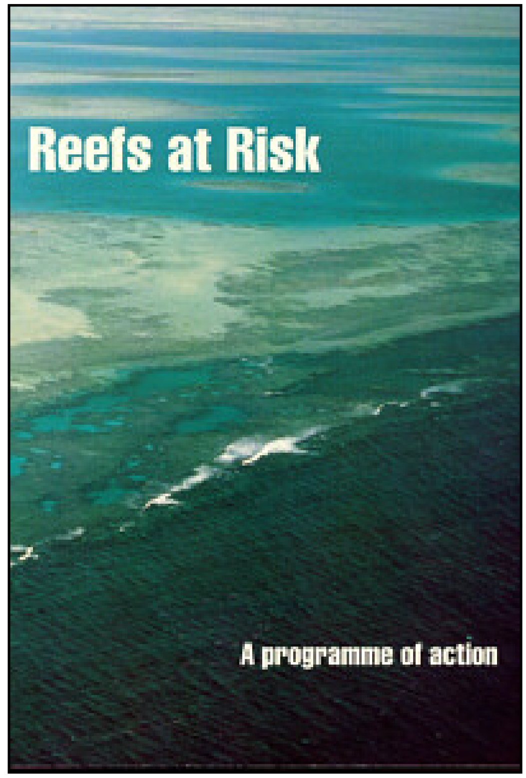
Reefs at Risk

A programme of action

IUCN
The World Conservation Union

AIMS School Resource Series



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human use

and

climate change

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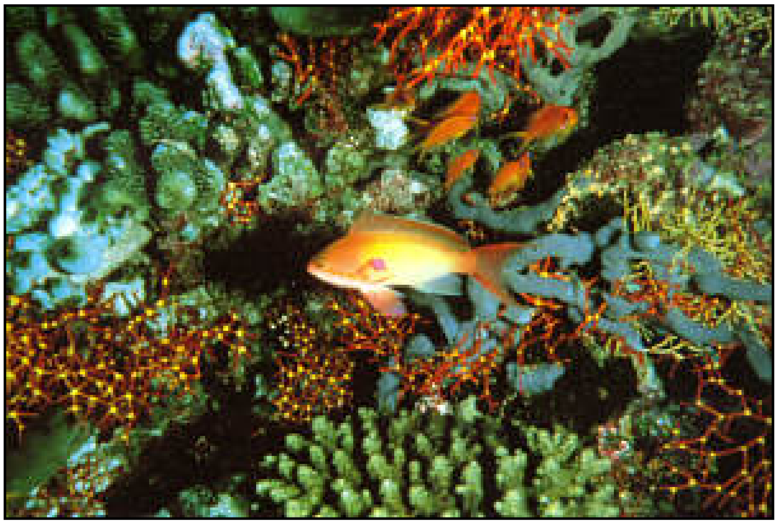


A coral reef in the Maldives. We have barely tapped the knowledge to be gained from the rich diversity of reef life.

Photo: WWF / B & C Lang

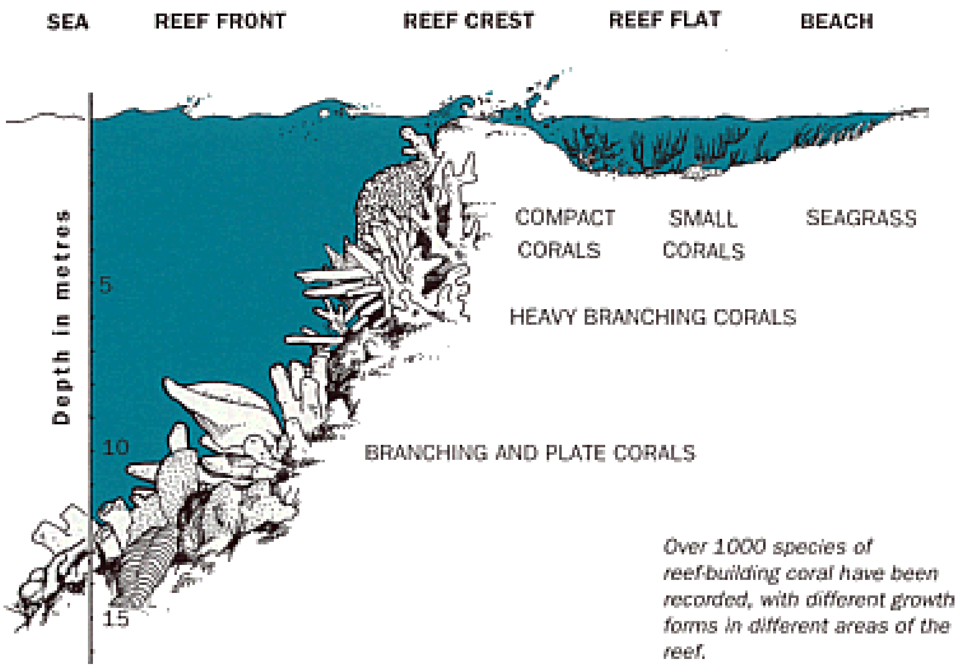
For once, the popular mythology contains some truth. Coral reefs can be likened to tropical forests in certain important ways. Both reefs and jungles are biologically diverse in comparison with other ecosystems. Reefs are an essential supplier of protein to subsistence communities; a valuable currency earner for low-income countries through exploitation of their resources and through tourism; a protector of land; and a naturalist's paradise.

Unfortunately, the analogy is equally apt with respect to the dark side of the picture: though we have barely tapped coral reefs for the knowledge to be gained or the natural products of interest to society, reefs are coming under increasing threat, almost exclusively because of human activities.

Effective management is essential and urgent if we are to prevent the collapse of two-thirds of the world's coral reefs.

Around the world coral reefs have suffered a dramatic decline in recent years. About 10% may already have been degraded beyond recovery. Another 30% are likely to decline seriously within the next 20 years. It has been predicted that more than two-thirds of the world's coral reefs may collapse ecologically within the lifetime of our grandchildren, unless we implement effective management of these resources as an urgent priority.

The reefs identified as being at greatest risk are in South and Southeast Asia, East Africa, and the Caribbean. An IUCN survey during 1984-1989 found that people had significantly damaged or destroyed reefs in 93 countries.



