Status of Coral Reefs of the Pacific and Outlook: 2011

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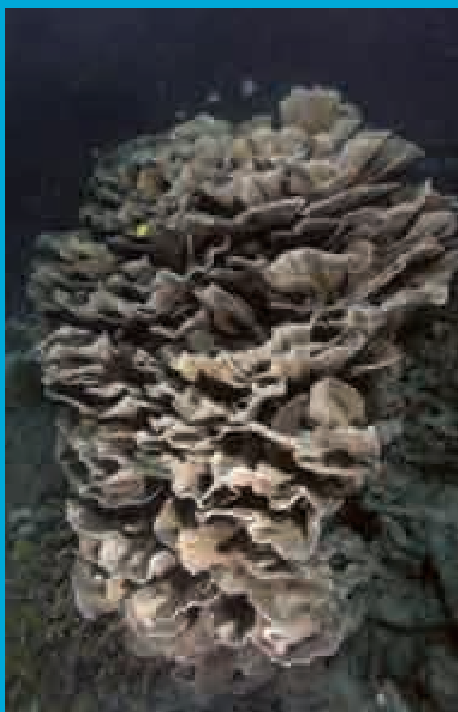
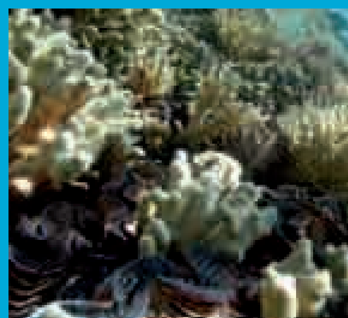
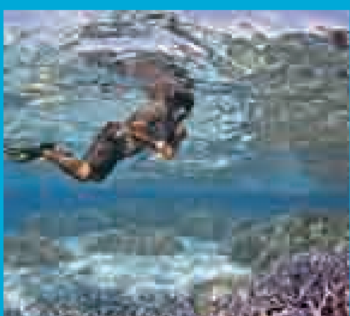
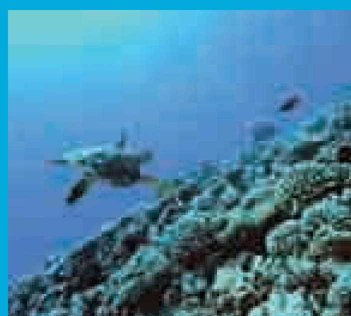

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We dedicate this report to the Peoples of the Pacific who are facing existing and increasing challenges on numerous fronts. It is our hope that this report will help to drive action that makes a real difference in the health and well being of the Pacific community, and in ensuring the protection and wise-use of their coral reefs and resources.

Photographs on the Front and Back Cover are explained and credited inside the back cover.

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Authors [see on the back page]

Foreword for the Pacific Report

Many of us were introduced to the coral reefs of the Pacific through the books and films of that famous French diver, Jacques Yves Cousteau. He was able to bring the beauty and pristine nature of Pacific coral reefs to people around the world.

Since the time of Captain Cousteau, however, large areas of the world's coral reefs have declined due to the many pressures put on them by global changes and human activities. Reefs have been damaged by destructive fishing practices, terrestrial and marine pollution, siltation from land clearing, poor agricultural practices, urban development, and, more recently, as a result of global climate change, which is causing ocean warming and increasing acidification. It has been estimated by the Global Coral Reef Monitoring Network that the world has effectively lost 19% of productive reef area, with another 15% under immediate threat of loss. This means that millions of people are being deprived of the goods and services provided by coral reefs, such as food from fish, molluscs and algae, tourism benefits and shoreline protection.

Fortunately, recent studies have found that the reefs of the Pacific are faring better than reefs in other parts of the world – almost 52% of Pacific reefs were recently assessed as being at "low risk"; however, for the other 48%, there is no room for complacency. This means that the Pacific holds a wealth of healthy reefs that must be maintained for the peoples of the Pacific and for the world.

Throughout the Pacific, there are literally thousands of islands that range from large mountains surrounded by fringing coral reefs to tiny coral atolls that are all that remains of collapsed volcanoes. Reefs are critically important to Pacific peoples and form an integral part of their livelihood and cultures. People living on small coral islands have developed rich cultural traditions to conserve the resources of their reefs for future use. For example, many communities declare part of their reef as temporary no-take areas (tabu or tambu or ra'ui) to guarantee larger fish catches for special feasts. We now recognise the value of this traditional knowledge and it is essential to include the best aspects into management methods.

In 2010 and 2011, the Governments of France and Samoa, in conjunction with Monaco, chaired the International Coral Reef Initiative. ICRI was launched in 1994 as the only global entity devoted solely to coral reefs. Its aim is to preserve coral reefs and related ecosystems by implementing Chapter 17 of Agenda 21 of the United Nations Convention on the Law of the Sea, and other relevant international conventions and agreements. At the same time, the Global Coral Reef Monitoring Network (GCRMN) was established as an operating network of ICRI, which assists in the development of coral reef monitoring and data management, with equal emphasis on ecological and socio-economic information, and compiles reports on the global status of coral reefs worldwide.

For the last decade, our governments have been very concerned about the health of coral reef ecosystems. In that regard, France, in 1999, launched the French Coral Reef Initiative, and have funded several regional programs, including the very successful Coral Reef Initiatives for the Pacific (CRISP). In Samoa, one of the most advanced Pacific small island States in coastal management, traditional culture and management methods are still alive for the benefits of its people and environment. For the past 2 years, France and Samoa have highlighted the threats to the ocean environment, including ocean acidification, pollution, and illegal and destructive fishing.

We also have urged the international community to work towards better management of coral reefs and related ecosystems, and have been pushing to bring the Ocean back into the next UN Earth Summit at Rio+20. Indeed Rio+20 is the opportunity to effectively tackle the international governance of the world's oceans and, in the context of sustainable development, recognize and address the possibilities of a "blue economy", which is vital for so many island and coastal States. We were also very successful in having ICRI recognized in the United Nations Report of the Secretary-General entitled "*Protection of coral reefs for sustainable livelihoods and development*" as the only global entity devoted solely to coral reef conservation.

We are very pleased to endorse this report, which provides the first comprehensive assessment on the status of all coral reefs throughout the Pacific, but particularly to emphasise the current management capacity and the outlook of these reefs in the face of increasing local pressures and climate change.

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Executive Summary

Synopsis

- Coral reefs are integral to the cultures and nutrition of many Pacific peoples; this report was developed to assist reef conservation for those peoples;
- Most coral reefs in the Pacific remain generally healthy, with strong potential for recovery of coral, fish and invertebrate populations after damaging events;
- There are, however, many signs of decline, especially on reefs around population centres and in lagoons;
- The main drivers of changes in coral cover at larger scales include major ‘natural’ stresses in storms and cyclones, outbreaks of crown-of-thorns seastars (COTS) and coral bleaching driven by climate change;
- The trends in coral cover vary considerably from country to country. Current reef status is a reflection of recent damaging events, predominantly ‘natural’, and most damaged reefs appear to be recovering. While trends in reefs can be detected for individual countries and territories, no strong Pacific-wide or regional trend is evident;
- At more localised scales, coral reefs are driven by the interactions between many, environmental and human factors. These damaging human factors include: over-exploitation of fishes and invertebrates; sedimentation from poor land-use such as agriculture; mining of coral and sand; urban and tourism developments; and pollution from domestic and farming wastes;
- Fishing and harvesting have definitely affected coral reef communities across the Pacific, especially in close proximity of towns, but the magnitude of these effects varies considerably between countries and islands;
- Traditional management practices, such as permanent or temporary closure of fishing areas or bans on catching some species, remain particularly strong in the Pacific and are a major force for coral reef conservation;
- Many countries and territories have sound legislation to manage coral reef resources, but lack the capacity, logistic resources and sometimes the political will to enforce these laws. However, many countries and territories are making efforts to improve capacity for enforcement and raise awareness of the need for reef conservation; and
- Our conclusions are that **the longer-term outlook for the coral reefs of the Pacific is considered to be Poor due to threats posed by climate change**.

Summary

The coral reefs of the Pacific are in better condition than those in other reef regions in the world, and remain the less stressed compared to reefs elsewhere. This is encouraging considering that recent global reports paint a gloomy picture of the status (and likely future prospects) of large areas of the world’s coral reefs. However, the longer term outlook for Pacific reefs is not encouraging with increasing human-induced threats and global climate change predicted to result in considerable damage in coming decades. This constitutes our conclusion, while many of the reefs in the Pacific appear healthy and resilient now, the outlook is poor.

Most Pacific reefs are in reasonable to good condition with either healthy or recovering coral communities and reasonably intact coral reef fish and invertebrate populations. There are large numbers of coral reefs spread over vast areas of the Pacific that are remote from human pressures; these remain among the best preserved reefs in the world. Many of these reefs grow around low lying and uninhabited atolls with few human pressures and no runoff from the land. Recently, there have been active processes to declare many of these reefs as protected areas with considerable success.

In contrast, coral reefs adjacent to larger population centres show clear evidence of over-fishing, pollution from nutrients and sewage, damage from coastal and catchment developments, and increasing damage from land-sourced sediments washing off high volcanic islands. Most of the high islands in the Pacific are steep and recent in origin, such that they contain readily erodible soils. Unsustainable exploitation of forest timbers is a major cause of severe sediment damage to downstream coral reefs.

Human population growth is generally very high in the Pacific, which will result in increasing fishing, pollution and development pressures. There is already clear evidence of damage arising from global climate change with erosion and inundation of shorelines of coral atolls from sea level rise, increasing temperatures resulting in coral bleaching and death, rising ocean acidification reducing coral growth, and predictions for more very damaging tropical cyclones.

This Pacific Status and Outlook report summarises all the readily *available and accessible information* about the coral reef ecosystems of the Pacific. This report has two objectives: provide an overview of the status of coral reefs of Pacific Island Countries and Territories (PICTs) by collating and synthesising recent regional summaries and national reports; and organise and standardise this information to develop a preliminary assessment of the future outlook for coral reefs of the Pacific. The report seeks to identify and describe the main trends and patterns for each of 5 themes: coral reef condition; coral reef health with emphasis on resilience; use of reef resources; factors affecting coral reefs; and governance and management.

In assembling this report, we identified many gaps and uncertainties in the available data and information. These gaps are not uniform throughout the Pacific, as some PICTs have assembled considerable data and information for many of their reefs; however, most PICTs have undertaken limited monitoring and assessment, therefore the level of 'confidence' used to describe each theme is often very low. The low level of information reflects the social, cultural, economic and political circumstances of many PICTs, which have inadequate resources and capacity for effective monitoring and follow-up assessment of management effectiveness.

Some PICTs have conducted long-term monitoring programs that assist in describing trends in coral reef communities, resources and use patterns. Other PICTs have started monitoring recently that will provide a critical baseline to assess trends and patterns in the future. The ongoing problem for reporting on reef status throughout the Pacific is that many of the island groups are scattered across vast stretches of ocean, making monitoring particularly difficult and expensive. This is also a challenge for management to gather fisheries catch and effort data, to enforce fisheries regulations and address illegal and/or unreported fishing, such as fish poaching and shark finning.

