



# World Atlas of Coral Reefs

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UNIVERSITY OF CALIFORNIA PRESS  
BERKELEY LOS ANGELES LONDON

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## **Prepared at**

The UNEP World Conservation  
Monitoring Centre  
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Cambridge CB3 0DL, UK  
Website: [www.unep-wcmc.org](http://www.unep-wcmc.org)  
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## **Printed in Hong Kong**

## **A Banson Production**

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The UNEP World Conservation Monitoring Centre provides objective, scientifically rigorous products and services that include ecosystem assessments, support for implementation of environmental agreements, regional and global biodiversity information, research on threats and impacts, and development of future scenarios for the living world.

The Centre became the biodiversity information and assessment arm of the United Nations Environment Programme in June 2000. It was founded in 1979 by IUCN and in 1988 was transformed into a joint activity of IUCN, WWF and UNEP. The financial support and guidance of these organizations in the Centre's formative years is gratefully acknowledged.

# Supporting institutions



The United Nations Environment Programme is the principal United Nations body in the field of the environment. Its role is to be the leading global environmental authority that sets the global environmental agenda, that promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and that serves as an authoritative advocate for the global environment. Its objectives include analysis of the state of the global environment and assessment of global and regional environmental trends, provision of policy advice and early warning information on environmental threats, and to catalyze and promote international cooperation and action, based on the best scientific and technical capabilities available. Website: [www.unep.org](http://www.unep.org)



ICLARM–The World Fish Center is an international, non-profit research center working to alleviate poverty and promote food security through the sustainable development and use of aquatic resources based on environmentally sound management. The focus of ICLARM's work is in developing countries and coral reefs are one of the key resources systems studied. A major coral reef project led by ICLARM is ReefBase: A Global Database on Coral Reefs. ReefBase aims to provide data and information on coral reefs and associated shallow tropical habitats, in order to facilitate better understanding of the relationship between human activities and the status and dynamics of these environments. Over 110 institutions and individuals have contributed information and expert advice to ReefBase. Websites: [www.iclarm.org](http://www.iclarm.org) and [www.reefbase.org](http://www.reefbase.org)



Scientists in the Earth Sciences and Image Analysis Laboratory at the Johnson Space Center work closely with astronaut crews and manage the Earth photography by astronauts on space missions. They also facilitate public access to the imagery, with an emphasis on using astronaut photographs for scientific studies. The cataloged data and imagery is located at <http://eol.jsc.nasa.gov>



The Aventis Foundation, based in Strasbourg, France, was formed in 2000. The Aventis Foundation promotes projects at the interface of culture, science, business and society. The Foundation aims to select projects that are international, interdisciplinary, and looking towards the future. One of its prime aims is to identify the people who will shape tomorrow and to enable them to contribute to sustainable development through their activities in science, politics and society. Website: [www.aventis-foundation.org](http://www.aventis-foundation.org)



PADI (Professional Association of Diving Instructors) Project AWARE seeks to increase both the diving and non-diving communities' environmental awareness, to encourage responsible interactions between humans and the aquatic environment and to emphasize the diver's role in preserving the aquatic realm. Aquatic World Awareness, Responsibility and Education at [www.projectaware.com](http://www.projectaware.com)



The non-profit Marine Aquarium Council is an international network that brings together environment organizations, the aquarium industry, aquarium keepers (hobbyists), public aquariums, government agencies and others to ensure quality and sustainability in the collection, culture and commerce of marine ornamentals. MAC is doing this by developing an international system of certification and labeling that will: establish standards for quality products and practices; document compliance with these standards and label the results; and create consumer demand and confidence for labeled "products" from certified industry operators. Paul Holthus, Executive Director, 923 Nu'uuanu Ave, Honolulu, Hawai'i 96817, USA. Tel: (1 808) 550 8217; Fax: (1 808) 550 8317; E-mail: [paul.holthus@aquariumcouncil.org](mailto:paul.holthus@aquariumcouncil.org); Website: [www.aquariumcouncil.org](http://www.aquariumcouncil.org)



The International Coral Reef Initiative is a voluntary partnership that allows representatives of over 80 countries with coral reefs to work with major donor countries and development banks, international environmental and development agencies, scientific associations, the private sector and NGOs to decide on the best strategies to conserve the world's coral reef resources. ICRI is not a permanent structure or organization, but an informal network linked by a global Secretariat. Website: <http://icriforum.org/>



The Dulverton Trust is a UK grant-making charitable trust, with an interest in the field of conservation. It was founded by Lord Dulverton in 1949.