Coral reefs and biodiversity

Coral forms range from compact brain corals found in areas of high wave energy, through heavy branching and plate corals in deeper water, off the reef edge, to smaller finely branched corals found behind the reef crest and in the lagoon.

Coral reefs are generally divided into four main types: atolls, barrier reefs, platform reefs, and fringing reefs. Atolls, where reefs form a ring around a lagoon, are mainly found in the Indian and Pacific Oceans. In the Pacific they are grouped into long island chains such as those of Micronesia and Central Polynesia. Barrier reefs are separated from the mainland by a deep channel or lagoon, in which are found platform reefs. Fringing reefs are directly attached to land or separated only by a shallow lagoon.

On an individual reef, the total count of fish species and smaller marine organisms may exceed several thousand, but the number of individual coral species is much lower.

The Indo-Pacific has some 700 reef-building coral species, many times more than the tropical Atlantic (with some 35). In general, reefs in the Indo-Pacific differ from those of the Atlantic by having many more coral species, and by supporting much richer animal communities on their intertidal reef fiats. The centre of coral diversity is the Southeast Asia region of the Indo-Pacific, and over 400 species of hard coral are believed to occur in Philippine waters.

Moving away from this region, coral diversity declines. Nevertheless, over 200 coral species are recorded from the northern and central Red Sea, about 200 from Madagascar and Chagos. The east coast of the Malaysian peninsula has 174 identified species, south-east India about 117, the Gulf of Thailand some 601 and the Persian Gulf 57.

2. The living reef

Corals are colonial animals that produce a calcium carbonate (aragonite) skeleton beneath their film of living tissue. Reef-building or hermatypic corals contain within their tissues symbiotic algae, so that the colony actually functions as a plant-animal combination. A coral reef is the physical structure created by the growth of the reef community.

When a coral colony dies through storm damage, is broken by the action of living organisms, or is eaten by a parrotfish, the skeleton becomes the basic material forming the reef structure. Dead coral branches form the substrate on which new corals grow, while the fragments are cemented together by the action of coralline algae. The fragmented skeletons form the sand which contributes to reef growth by filling in the spaces between the larger fragments of dead coral skeletons. Continual deposition allows a reef to keep pace with rising sea-level by upward growth.

Coral species, coral communities and the reef structure differ widely in the growth rates. Among the species, branching and staghorn corals can add more than 10cm a year to their branches. Massive corals grow at about a tenth of that rate, or roughly 1Omm a year. As for vertical reef growth, in Mauritius it reaches as much as 1Omm a year, but no more than a few millimetres for some reefs in the Red Sea.

Coral reefs depend very much on the prevailing environmental conditions. Some reefs did not survive the rapid sea-level changes experienced during the ice ages. We find many dead reefs drowned in earlier periods, or stranded above present sea-level. But under the right conditions coral colonies can survive for centuries.

Although we think of reefs primarily in terms of corals, they are home to a myriad of other organisms, all of them important to the overall functioning of the community, and all of them sensitive to climate and environmental conditions. Coating the exposed sand grains of a coral lagoon are microscopic algae and bacteria grazed by molluscs, crustaceans, sea cucumbers, sea urchins and sediment-eating fish. "Turf" algae cover all bare surfaces and are grazed by large populations of fish when the tide is rising. Many of

Reefs are home to a myriad of organisms, all of them sensitive to prevailing climate and environmental conditions these animals provide food for fishers and gleaners of reefs.

Other organisms play an important role in building the reef by breaking down the calcium carbonate skeletons of larger organisms to produce sediments. Some organisms, like sponges, worms and molluscs, bore into the coral skeletons so that they become fragile and fracture in strong waves. Grazing fish and sea urchins at the surface produce large quantities of sediment.

A major role in the functioning and survival of coral reefs is played by the tiny plants and animals known as plankton (from the Greek for "floating"), which provide food for sedentary reef corals and other animals. The life cycle of many corals and other species, including fish, involves a larval planktonic stage, enabling them to disperse over long distances and between different reef areas.

A coral reef in Honduras: because coral reefs survive only close to the interface between air and sea in warm waters, and often adjacent to land, changes in environmental conditions on land as well as in the atmosphere or sea are likely to have a major influence on reefs.

Photo: IUCN / Danny Elder.

Limits to abundance

The living matter produced by the plants and algae in a coral reef system, its gross primary productivity, is between 30 and 250 times as great as that of the open ocean. While the productivity of tropical oceans is very low (18-50 grammes of carbon per sq. metre in a year), coral reefs produce 1500-5000g. The reason for the higher productivity of reefs is that corals and coral communities recycle nutrients such as nitrate and phosphate which are in limited supply in open-ocean surface waters.

The amount we can harvest from a reef damage is severely limited.

But it would be a mistake to assume that the high productivity of a coral reef provides an automatic surplus of potential food. The primary production - the amount of energy produced by photosynthesis - is very nearly balanced by the reef's whole consumption. Net productivity is often only 2-3% of the gross, and only slightly higher than the net productivity per unit area in the surrounding ocean water. The highly productive coral communities also occupy only a fraction of the surface of a coral reef system.

So the amount of organic matter that can be taken out of the reef whether by harvesting or other means without causing damage to the community remains severely limited. One calculation puts the amount that could be extracted on a sustainable basis each year at less than 50 grammes of carbon without causing per square metre (less than 50 tonnes per km^2), an extremely small figure by agricultural standards. Modern rice-growing techniques can produce yields of. over 400 tonnes per km^2.

Brain coral at Curagao in the Netherlands Antilles.

Photo: WWF / Jeff Syb Esma.