This report follows two previous global reports [1, 2] that had similar findings, in summary:

- **coral reef condition.** The condition of most reefs in the Pacific is stable to healthy, with either good coral growth or recovering communities, and relatively healthy fish and invertebrate populations. The condition of the reefs is usually a direct reflection of recent major disturbances in the past 2 decades, especially major coral bleaching events, crown-of-thorns seastar (COTS) outbreaks, and major tropical cyclones. There is, however, clear evidence of damage resulting from over-exploitation and pollution on reefs near the major centres of human activity;

- **coral reef health and resilience.** In general, most Pacific reefs retain strong resilience to damage and demonstrate the ability of coral communities and fish populations to recover after major damaging events such as cyclones, coral bleaching and COTS outbreaks. However those reefs adjacent to population centres or major developments have lost much of their resilience and long-term decline in status is evident; these reefs are either not recovering or recovering slowly;

- **use of reef resources.** Pacific peoples are highly dependent on coral reef resources and have amongst the highest per capita consumptions of fisheries products in the world. However this dependence is resulting in over-exploitation near population centres with more people fishing and using more advanced and efficient technology. Destructive fishing practices are also reported from a few locations. The Secretariat for the Pacific Community has calculated that a 46% increase of fish production will be required to meet requirements to feed the growing populations in the next 20 years. The predictions are that Melanesia + Micronesia + Polynesia will require an increase from 245,000 to 369,000 tonnes in the annual supply of fisheries products [(3)]. Coral reefs are also mined for sand and rock for construction which results in localised damage; this is particularly serious in the face of rising sea levels. Tourism is a major use of coral reefs in some locations, and while delivering substantial economic benefits, poorly managed tourism can damage reefs through inappropriate coastal development and recreational overuse;

- **factors affecting coral reefs.** Reefs in the Pacific are threatened by the same stresses that damage reefs elsewhere in the world. The major factors (aside from direct extractive use) include nutrient pollution and eutrophication (from sewage, runoff of fertilizer and livestock waste), sediment pollution from poor land development including deforestation, agriculture and tourism resort construction, urban coastal development and dredging, destructive COTS outbreaks, and the more global threats of climate change resulting in coral bleaching, ocean acidification and increases in storm severity that all damage coral communities. The ameliorating factor in the Pacific is that most reefs are growing on the sides of seamounts in very deep water, such that pollution from the land is usually rapidly dissipated, except where it is retained in coral reef lagoons; and

- **governance and management**. Pacific Island Countries and Territories are acutely aware of the need for effective management of their coral reefs which are vital for their cultures and economies. However, few of these island states have the capacity and logistic resources to effectively manage their coral reefs that are often spread over vast distances. Most PICTs have effective legislation for reef management, but few have the capacity for effective enforcement of the regulations, and in some cases there is inadequate political will to enforce the laws. It is encouraging that most PICTs are increasing their efforts at reef conservation and there has been the recent declaration of very large areas of the Pacific Ocean with no-take protection aimed at conserving the coral reefs. The re-invigoration of community-based and traditional management in some locations is another promising development in managing reefs in the Pacific

The 2011 *Reefs at Risk Revisited* report identified slightly less than 50% of Pacific reefs as being threatened by local activities, of which only 20% are at high or very high threat. Overfishing and destructive fishing is the most widespread threat, followed by watershed-based pollution, coastal development, and marine-based pollution and damage [(1)]. However, 52 % of reefs were rated at a low risk level, which makes it the least threatened region, after Australia. *Reefs at*

Reefs at Risk Revisited - Integrated Local Threat Results by country (grouped by GCRMN 2011 Nodes in this report)

Region / Country	Area of Reefs (sq km)	Reefs at Low Threat	Reefs at Medium Threat	Reefs at High Threat	Reefs at Very High Threat	Total Reefs Threatened (Medium or Higher) by Local Threats
Southwest Pacific Summary	**38,460**	**43%**	**31%**	**19%**	**6%**	**57%**
Fiji	6,704	34%	34%	21%	10%	66%
Nauru	15	0%	0%	20%	80%	100%
New Caledonia	7,450	63%	30%	6%	0%	37%
Papua New Guinea	14,535	45%	26%	22%	7%	55%
Solomon Islands	6,743	29%	42%	24%	6%	71%
Tuvalu	1,210	84%	12%	4%	0%	16%
Vanuatu	1,803	8%	37%	41%	14%	92%
Micronesia Summary	**9,855**	**70%**	**21%**	**6%**	**3%**	**30%**
CN Mariana Islands	182	10%	6%	18%	66%	90%
FS Micronesia	4,925	70%	23%	6%	1%	30%
Guam	225	54%	1%	16%	29%	46%
Palau	966	69%	26%	3%	1%	31%
Marshall Islands	3,558	74%	20%	5%	1%	26%
Polynesia Mana Summary	**12,588**	**58%**	**27%**	**12%**	**3%**	**42%**
American Samoa	129	13%	32%	44%	11%	87%
Cook Islands	528	51%	39%	9%	1%	49%
French Polynesia	5,981	76%	15%	7%	2%	24%
Kiribati	3,041	29%	55%	16%	0%	71%
Niue	45	2%	71%	26%	0%	98%
Samoa	402	0%	6%	43%	51%	100%
Tokelau	155	55%	45%	0%	0%	45%
Tonga	1,662	63%	26%	9%	2%	37%
Wallis And Futuna	646	68%	12%	19%	1%	32%
Hawaiian Islands Summary	**3,834**	**83%**	**3%**	**6%**	**9%**	**17%**
TOTAL - PACIFIC REGIONS	**64,736**	**52%**	**27%**	**15%**	**5%**	**48%**
Australia (Pacific Coast)	36,834	86%	13%	1%	<1%	14%
Global Total	**249,713**	**39%**	**34%**	**17%**	**10%**	**61%**

Table 1a. These estimates of current threats to coral reefs from local pressures illustrate that Pacific reefs (and on the GBR of Australia) are under less pressure from local threats than reefs elsewhere in the world. Global climate change remains the largest single threat to Pacific reefs exceeding these local impacts. Predictions that include climate change effects out to 2030 and 2050 are included in the more detailed country assessments from Reefs at Risk Revisited section in each country chapter (from Reefs at Risk Revisited*)* [(1)] .

Status 2008 Regions	Reef Area (km^{-2})	Reefs effectively lost	Reefs at critical stage	Reefs at threatened stage	Reefs healthy
Southwest Pacific	27,060	3%	17%	35%	44%
Micronesia	12,700	8%	7%	15%	70%
Polynesia Mana	6,733	3%	2%	5%	90%
Hawaii & islands	1,200	2%	4%	8%	86%
Australia & PNG	62,800	3%	4%	10%	83%
Pacific Total	**110,493**	**4%**	**7%**	**16%**	**72%**
World Total	**284,803**	**19%**	**15%**	**20%**	**45%**

Table 1b. These assessments and predictions were assembled using predominantly expert opinion and anecdotal data in Status of Coral Reefs of the World: 2008 [(2)]*. While the assessments in Tables 1a and 1b vary in methodology groupings of countries, and the area of reef listed per country, they do illustrate that the Pacific reefs (including all those of Australia) are in a far healthier state than most reefs elsewhere in the world. Global climate change remains the largest single threat to Pacific reefs far exceeding local impacts.*

Risk Revisited results, grouped according to the regions used in this report, are presented in Table 1a.

Monitoring assessments combined with anecdotal reports gathered by the Global Coral Reef Monitoring Network listed 11% of reefs as either effectively lost or critically threatened, with 72% of reefs at a healthy stage (BUT excluding the threats of climate change) [(2)]. These assessments (Table 1b) point to the Pacific reefs being amongst the most healthy in the world, but both reports emphasise that this is no reason for complacency [(2)].

Major threats to the coral reefs of the Pacific

The major threats to the region can be categorised into two major classes:

- larger-scale, mostly global threats, some of which are truly natural and others linked to human activities operating at a global scale; and
- localised stresses that predominantly result from direct human activities.

The major medium to long-term threats are from global climate change. Rising sea surface temperatures inducing coral bleaching and mortality, probable increases in very destructive cyclones/typhoons, and increasing ocean acidification pose threats to all reefs in the Pacific. The specific nature of these threats at the local scale will vary considerably, particularly as most Pacific reefs are surrounded by deep ocean waters that will buffer some of the temperature and acidification rises. But unless the emissions of greenhouse gases decrease markedly, the future prospects for all coral reefs, including those in the Pacific, is bleak. Sea level rise poses a severe threat to low lying coral islands in the Pacific, particularly those sitting on seamounts that are sinking. There is a real threat that nations such as Kiribati, the Marshall Islands, Tokelau and Tuvalu will become uninhabitable in coming decades; they are already suffering significant erosion.

The other major larger scale threat is posed by outbreaks of COTS which have devastated coral communities on many Pacific reefs. Generally, reefs retain a latent capacity to regrow the corals after such devastating coral predation, however reefs under chronic local stress and bleaching damage may have much lower recovery potential.

The major local threats are from over-fishing and destructive fishing; this particularly threatens many reefs near human populations, particularly via the removal of herbivorous fishes. Reef damage is occurring from coastal development for urban infrastructure and tourist resorts, from local pollution by untreated or poorly treated sewage, and from some minor industries such as fish processing and sugar refining industries. Most reefs around high islands and atolls are surrounded by deep water which can rapidly dilute such pollution; whereas pollution is retained in lagoons and over broad reef flats, thereby damaging these reefs. These threats, however, are at a much lower level than in most other parts of the world, especially in nearby East Asia.

Pacific Island countries and territories face increasing pressures and challenges from population growth and globalization that will result in increases in local threats; and most of these will be exacerbated by global climate change. These threats and likely impacts are summarised in the 2005 UNEP/SOPAC Environmental Vulnerability Index [(4)].

Major conservation activities and initiatives

There have been a series of major conservation initiatives in the region over the past 5 years; the main ones being the:

- Coral Triangle Initiative, which includes Papua New Guinea and the Solomon Islands;

- The parallel 'Pacific Coral Triangle Initiative', which includes Fiji and Vanuatu;
- Micronesia Challenge which was launched by the leaders of Federated States of Micronesia, Guam, Palau, Northern Mariana Islands and the Marshall Islands with a commitment to have 30% of coastal waters and 20% of the land area under active conservation management by 2020;
- World Heritage Listing of the Lagoons of New Caledonia to protect large areas of coastal habitat;
- Man and and Biosphere Reserve (UNESCO) Listing of Fakarava in French Polynesia, which includes seven atolls in the Tuamotu archipelago;
- World Heritage Listing project of the Marquesas Islands in French Polynesia;
- Phoenix Islands Protected Area launched by the government of Kiribati with assistance from major NGOs;
- The major extension of protected area status with the designation and World Heritage Listing of the Papahānaumokuākea Marine National Monument covering the Northwest Hawaiian Islands; and
- The Declaration of the Marianas Trench Marine National Monument and the U.S. Pacific Remote Island Areas conserves many remote islands with extensive and healthy coral reefs.
- On 25 November 2011, Australia proposed that about 1 million km^2 of the Coral Sea be granted greater protection under the 'Coral Sea Commonwealth Marine Reserve'. This is proposal is open for public consultation.

