studied reefs in the Pacific because a French research station has been looking at the reefs for 28 years.

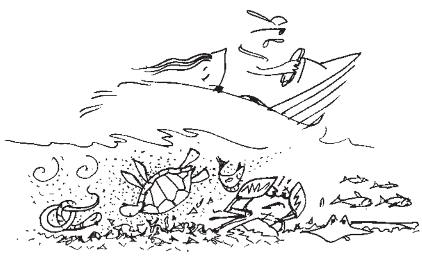
What has happened

The reef has been affected by a combination of natural events and human impacts.

Natural impacts: In the 1970s, the crown-of-thorns starfish damaged the barrier reef, destroying most of the staghorn corals (particularly *Acropora spp*.) and also caused some damage to the dominant massive coral heads (*Porites*). In 1982, and again in 1992, severe cyclones hit French Polynesia. On Tiuhura, the damage was not severe but the storms further damaged the corals that had been attacked by the crown-of -thorns starfish, or were weakened by the increasing levels of pollution. There was also a lot of coral bleaching in the area in 1991 and 1994, with the death of 20% of the living coral each time, particularly *Acropora* in the lagoon and *Pocillopora* on the outer slopes.

Human impacts: There was dredging to collect rock and sand from the reef flats for buildings and roads in the 1970s and in the 1980s. A large channel, 20 m wide and 4 m deep, was dredged along the shoreline to support the tourist industry and to help establish a major resort near the main pass. The tourist industry has grown from virtually zero to over 1,000 beds in the past 30 years. The resident population remains small but many tourists come over from Tahiti for weekends. All this results in low level fishing pressure in the area.

Sewage and wastewater have minimal treatment before being pumped into the lagoon, and they still contain large amounts of nitrogen and phosphate nutrients.



Shell collecting by tourists has removed most of the larger shells on the shallow reef flats. Tourist activities are now mostly focused on snorkeling, SCUBA diving and using jet skis in the shallow water, and SCUBA diving and shark feeding on the outer slope.

Reef condition now

The fringing reef is now bare with only the occasional *Porites* colony. The barrier reef, which used to have high coral cover in the 1960s and early 1970s, in not much better and the inner part is now dominated by sea urchins and large fleshy algae (*Sargassum, Turbinaria*), which virtually cover 100% of the bottom in the eastern areas. There were none there 30 years ago. Sea urchins (*Echinothrix, Diadema and Echinometra*) are common and they are scraping away at the few remaining coral colonies of *Porites, Acropora* and *Pocillopora.*

The outer reef is dominated by calcareous algae, with smaller populations of Turbinaria further down the slope. The only corals that resemble the populations of the 1960s and 1970s are found in the spur and groove formations of the outer slope. And even these have suffered from cyclones and bleaching.

What damaged the reefs

The reefs were not able to recover normally from natural stresses like storms, crown-of-thorns starfish and bleaching, because they were also stressed by sediment and dredging damage, changed water flow patterns and pollution. The combination of human and natural stress has changed them from rich coral reefs to seaweed reefs.

How to improve the reef

Fringing reefs: The water flow conditions and continuous human impacts have changed the fringing reef so much that it is unlikely to grow back the previous coral communities. If all engineering activities are stopped, some coral should grow back on the outer parts of the fringing reef.

Outer barrier reef: If human activities on the outer barrier reef and the slope can be controlled and the pollution from the hotels can be stopped, then the corals will grow back and take over some of the bottom from the large algae and sea urchins. The Turbinaria algae will continue to grow well if they are fertilised by nutrient rich waters from the land, so only sewage treatment that removes nutrients will encourage corals to dominate again.

What the government is doing

Local government recognises that they must control human activities and have declared a protected zone on the reef and banned all dredging. The government is now working on a larger management plan to regulate all activities along the whole northern coast and in the lagoon. An important first step will be to ensure that all sewage coming from the north coast is fully treated to reduce the nutrients that are the major problem. This should eventually extend to all sewage runoff from the island.

From Bernard Salvat of the CRIOBE Station on Moorea.

25.3 Changes on the reefs at San Blas Point: Panama

A Caribbean reef damaged mainly by natural disaster but also by human impacts

The reefs at San Blas Point

This reef system is located immediately to the east of San Blas Point (Lat. 10°5' S, Long. 78°5' E), which is about 100 km east of the Caribbean entrance of the Panama Canal. San Blas Point is at the western end of an area known in Panama as the Comarca de San Blas and called Kuna Yala by the local Kuna people, who govern it as an autonomous region within Panama. This is in the most tropical, southern part of the Caribbean and is one of the few areas outside the hurricane belt.

The San Blas Point reef system, which covers about 15 km^2, consists of several hundred small coral patch reefs set in extensive seagrass beds in a shallow (0.5-15m deep) lagoon. That lagoon is surrounded by emergent fringing reefs on both the seaward (north) and leeward sides. A submarine extension of the fringing reef continues several kilometres out to sea on the seaward side.

On the mainland coast there are well-developed mangrove forests to the west and south of the Point. Several small rivers flow in at the head of a bay that extends about 7 km to the south of the San Blas Point reefs. They discharge occasionally (about 10 times a year) and briefly (less than a day) and cover the entire reef system with dirty water after heavy rains.

The reefs before

In 1970, these patch reefs had abundant cover of *Agaricia* corals, large mounds of *Porites porites* in shallower water and thickets of *Acropora cervicornis* at between 1 and 10 m depth.

The reefs today

Coral populations declined considerably during the 1980s. Five reefs that were measured in 1985 to 1987 had an average of 32% coral cover (already down from the 1970s). By 1992, those reefs only had 8% coral cover. The amount of large fleshy algae (macroalgae) covering the bottom had increased from 32% to 76%. Other studies showed similar declines, with coral cover dropping from 40% to 20% during the 1980's. These changes were part of a general pattern of reef decline along the coast of Panama and elsewhere in the Caribbean. Reefs that are 5-20 km east of San Blas Point, in an area of sandy cays 10-15 km offshore have shown fewer changes than the reefs nearer the land during that same period.

Impacts on the reefs

There have been a many natural and human impacts in the area between 1970 and 1998.

Natural impacts: In early 1983, a disease killed 99% of the black sea urchin (*Diadema antillarum*) on San Blas reefs. In mid 1983, there was severe coral bleaching and many corals died and were replaced by macroalgae. Every summer since then there has been some coral bleaching, with another major event (less destructive than that in 1983) occurring in 1995. The algae have been able to grow unchecked because there are very few grazing sea urchins in many habitats and this has seriously affected coral recruitment, survival and recovery.

There have been large increases in sediment discharge onto inshore reefs in other parts of the Caribbean coast of Panama, due to greatly increased land clearing. This has been one cause for declines in coral cover to those reefs. However, this has not occurred at San Blas, where the human population is still low (about 40,000 people in 1990 along some 220 km of coastline), there has been little land clearing, especially inland from the coast and agriculture is restricted to traditional shifting cultivation of subsistence crops. In addition Kunas actively prevent non-Kunas from clearing land and living in Kuna Yala.

Human impacts: The Kuna population living on six islands along the southern edge of the San Blas Point reef system was about 7,000 at the 1990 census.

Overcrowding in the San Blas Islands

Mangrove forests and seagrass beds have only been lightly disturbed. Some mangroves have been cut for building materials and firewood but there has been no major clearing and little reduction in the overall mangrove area. Sand and mud has been removed manually from some of the shallowest seagrass beds for landfill but this has affected much less than 1% of the seagrass area.

Direct human impacts on the reefs include removal of live and dead coral and seagrass for landfill, and cash and subsistence fishing. These impacts come from the local population, both as a result of their needs and needs that arise from tourism. San Blas Point is the area most heavily used by tourists in Kuna Yala. They include both day trippers from cruise liners that call several times each week throughout most of the year and visitors to several small hotels who arrive by light plane from Panama City.

Household garbage and sewage are dumped into the sea, often directly over the reefs. Sewage is discharged from outhouses at the water's edge of the six inhabited islands. However, water flow is good through the lagoon and reefs and effluent usually is rapidly swept out into deep water. There are few noticeable effects of nutrient enrichment from sewage, except within a few meters off shore from the inhabited islands.

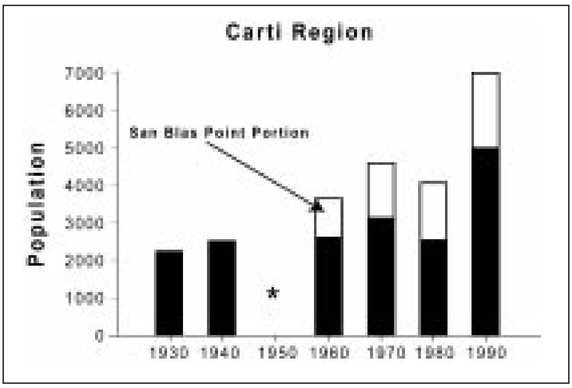


Figure 3 San Blas population growth

The Kuna population doubled between 1960 and 1990 and villages have outgrown the small islands. As a result people have manually taken live corals, coral rock and seagrass sod as land fill. Effects of this are most noticeable in the tops of the shallower areas of reefs within several kilometres of the inhabited islands. Coral populations are now considerably reduced in the shallows (under 2 m deep) near these islands.

Cash fishing occurs for lobsters, conch, octopus, Mithrax crabs, and some groupers and snappers. As a result adult lobster, crabs and conch have become rare, although octopus still seem fairly common and large predatory reef fishes have not been eliminated. There is subsistence fishing for fin-fishes, including both non-reef species (small tunas, mackerels, jacks) and reef species. However, fishing is mainly by line, or by seine (for jacks), and the use of traps, spearguns and gill nets is low. Poisons and explosives have never been used for fishing. Probably due to the abundance of non-reef fishes, fishing on reef fish populations has not yet caused serious declines.

What happened

The most likely reason for the algal takeover of reefs is the loss of the grazing sea urchin Diadema, rather than increased nutrients and sediment. While human impacts on reefs are seen close to the islands and these are adding to the loss of coral, the main impact on corals has arisen through bleaching and indirect effects of the Diadema die-off. Fishing has had relatively modest effects on most species, until the late 1990s.

Most fishing is done by free-diving and Kunas do not permit their own fishers to use SCUBA. Hence species restricted to shallow water, such as conchs, are the only ones that have suffered heavily. Species that commonly extend into deeper habitats effectively have refuges in those habitats that should help maintain their populations.

The chances of recovery

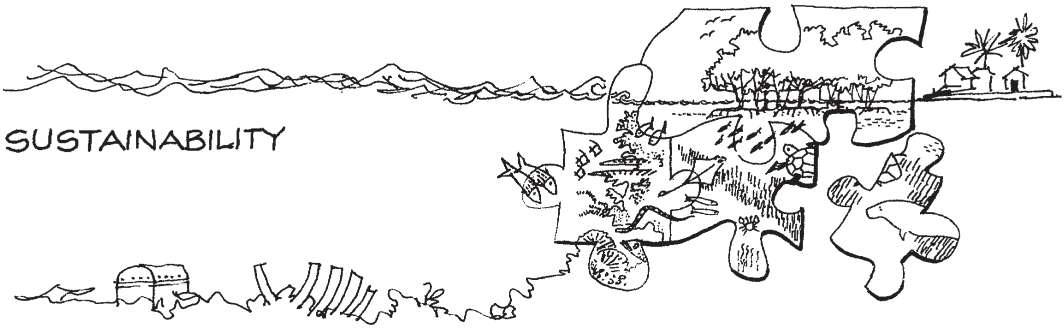
Populations of the sea urchin Diadema have shown little tendency to increase (at least till the late 1990s) and the continued bleaching events, reduces the long-term chances for recovery of the corals and reduction in macroalgae. In addition the local human population is increasing rapidly, as are the numbers of tourists. This will increase coral removal for landfill, increase fishing, and add more sewage and garbage. While human impacts have been relatively modest to date, they are bound to increase. The chances for recovery of the rich coral growth of the 1970s seem poor.