Reef growth and the environment

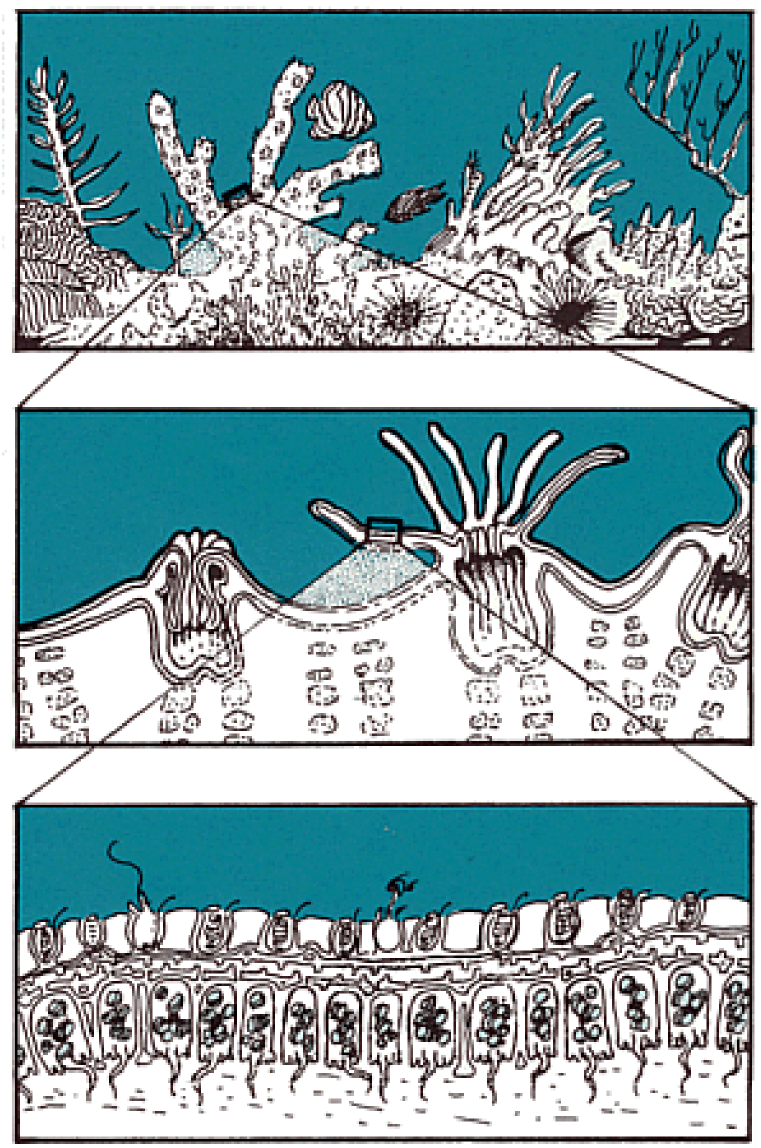
Reef corals do best in shallow, warm, clear oceanic water. Therefore reefs are most abundant away from large land masses, which produce too much freshwater runoff and sediments. Coral reefs are found in warm sub-tropical or tropical oceans where the annual temperature range is 20-30^{O}C. Nevertheless, reefs in the Florida Keys (USA) grow at 18^{O}C, and temperatures above 33^{O}C are tolerated by healthy coral communities in the northern Great Barrier Reef and the Persian Gulf. But when air and water temperatures in the Gulf fell to IO^{O}C in 1968, almost all the inshore coral colonies died. Even small temperature increases above the normal local maximum temperature may result in coral bleaching, which occurs when the symbiotic algae are expelled by the polyps in response to stress. (see symbiotic algae and bleaching).

Changes in the atmosphere, on land, or in the sea all influence reef systems.

Though corals can be found to a depth of 100m, reef-building corals do not grow well below 20-30m because their symbiotic algae depend on sunlight for photosynthesis. Too much fresh water can kill corals: heavy run-off has wiped out shallow reefs off the north coast of Jamaica. So have hurricanes. But the reefs' ultimate chances of survival are determined by the fact that they often coexist with large human populations in the tropics. This could doom many to extinction.

Because coral reefs grow close to sea surface in warm waters, and often adjacent to land, changes in environmental conditions in the atmosphere, on land, or in the sea are all likely to have a marked influence on the reef ecosystem.

The coral polyp



The individual coral polyp is a hollow, cylindrical animal (1). The mouth is surrounded by tentacles armed with stinging cells for capturing plankton. During the day these tentacles are folded in the digestive sac (2).

Microscopic single-celled algae that give the coral its green, blue or brown colour are located in the tissue of the living coral (3). These symbiotic algae process the wastes produced by the polyps. They use the nitrates, phosphates and carbon dioxide produced in the polyp. Through photosynthesis they generate oxygen and organic compounds which the polyps themselves can use. They may also help the polyp lay down calcium carbonate.

In addition to their role as primary producers, the other algae coating much of the reef's surfaces also produce substantial amounts of calcium carbonate. Algae are so important to reef life that it has been suggested that "coral-algal reefs" is a more accurate term than coral reefs

3. People and corals

It's hard to say precisely how large an area of the seas is covered by coral reefs. One commonly quoted estimate is 600,000 km^2 for reefs from the surface down to 30m. More important than their total area, however, is their role in global and local environmental processes and their contribution to human welfare. Millions of people in developing countries depend on reefs, at least in part, for their livelihood. Reefs provide an important source of food for the inhabitants of countries as populous as Indonesia, Jamaica, Kenya and the Philippines.

Coral reefs are not just passive parts of the environment. They form natural breakwaters, creating sheltered lagoons and protected coastlines. They protect mangroves - the nursery for many commercially important marine species - against wave damage, while the coastal mangrove systems act in turn as a barrier against sediments and nutrient loading that could create problems for the reefs.

The economy of atoll nations such as the Maldives is based on marine resources, mainly those of coral reefs. Atoll islands account for most of Kiribati, the Marshall Islands, Tokelau, Tuvalu, and French Polynesia. The Pacific is home to some 2.5 million people living on islands that are either exclusively built by coral or surrounded by significant coral reefs. Another 300,000 people live on coral islands in the Indian Ocean, and many more in the Caribbean.

Coral reefs provide 10-12% of the harvest of finfish and shellfish in tropical countries. Apart from snapper and grouper, jacks, grunts, parrotfish, goatfish and siganids are favourite catches. It has been estimated that coral reefs may account for 20-25% of the fish catch of developing countries. Up to 90% of the animal protein consumed on many Pacific islands comes from marine sources. In the South Pacific, reef and lagoon fish can make up 29% of the commercialised local fishery as well as supplying

Millions of people in developing countries depend on reefs for food and part of their livelihood.

subsistence food.

Tourism and recreational use of reefs on a large-scale are recent developments, but the use of coral for building has been a central part of some island cultures for nearly 2500 years (see Coral, Maldives and the sea-level rise).