Unlike elsewhere in the world, the Pacific retains many of the traditional management philosophies and activities. These were developed over hundreds of years to conserve scarce coastal resources, especially coral reef fish and invertebrate stocks. Traditional societies had a system of temporary closures of some of their reef area (called 'tabu', or 'ra'ui/rahui') to increase resources for special feasts. These have been incorporated in a rapidly expanding system of Locally Managed Marine Areas, driven largely by initiatives from Fiji. There is also a strong movement for co-management of coral reefs between communities and government. One particular example is the incorporation of local fisheries reserves into the national legislation in Samoa. Another is the management plan of Moorea's coral reefs (PGEM), voted in the local legislation of French Polynesia, and serving as a model for the management of several other islands (Bora Bora, Tahaa).

Recommendations for Action

- Be part of a global campaign to urgently combat Climate Change by reducing emissions of greenhouse gases;
- Maximise coral reef resilience by reducing overfishing and habitat degradation;
- Address excess population growth and unsustainable resource use;
- Develop national adaptation strategies for the social, cultural and economic impacts of climate change;
- Stop destructive fishing and manage coastal fisheries to ensure sustainable use;
- Improve catchment management to reduce downstream pollution and control damaging coastal development;
- Provide advice on reducing sediment and nutrient pollution in coastal areas;

- Improve sewage treatment and waste management;
- Develop alternative livelihoods to ease pressures on fisheries resources, including aquaculture;
- Develop more MPAs, link them into networks and strengthen enforcement;
- Train people in communities, NGOs and within governments in reef and socioeconomic monitoring and management;
- Support community-based management efforts through training and recognising traditional management methods; and
- Raise awareness of coral reef problems and possible solutions.

These recommendations are presented in more detail in 'Concluding remarks and recommendations' section on Page 250.

Knowledge gaps

There was insufficient information for some themes chosen in this 'outlook' process to adequately describe trends and patterns with a high level of confidence:

- **Reef health and resilience**: this requires long-term data from several locations over decadal time spans on disturbance and recovery cycles, and reef processes such as coral recruitment, changes in species composition, grazing by herbivores, calcification rates etc. This information is used to understand reef responses to pressures, to provide early warning before catastrophic changes, and to assess management effectiveness, and also for adaptive management;
- **Reef resource use**: trend analyses require long-term data on catch and fishing effort at the species level. Risk assessments, preferably collected over long periods for subsistence and commercial fisheries are especially useful in adaptive management;
- **Factors affecting reef health**: there were anecdotal reports describing damage to coral reefs with indications of worsening trends (e.g. increases in pollution and erosion), but detailed monitoring programs were rarely available to understand how coral reefs respond to management initiatives.
- **Governance and management**: There was little information on the effectiveness of management arrangements, plans, policies, laws and regulations, and little information on implementation. Socioeconomic monitoring of reef users to determine compliance and acceptance of these rules is used to support 'on-ground' monitoring of the reefs.

Country profiles: Southwest Pacific Node

The country and territorial profiles are clustered in the Nodes used by the Global Coral Reef Monitoring Network (GCRMN). The 3 main Nodes are **Southwest Pacific Node** which contains predominantly Melanesian islands coordinated out of the University of the South Pacific in Fiji; **Micronesia Node** coordinated through the Palau International Coral Reef Center (PICRC); and **Polynesia Mana Node** coordinated by CRIOBE in Moorea, French Polynesia.

The **Southwest Pacific Node** contains Fiji, Nauru, New Caledonia, Papua New Guinea, Solomon Islands, Tuvalu and Vanuatu. The reefs have high coral diversity (some of these countries/territories are in the Coral Triangle) and are predominantly in good condition with strong recovery capacity after major disturbances from coral bleaching, COTS and cyclones. The larger island archipelagos of Fiji, New Caledonia, Papua New Guinea, Solomon Islands and Vanuatu have many remote coral reefs with healthy commercial fish and invertebrate populations. Those reefs in close proximity to population centres, show evidence of stress and decline.

Fiji has reliable and consistent monitoring data that report reefs in good condition and strong resilience and recovery potential after coral bleaching, COTS outbreaks and cyclones. Human pressures from fishing, sedimentation, pollution from land-based sources, coastal development and population growth are all increasing around the more populated islands. Reef management is largely driven through traditional communities establishing their own MPAs; recent political disturbances have slowed progress.

Little information is available about the small reef area of **Nauru.** There is intensive reef resource use, and phosphate mining has caused localised damage to the reefs. Effective management is needed to ensure sustainable resource use.

Good long-term data from around Noumea in **New Caledonia** show stable reefs that recover from disturbances, although coral recruitment may be naturally low; data are more sparse elsewhere. Reef resources appear stable, but giant clams and sea cucumbers are depleted and sediment runoff and pollution, especially from nickel mining, has damaged some reefs. Management is improving with increases in MPAs and enforcement capacity, and the listing as a World Heritage site will help further improvements.

Vast areas of reefs in **Papua New Guinea** appear to be healthy with strong ability to recover after disturbances. There is some damage from sediments, pollution, and overfishing; harvest pressures are increasing and rapid population growth will further increase pressures. Legislation is strong, but management is limited by low capacity and political will, and poor access to remote reefs.

Only the Western Province of the **Solomon Islands** has been monitored and this shows reefs with high coral cover and relatively low pollution, but exploitation is increasing in some areas. There are growing pressures around the populated islands with deforestation a major threat. Locally Managed Marine Areas and other community efforts are promising management tools.

Occasional monitoring in **Tuvalu** suggests that reefs are stable. There is over-harvesting of fish and invertebrates around the main island, along with pollution and coastal development damage in the lagoon of Funafuti. Sea level rise is causing shoreline erosion. Community-based management appears to be the best mechanism for reef conservation.

Baseline data for **Vanuatu** indicate generally healthy reefs but declines in some harvested stocks, such as sea cucumbers, green snail, triton and some fish stocks. The government and communities have banned some exploitation, often through periodic closures. Community-based management shows positive results, when government enforcement is less effective.

Country profiles: Micronesia Node

This Node, coordinated from the Palau International Coral Reef Center (PICRC) with support from Japan and the USA, supports Commonwealth of the Northern Mariana Islands (CNMI), Federated States of Micronesia (FSM), Guam, Republic of the Marshall Islands (RMI) and Palau. These reefs have high biodiversity as they border the Coral Triangle diversity 'hot spot'. Most reefs are healthy with strong recovery potential following bleaching, COTS outbreaks and major storms. All countries have formed the Micronesia Challenge to protect 30% of their marine territory and 20% of their land, and there has been an increase in monitoring and management activity. Reefs around population centres are being polluted and over-exploited.

Long-term data from the **CNMI** indicate that reefs near more populated southern regions have reduced coral cover, altered species composition and reduced biomass of some reef fishes; whereas reefs in the north are relatively unstressed. Fish catches have declined and water pollution, coastal development and sedimentation have increased around populated islands. Reef management programs are showing positive results.

Most reefs in **FSM** have high coral cover and strong recovery potential, although reefs near population centres (especially Pohnpei) show damage from sedimentation, pollution, coastal development, and growing population pressures. Fish populations have declined and sea cucumber and trochus fisheries have collapsed. Reef management initiatives are expanding under the Micronesia Challenge.

Reliable long-term monitoring data from **Guam** show some reefs in good condition while others have declined from pollution and COTS outbreaks, with decreased fish stocks in high use areas. Tourism and rapid military expansion will increase sedimentation, land-based pollution, coastal development and recreational use. Enhanced management will be required by Guam and USA, especially to control overfishing.

Long-term data report that coral reefs in the **Marshall Islands** are relatively healthy with high coral cover and abundant fish populations, especially on remote reefs. There is damage to reefs around populated islands from overfishing, coastal development and pollution, along with COTS and storms. Involvement in the Micronesia Challenge will improve capacity for management.

Substantial monitoring around **Palau** started after massive coral bleaching in 1998 and shows that damaged reefs are recovering with strong resilience, but some fish and invertebrate stocks have declined. Increased sedimentation from coastal development, road construction, deforestation, land-based pollution, and increasing pressure from population growth are damaging reefs. Palau is combating overfishing and actively protecting shark populations.

Country profiles: Polynesia Mana Node

The Polynesian islands of American Samoa, Cook Islands, French Polynesia, Kiribati, Niue, Samoa, Tokelau, Tonga and Wallis and Futuna are assisted by the French CRIOBE centre in French Polynesia. Most of these islands are remote from human impacts and in good health, however overfishing, over-development and excessive sediment flows are damaging reefs around inhabited islands. Management effectiveness is variable with some particularly active through better capacity and resources.

Long-term data suggest that coral reefs in **American Samoa** are relatively stable and healthy with good long-term recovery potential. Fish catches and biomass have declined around the main island, Tutuila. Reefs have been damaged by pollution and sediment flows from coastal development and pig farms. Management efforts are weakened by inadequate fisheries management, enforcement and poor awareness.

Reefs around Rarotonga in the **Cook Islands** show strong coral reef recovery from COTS outbreaks in the 1990s. Target fish species, especially parrotfish, have declined. Damage has been caused by COTS, storms and cyclones, land-based pollution, coastal development, sedimentation, and declining water quality. Reef management varies considerably especially where traditional management exists.

The extensive monitoring in **French Polynesia** has documented many cycles of damage and recovery, especially on Moorea. Reef threats vary considerably from mild overfishing on remote atolls to over-exploitation, coastal development, land-based pollution on the populated high islands, in parallel with coral bleaching and COTS outbreaks. Reef management is actively improving with more MPAs, including some co-managed with communities.

Limited data are available from **Kiribati,** but most reefs are relatively healthy, with damage from coastal development and pollution around Tarawa. Resources have declined around towns, while the unpopulated Phoenix Islands are relatively pristine and protected as the Phoenix Islands Protected Area; there is little effective management elsewhere.

Monitoring on **Niue** after Cyclone Heta in 2004 shows reef recovery; but there is over-exploitation of several species, and pollution and sedimentation from land-based sources, inadequate waste management and contamination by agricultural chemicals. Niue has launched 3 new MPAs, but capacity is low.

Reefs in **Samoa** are recovering after Cyclone Heta in 2004 and now are relatively healthy with strong resilience. The abundance and size of some fish populations, especially parrotfish, is low around urban developments. Damage from pollution, sedimentation, as well as from COTS outbreaks, cyclones and from climate change related coral bleaching, has been observed. Community-Based Fisheries Management shows positive results.

Anecdotal reports of reefs in **Tokelau** indicate damage from cyclones and COTS with low coral cover evident. Target fish species have declined through over-harvesting with more efficient fishing practices. Continued traditional management will prove the most effective method for reef conservation.

The occasional surveys of reefs in **Tonga** show relatively low coral cover, with some increases between 2002 and 2008. Overfishing is a significant threat to fish and invertebrate stocks. Other threats are pollution, declining water quality, sedimentation and coastal development, severe storms, COTS outbreaks, tsunamis and volcanic activity. Community-based and government management actions are needed to conserve the reefs and resources.

Wallis & Futuna is a territory of France where monitoring started recently. The reefs are threatened by forest clearing, coastal development, pollution, over-fishing and destructive fishing. This has led to bans on some practices and actions by the French government to improve management on these 3 remote islands (Wallis, Futuna and Alofi).