A closed season for lobster fishing exists (during the period when strong trade winds make such fishing difficult) but is largely ignored. Unlike the situation with land tenure there is no system of individual or family ownership of reef areas or their resources. This will make control of future overfishing difficult.

From Ross Robertson, Smithsonian Tropical Research Institute (STRI), Panama.

E SUSTAINING COASTAL RESOURCES

CONTENTS



E26 Education and training

26.1 The need for training

Management of coastal resources can only succeed if the local people are well informed and agree. There is a need to educate and train local communities in self-management, particularly to understand the benefits of good management as well as the consequences of no action.

Most communities know that their resources are steadily being depleted but often they do not understand the reasons. Governments usually do not have the resources to enforce regulations effectively, therefore education and awareness raising of all stakeholders is the best mechanism to have self-enforcement of management rules. An essential component of education is actual participation; that means visiting the area and assessing and monitoring status and trends.

26.2 Who to educate

Education in schools

The best means to get good management of coral reefs and other systems is through education at all levels. The future users and leaders can be informed in primary, secondary and tertiary schools about the principles of ecosystems, good management and threats to systems.

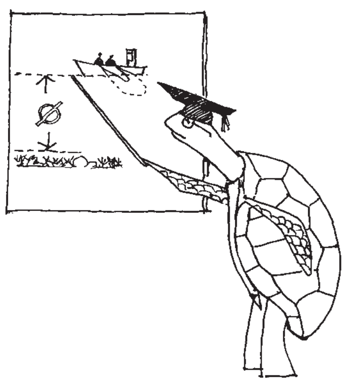
But this education needs good teaching resources, particularly teaching guides that include examples from the region. Courses should include field trips to nearby habitats so students can see the problems for themselves and conduct projects about ecosystem health.

The management team can assist schools prepare these materials and provide people to give talks to schools. Resource managers, scientists and NGOs can convert scientific knowledge into plain language texts and translations into local languages for schools and colleges.

Educating the public

All people involved with the resources (stakeholders) need to be identified (see C17 Integrated Coastal Management for Sustainable Use, p.84). These include community and religious leaders, village cooperatives and groups (such as women's associations), fishermen, tourist operators and local government officials.

The best management teachers for local communities are often other villagers who have successfully managed their areas. These people are trusted more than government officials and scientists and also talk the same language. This may mean bringing in people from successful projects elsewhere to talk to local people in their own language.



Many communities do not use all possible resources from a reef. The barriers are either cultural or a lack of awareness. Thus it may be possible to reduce harvesting pressures on some threatened resources by helping communities use other resources. It may be useful to ask outside communities who use different resources to educate on the use of new resources e.g. different invertebrates such as molluscs, squid, sea cucumbers, sea urchins, or making different cultural and curio objects (see Box 17 More food from the reef, p.156).

All education material must be prepared to fit the normal methods of communication in the community. All possible means have to be considered: direct talking to community groups; videos; radio; maps and posters; as well as written papers and pamphlets; and involving religious leaders. The management team should get the messages into the local media - newspapers, radio and television.

Material should be prepared in the language of the community. Simple words should be used so that people understand the message. For example, the scientific names of fish are not understood by local people because they use local names (and these can vary within a country). Words and concepts, like sustainable development, biodiversity and endangered species are rarely understood by the public. Therefore, these need to be interpreted for the public and decision-makers. For example: "sustainable use means that you and your children will be able to catch enough fish to feed your family every year if you manage the area wisely".

Educating government officials

Often senior decision-makers have little background knowledge on coastal resources. Therefore, resource managers can provide short briefings on important topics, preferably well before the decision making time. The staff who assist senior decision-makers are often happy to get short courses or part-time training so that they understand how ecosystems function and what are the stresses. They are then able to give better advice to their bosses.

26.3 Specific training

Training in communication

A big problem identified in many countries is that scientists and resources managers do not know how to communicate well with the media and public. Often good mechanisms of educating and informing the public are not used. Most local media outlets seek ‘good news' stories such as finding new species, interesting symbioses, as well as articles on the importance of ecosystems and how they function. Journalists often look for stories but find that scientists are unwilling to communicate or they use complex scientific jargon.

Therefore, there is a need to train scientists and managers in communication skills and the local media people are usually willing to help with such training.

Training in coastal management

Most countries don't have enough trained people to plan and manage existing Marine Protected Areas or new ones being considered. Often there are 1 or 2 top universities or colleges, so there is a need to spread the expertise to smaller teaching institutes. Providing better teaching materials (e.g. books and videos based on local examples) can help this. Also, developed countries and agencies providing aid funds can help with university post-graduate scholarships based on environmental problems or examples from the region.

Message:	*Education and participation are the keys to success for Integrated Coastal Management. With good broad education, you can reach out into the community and have a chance that they will help you manage the resources sustainably. Without education, there is little chance of success. Make sure that education is high on the list of tasks for your office.*

Box 17 More food from the reef?

Many communities do not take all the food that is possible from coral reefs. Instead they obtain only the particular species of fish and invertebrates that they have traditionally used. Often there are other food species that they could use but do not, because they do not have the special techniques or traditions. These unused kinds of foods may not be seen as important in their society.

Learning from others can help a community use more reef foods, and cook them in new ways to make them more acceptable.

For example, many tons of invertebrates can be taken sustainably from a reef. Some Philippine communities take the about equal amounts of edible invertebrate food and fish from the same reefs. It is estimated that some reefs can support an annual harvest of 15 tonnes year of invertebrate food per square kilometre. But in other parts of the Philippines, many of these invertebrate species are not used, because the communities do not know the fishing methods.

Social traditions determine the preferred foods and fishing techniques. But both traditions and techniques can change over time. Often a new technique has been learnt in one community, and then knowledge of its success has been transferred to other islands.

Although there is a limit to the sustainable yield from a coral reef, there are always lessons that one community can learn from another on how to use reefs better. A reef manager can use modern methods, like videos and workshops, to help educate communities in new methods. Another valuable method is to ask successful men and women to teach new skills to other groups, because they will often believe them more than scientists or reef managers.

Message: *It is essential to understand how communities use coral reefs to assist them in managing those resources. Lessons learnt in one community may be useful in another.*

From John McManus, Director, National Centre for Atlantic and Caribbean Reef Research, RSMAS, University of Florida.

E27 Monitoring

Simple and accurate methods for monitoring in shallow tropical waters

27.1 Why monitor?

We can measure resources by surveying, that is gathering data or information about resources in the ecosystem once and we may count or measure many things. A survey can give data and information on the status or health of a system (e.g. diseased or healthy corals or mangroves) and the resources being used (e.g. fish, shells, timber).

With monitoring we seek information about change over years, so the surveys, or parts of them, are repeated using the same or similar methods. Monitoring should be repeated for several years at least to be useful, because some things can change naturally between seasons or years (like the growth of large algae). It is essential to monitor only those important parts of the system that are needed for resource management (e.g. commercial fish species, or percent cover of coral on the bottom), otherwise monitoring takes too long and is too expensive. Monitoring will tell of changes or trends that happen in the system as indications of over-use or damage, or whether the system being managed is improving.

For example:

A Marine Protected Area (MPA) set up by government on a degraded coral reef may include a zone totally protected from fishing. The objective is to allow more fish to reach breeding size and increase recruitment of young fish into the areas near the MPA. Managers, fishermen and the public will want to know whether the MPA results in larger, or more breeding fish and increased catches in the area to compensate for the lost fishing in the protected area. Simple monitoring will help answer these questions.

Fish that are targets for fishermen can be counted and their size estimated using a visual method (see below) before the MPA is established and counted again one year later, and every year after that. This will show whether the size and/or number of target fish species is increasing. These results should be communicated to the fishermen; better still the fishermen should be involved in the monitoring.

One or more measures should be monitored for each management objective in the MPA to see whether the management regulations are working. Regulations are set up to solve problems and monitoring is used to see if the regulations are working.

Monitoring can also measure whether a system is recovering from damage e.g. a reef damaged by a tropical storm, sediment, or an oil spill. If the corals are not recovering, there may be other stresses to remove before the corals will come back.

Monitoring is also used to anticipate change. If something is being planned that may have an impact, like logging in the catchment, or development of an industry, or dredging of the harbour, or an increase in divers or fishing pressure, monitoring should be done before and after the activity. This will show the real impact, rather than what either the developers or conservationists claim.

Remember

There are changes in all natural ecosystems. Therefore, monitoring may be needed for a long time to show improvement due to management decisions, because of natural variations e.g. changes in annual fish recruitment. Stressed systems may show little change for a long time, therefore management must be continued for some years to show improvements. Also remember that there are often several impacts at one time. A system being stressed by sediment or pollution may show few changes but may collapse and not recover if there is further pressure e.g. a tropical storm or a freshwater flood.

Coral reefs, mangrove forests and seagrass beds can all be monitored in various ways but one of the best ways is to monitor resources that are harvested and collected, because these are the things of most importance to local communities.

Monitoring made easy - self monitoring by users

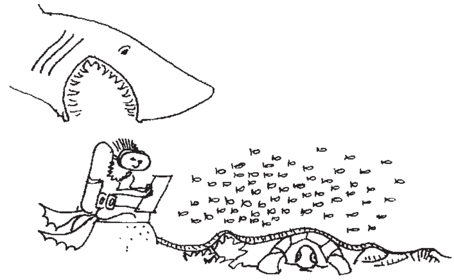
Monitoring can be complex or simple. Most changes can be monitored easily by the people using the resources. Self-monitoring by the people who consider they own the resource is often the best. The users can monitor resources to show change, e.g. loss of large fish, changes in % coral cover, reduced recruitment of corals, reduced area of seagrass beds, or dying tips on mangrove branches. More complex methods may then be needed to confirm the early warning signals provided by the users.

27.2 Monitoring fish populations

Market assessment

A good method to measure fish populations is to study the catches over time. This can be done in the local markets (if they exist) where most fish are sold. It is relatively easy to count and measure important species and record the prices paid for them. Fishermen can keep simple records of catches: how far they travel; how long it takes to catch a basket of fish; when they catch particular species. This basic monitoring can show whether there is a reduction or increase in common species, or the fishes are smaller or larger, or fishing effort is increasing.

Visual fish counts on coral reefs



An excellent and inexpensive way to monitor the fishes is to have a diver carefully count fishes over three 50m lengths or transects of reef. The lengths measured are best done with water resistant (fibreglass) measuring tapes on a wind-up reel. In water that is not so clear (e.g. such as in mangroves or seagrass areas) visual methods do not work and it is better to use nets for assessing the amount of fish present.