Preparing coral rock for construction on Fadiffolu Atoll, Maldives. Coral mining has been part of the island culture for nearly 2500 years.

Photo: WWF / Jack S. Grove

Coral, Maldives and the sea-level rise

People in the Maldives have been mining coral for over 2400 years. Before the 12th century, when Buddhism was the dominant religion, statues were carved from the slow-growing, massive *Porites* coral and temples constructed in part from the material. *Porites* was also used for steps in sacred baths and other special purposes such as decoration, while coral rock was used in boundary walls of monasteries.

In the mid-1650s *Porites* became widely used for building: mosques, wells and public baths were made of coral, sometimes even coffins where the water-table was high. The Friday Mosque, Hukuru Miskiy, built in 1656, is a 26x14m construction using nothing but *Porites*: its blocks, carvings and decorations are locked together without mortar.

Demand for coral as building material increased many times as a result of the construction boom resulting from the development of tourism in the early 1970s. Mined reefs show little or no sign of recovery even after 30 years. In some mined reefs, coral cover was reduced to less than 1%, resulting in a very low diversity and small numbers of fish. Severe erosion is found on almost all the islands that have a history of coral or sand mining.

Because the islands of the Maldives are no more than 2m above the mean sea-level and some 80% of the land is less than lm in height, global changes predicted to occur over the next 50 years threaten this country's survival. It has been estimated to cost over US$1.3 billion to create even minimal sea defences for about 50 of the 200 inhabited islands. Authorities have now banned the use, of coral in building tourist facilities and public buildings, and are making imported cement and aggregate more attractive for construction by reducing import duty. They recognise that the natural protection provided by the reef is of greater long-term value than the benefit from short-term unsustainable mining of the reef.

Mariculture and its problems

Faced with a decline in commercially attractive coral reef species, some countries have tried on-site mariculture to build up their export stock. Four countries at least are trying to farm the giant clam Tridacna on their reefs, following the local extinction of these shellfish on many Pacific islands and throughout large areas of Asia.

Clams are easily collected because they are found in clear, shallow waters. They are also relatively easy to breed in hatcheries. Since their tissues contain symbiotic algae like those in corals, they grow rapidly when exposed to steady light on shallow reef flats.

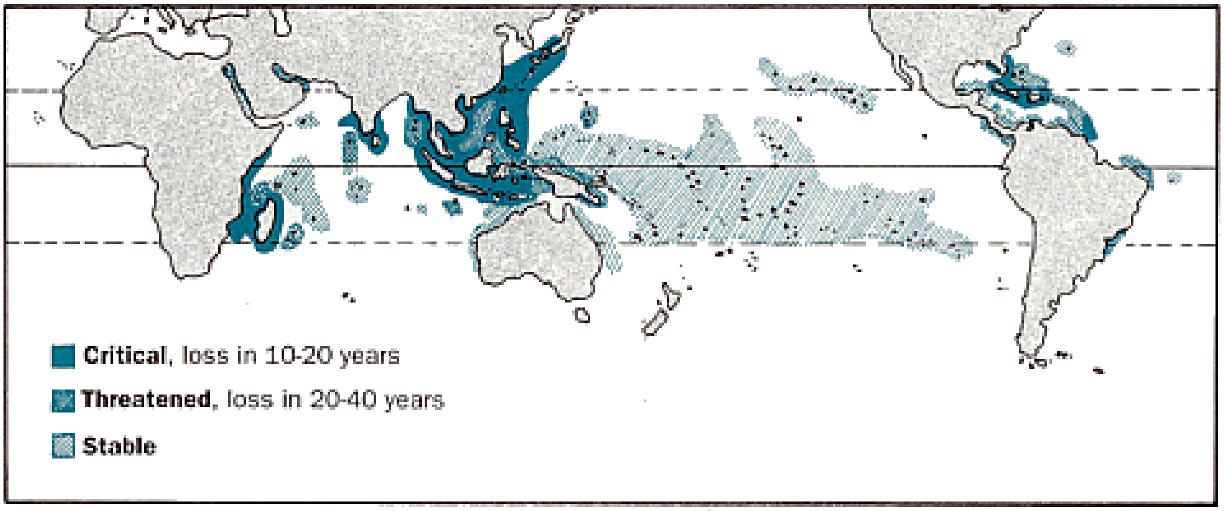
Commercial hatcheries have been established in the Solomon Islands, Micronesia, Samoa, and both northern and southern Philippines. The aim is to produce enough juvenile clams to establish village industries both for local consumption and export.

People depending on coral reefs may be forced to turn from rapidly declining natural resources to mariculture as a source of seafood. The potential effects of climate change, however, will have to be factored into their projects. They will need to consider the chances of storm damage and their distance from potential land-based effects. For example, clams seem vulnerable to bleaching in the same way as corals, putting their survival at risk under warmer conditions. To avoid this problem, growers may need to locate the clams in deeper water where light and temperatures will be more stable. This, however, may reduce the clam's growth rate markedly, and produce smaller returns to the clam farmer.

A fishing canoe in Western Samoa. The sea provides 90% of the animal protein consumed on many Pacific Islands.

Photo: J.W. Thorsell

4. The threats and the causes



Critical and threatened coral reefs of the world

The dangers facing coral reefs today have more than one cause, but they all result from global changes.

One of the major factors is demographic: rapid population growth found in tropical developing countries and migration to coastal areas where coral reefs are located, result in increasing pressure on coastal resources.

Another major factor in recent coral reef decline has been technological development. Pre-industrial peoples took material and resources from reefs with minimal impact on the environment. Mechanical dredges or hydraulic suction devices, dynamiting and large-scale poisoning of reefs to collect fish, produce "the 4 Ds" of coral reef impact: damage, degradation, depletion, and destruction.

Population growth and technology: operating together these two factors account for the major causes of coral reef decline - excessive domestic and agricultural waste pouring into ocean waters, poor

The dangers facing coral reefs all result from global changes.

land-use practices that increase sedimentation of rivers and then of reefs, and over-exploitation of reef resources, often in combination with practices such as harvesting with dynamite. and poison; all degrade reefs.