The coral reefs of the **Hawaiian Archipelago** vary considerably. There is well documented damage from pollution and over-exploitation of reefs around the ‘main’ Hawaiian Islands (MHI) with relatively large human populations; whereas the remote Northwestern Hawaiian Islands (NWHI) are virtually unpopulated and under strict protection with virtually no exploitation and pollution. The MHI coral reefs are particularly important for tourism which is the major economic activity and recognition of this is stimulating stronger and more cooperative management activity. Declaration of the Papahānaumokuākea Marine National Monument has meant that an enormous area of relatively pristine coral reefs is now given even greater protection, especially for the many endemic, rare, threatened and endangered species.

A short summary on the Great Barrier Reef of **Australia** is included in this report. The recent Outlook report was used as the model for this larger-scale report on the wider Pacific [(5)]. The final conclusion of that report was that the future outlook of the GBR was poor, even though this reef system is regarded as the best researched, monitored and managed in the world. The poor assessment was based on some land-based pollution and fishing pressures, but especially on predicted threats from climate-related threats of warming and acidifying seas that could overwhelm the inherent resilience of these extensive reefs.

Caveats: This report was prepared as a contribution to the International Coral Reef Initiative by a partnership of people from the Global Coral Reef Monitoring Network, the World Resources Institute, the Institute for the Coral Reefs of the Pacific (IRCP) and the Centre de Recherches Insulaires et Observatoire de L’Environnement de Polynésie Francaise (CRIOBE), and the Coral Reef InitiativeS for the Pacific (CRISP). The conclusions and recommendations within this report are solely those of the authors and contributors and do not necessarily represent the official positions of these organisations.

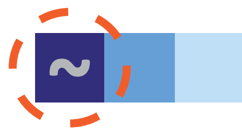
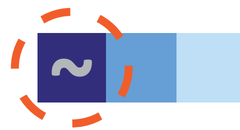
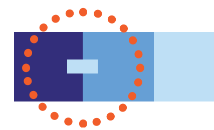
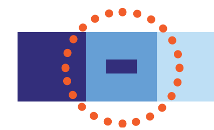
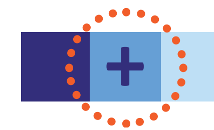
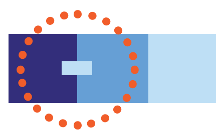
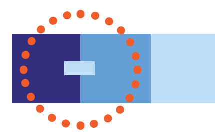
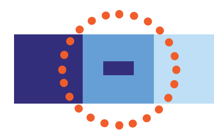
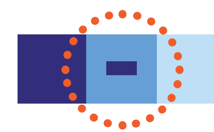
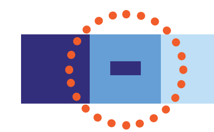
Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

+ – ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Fiji	+	~	–	–	~
	The reliable and consistent monitoring data for Fiji indicates that most coral reefs are in good condition and currently recovering from previous disturbances (coral bleaching, COTS and cyclones). There is little evidence of persistent declines in reef condition and health, and recovery rates indicate good resilience. However, other reefs show signs of chronic stress and impacts from fishing, sedimentation and pollution from land-based sources, coastal development and population growth. Climate change, through coral bleaching and sea level rise, could have serious ramifications. The 2011 Reefs at Risk Revisited report estimates that all Fijian reefs will be threatened by 2030, with more than 65% at high, very high or critical threat levels. Fiji has the legislative base for effective management, but most coral reef management is at the community level; more information is needed to assess effectiveness of management efforts.				
Nauru			–	–	–
	The few survey data from Nauru suggest some differences in reefs around the island, but the information is insufficient to describe status or trends. Long-term monitoring started in 2004 and should be continued. Social and economic data show intensive use of reef resources, with increasing effort coupled with decreasing resources; there are anecdotal reports of over-exploitation. Nauru's reefs have been damaged from previous phosphate mining and coastal development. Risk assessments identify Nauru as vulnerable to damage from climate change and population growth. Few management tools and logistic resources exist to address these issues; thus management needs to improve to ensure sustainable use of Nauru's reefs.				

Stable	Evidence of change	Altered	High confidence	Medium confidence	Low confidence	+ – ~ Directions of current trend
Situation over long term time scales						

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
New Caledonia					
	The long-term data from 10 sites around Noumea show stable trends and little evidence of decline. There is strong ability to recover from disturbances, although coral recruitment appears to be naturally low which reduces recovery potential. Information is insufficient to determine trends in reef resource use although most reef resources appear stable, with some declines in a few species such as clams and bêch-de-mer. There is also little information on factors affecting coral reefs; risk assessments suggest threats from sediment runoff and pollution for some reefs, and concern over potential effects of future population growth and climate change. Management is improving with increases in MPAs and investment in management and enforcement.				
Papua New Guinea					
	The few survey data for PNG indicate that the reefs are healthy with strong ability to recover from disturbances. However, some coastal reefs show damage from sediment, pollution and overfishing. There are increasing pressures on reef resources from harvesting with declines of some species in specific areas. Many reefs, however, are remote with low levels of harvesting. Anecdotal reports and risk assessments indicate that PNG's reefs are affected by pollution and sedimentation, mining and poor land-use practices. High population growth will increase pressure on reefs. PNG has strong legislative mechanisms, but management is limited by a lack of resources, capacity and political will, and ability to access to remote locations.				

Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

\+ – ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Solomon Islands	~		–	–	
	Survey data from the Solomon Islands are limited to 2006-07 in the Western province. These reefs have high coral cover, with natural events being the main drivers of change. There is insufficient information to describe trends in reef health and reef resource use; but there is low density and abundance of harvested fish and invertebrates in some areas, and some species such as sea cucumbers and aquarium species appear depleted. The primary factors affecting reefs are land-based pollution, tsunamis and earthquakes; population growth will pose an additional stress. Management trends are unknown although several challenges are identified. Locally Managed Marine Areas and other community efforts are promising management tools.				
Tuvalu	~		–	–	
	Coral reef monitoring in Tuvalu has been sporadic and limited to the main island of Funafuti. The reefs appear stable, but the long-term trends, patterns of reef resource use are unknown. Anecdotal reports suggest over-harvesting of some fish stocks and sea cucumbers. Other damaging factors include pollution and coastal development (especially around Funafuti); population growth will increase these stresses. Tuvalu is particularly at risk of climate change. There is legislation to manage the reefs, but effectiveness is unknown. Community based management could be an effective mechanism to address specific threats.				

Stable | Evidence of change | Altered

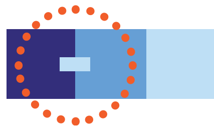
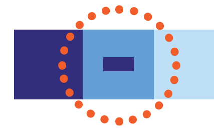
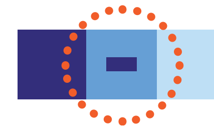
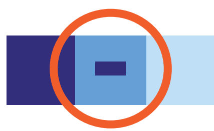
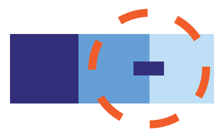
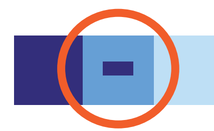
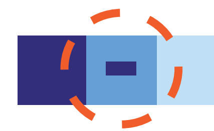
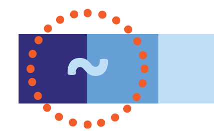
Situation over long term time scales

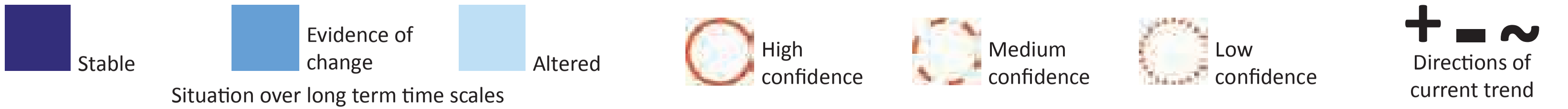
High confidence | Medium confidence | Low confidence

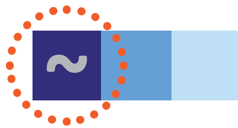
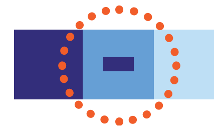
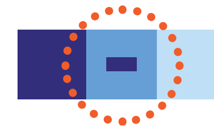
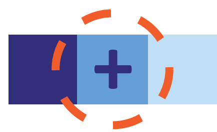
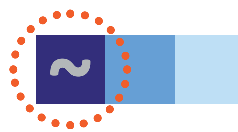
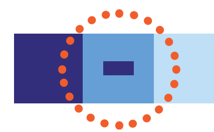
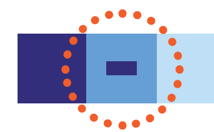
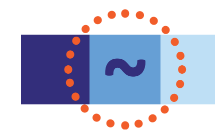
\+ – ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Vanuatu			–	–	~
	Valuable baseline data were collected for shallow reefs in Vanuatu from 2005 to 2007, but these were insufficient to describe long-term trends and health status. Reef resource use data indicates some harvested stocks have declined, which has led to bans on trade in some species (sea cucumbers, green snail, triton), and low densities of targeted finfish and invertebrates in some locations. The primary factors affecting reefs are natural disasters (e.g. cyclones, tsunamis), land-based pollution, sedimentation and population growth. There is legislation for the management of coral reefs, but management effectiveness is not well documented; however, community based management efforts have shown positive results.				
Commonwealth of the Northern Mariana Islands	–	–	–	–	+
	The historical data on coral reefs in the CNMI suggest that reefs in the more populated southern regions have reduced coral cover, altered species composition and reduced biomass of some reef fishes; this includes decreased health and resilience around Saipan. Fish catches have declined with lower biomass around populated islands compared to remote areas. Declining water quality, pollution, coastal development and sedimentation are damaging some reefs around the populated islands. In contrast, the reefs in less populated and remote northern islands are relatively healthy. Climate change is predicted to have significant effects on the reefs. There are programs to manage the reefs with positive results from some initiatives. However, more data are needed in order to describe management effectiveness.				

Stable	Evidence of change	Altered	High confidence	Medium confidence	Low confidence	+ – ~ Directions of current trend
Situation over long term time scales						

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Federated States of Micronesia					
	Long-term reef monitoring in the FSM occurs a few sites and shows reefs with high coral cover, but with damage from human activities (especially those near Pohnpei). The long-term trends in reef health and reef resource use is uncertain. Anecdotal reports suggest declining fish populations and collapses of sea cucumber and trochus fisheries. Destructive fishing occurs in some areas; other damaging factors include sedimentation and pollution around populated islands, coastal development, and increasing pressures from growing populations. FSM will also be affected by climate change. Some recent reef management initiatives are promising; but the effectiveness of these measures is unknown.				
Guam					
	Long-term monitoring of Guam's coral reefs has recently begun, but there are data from the last 40 years. Some reefs are in good condition while other reefs show signs of long-term decline from the status in the 1960s. There are clear signs of declining reef health in some areas. There are good data on reef resource use and some fish communities that show declines in some fish stocks, and damage from tourism and recreational use in high use areas. Some of Guam's coral reefs have been affected by sedimentation, land-based pollution and coastal development; these pressures will increase with more population and expanded military bases. Guam's reefs are also affected by storms, COTS, and are at risk from climate change. Guam has management tools and strategies to address some of the pressures facing coral reefs, with efforts showing signs of success. However, there are few effective fishing regulations, and management challenges are increasing.				