Sets of counts should be done in the major areas of a reef: shallow and deep areas of the fore reef facing the prevailing winds; and on the back reef. If the MPA is large, monitoring should be done on many reefs. At each place, use 3 transects separated by about 100 m. Each transect is 50 m long and laid on the coral. We suggest that you mark the start of the transect the first time by hammering in a steel stake (steel fence post, or 1 m length of reinforcing bar). A second stake at the end will make it easier to monitor that same site again. This ensures that you are measuring similar areas in successive counts. After marking the transect leave the area for 20 minutes or more before counting to allow the fish population to get back to normal.

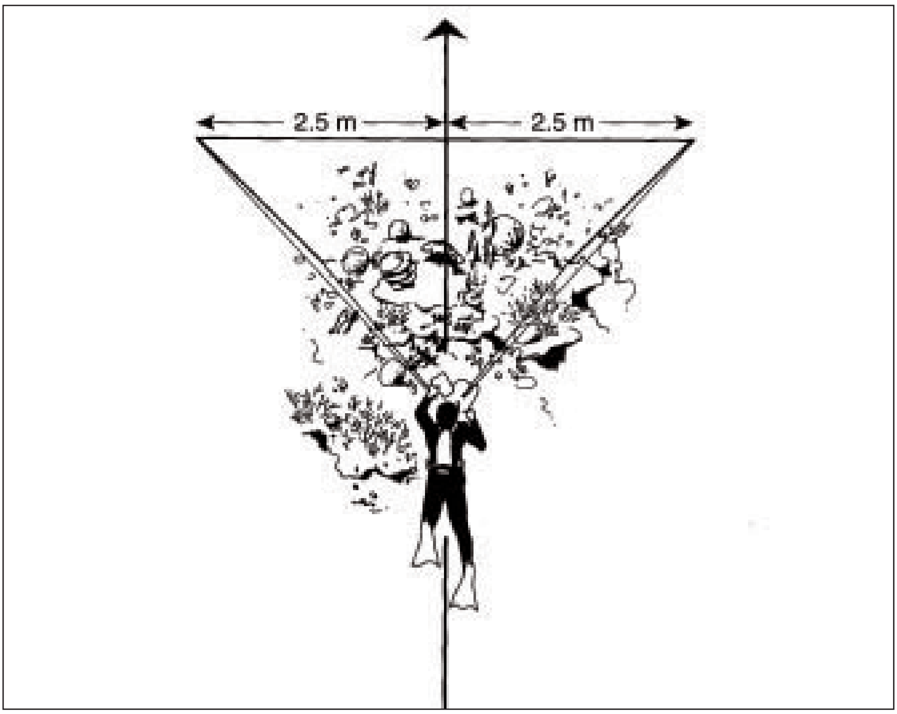


Figure 4 Counting fish with transects

The diver then swims slowly along the line counting the fish in a 5 m band (2.5 m each side of the line) and records the fishes on a sheet which has all the names of common fishes. Make sure that the list includes fishes that are the preferred targets of fishermen, such as groupers, snappers, sweetlips, emperors and surgeonfishes.

This monitoring will show whether the fishery is changing. Butterfly fishes, angelfishes and other easily identifiable small reef fishes are easy to recognise and will show if there are structural changes in the corals. Divers need testing to see how well they measure the 5m strip by eye, practice and comparison with counts by other divers to improve accuracy.

Using a beam trawl net for monitoring fish in seagrass beds

Seagrass meadows are important places for juvenile fish and prawns to shelter, feed and grow. Fish and prawns are most easily collected in a small beam trawl, towed by a boat. The best is 1-2 m across (1.5 m is a good size) and can have different mesh sizes for different purposes (3-10 mm for prawns and juvenile fish; 10-20 mm for adult fish).

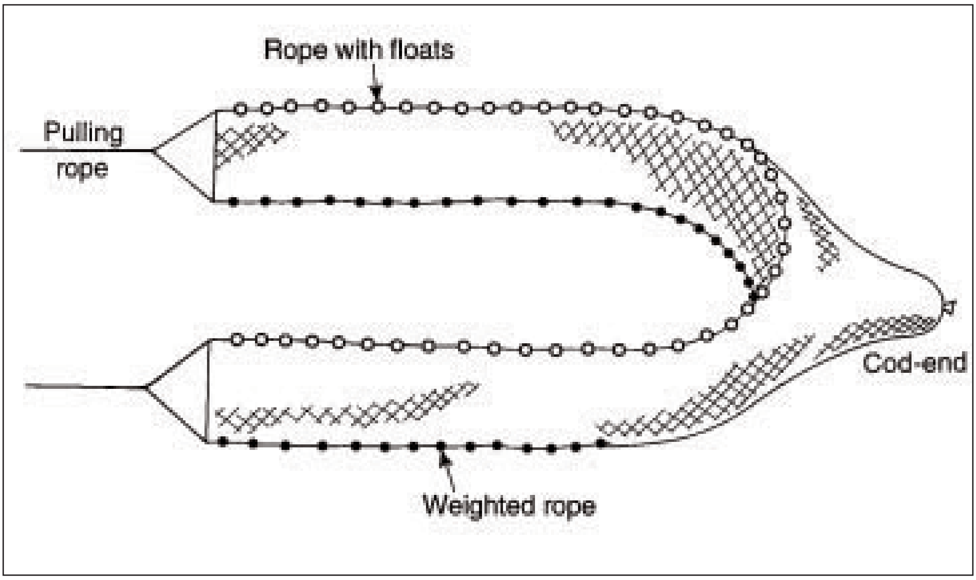


Figure 5 Small seine net

The trawl can be pulled behind an outboard powered boat of moderate horsepower (or larger fishing boat), for a fixed distance (or for a fixed time if the same power is used and wind speeds do not change much). Three or more trawls, separated by 50-100 m, should be made at each monitoring site. It is very important to trawl both night and day, and at different times of year e.g. every 1 to 3 months, because fish and prawns change their movements between day and night, and migrate or breed at different times of the year.

Net fishing in mangrove forests

Two methods are recommended: gill nets for all mangrove areas; and encircling nets for intertidal areas in mangrove forests. Encircling nets can be carefully laid around a mangrove area at high tide and fish, prawns and crabs can be collected when the tide goes out. It is best to encircle a larger area of mangroves with a net preferably longer than 600 m to prevent all the larger fish from being scared away. Lay the net very quietly, so it is better to hammer in the holding stakes for the net at an earlier low tide. Using a fine net, the recommended mesh being 10-20 mm (English et al. 1997). Several replicate samples should be taken at both day and night. The encircling net should be laid during both day and night high tides, with dark nights being better than moonlit nights.

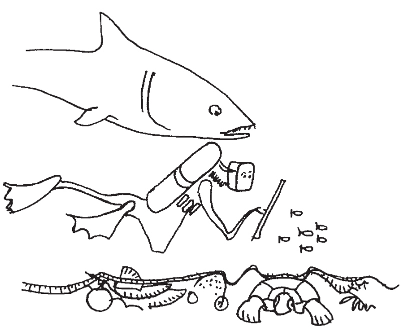
Gill nets of different mesh sizes are good for monitoring fish other than small juveniles. These can be set in mangrove creeks, across main mangrove channels, or in mangrove forests to catch fish moving during the high tide. At least 3 or more samples should be taken from each site.

27.3 Monitoring corals

Coral cover measure, using the line transect method

Measuring the amount of coral on the bottom is a very common measure of the coral reef health. Coral may be lost after pollution by sewage, or sediment, or by destructive fishing methods (muro ami, dynamite, or cyanide). Also coral cover may decrease if there is overfishing, particularly if the grazing fishes are removed in traps or nets because corals can be overgrown by large algae (see case studies 18.1, p.95 and 18.2, p.99). Loss of coral usually means a loss of fish and shellfish production, and unattractive reefs for tourists.

The line transect (line intercept transect) method is simple, needs no complex equipment and can give a good measure of % coral cover. Lay 5 lines at both shallow and deep areas of the fore-reef, each 20 m long, roughly parallel to the reef crest. It is best to measure corals and fish on the same transect, so the first 20 m of each fish transect is used, and 2 other 20 m transects are used along the 50 m fish transects.



SCUBA divers swim along the line and measure the length of line covering different corals, algae, dead coral, rubble, sand, etc. This can give a percentage measure of coral and algae in the area. Broad categories of coral are used because it is often difficult to identify coral species.

Measuring of the same transects should be repeated every 1 or 2 years, so steel (concrete reinforcing steel is fine) stakes should be used to mark the transects. Two similar methods are recommended depending on the expertise of the person doing the monitoring: the Reef Check methods[6] are more basic and for use by less trained people; the GCRMN methods[7] need more training and provide more detail.

Manta tows

These are used to study large reef areas to get the 'big picture'. Other methods give much greater detail for smaller areas but manta tows give an estimate of the health of the whole reef. They are also useful for estimating coral cover (see figure 6 below) and counting crown-of-thorns starfish numbers, or other large organisms like giant clams. It is also possible to record damage from anchors, dynamite blasts and the amount of bleaching or disease.

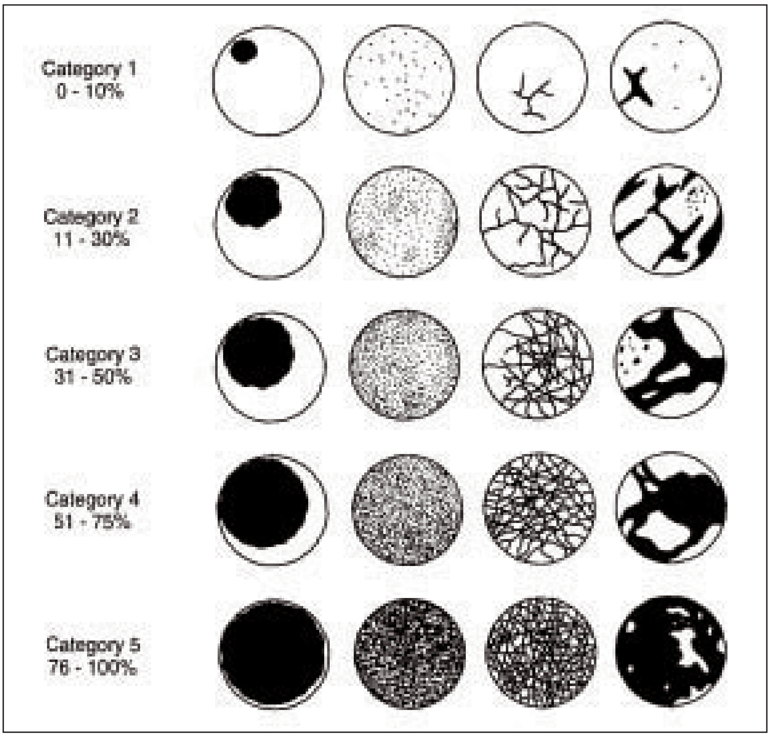


Figure 6 Schematic representations for percent cover can be used to estimate quantities, relative health or damage

[6] Reef Check methods in www.ReefCheck.org
[7] GCRMN methods in English et al. 1997

The materials needed include a small outboard powered boat, a 17 m tow line and a flat manta board to hang on to and to attach writing paper or slates (see figure 7 below). It is best to use SCUBA but monitoring can be done with a snorkel if the water is clear. A trained pair of divers alternate between being towed and driving the boat.