Domestic, agricultural and industrial wastes are discharged into coastal waters in many countries. Apart from the pollution and risks to human health created by such wastes, nutrient-rich waters diminish rather than increase the health of coral reefs. Deforestation, over-grazing, and poor land-use practices, often far inland, are leading to massive soil erosion and siltation of rivers and washing large loads of sediment onto coral reefs.

Because reefs have such high species diversity, overfishing may not be noticed until depletion of resources is relatively advanced. Fish stocks have certainly declined markedly in many reef areas, particularly close to centres of human population in developing countries. Landings of many fish species are continuing to decrease and it takes much more energy and effort to catch the fish in many areas. Average and maximum sizes have diminished, and the mix of species in the catch has changed. As early as 1959 in Jamaica, for example, fish catches in coral reef waters contained only juvenile fish.

in some areas fishermen say they have been forced by the decline in catches to use destructive techniques to get enough fish to feed their families and make a living. These practices, which have now lasted several decades, are today considered part of the "traditional" culture. Dynamite fishing is illegal in the Philippines but is still commonly practised in some areas.

Destructive fishing techniques have now lasted for so long they are considered part of the traditional culture.

The over fishing of some species has other effects which accelerate the degradation of coral reefs. Removing fish and other grazers of reef algae such as molluscs from the system allows the algae to compete with, the corals for substrate. Jamaica provides an example of the devastating effect that can result. A hurricane hit this Caribbean island in 1980 causing severe destruction of corals. The normal recovery process was impeded by a second event. The major algal grazer on these reefs, a long-spined sea urchin, was wiped out by disease. This allowed the macro-algae to smother juvenile corals trying to settle. Coral cover dropped from 50-70% to under 5%, and 10 years afterwards, there is still no sign of recovery.

Particularly in Southeast Asia, export of reef fish to Japan, Taiwan, Hong Kong and Singapore is contributing to overfishing. Taiwanese harvesting of the giant clams Tridacna spp. has led to population crashes and local extinction on isolated reefs. Tobacco and soap may also be killing giant clams. In the Philippines many tridacnid clam species have become locally extinct. The main cause is the trade in shells, frequently sold to tourists as ashtrays and soap dishes. This country probably remains the major exporter of coral reef curios, though largely prohibited within the country and by the states where tourists import them. Giant clams have recently been added to the list of species covered by the Convention on International Trade in Endangered Species (CITES) as a means of reducing the trade.

Collecting aquarium fish and live corals for European and North American markets has developed into another lucrative but damaging industry. The techniques used in harvesting fish for this trade are often destructive, killing organisms not intended for collection. Cyanide is widely used to force fish out from the coral and stun them so that they can be easily captured. Probably more than 50% of the fish collected in this way die before reaching the retail market.

Tourism can be an environmentally friendly way of generating income from coral reefs, but only when resort development and operation are carefully controlled. Unlimited collecting, sport fishing and accidental damage by waders, swimmers and boat anchors can all degrade the reefs that earn the tourist dollars. Allowing sewage and other wastes from tourist facilities to pollute reef areas, or siting resorts so that beach erosion increases, can be even more degrading to the health of the reef than the direct damage caused by visitors.

Tourism can only be environmentally friendly to reefs when carefully controlled.

As a result of human activities, many coral reefs suffer chronic stress. Waste disposal, pollution, sedimentation, overfishing, coral mining, tourism and curio collection: all combine to degrade and threaten the ecological collapse of an estimated 30% of the world's reefs within two decades.

The new factor: global climate change

Lately another factor has entered on the scene: global climate change. According to the best available predictions of scientists, the next century will bring higher world temperatures and a rate of change in climate greater than we have seen for more than 6000 years. Other predicted results include an accelerated rise in sea-level, while cyclonic storms and floods could become more frequent in some places. Ocean circulation patterns may alter, and even the chemistry of sea-water might change because of higher concentrations of carbon dioxide.

What will be the effect on coral reefs and the people who depend on them?

A Global Task Team of experts sponsored by the United Nations Environment Programme (UNEP), the Intergovernmental Oceanographic Commission (IOC) of UNESCO (the United Nations Educational, Scientific and Cultural organisation), and the Association of South Pacific Environmental Institutions (ASPEI) looked at the situation and prospects. Working together with the World Meteorological Organisation (WMO) and IUCN-The World Conservation Union, the Task Team has produced a report which reviews the possible impacts of climate change and sea-level rise on coral reefs.

Crinoid, black coral and fish in reefs of Irian Jaya, Indonesia. Changes in temperature and frequency of storms could affect such reef organisms.

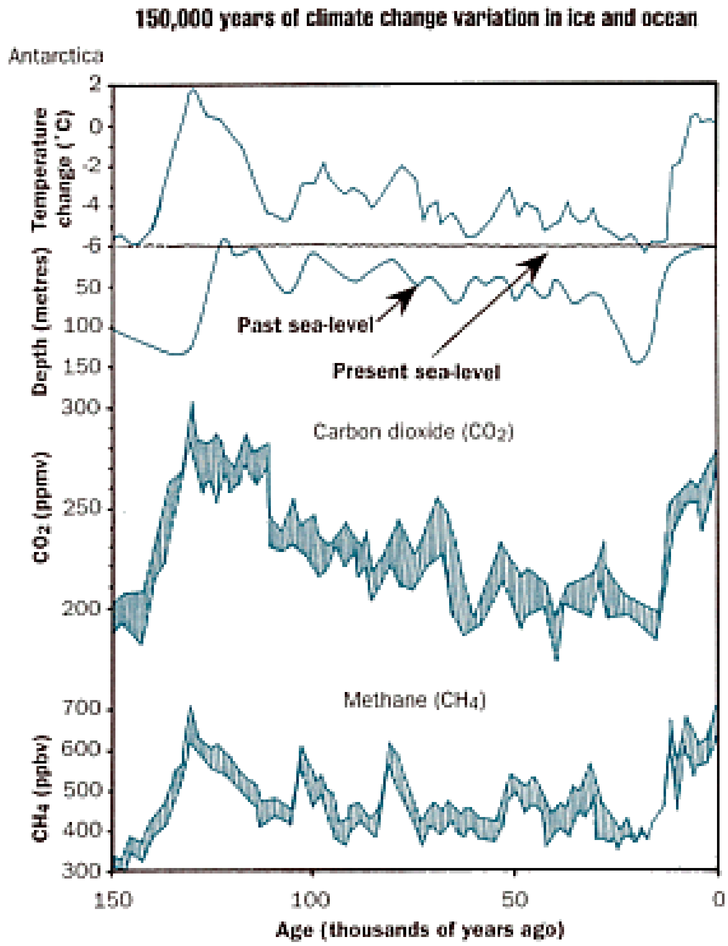
Photo: WWF / Rod Salm

Acropora coral and fish at Pase Hays, New Caledonia. Harvesting of giant clams in the Pacific has led to local extinction.