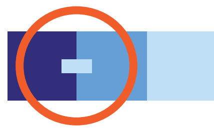
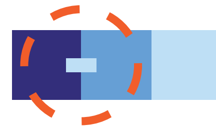
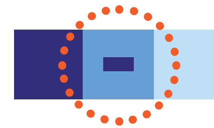
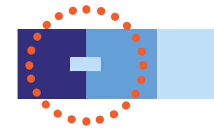
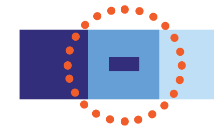
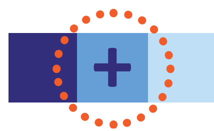
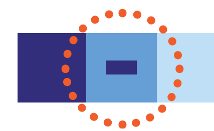


Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Republic of the Marshall Islands					
	Limited long-term survey data for the RMI provide valuable baseline information, and show reefs that are relatively healthy with high coral cover and abundant fish, especially in remote locations. However, there are declines in status around the populated islands. The data are insufficient to describe trends in reef health, patterns of resource use and effects on reefs. Anecdotal reports indicate that fishing and harvesting have reduced reef resources more around populated than remote islands. Increasing pressures from population growth, coastal development, pollution, crown-of-thorns seastars and storms are damaging the reefs; and climate change will exacerbate these declines.				
Republic of Palau					
	The long-term data from Palau show that the reefs seriously damaged by coral bleaching in 1998 are recovering. This indicates long-term stability and good health and resilience. Fisheries catch data, anecdotal reports and risk assessments suggest declines in some fishes and invertebrates, but more data are needed. Other factors affecting Palau's coral reefs include sedimentation from development and deforestation, land-based pollution, coastal development, and increasing pressures from population growth; climate change will add to these stresses. Palau has many promising programs to manage coastal resources, including bans on harvesting some species. However, Palau still faces management issues, such as illegal fishing and more information is required to describe management effectiveness.				

Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

+ – ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
American Samoa					
	Long-term data from American Samoa suggest that the coral reefs are relatively stable (i.e. they recover from disturbances) and healthy. The trend and recruitment data suggest resilience, although some reefs have not recovered to the 1970s baselines, suggesting some damage, especially around Tutuila where fish catches have also declined. There are also changes in reef fish and coral composition; with reduced fish biomass around populated islands compared with remote locations. Reefs have experience localised pollution and sediment damage, and are also threatened by coastal development, increasing populations, storms, COTS and the emerging effects of climate change. There is a legislative basis and capacity to address some issues, but fisheries management and enforcement remain challenges.				
Cook Islands					
	Long-term data for the Cook Islands is restricted to the main island of Rarotonga, but this shows strong coral reef recovery from COTS outbreaks in the 1990s. Reef fish community changes appear to be explained by natural variation, but the data are insufficient to describe reef health and resilience. Targeted reef species, especially parrotfish, have declined and the long-term trends are uncertain. The reefs have been damaged by COTS, storms and cyclones, and climate change will increase this vulnerability. Some reefs are threatened by land-based pollution, coastal development, sedimentation, and declining water quality. Reef management varies considerably between islands; there are many traditional management arrangements. However, trends in management and effects on coral reefs are unclear.				

Stable | Evidence of change | Altered | High confidence | Medium confidence | Low confidence | + – ~ Directions of current trend

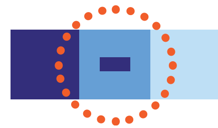
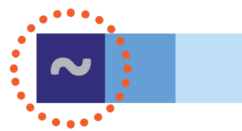
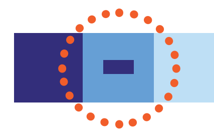
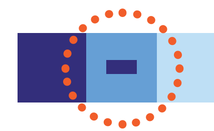
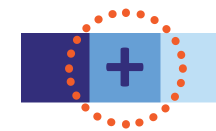
Situation over long term time scales

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
French Polynesia					
	French Polynesia's reefs have a long history of research and monitoring, focused mainly on the Society Islands with some studies done on the more remote reefs. Reefs are generally healthy, especially those exposed to few human pressures. The reefs are damaged by COTS outbreaks, storms and cyclones, and coral bleaching, but the reefs usually recover. Some reefs around the main populated islands have declined, with changed coral and fish communities and inshore reefs lost from pollution and coastal development. Over-harvesting occurs around populated areas. Tourism is a major non-extractive use of reefs, but tourism increases coastal development and demand for reef resources. There is a strong basis and capacity for management that is already implemented, but compliance and enforcement needs improvement in some areas along with measures to determine management effectiveness.				
Kiribati					
	Monitoring in Kiribati is focused on the Gilbert Islands such as Tarawa, and the Phoenix Islands, although monitoring has begun in Kiritimati (Line Islands). The data indicate relatively healthy reefs, with some human-induced damage around the capital Tarawa and coral bleaching on North Tarawa and the Phoenix Islands. The long-term trends in reef health and resilience are uncertain, but new monitoring has started. Resources around towns on Tarawa and Kiritimati have declined, while the unpopulated Phoenix Islands are relatively pristine. Coral bleaching has damaged many reefs, and low-lying islands are vulnerable to sea level rise. Coastal development and pollution cause local damage to reefs, and there are few effective management measures in operation, demonstrating significant management challenges. The establishment of the Phoenix Islands Protected Area was a major step in protecting Kiribati's coral reefs.				

Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

+ ▬ ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Niue					
	Monitoring on the west coast of Niue showed a decline in coral cover after Cyclone Heta in 2004, but with some signs of recovery since. The data are insufficient to describe trends in reef health, resilience, and the use of reef resources, although there are signs of over-exploitation of several species. Other factors damaging factors are pollution and sedimentation from land-based sources, inadequate waste management and contamination by agricultural chemicals. Niue has implemented a range of coral reef management programs, including 3 new MPAs with fishing restrictions; these are promising signs.				
Samoa					
	Monitoring in Samoa started in the 1980s; but systematic long-term monitoring only began in 2002. These surveys indicate healthy coral reefs that are recovering after Cyclone Heta in 2004. This recovery suggests strong resilience, but more data are needed to describe trends in reef status and health. Patchy data on reef resource use suggest declines in diversity and abundance of some fish groups, especially parrotfish, and decreased fish size. Some reefs have been affected by pollution and sedimentation, as well as COTS, cyclones and coral bleaching; the bleaching is linked to increasing sea temperatures from climate change. A variety of management initiatives have been established and the Community-Based Fisheries Management Program shows positive results.				

Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

+ ▬ ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Tokelau				−	
	Sporadic surveys and anecdotal reports since the 1960s indicate damage from cyclones and COTS on Tokelau's reefs. Long-term monitoring started recently showing baseline live coral cover of 12 to 30%, but more data are required to describe trends in reef condition, reef health and trends in reef resource use; although anecdotal evidence suggests declines in some targeted species and concerns about over-harvesting through the use of more efficient fishing practices. Risk assessments have identified coastal development as a threat to the reefs. Tokelau's low lying islands are particularly at risk from rising sea levels. Tokelau relies on traditional management systems and reports indicate varying effectiveness between locations; however the effectiveness of governance and management is unknown.				
Tonga	+		−	−	
	Periodic surveys since the mid 1990s and long-term monitoring since 2004 show that Tonga's coral reefs have relatively low coral cover, but cover has increased at some sites between 2002 and 2008. More data are needed to describe overall trends in reef status, as well as reef health and resilience. Overfishing is a significant threat with evidence of declining finfish and invertebrate stocks, including local extinctions. The reefs experience severe storms, COTS outbreaks, tsunamis and volcanic activity, as well as pollution, declining water quality, sedimentation and coastal development. Establishing effective legislation, enforcement and management are significant challenges in Tonga, although several community-based management initiatives show promising results.				

Stable | Evidence of change | Altered — Situation over long term time scales

High confidence | Medium confidence | Low confidence

+ ▬ ~ Directions of current trend

Country	Reef Condition	Reef Health and Resilience	Reef Resource Use	Factors Affecting Reef Health	Management and Governance
Wallis and Futuna					
	The available information about reefs in Wallis and Futuna suggests there is high coral cover and diversity, although some fringing reefs around Alofi and Futuna show signs of local stress. Most reefs appear to show recovery and recruitment of new corals following disturbances, suggesting good health and resilience, but the long-term trends are unknown. The available data suggest declines in reef resources and stresses affecting the coral reefs include sedimentation, pollution and coastal development. Climate change is predicted to have significant effects on these reefs. Management arrangements have been developed but have not been completely implemented, and the efficacy is not known.				
Hawaiian Islands					
	There is good information about coral reefs of the Hawaiian Islands. Reefs in the more remote Northwestern Hawaiian Islands (NWHI) are in good condition, while the condition of reefs in the Main Hawaiian Islands (MHI) varies with some reefs showing signs of stress and decreased health and resilience. Fish populations in the remote NWHI are relatively pristine compared to the MHI, with fishing impacts increasingly evident in more accessible fishing grounds. Tourism is a major industry in the MHI and may cause localised impacts. Some reefs in the MHI are also affected by pollution, sedimentation, invasive species and coastal development. Marine debris is an issue in both the MHI and NWHI, and climate change could have significant impacts on reefs throughout the archipelago. Management planning, capacity and implementation are generally strong, especially with the designation of large MPAs. However, there is room to improve coordination and enforcement, particularly in the MHI.				

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Introduction

The island countries and territories of the vast Pacific Ocean are scattered across 180 million square kilometers, a third of the earth's surface. There are approximately 200 high islands and 2500 low islands or coral atolls that are home to more than 9 million people [1]. These people live in independent countries and dependent or semi-dependent territories of larger countries. These Pacific countries and territories, however, have a combined land area of just over 550 000 km^2, while they lay claim a wide expanse of ocean with a combined Economic Exclusion Zone (EEZs) of just under 30 million km^2 (Fig. 1).

While the Pacific is vast, it is coming under increasing pressure. The population of Pacific Island Countries and Territories (PICTs) is projected to double to more than 18 million by 2050 [1], and numerous threats have already been identified ranging from localised effects of fishing and pollution, to regional and global threats arising from geo-physical forces, oceanography and climate change [2, 3].