The recommended method is a series of 15 two-minute tows. After 2 minutes of towing, the boat is stopped and the observer writes up the data. After 15 tows the diver and driver exchange and repeat the process until all the reef has been surveyed. Visibility should be not less than 6 m.

Careful training and annual re-training of the divers in the use of all methods is necessary to make sure that the results are consistent, and change is not due to differences between the divers.

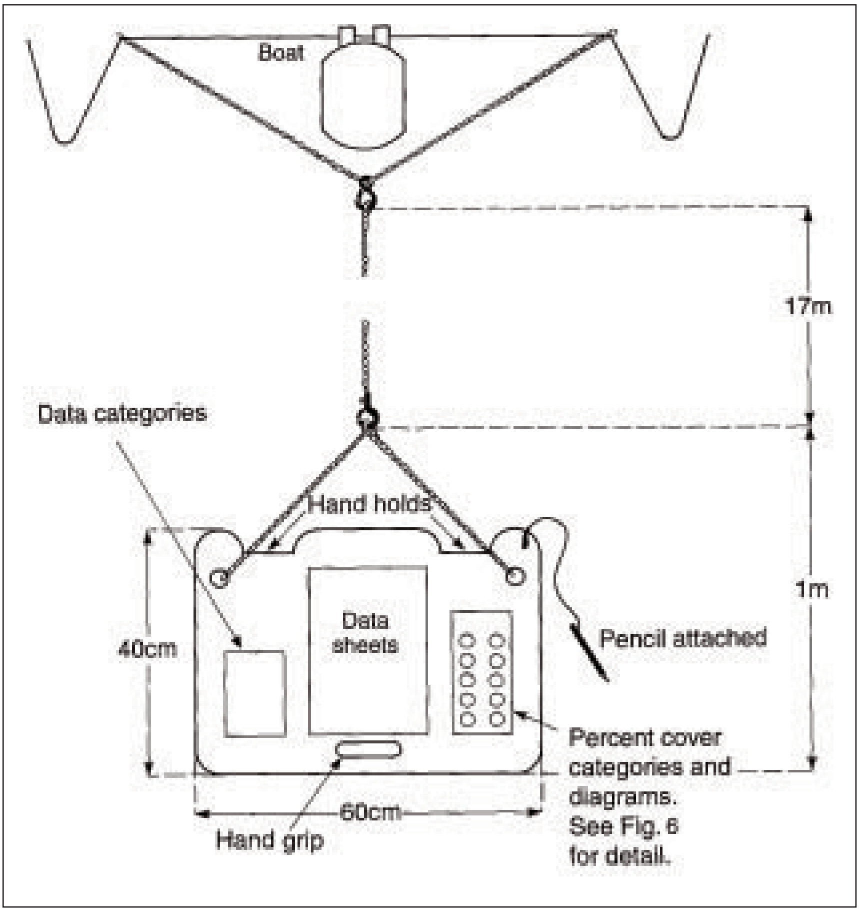


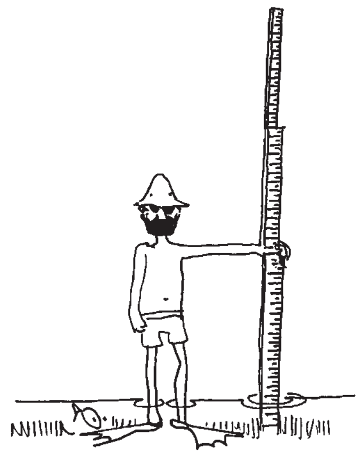
Figure 7 Manta tow board and associated equipment

Estimating coral diseases

While coral cover is an indication of coral health, many coral diseases have been described and the number and amount is a good indication of coral health. Diseased corals often develop large dead patches and may have black, white or yellow bands at the edge of the dying coral and sometimes yellow blotches. These can either be measured using the AGRRA-RAP methods along 10 m belt transects.

Usually about 10 transects are laid at least 1 m apart and coral cover is measured under the line and the amount of coral disease and dead coral is estimated in five 25cm x 25cm quadrats placed every 2 m along the line. Corals are checked whether they healthy, diseased or bleached and the transects usually take about 3-4 hours to do 50 quadrats and belt assessments. To learn about AGRRA-RAP transects see the website: HTTP://coral.aoml.noaa.gov/agra/rap-revised.html.

27.4 Monitoring seagrass beds



Seagrass beds are highly productive for fisheries by providing food and shelter for grazing fish and a place to grow for algae and invertebrates that the fish feed on. Seagrasses are 'nursery' grounds for juveniles of commercial prawns and fishes. Monitoring the amount of the seagrasses gives important information for fisheries but seagrass beds are naturally variable and some have annual periods of dieback. This should be considered and monitoring should be repeated at different times of the year.

Manta towing is rarely possible in seagrass beds as the visibility is too low. Three methods can be used: first is measuring the weight of living material or biomass by removing samples of it. As this is destructive, it should only be done in large seagrass beds. Second is a method to visually estimate the weight of the seagrass (biomass) by trained divers. Both methods need training and laboratory work. Details can be found in the Survey Manual for Tropical Marine Resources[8] .

A simpler method is to monitor the seagrass area from year to year to see whether they are declining or enlarging. This can be done using natural landmarks and marking the outlines of the seagrass beds on a map at a very low tide. Even better is using aerial photography on a sunny day at low tide, when shallow water seagrass beds are obvious. Doing this annually at the same time of year will give a good idea of change in seagrass beds. Aerial photography will give a good indication of what is happening and what are the causes.

[8] English, et al (1997); and in Mellors, J.E. (1991), An evaluation of a rapid visual techniquefor estimating seagrass biomass, Aquatic Botany 42: 67-73.

27.5 Monitoring mangrove forests

Monitoring dead and damaged trees

The main way that mangrove forests are damaged is by chopping down the trees for building timber, charcoal, firewood, scaffolding, fish traps, tannin production, and to build fish and prawn farms or for salt making. The area covered by mangroves may change and this can be monitored by land surveying or by aerial photography.

Often damage to trees in a mangrove forest is obvious, however, when mangroves are stressed either as a result of natural factors (elevated salinity) or as a result of human activities such as pollution, the signs may be less obvious. Use the list in Box 18 below to recognise a stressed mangrove forest from a healthy one.

Make careful examinations over time of these characters to show a whether a mangrove is recovering or being further damaged.

Box 18 RECOGNISING STRESS IN MANGROVES

Mangrove forests may show stress in the following ways:

- ❑ There may be large or small areas where trees have been removed.
- ❑ Trees may have branches cut off.
- ❑ Branches and trunks may have bark with cracks or crevices.
- ❑ The uppermost branches in the sun may be dying at their tips.
- ❑ Leaves may be fewer, smaller, show twisting and curling, and have dead parts or spotting; the distance between leaf pairs on shoots may be very much shorter than in a healthy tree.
- ❑ There may be no flowers.
- ❑ Fruits may fall off before they have matured.
- ❑ The seeds may be deformed – have abnormal growth.
- ❑ Established seedlings may begin to grow abnormally.
- ❑ Seedlings may die.
- ❑ The small upright aerial roots (pneumatophores) coming up from the mud may be branched, twisted or curled, and aerial roots may develop on the tree's trunk.
- ❑ Young trees may grow at an angle.

From Sam Snedaker and Peter Saenger.

Counting the number and size of trees

This is an accurate method but is takes time and experience or training. Trees are counted and their diameter measured at chest height in a series of plots (quadrats) along a transect. A transect line should run (if possible) from the seaward edge of the mangrove forest back to its inland edge and run through typical mangroves of the area. Two or three transects must be made in each area monitored. In each major mangrove type along the transect line, mark out 3 replicate plots, 10 m x 10 m or plots that are large enough to have at least 40-100 trees in them. The plots should be permanently marked with stakes driven well into the ground.

Each tree larger than 4 cm circumference should be identified, measured around at chest height and its position plotted (see English et al. 1997), or it should be marked with a permanent tag so it can be identified again. All seedlings should be counted. Where there is more than one large trunk at chest height, all should be separately counted and measured. It is recommended to hammer a nail half into the stem 10 cm below the measuring point, to get the same spot for the next measure.

Finally

In all measures, it is essential that the data collected must be recorded and stored in a safe place for future years. When entering the data into a computer, each measure should be checked by a second person because many errors can be introduced here which will ruin careful field work. Data should be entered into database packages that allow for easy statistical analysis. These points are outlined in the back of English et al. 1997.

Segment 27.5 from Peter Saenger, Director, Centre for Coastal Management, Southern Cross University.

E28 The law and coastal resource management

The law plays a vital role in the management of coastal resources. While it is not possible to use legal mechanisms to solve all problems of damage or conflicts in the use of resources, the law and legal regulations are an important part of the process[9] . Plans to conserve and manage coastal resources must be compatible with laws at all levels of government – local, state or province, and national. In addition, many plans may also need to consider international or regional laws, treaties and conventions. Remember that you may be able to use regional or international laws to support plans for coastal conservation e.g. Ramsar Convention on Biological Diversity.

Resource managers should examine the laws to determine which levels of government have control and power over the resources or areas they are trying to manage and which acts and regulations of parliament govern the resources. Often there will be several laws for the same resources. National laws are normally the most important but international laws and conventions that a country has signed may provide important support for protection or management of natural resources.

28.1 *National laws*

In most countries, national laws will over-rule state or province, and local laws. Therefore managers should understand the laws of the country that control the use and protection of coastal areas and resources. The definition of coastal boundaries is an important example:

- does national control start at high or low tide, mean or spring tides?
- does the national responsibility start at the 3 or 12 mile limit?
- what will be the impacts of the 200 mile Exclusive Economic Zone?
- where does state or local control start?

Managers need to determine which government departments are involved in, and have control over, the coastal zone. These departments may have many laws that have some control over coastal resources, even though they do not mention them in the title, e.g. a Transport Department may have the power to build an airport or a shipping port anywhere that is regarded as being in the national interest. This may be through an important resource, such as a mangrove forest or a coral reef.

[9] For more information refer:
Coral Reef Management Handbook 2nd Edition, UNESCO, pp47-51; and *The Law of the Sea: Priorities and Responsibilities in Implementing the Convention*, IUCN.

Managers with a good understanding of the laws affecting their resources will find that their work is easier. They can also make suggestions how the law can be changed to improve the management of renewable natural resources and the sustainability of those resources.

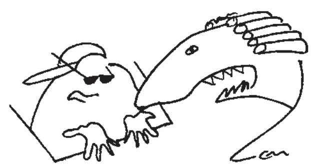
Overlapping or conflicting law

Usually one or more government departments (national, state and local), as well as traditional owners (with local traditions and laws) are legally involved in the resource being managed. Rather than having conflicts over the resource, such situations demand collaboration. Management or advisory groups or committees may be necessary to slowly work out the right way to manage the resources and sort out different laws.

It is common for different agencies of the same government to have conflicting needs. Environment and National Parks agencies try to protect the environment and endangered species. Forestry, Agriculture and Fisheries departments try to get the most money and the most jobs out of the resources.