Photo: WWF / Thierry Petit / BIOS

The scientists warn: "The condition of many of the world's coral reefs has reached a crisis point. (...) Global climate change may directly impose new stresses on reefs, or it may interact synergistically with other more direct human pressures to cause added and Accelerated environmental damage. These [climate change] effects could accelerate the current rate of coral reef degradation in areas already stressed."

Global climate change, the Task Team said, may not pose an immediate threat to the existence of reefs worldwide, but locally the impact may vary from disastrous to benign. Some reefs may be destroyed, others badly affected, while some could even experience more vigorous growth in the medium term.



For the next 10-40 years, local stresses from human sources are a greater threat to most reefs than climate change. On the other hand, the long-term threat from climate change and sea-level rise may make reef islands uninhabitable. This long-term threat may be of greater significance to the human populations than the short-term problems of these islands.

The scientists point out: "Climate change is the only potential threat on the horizon for those reefs remote from large human populations in the central Pacific and Indian Oceans and along much of the Australian Great Barrier Reef."

The menace hanging over these reefs is as dangerous as the threat facing coral systems close to human populations: "The more remote reefs have the important potential to serve as refuges for coral reef biodiversity," the Global Task Team observes. "Their health and preservation are important to the ecosystem on a global scale."

Climate change is the only potential threat on the horizon for those reefs remote from large human populations.

5. The effects of climate change

Over the coming century global climate change is expected to lead to:

- increased air and sea-surface temperatures;
- rises in sea-level;
- changes in weather patterns;
- more frequent storms, droughts, floods and other extremes of weather in some place;
- possible alterations in the pattern of ocean circulation; and
- changes in the chemistry of seawater from higher concentrations of carbon dioxide

Admitting the many uncertainties about the mechanisms involved, the intergovernmental Panel on Climate Change (IPCC) has concluded, in its latest (1992) update on climate change, that:

- the carbon dioxide in the atmosphere will double by the middle of the next century (from 200 years ago, before the industrial revolution greatly increased atmospheric $C0_2$ concentrations through the burning of fossil fuels);
- the average temperature across the globe will increase by just under 0.3^{O}C per decade, producing an increase of about 2.5^{O}C by 2100. (The panel cautions that the average could range from 1.6-3.8^{O}C.) Warming will be greater in higher latitudes and greater over land than over the ocean;
- sea-level will probably rise by about 5cm per decade (with an estimated range of 1-9cm per decade). This means a probable sea-level rise of 45cm by 2100 (perhaps as little as 15cm, or as much as 90cm);
- extreme weather conditions are likely to be more frequent

While corals and reef communities can recover from severe episodic disasters such as cyclones and storms, they are vulnerable to many low-level but continuing, chronic stresses created by human populations.

and more intense. (For coral reefs, two possible changes are important: more of the total rainfall will occur in heavy storms, and the range, frequency and intensity of major storms may increase); and

- depletion of the ozone in the stratosphere, as a result of
- chlorofluorocarbon emissions will increase Earth's exposure to ultraviolet light.

How will corals and reefs react?

While corals and reef communities can recover from severe episodic disasters such as cyclones and storms, they are vulnerable to many low-level but continuing, chronic stresses created by human populations.

Many corals appear to live close to their upper temperature limit. Transient increases of only a few degrees above the usual maximum can kill corals. Even small increases can result in bleaching, a stress response which varies within and between species. In today's oceans, rates of growth or calcification as well as species diversity seem to increase with higher average water temperatures.

Coral reefs in the region of the Equator do not have to contend with frequent cyclonic storms. "Hot spots" of storm activity are found outside the equatorial zone at individual sites such as Guam, where storms are frequent and violent and the coral reefs tend to have high diversity but a low profile. By contrast, reefs in Micronesia, French Polynesia, Thailand or the southern Caribbean, for example, fall victim to such storms less than once in 50 years. These rare-storm reefs tend to develop more fragile coral communities of highly complex structure. So changes in the frequency and force of cyclonic storms can be expected to have major effects on the structure and growth rates of coral reefs.

Wave action strongly influences the depth to which reef corals, algae and other key organisms are distributed. Storms provide catastrophic pruning of reefs and substrate renewal. This makes it easier for new corals to recruit from elsewhere and thus influences the way the community is made up or operates. Storms, waves and currents also mobilise sediment and nutrients as well as shaping the coastline, and affect local sea-level. Currents play a major part in transporting pathogens and nutrients and in dispersing larvae that control the distribution of reefs. So changes to these physical parameters could alter the distribution of reefs and reef organisms.

Freshwater runoff or groundwater discharge affect reef development adjacent to land masses. Reef communities need a fairly stable range of salinity. If the salinity drops below 20 parts per thousand (ppt) (normal sea-water is 32ppt) for more than 24 hours, then corals and many other reef organisms die. Salinity variations that damage nearshore reefs could become more frequent if storms, rainfall and flooding increase.