This report covers 22 island countries and territories of the tropical Pacific, commonly referred to as the Pacific Island Countries and Territories (PICTs) of predominantly Melanesian, Micro-

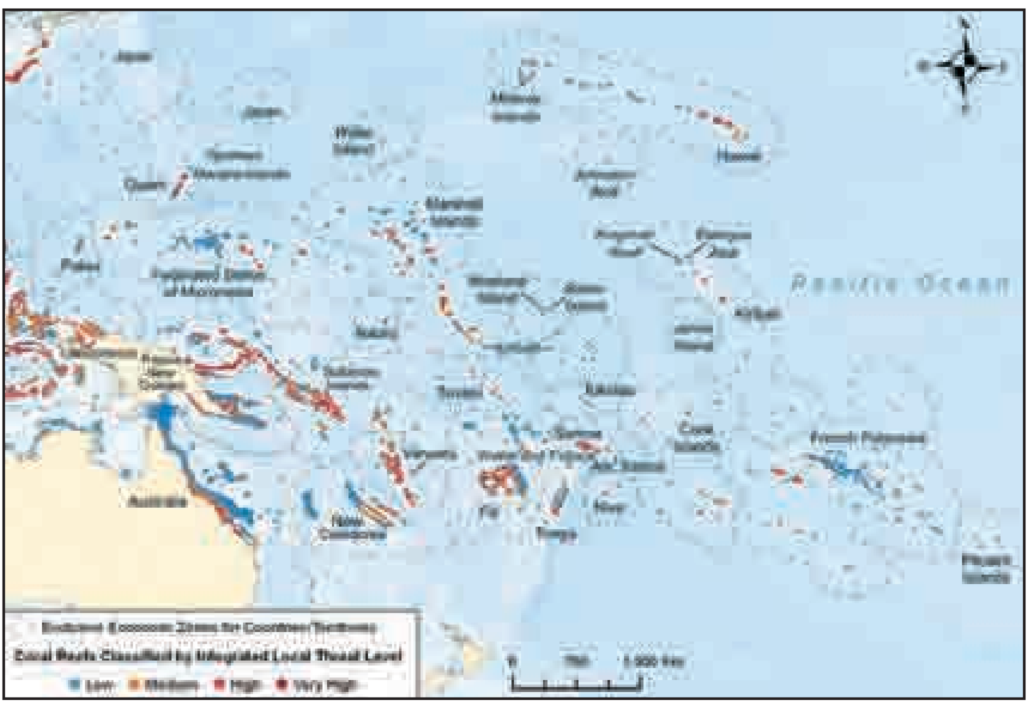


Fig. 1. This map from the World Resources Institute (WRI) illustrates the immense area of the Pacific Ocean and the location of the 22 countries and territories in this report. The map illustrates the current level of threat to coral reefs in each 'country' as found in the WRI 2011 report, Reefs at Risk Revisited. Each country chapter contains a more detailed analysis of that information and predictions for these reefs out to 2030 and 2050. These analyses and predictions were synthesised from the key available information on the status of coral reefs in each country, the present threats to coral reefs from local activities, and projected threats due to climate change.

nesian and Polynesian peoples. Also included in this report is a report on Hawai'i and a short summary of the Great Barrier Reef of Australia.

This report focuses specifically on coral reefs, and associated ecosystems and all their marine species, especially corals, fishes, and other valuable resources for Pacific peoples. This report complements existing reports that are part of the Global Coral Reef Monitoring Network's (GCRMN) publication series (*Status of Coral Reefs of the World.)*. The PICTs are arranged in a semi-geographical manner that represents the current managing Node structure of the GCRMN: Micronesia; Southwest Pacific; and Polynesia Mana (explained on P. 33).

This report was produced under the guidance of the International Coral Reef Initiative (ICRI) and the Global Coral Reef Monitoring Network, which is an operational unit of ICRI (www.icriforum.org). The focus of ICRI is the conservation and management of coral reefs and related ecosystems, such as mangrove forests and seagrass beds. ICRI is a partnership among governments, international organizations, and non-government organizations that was established in 1995 to implement Chapter 17 of Agenda 21 from the 1992 UN Conference on Environment and Development. ICRI and the GCRMN were formed with the recognition that multi-agency and multi-disciplinary cooperative approaches are required to reverse the declining trends in the status of the world's coral reefs and resources. As such, the managing secretariat has been shared among participating countries; it is currently shared by the governments of France and Samoa with a strong emphasis on seeking mechanisms to conserve the reefs of the Pacific.

More than a 'Status Report'

Organisations such as the GCRMN and the World Resources Institute (WRI) have a long history of producing status reports and risk assessments on the world's coral reefs. The most recent GCRMN global status report was released in 2008 [(4)]., and the next global status report is due in 2012. The WRI published Reefs at Risk Revisited in early 2011 which analyses and summarises threats to reefs throughout the world, including those in the Pacific. We have built on these published reports to produce a *synthesis* report that combines the material into national summaries and seeks to present the future ***Outlook*** for these island states and their coral reefs. Thus the report about coral reefs in the Pacific was written to meet four aims:

1. To collate and synthesise information from a diverse range of sources on Pacific coral reefs into standardised, concise accounts of the status and trends for each country or territory;
2. To help readers locate key information sources and products;
3. Using the collected information, to present a synthesis of the key threats identified for coral reefs in the Pacific and to develop preliminary predictions about the long-term outlook for Pacific reefs; and
4. To locate and describe case studies of projects and programs implemented across the Pacific that address these issues, and may help to secure the future of the Pacific's coral reefs and the people who depend upon them.

To meet these aims, this report is divided into two main strategies:

- **Strategy 1** starts with a synthesis table of the main trends in the status, use and management of coral reefs of the Pacific presented at the end of the Executive Summary. This summarises the main issues and threats identified from existing risk and threat assessments for Pacific coral reefs, and what these threats might mean for the future outlook of Pacific coral reefs. The **country profiles** for 22 Pacific island countries and territories follow as separate chapters; and
- **Strategy 2** contains a brief selection of case studies and examples that illustrate the variety of approaches and programs implemented throughout the Pacific by various organisations to address some of the issues identified in **Strategy 1**.

Country reports: information sources

This report is based entirely on data gathered by dedicated coral reef scientists, managers and specialists working across the Pacific. Each country summary in **Strategy 1** contains a synthesis of information for specific Pacific Island Countries and Territories. The main information sources used include:

- ReefBase Pacific, WorldFish Center and Coral Reef InitiativeS for the Pacific (CRISP);
- The Pacific Environmental Information Network (PEIN), Secretariat of the Pacific Regional Environment Programme (SPREP);
- The SPC (Secretariat for the Pacific Community) Statistics and Demography database and website;
- GCRMN status reports, particularly those from 2004 and 2008;
- Status reports (2004, 2007) on the Southwest Pacific, University of the South Pacific and the GCRMN through the CRISP and Canadian (South Pacific Ocean Development) programs;
- Reefs at Risk Revisited, World Resources Institute (2011);
- The Pacific Ocean Synthesis Report 2009 (Centre for Ocean Solutions);
- Data collected by research agencies such as the Centre de Recherches Insulaires et Observatoire de L'Environnement de Polynésie Française (CRIOBE) and the INSU 'CORAIL' Observatory;
- The Institute for the Coral Reefs of the Pacific (IRCP);
- Environmental Vulnerability Index country profiles – United Nations Environment Programme (UNEP) and SPC Applied Geoscience and Technology Division (SOPAC).

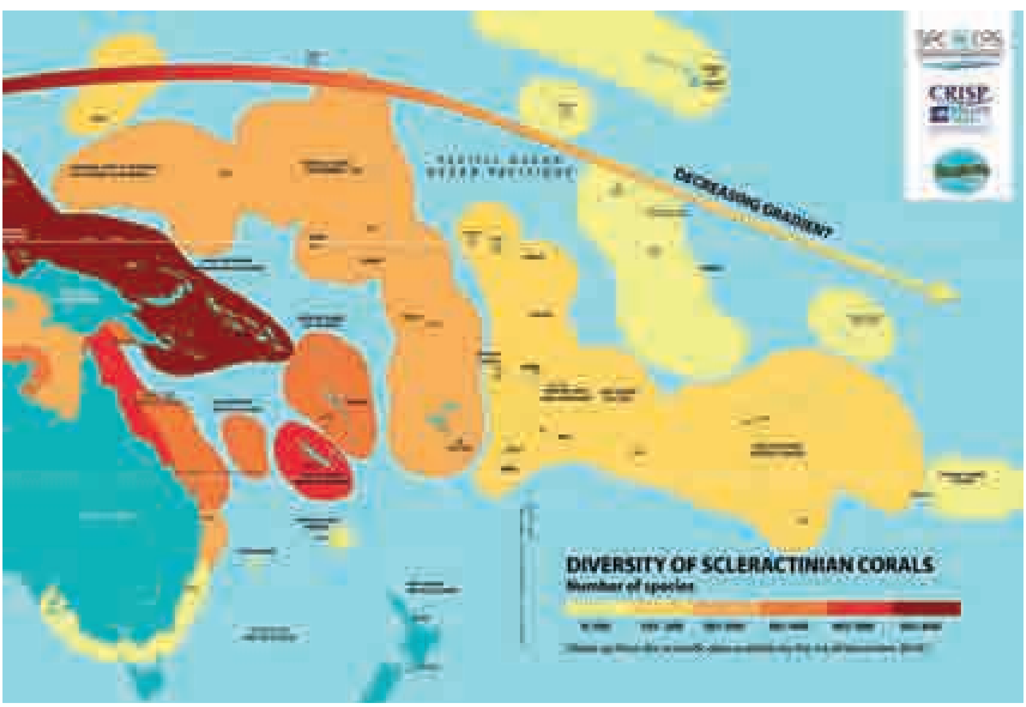


Fig. 2. This map of the Pacific clearly illustrates the gradient of hard coral biodiversity as the number of distinct species, from the world's highest concentration in the Western Pacific and Southeast Asia towards the far east where diversity drops dramatically. This gradient is a clear reflection of the large distances between island 'stepping stones' which limit the successful ocean transfer and settlement of coral larvae to new islands. This map was developed under the CRISP programme.

These sources are standard sources used for each Pacific country or territory. Other information sources such as scientific papers and technical reports were used, **especially reports that are readily available** to the reader.

An important feature of coral reefs in the Pacific is the high level of biodiversity on these reefs. However, this is not a uniform feature across the Pacific as there is a distinct gradient of biodiversity, especially for corals, from west to east. Reefs on the western side of the Pacific are within, and adjacent to, the 'Coral Triangle' which has the highest marine diversity in the world; this diversity drops rapidly to the Eastern Pacific as is illustrated in Figure 2 below.

Country reports: Synthesising status and trends

This report aims to describe trends in the status, health, pressures and management of coral reefs, and use this information to attempt a synthesis of the ***future outlook*** for the coral reefs of the Pacific. The report presents a rapid, preliminary synthesis of readily available information from a wide range of sources to identify common threats, and provides an initial indication of the future outlook. However, for many of the PICTs, the resource information was sparse, leading to limitations in statements or predictions.

The approach used in this report has been modelled on the 'outlook' report process implemented in the Great Barrier Reef over 3 years, culminating in the publication of the Great Barrier Reef (GBR) Outlook Report in 2009. This Report is recognised as setting a new benchmark in state of the environment reporting, and is now the cornerstone of future management and planning for the Great Barrier Reef [(5)].

Each country chapter synthesises the key available information on the status of coral reefs in that country, and the chapters include maps and statistics derived from the World Resources Institute's 2011 report, *Reefs at Risk Revisited*, which is a global assessment of the present threats to coral reefs worldwide and projected threats due to climate change.

Reefs at Risk Revisited - Data and Methods

Each 'country' chapter contains maps and data analyses that are considerably expanded versions of what was published in the *Reefs at Risk Revisited* report released in February 2011. The analyses included in that report categorised threats to coral reefs into two broad categories: 1. human activities near reefs that have a direct and relatively localised impact (called 'local' threats); and 2. activities that have an indirect impact, such as increased greenhouse gas emissions that cause changes to global climate and ocean chemistry (called 'global' threats). The assessment included the following specific types of local and global threats:

Local threats:

- Coastal development: including coastal engineering; land filling; runoff from coastal construction; sewage discharge; and impacts from unsustainable tourism.
- Watershed-based pollution: focusing on erosion and nutrient fertilizer runoff from agriculture delivered by rivers to coastal waters.
- Marine-based pollution and damage, including: discharge of waste and pollutants from ships; toxins from oil and gas installations; and physical damage from anchors and ship groundings.
- Overfishing and destructive fishing: representing unsustainable harvesting of fish or invertebrates, and damaging fishing practices such as the use of explosives or poisons.