Agriculture and Fisheries departments are now trying to reduce impacts, so that the activities are sustainable. Farming methods are being improved to reduce sediment runoff. Fisheries and the health of coral reefs, mangroves and seagrass beds are interlinked. Overfishing can damage coral reefs. Loss of seagrass beds and mangrove forests certainly reduces fisheries. Consultation between Forestry and Conservation agencies can advise on forestry methods that will reduce the amount of erosion and sediment in rivers that flows into estuaries or onto coral reefs.

Conflicts can be avoided so that resource management achieves the goal of sustainable resource use. Conflict between different agencies is often the largest problem for a resource manager and the reason why some management plans fail (see C17 Integrated Coastal Management for Sustainable Use, p.84).



Tourism departments have a strong interest in an undamaged environment, with the income derived from tourism often being greater than fisheries or forestry. In most countries, tourism is the fastest growing industry.

Water and Irrigation departments can also have major effects on shallow water coastal ecosystems. Their laws often impact on estuaries and the coast, and their catchment laws and regulations, and possible ‘environmental flows’ (where water is deliberately released to help fisheries), need consideration. Industry departments have laws affecting industrial pollution and sewage release, which are important to the coastal manager.

Other important departments include Mining and Energy departments; Shipping and Transport; Harbours and Ports; Defence (particularly the Navy); Health and Welfare (seeking clean inshore waters and no toxic algal blooms); and often the Prime Minister's or President's Department may play a coordinating role. Whenever possible, it is advisable to work through department of the Prime Minister or President. Another important department, is the one that deals with the rights of indigenous people.

Conflicts between different levels of government

National laws apply to the whole country but laws made by local governments may be more effective at controlling activities that damage coastal resources or protect MPAs. Local laws may be established more easily for a management area or system and help the manager determine the boundaries and define who has the authority to control the area or resource. A wise national government will recognise the value of local laws and encourage local government control over resources. However, many national governments do not respect local government and are worried about losing power to them.

It should be remembered that whatever the strength of the legal system, there will always be conflicts. No legal system is perfect and the strongest laws can be overturned. Protection for a manager's policies lies in good public relations, strong public support and support from the majority of stakeholders.

28.2 *International laws and conventions*

Most international laws and conventions come from United Nations agencies. Others may be regional (between one or more countries). Governments may sign such agreements and ratify them but, unless they place them into their own laws, they are not binding. They are nevertheless important forces in helping to keep ecosystems healthy and their use sustainable. The international agencies often disseminate good information and ratification indicates the intention of governments, which gives a lever to resource managers, NGOs and the public. The following could affect the manager:

- ***United Nations Convention on the Law of the Sea (UNCLOS)***: This was agreed to in 1982 and defines marine boundaries (e.g. a country may control the fisheries to 200 nautical miles offshore). The International Tribunal for the Law of the Sea decides on disputes between governments over boundaries.

- ***The United Nations Conference on Environment and Development (UNCED)***: This major international conference in Rio de Janeiro in 1992 passed a resolution on protecting the environment called Agenda 21. Chapter 17 of this document dealt specifically with the marine environment. Many governments agreed to Agenda 21.

- ***World Heritage Convention***: The Convention for the Protection of the World Cultural and Natural Heritage in 1972 was designed to protect both cultural heritage (like the temples of Borobodur, Indonesia) and specific natural sites of outstanding world value (e.g. the Belize Barrier Reefs, the Great Barrier Reef). This is the highest international protection of a marine site and is only used for sites of great natural value, and only with the full approval of the national government.

- ***The International Convention of the Prevention of Pollution from Ships (MARPOL)***: The MARPOL convention deals with the release of ballast water and the dumping of pollutants. This convention gives governments the power to fine owners of ships that release pollutants, usually oil, into territorial waters. Using special chemical analysis techniques, the source of oil can often be traced back to a particular ship.

- ***International Convention on Wetlands (Ramsar)***: This convention was held in Ramsar, Iran, in 1971 and is commonly known as the Ramsar Convention. Over 100 countries have signed this convention, which is to encourage the wise use (defined as sustainable use) of wetlands which includes coral reefs, mangroves and seagrass areas. Many coastal wetlands act as either breeding or feeding grounds for migratory birds.

- ***The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)***: This was prepared in 1973 and has been updated several times since then. Countries who signed this convention agree to prevent trade in rare and endangered species and their products. Coral reef products like corals, giant clams, other shells and turtles are on the CITES list.

- ***The Convention on Biological Diversity***: This convention encourages the integration of biological diversity conservation with sectoral activities such as fisheries and other natural resource use. It aims to protect large resources of biodiversity and coral reefs are a particular target.

- ***Small Island Developing States (SIDS)***: This grouping calls for the planning and sustainable development of these states, that are in some cases very small and in need of support. Many of these are coral reef atolls or islands with few resources other than coral reefs and mangrove forests.

There are others that relate to climate change issues: United Nations Framework Convention on Climate Change (1992) and the two that deal with the ozone hole: the Vienna Convention for the Protection of the Ozone Layer (1985) and the Montreal Protocol on Substances that Deplete the Ozone Layer (1987). Another important Convention was that for Sustainable Development that was formed after the Rio meeting in 1992 – CSD operates directly though the UN General Assembly and links all agencies involved in resource management and conservation. All these impact on marine resources but are outside the immediate interest of the local resource manager.

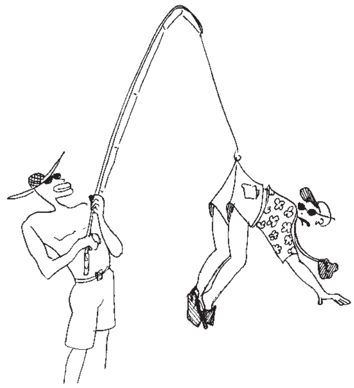
Agreements with adjacent countries

There may also be regional arrangements (e.g. as in the ASEAN countries, central American states), or agreements with a single neighbouring country and these could affect the manager. You should look these up for your region.

Message:	*Resource managers should establish contact with people and departments with expertise in the law. These people can assist managers in preparing their case for conservation of resources which can include the legal language that governments use.*

E29 The potential of tourism

29.1 *Fishing for tourists*



Many countries in the tropics have found that developing the tourism potential of selected coastal areas can generate rapid income growth, with benefits that flow right through the community. It is a service industry that capitalises on an area's natural resources, without depleting them. Properly managed, it can be an infinitely renewable resource.

With so much scope to earn foreign exchange, the tourism industry is appealing to many countries. This means they are competing to attract international tourists. To win in this market, it is important to avoid getting a bad reputation. Tourists who have a bad experience talk about it and news travels fast. But if they enjoy their holiday, they may well come back. Popular resorts earn more money for the whole community.

29.2 *What does the international tourist want*

Tourists are little different from the rest of us. Many of the things that they want in order to enjoy their holidays are the same things we all wish for in our day to day lives. What is different is the priority they attach to some of these things. Plus the fact that, if conditions are not to their liking, they have the option to go somewhere else, taking their money with them.

Safety and security

The first thing the tourists asks - is it safe to walk at night without getting beaten or robbed? Are there wars or terrorists? Tourists want hotels that are safe from thieves. These are mostly beyond the control of the environmental manager but there are ways that they can assist.

Action: Encourage good street lighting and pressure the police to keep thieves away. Tourist operators should make resorts safe with good staff, security guards and building security.

A clean and healthy area

The next worry is health - diseases and accidents. The environmental manager can help make drinking water safe, which also makes it easier to ensure safe food. Malaria and other diseases are hard to control, even if rooms are air conditioned or screened. Tourists may need education on dangers (e.g. opening windows in air-conditioned rooms, need to take malaria pills).

Action: Assist in removing mosquito breeding sites, clean up rubbish dumps and bury garbage. Educate guests and staff of risks in the area.

Clean beaches and streets

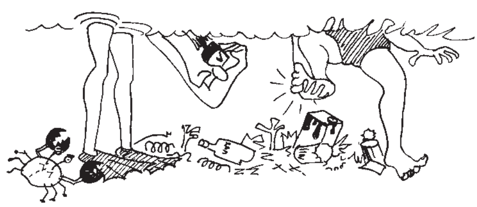
Tourists do not like rubbish on streets and beaches, smells from open drains and poorly maintained sewage systems.

Action: Inform local government of the need for clean streets and beaches. Educate the local population that rubbish will keep tourists away and provide rubbish bins and empty them regularly. Train staff to clean up the general area and the beach.

Clean clear seawater

Tourists expect the bright blue waters advertised in the brochures - not warning signs that the waters are unsafe for swimming. They want to see corals and fish, not plastic bags, bottles and cans.

Action: Regulate the sediment runoff into the streams and sea. Ensure that all developments have sewage treatment systems that are regularly maintained. Pay dive staff to clean rubbish off dive sites.



Unhappy tourists take their money home

Beautiful coral reefs

Clean, healthy coral reefs bring money from tourists for the community; sick reefs and dead corals keep tourists away. Smashed and broken corals can be prevented by good management.

Action: Control flow of pollution and sediment from land. Educate local fishermen to protect coral reefs and teach tourists to dive carefully and not stand on corals, or collect corals and shells. Install permanent mooring buoys at the best sites to prevent anchor damage.

Large fish populations

Tourists expect to see many fish and big ones. But high fishing pressures remove fish around many dive sites in tropical countries. The problem for management is how to keep fish populations in areas, where people traditionally obtain food from the sea. Large fish populations are very valuable in attracting tourists, so this requires both education of the local population and provision of money incentives.

Action: Establish Marine Protected Areas (MPAs) with fishing reserves around tourist resorts and favourite dive sites. Educate locals to control destructive fishing and employ fishermen as tourist guides and dive monitors.

Happy tourists spend their money

Exotic and fresh seafood

Local seafood can be assured through sustainable mariculture of prawns and cage culture of fish.

Action: Encourage sustainable local mariculture and assist in finding markets and good storage facilities for produce.

Educational experiences and cultures

Tourists want to learn about local cultures and environments like coral reefs. The fastest growing market is 'ecotourism', with SCUBA diving being the fastest increasing tourist recreation activity.

Action: Provide educational materials on basic marine ecology and need for conservation. Employ local scientists and encourage local universities to include ecotourism in courses. Train dive guides. Encourage employment for local artists, musicians, dancers and cooks.

All this at the right price

The international tourism market is competitive but still growing. Good clean coral reefs with abundant fishes provide the best economic return from the resources and should be totally sustainable. Poorly managed tourist operations degrade the environment and eventually lose money.

E30 Restoration

30.1 Coral reefs

Restoration or rehabilitation of a coral reef is a very expensive process and should only be considered in very special cases e.g. when a ship has hit a major tourist reef or when the corals have been lost near a major tourist resort. Normally it is best to allow natural restoration of the reef by removing damaging human impacts. This will mean that valuable resources can be used for other management needs.

Natural change

Coral reefs are always changing with a balance between natural damage and recovery. Therefore there is never a 'perfect reef'. Normal, natural impacts, particularly storm damage, diseases and the crown-of-thorns starfish, can damage reefs and it may take decades for the coral to regrow after severe damage. This regrowth of the coral reef will continue until the next major natural impact. Most reefs therefore, can be considered in a state of recovery. But when there is no recovery from a natural impact or recovery is slow, this is a signal to the resource manager that other damaging stresses may be involved.