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# Introduction

**C**oral reefs are one of the world's most spectacular ecosystems. They straddle the tropics and cut a broad swathe around the globe. They are clearly visible, even from space, as patterns of dazzling colors tracing the edges of coastlines and scattering far out into the oceans. Up close, the magic of coral reefs is magnified. These ecosystems are packed with the highest densities of animals to be found anywhere on the planet. Thronging with life, they rival even the tropical rainforests in terms of diversity.

From a human perspective coral reefs are not only a source of wonder and fascination. They also represent a critical resource for millions of people. For millennia coastal peoples have relied on coral reefs as a source of food. The wide strips of coral reefs lining their shores have also provided protection from the worst onslaughts of tropical storms. Over the centuries, these same reefs have actually provided the sand for the beaches and even the rocks which make up the islands on which so many people live. In more recent times coral reefs have become the treasured destination for millions who have sought peace and rest on tropical shores, or adventure, diving into the world of the coral reef. These same travelers are providing a new source of income and employment for some of the world's most impoverished nations. Into the future, reefs have the capability to provide new resources for the world's burgeoning populations, most notably with the development of new pharmaceuticals.

## How little we know

It is possible, even today, to pick up the best navigational charts for certain areas and find quite shocking gaps in our knowledge. For some parts of the world, the best information about the location and dimensions of coral reefs was gathered by Captain James Cook and others in the 18th century. On some of these "modern" charts there remain dotted lines showing "possible" locations of reefs, or notes describing reefs as "position unconfirmed". While sea monsters no longer populate our maps, many of the gaps where they once sat still remain.

This lack of knowledge is not simply confined to knowing where the reefs are. Efforts to quantify the total numbers of species which are found on reefs remain largely restricted to wild extrapolations and educated guesses. As many as 100 000 species may have been

named and described from coral reefs, but the total number inhabiting the world's reefs may be anything between half and 2 million, perhaps more.

In some ways this lack of knowledge is not surprising. Many reefs are remote and, as they are far from regular shipping traffic, efforts to map these areas have not been prioritized. Without good charts other navigators remain cautious about sailing in such areas. From an ecological perspective our knowledge has been further hampered by the fact that humans are terrestrial, air-breathing creatures. Early scientists could only peer down with fascination through the intervening waters which separated them from the reefs, or haul up dead or dying samples for inspection. Only in the 1950s did scuba-diving become a popular and relatively safe activity, and our scientific knowledge of the ecology of reefs has almost entirely been amassed over the last 50 years.

## The World Atlas of Coral Reefs

This atlas presents a unique compendium of information. It provides a summary of what we know about the geographic distribution and status of coral reefs at the start of the third millennium. Unfortunately, even as we have begun to gather this information, the reefs themselves have been changing. The atlas also provides information on the changes which have already occurred, and on the human impacts on the coral reefs in every country.

This atlas is primarily an information resource. Putting such information together at the global level is more than a summary, however, and provides us with an entirely new perspective.

The first three chapters provide a global review of the coral reefs, firstly taking an ecological and geological perspective, then a human perspective, and finally looking more specifically at the task of mapping coral reefs. The main bulk of the book is then focussed towards a region-by-region review of coral reefs.

The most important resource in any atlas is the maps themselves. The UNEP World Conservation Monitoring Centre first commenced its global coral reef mapping work in 1994 and has now developed the most detailed global maps of coral reefs in existence. These maps show the distribution of the vast majority of the world's shallow coral reefs. Equally important with the maps in this atlas has been to place the location of coral reefs in a wider

context. The maps in this book thus show major natural features (forests, rivers, topography and bathymetry), but also significant human factors, including settlements, dive centers and marine protected areas.