Global threats:

- Thermal stress, including: warming sea temperatures, which can induce widespread or 'mass' coral bleaching. Two types of thermal stress data are employed: past thermal stress, which includes coral bleaching observations and satellite-detected above-average sea surface temperatures between 1998 and 2007; and future thermal stress, which includes modeled projections of above-average sea surface temperatures in the 2030s and 2050s based on a business-as-usual CO_2 emissions scenario.
- Ocean acidification: driven by increased CO_2, which alters ocean chemistry and can reduce coral growth rates (indicator data are modeled projections of aragonite saturation levels in 2030 and 2050 based on a business-as-usual CO_2 emissions scenario.)

Each threat was modeled independently, as well as combined into various indices to assess the cumulative impact of multiple stressors on reef ecosystems. There are two indices of present threat to coral reefs (integrated local threats, and integrated local threats + past thermal stress), as well as two indices of future threat to reefs (integrated local threats + future thermal stress + future ocean acidification in 2030 and 2050). All individual threat indicators have grades of 'low', 'medium' or 'high', both to simplify the findings and to enable comparison between findings for different threats. The integrated local threat indices include an additional category of 'very high' and the future indices include categories of 'very high' and 'critical' to capture the increased risk associated with compound threats. The future threat indices incorporate present local threats as a base. As such, they are likely to be conservative estimates; they assume no increase in local pressure on reefs, but also assume no reduction in local threats due to improved policies and management.

Each country chapter contains a national map of coral reefs classified according to the integrated local threat index, as well as bar charts summarizing the estimated threat level for each type of local threat and each of the integrated threat indices for present and future threat to 2030 and 2050.

Limitations, caveats and uncertainty

This Pacific report presents information from across Pacific island countries and territories in a standardised format, and provides a rapid overview of the factors that may affect the future outlook for the coral reefs. Nevertheless, these descriptions are preliminary assessments that ***qualitatively*** synthesise data from specific information sources. Consequently, a number of limitations must be recognised:

- This report only considered information readily available from ReefBase, the SPREP Pacific Environmental Information Portal, the GCRMN and GCRMN node coordinators, Reefs at Risk Revisited, and easily accessible and reliable information from web based sources. Consequently, the information used to describe each criterion is focused on these sources;
- The criteria are used to ***describe*** the trends evident from the available information, thus they are ***not*** thorough and comprehensive risk assessments;
- This report presents a preliminary synthesis of available data and may be regarded as a starting point for a thorough and comprehensive *Outlook Report* for each country of the Pacific;
- In many instances, the limited amount of data and information available results in uncertainty in describing trends and risk assessments. We asked expert reviewers in each country and across the Pacific to assess these assessments; in the case of differing interpretations, we have presented both views (see *Dealing with Uncertainty*); and
- In many countries, it is physically impossible to survey every reef. Countries have selected a small number of monitoring sites, frequently the more accessible reefs. Most remote or

uninhabited reef islands have not been surveyed. Where possible, we have included details about the number of sites, location and depth (reef-slope etc.), and survey methods used. In many cases, however, these details were not available from the source documents. This increased uncertainty in describing reef status and health.

This report summarises data and information in the listed references for each country; readers are advised to examine these references for more detailed information.

The 5 Descriptive Themes

The 5 descriptive themes used in this report ***describe*** trends in: 1. the current condition of reefs; 2. their health and resilience; 3. trends in reef resource use; 4. factors affecting coral reefs; and 5. management and governance. For each 'country', the 5 themes were assigned a ***descriptive rank*** based on the trends as evident in the available data. The descriptive ranks are: ***(1) Stable****;* ***(2) Evidence of change****;* and ***(3) Altered***.

Stable reflects that at present, the data indicate no sign of decline or changes occurring that might threaten coral reefs. The example is '*a pristine reef system in stable condition with no emerging threats or signs of unsustainable or destructive use*'.

Evidence of change reflects that conditions are changing. An example could be '*a damaged reef that may be recovering and reef condition is still changing as it continues to recover'*; or '*a healthy reef showing signs of decline that may need further investigation and patterns of reef use may be changing indicating emerging threats*'; or '*the impacts of reef use are reducing, indicating that management efforts are succeeding and need to be maintained. Changes may require further investigation or consideration of management response'*.

Altered reflects that reef resources are in an altered state, or that changes in reef use patterns or other factors have occurred that may threaten the long-term stability of coral reefs. This also indicates that management response may be required.

Not Considered is used where there was insufficient information to allow trends in a criterion to be described.

+ − ~ Plus and minus signs were used to indicate the ***direction*** of the change, i.e., whether the trends indicated have, ***positive, negative*** or ***unknown*** outcomes for coral reefs.

A full description of each of the 5 criteria is included in Appendix 1.

Variations on the 'traffic lights'

Many reports have used a 'traffic light' system of green, yellow and red circles to represent the condition of the entity. However, there are potential drawbacks with this system. Firstly, the colours green, yellow and red, and the traffic light system itself, are powerful symbols with strong meanings. There is a risk that readers will form interpretations based only on the colours instead of reading the associated text that explains the rationale for the given rating. Additionally, in traffic light systems, the colour yellow strongly suggests that conditions have deteriorated from good (green) to moderate (yellow). However, in describing the condition of natural systems, a reef could also be 'yellow' because it is recovering, i.e., it has changed from poor condition (red) to moderate condition (yellow) which is a positive change. However, readers who see yellow may instinctively interpret yellow to mean that the reef has deteriorated when in fact, it is improving. Consequently, this report uses shades of blue which are neutral, 'cool' colours without a positive or negative meaning. This approach mirrors the approach used in the Great Barrier Reef Outlook Report.

Terminology

This report uses terminology to ***describe*** the trends evident from the information. These descriptions are ***not*** assessments of risk. The language has been specifically chosen to be emotionally 'neutral' so that the reader needs to read the text instead of forming interpretations based on single, emotive words such as 'excellent', 'poor', or 'high risk'. Additionally, the terminology is intended to clearly identify where there is a need for closer examination and scrutiny, and that the issue being ranked is of higher priority. Hence the use of the term 'Evidence of change' (indicating that conditions are changing) instead of more commonly used terms such as 'moderate', 'acceptable', 'satisfactory', which actually mean that conditions are 'good'.

Dealing with uncertainty

The level of confidence or certainty needs careful consideration. In this report, certainty is mainly considered in terms of 'value uncertainty' which reflects the amount of information available, and the accuracy and reliability of this information. Certainty increases when high quality information is regularly collected over many years in numerous locations. Certainty further increases when the information is collected by trained and capable persons in a structured monitoring program that uses appropriate methods, adequately manages the data, analyses the data appropriately, and where findings are reviewed by independent experts. However, where this information is not available, this uncertainty must be acknowledged. This report uses three ratings for certainty which are based on the guide for authors developed by the Intergovernmental Panel on Climate Change [(6)].

Certainty is represented by the 'line weight' of the circle that is used to indicate the criteria ranking.

High confidence: Good information from a number of years and locations indicating that the stated trends, occurrences or effects are *highly likely*. Information is detailed, reliable, collected using appropriate techniques, and has been independently reviewed by experts in the field.

Medium confidence: Good information is available for some years and locations indicating that the stated trends, occurrences or effects are *likely*. A range of information is available, only some of which is detailed. Reliable data from trained and experienced observers are only available for some regions. Some data have been independently reviewed by experts in the field.

Low confidence: Information covering several years and locations is not available, indicating that the stated trends, occurrences or effects are *possible*. Most of the data are patchy, consisting of pieces of information collected from a range of locations at random times, and at a low level of detail. Data have been collected opportunistically by persons with limited or unknown training and capability, and data have not been independently reviewed by experts in the field.

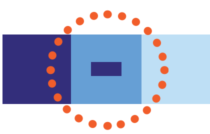
A note for coral reef managers about uncertainty

Coral reefs are dynamic ecosystems that can differ greatly from place to place, and from time to time. Reefs are influenced by an enormous range of environmental, chemical, physical and biological factors, and may experience catastrophic disturbance events which are then followed by recovery. Uncertainty is unavoidable in studying such dynamic ecosystems. Additionally, the coral reefs, islands and atolls of the Pacific are scattered over vast areas of ocean which cannot be regularly accessed by survey teams. As a consequence, many of the 5 themes presented in **Strategy** 1 are described as being of low certainty. Nevertheless, this uncertainty does *not* indicate that further action is not necessary. In many cases, the threats facing coral reefs are well known. A description stating that effects of sedimentation on coral reefs in one specific country have not been studied (i.e. low confidence) does *not* mean that sedimentation is not an issue. On the contrary, it indicates that sedimentation is a potential issue that requires further attention to assess the risk and if necessary, develop a management response.

Presenting the information: icons and symbols

A system of coloured boxes and circles is used to describe the trends emerging from the available information. Three boxes of different shades of blue appear next to each criterion and a sign inside an orange circle represents the trend suggested by the information, while the circle represents the certainty about the information suggesting that trend. Each descriptive theme has accompanying text which explains the rationale for the rating.

This is an example for the descriptive theme *Reef Condition* for a hypothetical country.



Reef Condition – Evidence of change (low confidence)

Signs of deterioration in coral cover and diversity at a number of sites. However, the causes are unclear. Data are only available at a few sites and there is no regular monitoring program in place. Scientific survey information is only available for two years (2000 and 2004) at 3 sites, which showed declining coral cover. Remaining observations of historic declines in the last 5 years are from recreational SCUBA divers, and anecdotal reports from local fishermen suggest loss of coral cover.

Country reports: review and local input

Review and input from local experts was vital to ensure the accuracy of the report. The country summaries were based on reports and publications written by local experts, and the following process was used to collate, check and review the summaries for each country:

- Report editors collected and synthesised information for each 'country' from published material, including previous status reports;
- Country summaries and case studies were sent to the Institute for the Coral Reefs of the Pacific (IRCP), WRI, GCRMN Node Coordinators, and local experts for review and additional material;
- The revised chapters and case studies were revised by the editors and sent to key agencies involved in the Pacific and on the Management Group of the GCRMN;
- The revised material was proofed by the GCRMN Coordinators and WRI;

- The final version was proofed a second time by IRCP, and the authors, after formatting in the report style; and
- This was printed in France for distribution around the world using funds supplied by generous donor countries and organisations.

Information, agencies and programs

There are many agencies and organisations working in the Pacific. These include government agencies representing national interests, inter-governmental agencies working across national boundaries, non-governmental organisations and privately owned organisations and interests. The information presented in this report was collected through programs and efforts carried out through the following agencies and programs, arranged in alphabetical order, with expanded details on these in Appendix 2.

- Centre de Recherches Insulaires et Observatoire de L'Environnement de Polynésie Francaise (CRIOBE);
- Conservation International (CI);
- Coral Reef InitiativeS for the Pacific (CRISP);
- Global Coral Reef Monitoring Network (GCRMN);
- Global Environment Facility, Coral Reef Targeted Research and Capacity Building for Management (CRTR);
- Institute for the Coral Reefs of the Pacific (IRCP) ;
- National Oceanic and Atmospheric Administration (NOAA), USA;
- Secretariat of the Pacific Community (SPC);
- Secretariat of the Pacific Regional Environment Programme (SPREP);
- University of the South Pacific (USP) – Institute of Marine Resources;
- WorldFish Center, Penang Malaysia and Solomon Islands;
- World Resources Institute (WRI), Reefs at Risk Revisited project; and
- WWF South Pacific.