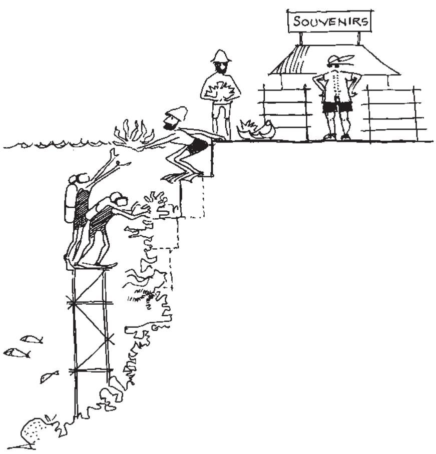
Recovery from human impacts

In the past few decades, there have been major increases in human impacts such that many reefs are not recovering. Some of these reefs are now lost and may never recover. Before restoration of coral reefs can be effective, it is essential that the major human impacts either are removed or at least reduced (this usually means reducing nutrient pollution from sewage and agriculture, silt from roads and poor land practice, pollutants from industry and overfishing). If these are not done the reef may never recover.

When the negative human impact ceases, the first stage in recovery is for new coral larvae to settle (but see case study 18.3, p.102), grow and then other organisms will follow. Reefs often recover well, with good coral cover of the faster growing species in about 10 to 20 years. It may take hundreds of years before large boulder (or brain) corals recover (some of the largest corals are over 1,000 years old). But even without older corals, the reef will still be productive for fishes, shellfish and crustaceans, and most tourists will not notice the difference.

There are some cases of coral reef recovery but note that, in the last two cases below, there was some management help for the recovery.

- Corals in Thailand killed by short-term dredging regrew when the dredging stopped (case study 24.2, p.137).
- A dead coral reef slowly recovered in Mamala Bay, Hawaii when sewage impacts were stopped after the outfall pipe was extended into deeper water (case study 19.2, p.113).
- Coral recovered in Kaneohe Bay after major changes were made in the surrounding townships reducing both sewage and sediment input into the Bay (case study 19.1, p.110).
- Removing sea urchins and algae as well as reducing fishing, in Kenya helped restore parts of a coral reef (management case study C10, p.58 and Box 15, p.115).
- Corals did not recover without help on the tops of small reefs after coral mining in the Maldives, because loose sand and moving rubble provided no base for young corals to settle (case study 20.1, p.116). When structures were built providing a base for coral settling there was regrowth but the structures needed were very costly.



Corals can be transplanted and glued to coral rock, or tied together with string into bundles in areas without major wave action. But this is expensive and usually only done where there is a special viewing area for tourists.

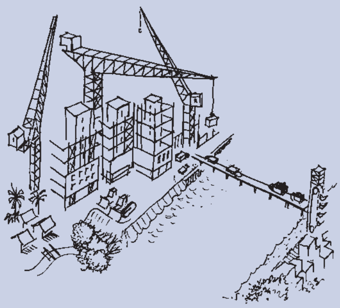
Recently there have been some proposals to restore coral reefs using electricity and chicken wire. This is extremely expensive and not practical for almost all cases, because the area restored is very small: compared to the scale of damage that occurs on coral reefs; and compared to the budgets available for reef managers.

Box 19 Reefs as breakwaters: the cost of replacement

The self-repairing breakwater

One of the functions coral reefs perform is that of self-repairing breakwaters. When healthy, reef ecosystems tend to be accreting systems, or at least in equilibrium with the eroding power of the waves. They also tend to be sources of sand for the lagoons and beaches they protect. This sand comes from the continual death and breakdown of calcareous algae, the corals themselves, and other invertebrate animals with silica or calcium carbonate based skeletons (e.g. crabs, urchins, molluscs, sponges) living on the reef.

If mining or other human activity degrades reefs they tend to start eroding, gradually losing their efficiency as breakwaters as waves pound them to sand and rubble. The shoreline that they protected will therefore be subjected to greater wave energy and may move further inland.

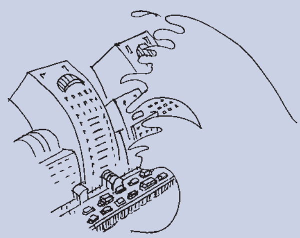


The "reclamation" (infilling of the lagoon and backreef areas) of some 60ha of land on the south side of Male in the Maldives (see case study 20.1, p.116) extended the shoreline about 250 m seawards and took almost a million cubic metres of infill.

The corals were more or less wiped out to about 15m depth because of the high levels of sediment. Not only was the protecting reef destroyed but the shoreline was moved seaward outside its equilibrium position on the south side of the island which is exposed to oceanic swells.

The results of the loss of protection: replacement at high cost

In 1987, soon after this infilling "reclamation" was completed, 2.5-5.0 m swell waves from the south-east (originating from a storm off western Australia) pounded the island for two days, removing 20-30% of the infill and inundating almost all of the reclaimed land on the island.



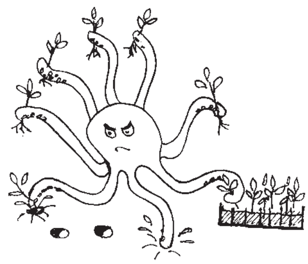
The cost of building detached breakwaters made of concrete tetrapods to replace the protection given by the old reef, and also to protect the new non-equilibrium shore-line, was very high - at $10,000 per linear metre, or a total of $14 million.

From Alasdair Edwards of the University of Newcastle-upon-Tyne.

30.2 Mangroves

Much more restoration has been achieved with mangroves and it is possible to restore mangrove forests that have been damaged. It is possible to plant whole new forests or replace parts but only a few species of the 70 trees and shrubs have been used in such projects. True mangrove restoration would involve replacing the species that were there originally but most projects attempt to grow valuable timber and charcoal species which grow rapidly, rather than restore the whole ecosystem.

The largest replanting of mangroves has been after damage by cyclones in Thailand, Vietnam, China and Bangladesh. Large numbers of 2 mangrove species (*Sonneratia apetala, Avicennia officinalis*) were replanted in Bangladesh in 120,000 hectares of new land formed by sediment deposited after cyclones. The trees stabilised the coastal area and are providing a source of harvestable timber on a regular rotation basis.



The following will help to determine whether a site is suitable for planting or replanting:

- Muddy areas with normally low wave action and sheltered planting sites, because the young seedlings cannot withstand strong winds or fierce currents (barriers that stop wave action but still allow tidal flooding can be used to protect young plants).
- The soil should be stable but not eroding.
- Mangroves will grow best where there is high rainfall or an abundant freshwater supply (a mix of salt and freshwater is best for most species).
- Mangroves will not grow well in higher salinity than normal seawater (as in some shallow or enclosed areas where there is evaporation from hot sun).
- It is important that the young plants be inundated by the tide regularly but they should also be exposed to air for reasonable periods.
- The presence of seagrasses, naturally regenerating mangrove seedlings or scattered grasses indicates that the site may be worth planting.
- Some mangrove species need shade and will not thrive in open sites.
- Generally very little preparation of the site is needed but sometimes it is necessary to clear debris (e.g. coconut or banana trunks, leaves, bamboo, tree branches).
- Some sites may have a high acid content, particularly those in drier land, from the oxidation of acid sulphate soils. There may also be toxic levels of aluminium in such soils. To restore natural soil condition it is necessary that such soils are well flushed by incoming tides and fresh water from rain runoff.

- If the site is infested with Acrostichum fern, it is important to clear the site fully.
- In some sites predators may be important (monkeys in some places, crabs that may eat seedlings) and tests should be made before extensive planting.
- It is also important that the local inhabitants of the planted area be involved and be supportive of the project.

Natural regeneration

If the regeneration is natural with wild propagules (seedlings) that reach the site, the final forest will be more similar to the original mangrove forest. It is also cheaper, requires less labour, there is less soil disturbance and seedlings establish more vigorously. But there must be a sufficient natural supply of seedlings, which can usually be checked by determining that there are many seed bearing trees in the area (for the genus *Rhizophora* the number of seed bearing trees should be 12 trees per hectare). Soil conditions need to be good for natural generation, there should not be excessive amounts of weeds or debris and the water flow of the site should not be disturbed (e.g. by old pond walls, roads or causeway construction).

Artificial regeneration

Mangroves should be planted where there is insufficient natural regeneration using:

- seedlings collected and replanted on the site;
- ripe seeds (or young propagules collected from the parent plant) planted directly on the site; or
- seedlings or small trees raised under nursery conditions and then planted.

This last of these methods is not the easiest but it allows species to be chosen and allows the introduction of genetically selected or improved trees, if available.

Selection

The selection of mangroves, in order of importance should be dependent on:

- the species that grow naturally in the locality (which should do best);
- the availability of seeds and propagules;
- the objective of the planting project (e.g. wood, coastal protection);
- the species come from the similar soil and water conditions.

It may be useful to get expert technical advice to check this list when the reasons for planting have been determined. But local people with a minimum of technical guidance can do most of the actual planting of the forest.

Monitoring

It is essential to monitor the progress of the mangrove forest, using similar methods for a forest on land. Some of these methods are given in Box 20 below.

Box 20 Monitoring a regenerating mangrove forest

To ensure that a replanted mangrove forest is developing successfully, and that it is cost effective, the following can be monitored:

- Observe differences in species (some may be more successful than others).
- Measure rate of growth annually (e.g. number of successful seedlings per hectare, height of trees, diameter at breast height, and volume of wood).
- Monitor growth characteristics (including fruiting and resistance to pests).
- Record the amount of seedling death.
- Record pests and disease (and methods used to prevent this).
- Record rubbish accumulation (and steps to minimise this).
- Record impacts of grazing, cutting, loss through fish pond building (and also of control methods e.g. fencing to reduce impacts).
- Record methods to achieve optimum numbers of seedlings per hectare (degree of thinning, or replanting, or natural regeneration).
- Estimate costs of each mangrove forest project (including money spent on land purchase and legal costs).
- Assess the restored mangrove ecosystem (this can be compared for flora, fauna, and the physical environment of the restored forest with undisturbed ecosystems nearby).
- Objectively judge the success and cost of the restoration project against the original objectives.

30.3 Seagrass beds

Removing the problem is the solution

Seagrass restoration is best achieved by removing the problems that caused the decline in the first place. Solutions are possible but the real task is to identify the problems, rank them in order of severity and then deal with them. The best solution is to reduce or remove the problem and allow the seagrass communities to re-establish naturally.

Some recommendations for achieving healthy seagrass habitats and encouraging recovery of their associated marine life include:

- improving wastewater treatment;
- controlling surface runoff;
- regulating boat traffic;
- restricting fish, shellfish and seaweed harvest by providing alternative livelihoods (especially in developing countries);
- enforcing regulations against unsustainable coastal practices, such as blast fishing and using fine-mesh nets; and
- restoring seagrass beds.

The rapid recoveries of the Singapore River and an estuary in Connecticut demonstrate that coastal ecosystems can recover. But only after significant reduction in nutrient loading and impacts of physical disturbances, along with the concerted effort and determination of the community.

There is little information available on the rate of seagrass recovery, which makes it hard to predict how long such recovery might take. For example, 70 years after the eel grass 'wasting disease' occurred along the North Atlantic coast most areas had recovered but in some places eel grasses never grew back.