The texts and tables provide information which enables a more detailed interpretation of the information provided on the maps, including information which cannot directly be shown on the maps themselves. For all countries and territories where there are reefs, basic information is provided describing the distribution of the reefs and some ecological features. Human uses and impacts on coral reefs are further considered, including efforts to control such impacts or protect coral reefs. Data tables list all the protected areas with coral reefs, but also provide directly comparable information describing the countries, their reefs, and the human impacts on these.

Users of this book can learn about the location and status of coral reefs around the world. Those traveling regularly to coral reef areas, for leisure or for work, can use the *World Atlas of Coral Reefs* to learn about new areas before they visit, to get a basic grounding in the ecology of coral reefs, and to consider the issues and challenges facing reefs in particular areas. Experts from particular locations, or in particular subjects, can learn about other areas, and gain useful information about different parts of the world.

A considerable amount of information held within the pages of this atlas has never been published before.

■ The work includes a new, revised global estimate of the total area of coral reefs worldwide. In Chapter 1 it is estimated that shallow coral reefs worldwide occupy some 284 300 square kilometers, an area about half the size of Madagascar. This is less than 1.2 percent of the world's continental shelf area, and only 0.09 percent of the total area of the world's oceans. Coral reefs are a scarce, but critically important resource.

■ An assessment of the area of coral reefs in individual countries provides an important perspective on the ownership and responsibilities associated with this critical heritage. Indonesia is the largest coral reef country in the world, followed by Australia and the Philippines. Also high up the list are many small nations in terms of land area: Papua New Guinea, Fiji, the Maldives, the Marshall Islands, Solomon Islands, Bahamas and Cuba.

■ The same statistics also point to the important role which a number of the world's very wealthy nations could play in protecting the world's coral reefs. Australia, France, the UK, the USA and even New Zealand hold jurisdiction or significant influence over coral reefs in their own waters and in the waters of their overseas territories and associated states. Together these cover over one quarter of the world's coral reefs.

■ Using information from the new taxonomic work *Coral of the World*, JEN Veron has provided the very latest information on coral biodiversity around the world. National statistics have been calculated for all countries and clearly illustrate the critical heritage which is currently being threatened by human activities. The most diverse region of the world for coral reefs is centered on the Philippines, Indonesia, Malaysia and Papua New Guinea, with between 500 and 600 species of coral in each of these countries. Unfortunately these are also some of the most threatened coral reefs in the world.

■ Reef tourism is now a major global industry. Visitors to the Great Barrier Reef increased from 1.1 million in 1985 to over 10 million in 1995. Scuba diving is probably the most popular adventure sport in the world, and vast numbers of scuba divers visit coral reefs every year. A new database has been gathered which gives the location of dive centers around the world. This contains information on over 2 000 dive centers, marked on the maps throughout this work. They show, quite clearly, that diving tourism is now ubiquitous, and is located in 91 countries and states.

■ Marine protected areas are becoming a critical tool for the protection of coral reefs worldwide. They are being widely used, not only for conservation, but also to enhance fish catches, by protecting small stocks of fish which are able to resupply adjacent areas. There are now some 660 marine protected areas worldwide which incorporate coral reefs. These include two of the world's largest protected areas, Australia's Great Barrier Reef and the northwestern Hawaiian Islands, covering entire large ecosystems.

■ Unfortunately, many protected areas exist on paper only – they are poorly managed and have little or no support or enforcement. Equally worrying is that in almost every single case, protected areas are aimed solely at controlling the direct impacts of humans on coral reefs. Fishing and tourist activities may be controlled, but the more remote sources of threats to reefs, notably pollution and sedimentation from the adjacent land, continue unabated. Without a more concerted effort to control all of the impacts of humans on coral reefs even the best managed marine protected areas may be managed in vain.

■ There are other stories, however, which provide valuable examples of success. Fisheries reserves in a few areas are now revitalizing the food supplies and economies of local villages, while tourist income is paying for the wise management of a number of important areas. It is vital that the messages from these sites are carried as swiftly as possible to all countries and communities who depend on coral reefs.