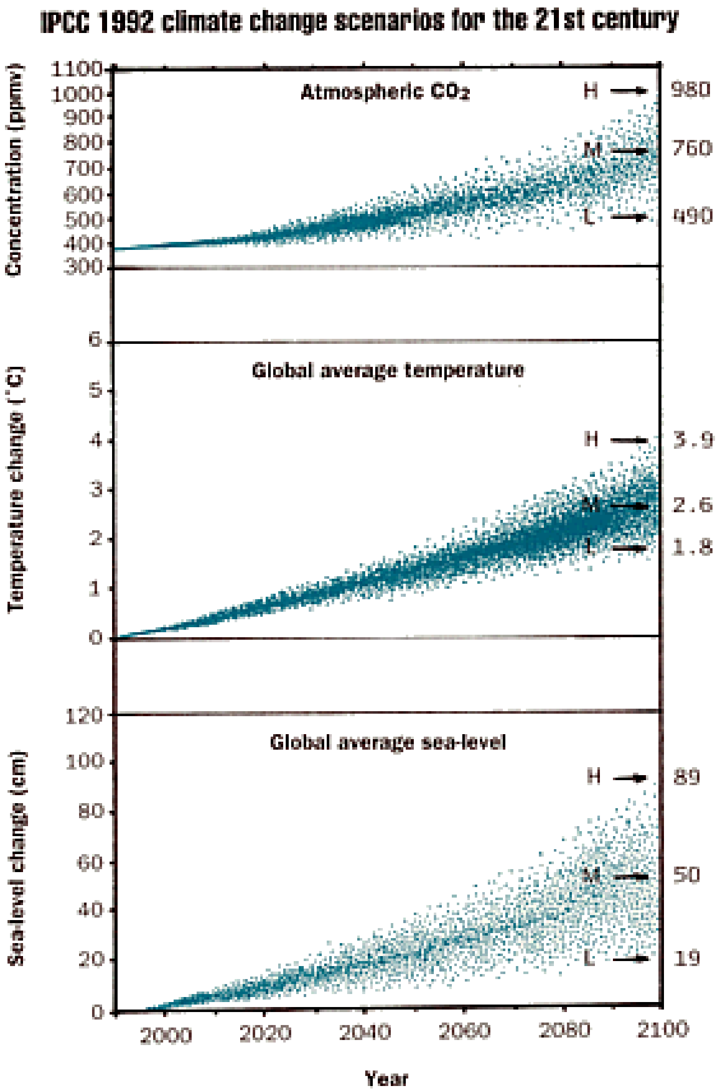
Ultra-violet radiation is known to have detrimental effects on reef organisms.

Most adult corals and shallow water reef animals and plants have developed mechanisms to either block out or avoid this harmful radiation. However, the larval stages of reef organisms are vulnerable, during their planktonic stages, to increased ultraviolet light.

Increased sea-surface temperatures or dissolved nutrients from freshwater run-off could ' affect coral reef plankton and encourage the growth of phytoplankton. Increased phytoplankton, the food of larval crown-of-thorns starfish, may result in increased populations of this harmful species that has devastated many reef systems in the past.

Increased carbon dioxide concentrations affect the acidity of the ocean's surface waters and reduce the amount of dissolved calcium carbonate available to reef-building corals.

Changes in light, UV radiation and temperature can make a profound impact on a reef through their effect on plankton.



The Intergovernmental Panel on Climate Change has produced scenarios of how the global climate could change in the 21st century. This illustration shows the latest revisions (1992).

6. Managing for change

The local variations in impact expected to result from global climate change, and the complex ways in which coral reefs and human societies interact mean that there is no single way to manage reef resources for their conservation -- and a narrow scientific approach to management is likely to prove inadequate.

Policy-makers, environmental managers and scientists will need information on local and regional trends in demographic, economic and environmental conditions to provide not only management information but the background against which climate change and sea-level rise impacts on reef systems can be evaluated. As global and regional models of climate improve, assessments will need to be reviewed and updated at regular intervals. We have to monitor the health of coral reefs and their communities more systematically than before.

Managers and planners must also start to listen to indigenous people who have been taking good care of their natural resources for centuries. Many Pacific Island cultures, for example, developed traditional conservation and management systems that controlled over-exploitation. Free access to marine resources was generally not the rule in these island communities. Long before biologists and economists trained in the industrialised world promoted the idea, these peoples operated "limited entry" rules that conserved fishery stocks on small coral reefs.

A system of resource management that makes full use of the knowledge and expertise of local communities is vital if we are to develop integrated coastal zone management that is effective in a changing world.

A narrow scientific approach to management is likely to prove inadequate.

Bleaching and crown-of-thorns starfish: a shortage of facts

Since the mid-1980s, corals in the Caribbean region and elsewhere have suffered a series of bleaching events. In extreme cases the corals have died. Bleaching has been linked by some scientists to abnormally high seawater temperatures or prolonged peak seawater temperatures in summer. Other scientists argue that the satellite measurement of seawater temperature is not a true reflection of the actual temperature of the water surrounding the reef and thus that the evidence for temperature causing these events is not conclusive.

The crown-of-thorns-starfish, which caused serious damage in the Great Barrier Reef of Australia two decades ago, has been blamed for die-off of corals in large numbers in Sri Lanka, Mauritius, Malaysia and Indonesia. Are these natural fluctuations or are they caused by human activities?

Again the scientists are divided in their opinion concerning the cause of these outbreaks. Some believe that these reflect natural population changes, others that they result from human interference and in particular increased loads of nutrients to reef systems. More information from co-ordinated global research and monitoring is required to resolve these uncertainties.

7. The monitoring programme

Corals may be almost ideal indicators of climate change. Some corals show annual bands that can be read like tree rings, and provide better evidence of past climate than deep-sea sediments, which tend to get mixed by the organisms in them. Scientists have already used this source of information to obtain a picture of past climate and environmental conditions on particular reefs.

As climate change has forced itself onto the agenda of the international community, the scientific and management potential of coral reef monitoring has become more widely appreciated. Unfortunately, our knowledge of the status and health of the world's coral reefs remains patchy. Informal networks of scientists, bilateral programmes such as the ASEAN-Australia Project on Living Coastal Resources and regional efforts such as the Caribbean Coastal Marine Productivity Programme (CARICOMP) are all taking measurements on coral reefs. Most of these efforts are directed towards answering questions about specific and limited issues such as fisheries, pollution or scientific problems. As a result there is still no authoritative and quantitative global assessment of reef health and condition. Even in the case of bleaching that has killed corals across the world, scientists are divided as to the causes. Some see the bleaching as an early signal of greenhouse warming. Others consider the coral deaths as an indicator of stresses on reefs caused by human activities or simply a result of tile natural variability of the environment. They believe that bleaching may be part of a natural adaptation process.

Corals may be almost ideal indicators of climate change. Scientists have already used corals to obtain information on past climate.

The Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change

In 1990 IOC in collaboration with UNEP and WMO commissioned a study on the need for a global network of coastal sites at which to monitor the impact of climate change. This led to a meeting of experts held in Paris in December 1990. The sponsoring agencies approved the recommendations from this meeting for a global coastal monitoring programme with six activities in the pilot phase.

The programme provides for a Long-Term Global Monitoring System of Coastal and Near-Shore Phenomena Related to Climate Change. This will draw on existing and planned activities for collecting and exchanging data. It will also make arrangements to carry out measurements that are not taken at the moment, such as biological and chemical observations.

The pilot phase activities cover:

- sea-level change and coastal flooding;
- coastal circulation;
- assessment of organic carbon accumulation in surface coastal sediments;
- changes in plankton community structure;
- benthic communities of coral reef ecosystems; and
- terrestrial vegetation in mangrove communities.

The programme has six activities in its pilot phase, giving coral reef and mangrove monitoring priority among biological systems.

Nudibranch in a coral reef at Tuamotu, French Polynesia. Monitoring the health of reef systems and their components could yield essential data for determining the effects of climate change.

Photo: WWF / Yves Lefevre / BIOS

The whole monitoring system will form part of a proposed Global Ocean Observing System (GOOS), itself part of the Global Climate Observing System (GCOS) being put together by a number of international organisations.

The first two pilot activities are important components of the ocean-observing system, while carbon accumulation is an important issue for scientists seeking to understand the sources and sinks of carbon on a global scale. Studying the plankton, mangrove and coral reef communities will provide essential information about the biological systems of coastal wetlands, marine benthic ecosystems and pelagic communities. Of these three, coral reef and mangrove monitoring have been given priority.

Experts at the Paris meeting said that data collected over 2-3 years could provide a baseline status report on the health of reef systems in selected sites. This would be valuable to coastal zone managers in places where reefs form a major source of renewable resources. Priority during the pilot phase will go to developing standardised formats for exchanging data.

Two further meetings were held in December 1991. The first was a workshop in Amersfoort, Netherlands, organised by IUCN, WWF International, the Royal Netherlands Institute of Public and Environmental Health and the US Environmental Protection Agency which reviewed the potential impacts of climate change on coral reefs. The workshop indicated five key research needs and also called urgently for a reduction of sediment and nutrient loads on coral reefs.

The second meeting co-sponsored by UNEP, IOC, WMO and IUCN brought together 18 experts on coral reef and mangrove biology. This meeting took into

consideration the reviews prepared in Amersfoort in amplifying and developing the proposed monitoring scheme recommended by the Paris meeting.

Several other organisations joined the original sponsors in holding a workshop in Guam on 22-26 June 1992 in conjunction with the 7th International Coral Reef Symposium. This meeting enabled the organisers to test the reactions of the scientific community to the proposed network and pilot phase monitoring programme. They backed the programme and suggested all institutions and organisations should be encouraged to participate in implementing the pilot phase.

The scientists noted that 5-10 laboratories are currently capable of very

Data collected would be valuable to coastal zone managers in places where reefs form a major source of renewable resources.

sophisticated monitoring and analysis, but they also found an obvious need for a more extensive network so that more institutes and researchers could be involved, particularly to identify global trends. This means simple data collection methods should also have a place in the programme. The scientists suggested these less technology-dependent techniques could be linked with more sophisticated systems through simultaneous activities.

The pilot phase

The pilot phase of the global monitoring system is deliberately low-key. It does not aim to replace or overshadow existing programmes. The objective, in fact, is to provide a framework for closer co-operation. Governments and organisations contributing to the system will be able to get access to much larger amounts of information and expertise.

To obtain a comparable global overview of the state of the world's coral reefs, only a "one-off' monitoring exercise would be needed. Provided enough laboratories and individuals took part, the data collected would give sufficient information to provide a baseline from which to work. The "one-off" monitoring effort would also enable the scientists to revise the way they work to ensure that future data generated through the programme is more compatible and exchange of information is easier.

The one-off project will facilitate the selection of the most suitable sites for long-term monitoring of coral reefs and will encourage some countries to continue of their own accord.

The program's initial objectives are:

- to secure the commitment of member States to start the pilot phase;
- to ensure co-ordination between existing and planned activities to
- monitor coral reefs;
- to begin preliminary monitoring of selected sites worldwide; and

The programme's objectives are to: secure commitment, ensure co-ordination, begin monitoring, and strengthen existing networks.

- to strengthen existing regional networks of institutions, particularly by providing facilities for inter-regional and global collaboration in data handling and exchange.

During the initial stage the GOOS Support Office of the IOC Secretariat has been designated to co-ordinate implementation of the work programme, particularly with regard to quality control, handling and exchange of data from the monitoring system.

IOC and WMO have considerable experience in international data management, quality control, handling, storage and exchange of technical information. They specialise in systems that enable contributors to tap into a much larger network.

The intergovernmental agencies sponsoring the programme have long experience in promoting international co-operation between governments and can provide a mechanism to stimulate support activities at a national level. They are also specialists in facilitating the transfer of expertise, funds and equipment from higher-income nations to developing countries to enable the lower-income states to take part in international activities. The agencies' programmes already cover training, education and assistance in marine science.

With national government focal points for their activities, the UN agencies can help avert a conflict of interests. IUCN-The World Conservation Union, with some 770 members among governments, agencies and environmental organisations, also has several networks of scientists. Its specialist commissions can mobilise a unique pool of ecological expertise. IUCN is particularly interested in using marine parks and protected areas as long-term monitoring sites, and could include such monitoring as a management objective in guidelines it is drawing up for administering such areas.

Coral reefs are important to the well-being of people

8. Facing the challenge

The coral reefs of the world represent an important resource, both in terms of global biological diversity and with respect to the well-being of the people who live near and depend upon them. With a history of survival over geologic time and clear present evidence of vulnerability to the combined stresses of human overexploitation and climate change, reefs are an ecosystem at once threatened and saveable. They represent a clear challenge to the scientists, managers, national bodies and international programmes concerned with such issues -- a challenge that the programmes and information described in this booklet are intended to address. Further work, much co-ordination, and more resources will be needed, but the reefs of the world can and must be preserved.

Coral reefs can and must be preserved.