Seagrass recovery from physical disturbance and catastrophic decline depends on new colonisation by seeds (propagules) and the overgrowth of bare substratum through expansion of the underground parts. In highly mobile sediment conditions, recovery is helped by a balance between the rates at which new shoots grow and old grasses die off, suggesting the importance of both factors for successful growth and seagrass recovery.

Replanting a second best option

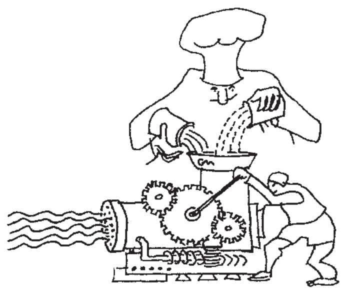
Unfortunately, most of the efforts towards environmental protection have not dealt with the source of the problems: by improving land based development activities and restoring water quality. Instead, they have concentrated on replanting and, sometimes, using artificial seagrasses. Given that developing countries may lack the resources and time to reduce human impacts, such replanting may be the only practical option in the short term. It can produce useful results and quite quickly. In the longer term, the best results will come from dealing with the problems at their source.

Methods and techniques for seagrass bed transplantation and restoration have been developed over the past 10 years. While there have been no complete restoration successes as yet, positive gains have been made (see Box 7, p.47). Transplanted seagrasses often show slow growth rates and some species have been more successful than others. After areas in Florida were dredged for real estate development, planting of seagrass clumps was moderately successful with the genus *Halodule* but failed with *Thalassia*. Other people successfully replanted *Thalassia* in Tampa Bay, Florida, after dipping the clumps in a 10% solution of napthalene acetic acid to stimulate growth.

Studies[10] have nevertheless shown that, within one year of transplanting, seagrasses can effectively speed up the cleanup process and help towards returning the environment to a healthy productive ecosystem.

The recommended way is to cut out plugs of seagrass and transplant them into similar sized holes in the sediments. The new plants are relatively undisturbed in their original sediment and the success rate is high. A cheaper alternative, which works for almost any seagrass species, is to tape 4 - 5 shoots to a bent wire coat-hanger and push the long free end into the sediment. These clumps are planted about 0.5 m apart.

Artificial seagrasses



Artificial seagrass has been used with some success as a way of attracting fish larvae and improving the total amount of fish and shellfish in degraded coastal areas. In Singapore, there was an increase in fish and shrimp three months after planting artificial seagrasses in the Singapore River. The structures became good habitats for restocked seabass (*Lates calcarifer*).

The technique was used in the Philippines to improve the biodiversity and productivity of a biologically desolate area in Cape Bolinao and also to mitigate the impacts of mine tailings in Calancan Bay (see Box 7). At Cape Bolinao, the number of fishes in the artificial seagrass significantly exceeded that found in natural seagrass beds in the area. 62% of the species were new to that specific area, including many species not found in adjacent seagrass beds. This shows active fish recruitment by the artificial seagrassses and demonstrates that they are useful for improving and rehabilitating otherwise desolate areas.

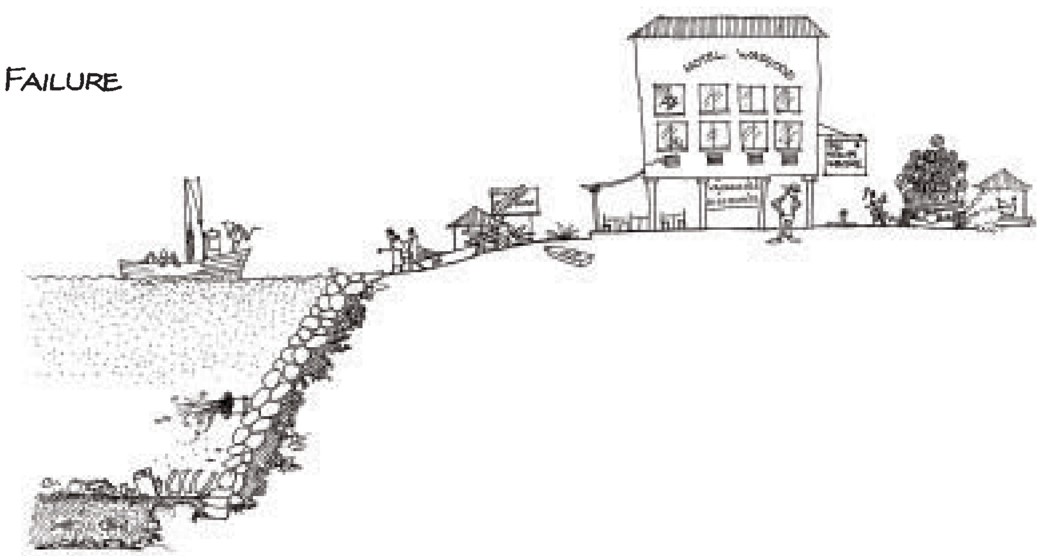
[10] Phillips, R.C. "*Transplant Methods*" *in Seagrass Research Methods,* ed. Phillips, R.C. and McRoy, C.P. UNESCO, Paris pp1-210.

In Calancan Bay a 1,000 sq m area 'planted' with artificial seagrasses attracted many more of the natural fish fauna of the bay. There was also a measure of success in resisting decay and fouling, despite the massive colonisation by plants attaching to the artificial grasses. The number of fish species found in the artificial seagrass areas was 46.2% of those found in the nearby seagrass bed and 86% of that found in the transplanted seagrass areas.

Message:	*It is most important to remove the problems first (sediment flows, pollution, damaging boat activities, overfishing and trawling) and then consider whether replanting natural seagrasses, or even artificial seagrasses, is worth the considerable effort in time and cost.*

Conclusion

We have shown in many of our case studies that it is easy to damage or destroy coastal values and ecosystems. Damaged tropical coasts are all too common and many coastal states have found, too late, that their coasts are degrading.

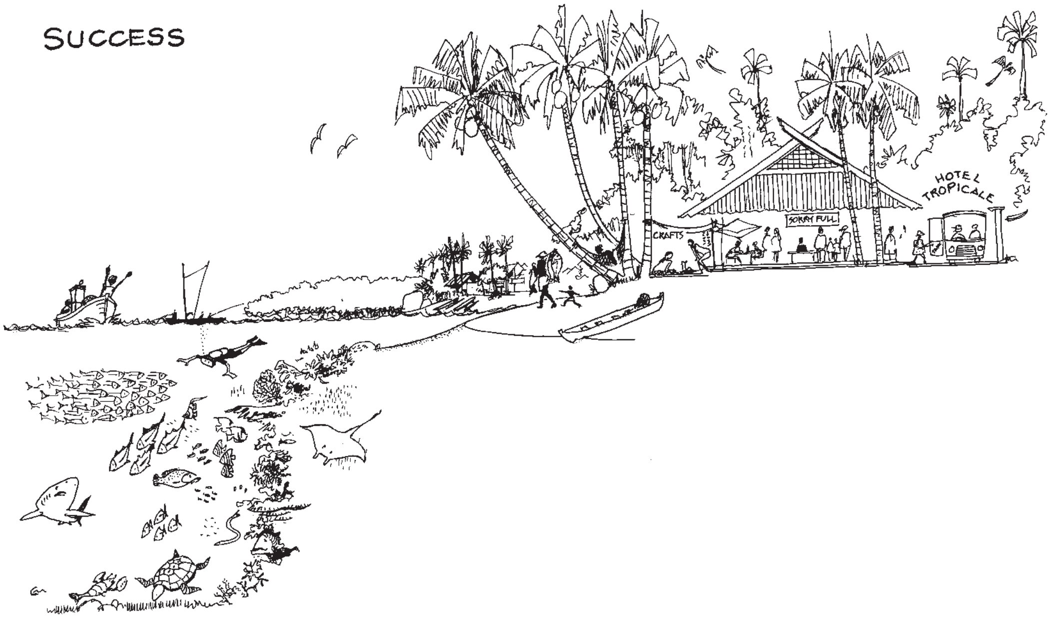


Actions cause damage if they result in:

- mangrove forests permanently reduced;
- shallow water areas with seagrass beds filled in for more land;
- unchecked city pollution dirtying lagoons, estuaries and the coastal sea;
- careless dredging of harbours, and poor forestry and agricultural practice inland, which add silt and nutrients and make the water brown or green;
- fishing with methods that damage the reef; or
- overfishing that reduces the size of fish caught and finally lowers the whole catch by removing breeding adults. It can even reduce the productivity of coral reefs and turn them into algal reefs.

Actions like these are extremely shortsighted, chasing away tourists and steadily lowering coastal income. Not only do they spoil the chance to improve living standards, they actually lead to hardship. Families which have got their livelihood from the reef for generations may find it hard even to feed themselves.

Many coastal habitats will recover if the pressures are removed but to restore a severely damaged habitat may be impossible, if the major marine resources have been removed. Even if it is possible, it may be prohibitively expensive and take many years to recover. If damage is evident, then the earlier you can start with good management, the greater the chance of success. Only well managed reefs can provide sustainable resources for the people.



The right way to conserve coastal resources is to learn from the lessons of others – from both the good and bad examples. With good management you can gain high economic returns from your tropical coasts without destroying them and they can produce good profits indefinitely. It is likely that the highest values will be from fisheries and from tourism.

Tropical coasts need the following to keep their highest sustainable value:

- healthy mangroves in protected bays and estuaries;
- rich flourishing seagrass beds;
- coral reefs with good coral cover and with good populations, and good variety of fish and shellfish;
- some areas set aside as replenishment areas for fish and other animals to ensure a good supply of larvae to other areas; and
- clear unpolluted water.

Good management can achieve this but we have shown that the coastal zone must be managed in an integrated way. The worst pollutants from coastal cities are usually sewage, industrial wastes, and silt from land development and harbour dredging. But there may even be more damage from inland forestry and agriculture. These activities need to be well managed so that silt and nutrients do not pour into the coastal zone down the rivers – and this is also a loss to the land. While it is always tempting to fill in shallow areas and cut mangroves, this is dangerous. Shallow waters with seagrass beds and mangrove areas are essential to sustain coastal fisheries.

With simple but careful monitoring you can prepare a regular 'state of the environment' report, so that changes can be seen which check the success or failure of management actions. These reports are useful to convince decision-makers that conservation action is necessary.

Rich rewards can result from good coastal management.

Good management of hotels, tourist diving operations, fishing and boating can be sustainable. These can drive an economy and provide many jobs.

From fisheries alone, the yield can be hundreds of thousands of dollars from a few kilometres of coastline.

Well-managed tourism that leaves the key tropical habitats in a natural state will often provide more money and work than can be obtained from direct exploitation, including fishing.

The best results come from integrated management of the whole coastal zone.

Suggested reading

The following are particularly useful references:

Brown, B.E. (1997). *Integrated Coastal Management: South Asia*. Department of Marine Sciences and Coastal management, University of Newcastle, Newcastle upon Tyne, United Kingdom.

English, S., Wilkinson, C. and Baker, V. (1997). *Survey Manual for Tropical Marine Resources, 2nd Edition.* Australian Institute of Marine Science, Townsville, 390pp

Kelleher, G. (1999). *Guidelines for Marine Protected Areas.* World Conservation Union, Washington D.C., 107pp

Kenchington, R.A. and Hudson, B.E.T. (eds) (1987). *UNESCO Coral Reef Management Handbook, 2nd Edition.* UNESCO ROSTEA, Jakarta, 321pp

Other useful references include:

Field, C. (1998). *Rationale and Practices of Mangrove Aforestation. Marine & Freshwater Research* 49:353-358.