Aside from such clear statistics, the pages of this atlas reveal a startling, recurring tale of degradation and loss.

■ Corals are extremely sensitive to increases in temperature, exhibiting a stress response known as coral bleaching. Records of such bleaching have increased considerably in recent years, and in 1998 a global mass bleaching event occurred, with devastating mass mortalities of corals in many areas. Recovery is now underway, but there are very real concerns about the recurrence of such events with global climate change.

■ In the Caribbean apparently natural damage from disease and hurricanes has been exacerbated by the impacts of human activities, and reefs have lost coral cover and diversity in almost every country, even in many apparently remote and protected locations.

■ In Southeast Asia burgeoning populations and rising living standards are placing untenable pressures on the coral reefs, and many are succumbing, no longer able to provide the fish and other resources which have supported coastal populations for generations.

■ Even the more remote reefs worldwide are not secure. In the past, remote atolls in the Pacific have been used for testing nuclear weapons and for dumping waste, and even today a number are still used for military target practice. More widespread has been the impact of fisheries. In many places traditional management and restraint has enabled sustainable use of fish resources, but such traditional systems are breaking down in some areas, while better transport and high prices are driving stocks of some target species towards complete disappearance, even in quite remote locations.

### **The problems facing the world's reefs**

Natural changes are a part of any ecosystem, and we are still at the early stages of understanding the natural dynamics of coral reefs. However, the 20th century saw the near exponential growth of human populations, combined with even more rapid increases in consumer demands being placed on the planet's limited resources, and such trends are set to continue through the 21st century. Humans are thus bringing new pressures to bear on the world's coral reefs and driving more profound changes, more rapidly, than any natural impact has ever done. Overfishing has become so widespread that there are few, if any, reefs in the world which are not threatened. This, combined with such destructive practices as blast fishing, is shifting the patterns and balances of life in many reef ecosystems. From onshore a much greater suite of damaging activities is taking place. Often remote from

reefs, deforestation, urban development and intensive agriculture are now producing vast quantities of sediments and pollutants which are pouring into the sea and rapidly degrading coral reefs in close proximity to many shores.

The impacts of these activities affect not only the reefs, but also the many millions of coastal peoples who depend upon them for sustenance and income. In many areas these changes are so rapid that we are unable to document the existence of reefs before they are degraded. We have no idea how much has already gone.

A further specter overshadowing the world of coral reefs is that of global climate change. It is now universally accepted that the global climate is changing at an accelerated rate as a result of human activities. Coral reefs, it would appear, are among the most vulnerable ecosystems to rising sea surface temperatures. Coming on top of the other threats already mentioned, it seems highly probable that the predicted rises in sea surface temperatures over the next century may well cause the total demise of at least some of these critical, valuable and beautiful ecosystems.

### **Faint glimmers of hope**

As our knowledge and our concern about coral reefs is increasing, so are the efforts to redress the problems. Overfishing is a worldwide problem, and its most damaging impact is on the fishing communities themselves. Thankfully, examples are now cropping up around the globe of successful management efforts which can remedy the problem. By setting aside small areas as "no-take" zones, local communities are finding that there are enormous benefits. Fish stocks build up in these zones and spill over into the surrounding area such that the overall yield of fish from the wider area is increased. Everyone benefits.

Tourism has caused considerable damage, through the unplanned coastal development and pollution which are so often linked to it. The sewage systems of many hotels empty directly into the waters where the guests swim, and the damage to reefs can be considerable. Increasing awareness, however, is leading to better controls on development and major efforts to improve sewage treatment. As such measures develop, tourism can become a force for good, giving an added value to reefs in the eyes of the local communities, and often providing a direct income, through park fees, for the management of marine protected areas.

Most importantly, our increasing understanding of the interactions between humans and reefs, and between terrestrial activities and their downstream impacts in the coastal zone, are allowing for the development of integrated planning. We are aware of the problems, and have the solutions. The challenge is to apply them.