Grigg, R.W. (1995). *Coral Reefs in an Urban Environment in Hawaii: a complex case history controlled by natural and anthropogenic stress. Coral Reefs* 14: 253-266

IUCN (1995) *The Law of the Sea: Priorities and Responsibilities in Implementing the Convention.* World Conservation Union, Washington D.C., 156pp

Keller, B.D. and Jackson, J.B.C. (1991). *Long-term Assessment of the Oil Spill at Bahia Las Minas, Panama: Interim Report, Volumes 1 & 2.* US Department of the Interior, Minerals Management Service, New Orleans.

Mellors, J.E. (1991), *An evaluation of a rapid visual technique for estimating seagrass biomass, Aquatic Botany* 42: 67-73.

Phillips, R.C. (1990). *Transplant Methods. Seagrass Research Methods*, ed. Phillips, R.C. and McRoy, C.P. UNESCO, Paris 210pp.

Pollnac, R.B. and Crawford, B.R. (2000). *Assessing Behavioral Aspects of Coastal Resource Use.* Proyek Pesisir Publications Special Report. Coastal Resources Center Coastal Management Report #2226, University of Rhode Island, Narragansett 139 pp.

Saenger, P and Bellan, M.P. (1995). University of Toulouse press, Toulouse. 96pp.

Salm, R.V., Clark, J.R. and Siirila, E. (2000). *Marine and Coastal Protected Areas: A Guide for Planners and Managers.* IUCN Washington DC 371 pp.

List of Acronyms

AGRRA	Atlantic and Gulf Reef Assessment
AIMS	Australian Institute of Marine Science
ASEAN	Association of South East Asian Nations
BAPPEDA	Council for Provincial Planning and Development
CATIE	Centro Agronomico Tropical de Investigacion y Ensenanza
CFC	Chlorofluorocarbon
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
COTS	Crown-of-thorns starfish (Acanthaster planci)
CNA	Clean Nigeria Association
CSD	Convention for Sustainable Development
DNA	Deoxyribonucleic Acid
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FKNMS	Florida Keys National Marine Sanctuary
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GEF	Global Environment Facility
ICRI	International Coral Reef Initiative
ICAM	Integrated Coastal Area Management
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
IMO	International Maritime Organisation
IUCN	World Conservation Union
MARPOL	International Convention of the Prevention of Pollution from Ships
MPA	Marine Protected Area
NGO	Nongovernmental organisation
NOAA	National Oceanic and Atmospheric Administration (of USA)
Ramsar	International Convention on Wetlands
RAP	Rapid Assessment Protocol
SAC	Sanctuary Advisory Council
SCUBA	Self-contained underwater breathing apparatus
SIDS	Small Island Developing States
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organisation
UV	Ultraviolet radiation

Hoo'mi

Supporting Organisations

AIMS - Australian Institute Of Marine Science

AIMS is one of Australia's key research agencies and the only one committed primarily to marine research, with an emphasis on tropical marine science. It undertakes research and development to generate new knowledge in marine science and technology, and to promote its application in industry, government and environmental management. The research programme involves medium- to long-term research that is geared towards improved understanding of marine systems and the development of a capability to predict the behaviour of complex tropical marine systems. In the past 25 years the Institute has established a sound reputation for high quality research on coral reef and mangrove ecosystems, and on the water circulation around our coasts and continental shelf. Researchers have not only published extensively in scientific journals but have also written field guides, books and monographs for regional use. This work supports a wide range of studies for effective coral reef management.
Contact: Clive Wilkinson (c.wilkinson@aims.gov.au) or Web site: www.aims.gov.au

CORDIO – COral Reef Degradation in the Indian Ocean

CORDIO is a regional, multi-disciplinary program developed to investigate the ecological and socio-economic consequences of the mass bleaching of corals during 1998 and subsequent degradation of coral reefs in the Indian Ocean. CORDIO is an operating program within ICRI. The objectives are to determine the: biophysical impacts of the bleaching and mortality of corals and long-term prospects for recovery; socio-economic impacts of the coral mortality and options for mitigating these through management and development of alternative livelihoods for peoples dependent on coral reefs; and prospects for restoration and rehabilitation of reefs to accelerate their ecological and economic recovery. CORDIO assists and coordinates with the GCRMN in the Indian Ocean with monitoring and running the Node in East Africa. The participating countries are: Kenya, Tanzania, Mozambique, Madagascar, Seychelles, India, Maldives, Sri Lanka, Reunion, Comores, Mauritius and Chagos.
Program Coordination Contacts: Olof Linden, David Souter, Dept. Biology and Environmental Sciences, University of Kalmar, 391 82 Kalmar, Sweden (olof.linden@cordio.org; souter@pi.se).
CORDIO South Asia: Dan Wilhelmsson, CORDIO, c/o Stockholm International Water Institute, Sveav. 59, 113 59 Stockholm, Sweden; (dan.wilhelmsson@telia.com)
CORDIO East Africa: David Obura, CORDIO, PO Box 10135, Bamburi, Kenya; (dobura@africaonline.co.ke)

CORDIO Island States: Jean Pascal Quod, ARVAM (Agence pour la Recherche et la Valorisation Marine) 14, Rue du Stade de l'Est, 97490 Sainte Clotilde, La Réunion; (jeanpascalquod.arvam@guetali.fr)

GBRRF - Great Barrier Reef Research Foundation

The Great Barrier Reef Research Foundation was established to build on the world-class science flowing from the collective knowledge of the world's leading tropical marine researchers.

Its guiding aim is to foster research applications, informed by international developments, to ensure the sustainability, conservation, protection and responsible use and management of all the world's reefs and to encourage the application of the outcomes for the benefit of coral reefs globally

To achieve this, the Foundation raises funds from non-government sources and applies these on the advice of its International Scientific Advisory Committee. The GBRRF actively pursues collaborative research and the coordinated dissemination of information, for incorporation into policy-making.

The Foundation is pleased to support the publication of this valuable sourcebook to aid in the conservation of the world's coral reefs for the benefit of all who share our goals. www.barrierreef.org

GCRMN - Global Coral Reef Monitoring Network

The GCRMN is an operational unit of ICRI formed in 1995 with contributions from the governments of USA and other countries, and co-sponsored by the Intergovernmental Oceanographic Commission of UNESCO, the UN Environment Programme, IUCN, the World Bank, and co-hosted at AIMS and The World Fish Center (ICLARM) which runs ReefBase, the global coral reef database. Equal emphasises is placed on biophysical and socioeconomic monitoring to gather data, observe trends and raise awareness, especially via Status of Coral Reefs of the World reports every 2 years (www.reefbase.org). The GCRMN encourages and coordinates coral reef monitoring by: communities and volunteers using Reef Check methodology; government environment and fisheries departments using methods developed in Southeast Asia; and high resolution monitoring by researchers. The GCRMN functions as a network of independent Regional Nodes that coordinate training, monitoring and databases in participating countries (contacts): Middle East, Fareed Krupp (fareed.krupp@persga.org); South-west Indian Ocean, Lionel Bigot, (lionelbigot.arvam@guetali.fr); Eastern Africa, David Obura (dobura@africaonline.co.ke); South Asia, (reefmonitor@eureka.lk); South East Asia, Jamie Oliver (j.oliver@cgiar.org); East Asia, Marine Parks Center of Japan (marpark@blue.ocn.ne.jp); Australia PNG, Hugh Sweatman (h.sweatman@aims.gov.au); Southwest Pacific - IOI-Pacific Islands, Robin South (south_r@usp.ac.fj); Southeast, Central Pacific, 'Polynesia Mana', Bernard Salvat (bsalvat@uni-perp.fr); Micronesia, 'MAREPAC', Carol Emaurois (emaurois2000@yahoo.com); US Hawaiian Islands, Dave Gulko (david_a_gulko@exec.state.hi.us); US Caribbean, Donna Turgeon (donna.turgeon@noaa.gov); Mesoamerican Barrier Reef, Marea Hatziolos (Mhatziolos@worldbank.org); Eastern Caribbean, Allan Smith (smitha@candw.lc); Northern Caribbean, Dulcie Linton, (dmlinton@uwimona.edu.jm); Southern Tropical America, Jaime Garzón-Ferreira (jgarzon@invemar.org.co). Global contacts: Clive Wilkinson, (c.wilkinson@aims.gov.au) and Jamie Oliver (j.oliver@cgiar.org); or www.gcrmn.org

ICRI - International Coral Reef Initiative

ICRI was launched in 1994 in response to the 1992 UNCED Rio Earth Summit and the concerns of Small Island Developing States about the declining status of coral reefs. ICRI is partnership of countries, UN agencies, NGOs, development banks, foundations and scientific bodies, with the objectives of mobilising global support for coral reef actions via diplomatic and international flora. USA chaired the first ICRI Secretariat (1995-96), followed by Australia (1997-98), France (1999-2000), and the Philippines and Sweden (2001-02). ICRI held international workshops in the Philippines (May 1995, with 40 countries), and Townsville Australia (November 1998, with 50 countries - International Tropical Marine Ecosystems Management Symposium) to develop *A Call to Action*, *a Framework for Action*, and a *Renewed Call to Action*. Ten Regional ICRI workshops have also been held to assemble the concerns of over 100 countries. ICRI represents coral reef partners on international fora, such as: the UNEP and IOC governing councils, Conventions on Sustainable Development, Biological Diversity, Framework Convention on Climate Change; Global Meetings of Regional Seas Conventions and Action Plans, Global Plan of Action to Protect the Marine Environment from Land-based Activities, Global Conference on Sustainable Development in Small Island Developing States, and CITES. Membership of the ICRI Coordination and Planning Committee includes all interested countries and agencies, which meet each 6 months. ICRI Global Secretariat: Robert Jara (icri_secretariat@hotmail.com) or Olof Linden (olof@timmermon.se). www.ICRIforum.org

IUCN - The World Conservation Union

Founded in 1948, IUCN brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 900 members in all spread across nearly 140 countries. As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. Through its network of regional and country offices, expert Commissions and member organizations, and Marine Program, IUCN supports a variety of coral reef conservation and management efforts that promote: protection of critical habitats and threatened species; design of management plans with stakeholder participation; development of ecological and socio-economic assessment methodologies; enhanced capacity building for sustainable management; and support of effective governance structures. IUCN is an original partner of the International Coral Reef Initiative (ICRI) and a founding co-sponsor of the Global Coral Reef Monitoring Network (GCRMN).
Contact: Carl Lundin E-mail: clundin@iucnus.org or Web site: www.iucn.org

WWF – The Worldwide Fund for Nature

WWF is the largest and most experienced conservation body in the world with 4.7 million members in 100 countries. The mission is to protect nature and the biological diversity that we all need to survive. WWF has an active coral reef programme coordinated through WWF in the Netherlands with activities in all oceans. They have established 11 high priority coral reef regions for conservation to maintain the natural ecological character including the entire suite of biodiversity and natural resources. WWF works in partnership with other communities and NGOs to establish Marine Protected Areas to protect valuable biodiversity for future generations.
Contact: Carel Drijver E-mail: CDrijver@wwfnet.org