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Section 1: Country reports

The following chapters present the status, trends and future outlook for 22 countries and territories in the Pacific and a short summary on the Great Barrier Reef of Australia. These countries and territories are arranged in the groupings (Nodes) developed by the Global Coral Reef Monitoring Network (GCRMN) in 1996 based on the existing monitoring and reporting capacity in the Pacific. There are 4 Nodes of the GCRMN in the Pacific plus Australia that bridges the Indian and Pacific Ocean. The inclusion of countries in these Nodes was based on 3 criteria: geographical proximity; location relative to existing centres of monitoring capacity; and the political, logistical and financial reality. Sometimes the listings did not appear geographically logical, but they were for logistical and financial reasons. The main Nodes are **Southwest Pacific Node** which contains predominantly Melanesian islands; the **Micronesia Node**; and **Polynesia Mana Node**. In addition there is the US Pacific Node that includes the Hawaiian Islands, Northwestern Hawaiian Islands and US Pacific Remote Island Areas. They are all listed in Figure 1 in the Introduction (page 23).

Southwest Pacific Node: these are predominantly Melanesian countries which receive support from Institute of Marine Resources of the University of the South Pacific in Suva Fiji, along with support from local NGOs and tourist operators. Support has been received from both the University and also Canada to assist the following countries:

Micronesia Node: the Palau International Coral Reef Center (PICRC) was established with financial support from the governments of Japan and the USA with a focus on building capacity in these Micronesian countries for research and monitoring on coral reefs. The Node originally contained American Samoa in recognition of its close relation to the USA, however in 2009, it was decided to link the two Samoas in recognition of the Two Samoas Initiative. The countries are:

Polynesia Mana Node: the government of France offered assistance for predominantly Polynesian countries through the CRIOBE station in Moorea. This has continued through the ICRP in consultation with SPREP in Apia for these countries:

Fiji

- Marine Area: 1 055 000 km^2
- Coastline: 1 129 km
- Land Area: 18 270 km^2
- Reef Area: 6 704 km^2
- Total MMAs: 246
- Area of MMAs: 10 880 km^2
- Total LMMAs: 217
- Mangrove Area: 385 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 80%
- Population (2007 est): 827 900
- Population (2050 proj): 1 036 000
- GDP: USD $60 million (2005)
- GDP/Cap: USD $4 014 (2007)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* and Govan (2009). Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated, proj = projected).

Overview

The Fiji Islands archipelago includes 320 islands and more than 500 islets and cays with a total land area of 18 270 km^2. Of these, around 106 islands are inhabited. The two largest Islands are Viti Levu and Vanua Levu, with Fiji's largest continuous fringing reef stretching over 100 km along Viti Levu's south western 'Coral Coast' (2). The Yasawa Island group and Mamanuca Islands lie to the northwest of Viti Levu, while the island and reefs of Kandavu are south of Viti Levu. Other islands and reefs stretch north to southeast of the two main islands. Fiji has a great diversity of coral reefs that includes fringing, barrier, platform, oceanic, ribbon and drowned reefs (2, 3). The Great Sea Reef (also known as the Cakaulevu Barrier Reef) is Fiji's largest barrier reef, extending 200 km from Vanua Levu northeast towards the Yasawa Islands, and is one of the world's largest barrier reefs (3). Fiji's reefs have high biodiversity with at least 219 species of hard corals, 2031 species of coral reef fishes (4), 478 species of marine molluscs and 422 taxa of marine algae. Fiji also has mangrove forests and seagrass beds, with 9 species of mangroves and 4 species of seagrass (2, 3).

Fiji's population increased by 52 823 in the last decade, rising from 775 077 in 1996 to 827 900 in 2007 (2). Over half the population is rural with many communities relying on small scale commercial and subsistence fishing (3). About 75% of the dietary protein is sourced from the ocean. Traditionally, indigenous Fijians have strong links to management and ownership of marine areas and fishing rights (*i-qoliqoli*). Tourism is the major source of foreign income, with most tourist activity concentrated on the beaches and reefs on the coast of the main islands and adjacent islands (2).

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Status, health and resilience of coral reefs

Fiji's reefs have a rich history of monitoring through many projects by various organisations and institutions. The University of the South Pacific (USP) has collected considerable data, and has co-coordinated the Global Coral Reef Monitoring Network (GCRMN) Node for the South West Pacific since 1999, in partnership with Marine Ecology Consulting, Fiji Ltd.[2]. Regular monitoring is maintained through a volunteer network consisting mostly of a private sector consultancy and dive tourism operators, and the Fiji Locally Managed Marine Area Network (FLMMA); these data are reported here. Long-term monitoring surveys established in 1999 use Point Intercept Transects (PIT) and Belt Transects (BT). There are 13 core locations that are monitored annually, as well as other sites surveyed opportunistically. More detailed survey methods developed by the Australian Institute of Marine Science are employed on some sites to collect detailed data on coral communities and fish populations. A network of water temperature loggers was deployed in 1996, and by 2006 had expanded to include 15 loggers in various locations [2].

Fiji's reefs have an average live coral cover of 45% (range 8% to 60%). Monitoring between 1997 and 2007 showed considerable variability in coral cover, reflecting the diversity of Fiji's reefs between different areas, and changes over time due to episodic disturbances [2]. However, there was a clear signal of declining coral cover between 1999 and 2001 at the scale of all surveyed sites, followed by relatively rapid recovery to 2007 [2]. Warm water temperatures in 2000 resulted in mortality of 40% to 80% of hard corals; there was coral bleaching in 2002 and 2006, although these events were more localised and less severe. Analysis of water temperature and coral cover showed a bleaching 'threshold' where exposure of corals to temperature > 29^{o}C for more than 60 consecutive days leads to coral bleaching [2, 3]. Much of the decline in hard coral cover is attributed to declines of faster growing *Acropora* corals. However, the rapid recolonisation and growth of acroporid corals on affected reefs has led to increasing hard coral cover in some locations that reached pre-disturbance levels by 2007 (Fig. 1), with some sites showing 80% live coral cover by 2006. This recovery indicated that Fiji's reefs are in relatively good condition and exhibit strong resilience [2].

Fiji's coral reefs are also affected by crown-of-thorns seastars (COTS) and *Drupella* snails, which from time to time reach high population densities and can consume large amounts of live coral.

There has been a slight increase in COTS density between 2002 and 2007, with localised outbreaks of COTS recorded in 2005-2006. A COTS control program at dive sites in the Mamanuca Islands shows a decreasing trend in COTS numbers between 2006 and 2007; this could be due to the success of active COTS control measures. Interestingly, while village elders recall an intensive COTS outbreak during the 1920s and 1930s, they perceive that COTS outbreaks have become more frequent in recent years [3]. Coralline Lethal Orange Disease was observed after the bleaching event of 2000 but has been seen less frequently since [3]. White syndrome disease was also reported in 2007. Cyclones also affect Fiji's coral reefs with cyclones in 2001 and 2004 causing localised damage. Overall, the trend in coral cover on Fiji's coral reefs over the last decade is dominated by the effects of, and recovery from, the 2000 coral bleaching event, with damage by COTS, *Drupella*, cyclones and other factors being localised to specific areas at specific times. However, there are indications that some reefs, particularly fringing reefs and reef flats, are being affected by land-based pollution, leading to eutrophication and phase shifts from coral dominated to algal dominated systems [2, 3].

Surveys of fish populations between 2000 and 2007 showed no obvious trends over time. Some fish species, particularly those dependent on specific coral communities, declined after the 2000 coral bleaching event, but their numbers appear to have recovered [2]. Except for a sudden increase in the density of snappers in 2006 due to a very large school appearing at one site, surveys showed that numbers of large food fish (wrasse, large parrotfish, groupers, sweetlips) were low, particularly at sites near villages suggesting significant local fishing depletion [2]. There is also anecdotal evidence of declines in large pelagic fishes such as tuna, mackerel and sharks, potentially due to fishing by larger commercial fishing vessels, particularly long-line vessels [3]. The number of sea cucumbers and giant clams was also low close to villages [2, 3].

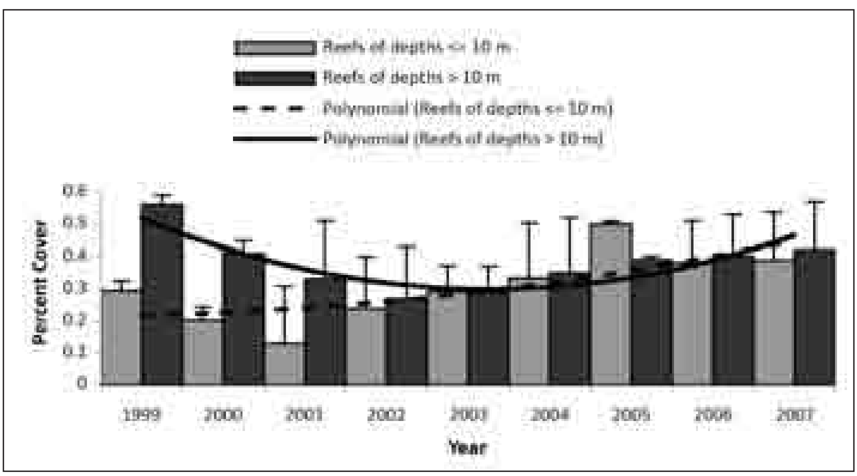

Fig . 1. Average coral cover across core survey sites at 2 depths. There is a clear trend showing a decline in coral cover in 2000-2001 resulting from coral bleaching and COTS outbreaks, followed by recovery. The trend line is a polynomial statistical analysis showing trends in coral cover. The number of monitoring sites is shown in parentheses below the year (from Morris and Mackay 2008 [1]).

Status of coral reefs – STABLE (high confidence)

There is good information about some of Fiji's coral reefs. Long-term surveys from many sites show that, while reefs are affected by a variety of disturbance events, live coral cover has been increasing to pre-disturbance levels, suggesting relatively stable coral cover over the long-term. There is little evidence of widespread and prolonged stress, damage, or loss of coral cover at the reefs surveyed.

Coral reef health and resilience – EVIDENCE OF CHANGE (medium confidence)

Good, long-term information on Fiji's coral reefs shows rapid recovery (within 5 years) from significant declines in coral cover, indicating strong resilience. Reefs appear to be relatively intact with little evidence of widespread, long-term changes in reef communities or processes. However, some coastal fringing reefs are exhibiting signs of degradation, potentially due to impacts from land-based pollution. Reefs near to villages also showed low numbers of exploited species.

Use of reef resources

More than half of Fiji's population is rural, with many communities dependent on marine resources. The Institute of Applied Science at the USP has completed socioeconomic surveys at 29 locations showing that villages averaged 312 people in 54 households, averaging more than 5 per household. Average village monthly income was FJD $636 (USD $400) mainly from selling root crops (kava, yaqona, taro, etc.), marine resources (fish, sea cucumbers), and other paid employment [2]. Most households harvest marine resources for domestic consumption with a small amount sold, while a small proportion of the communities are commercial fishers. Men use nets and spears to fish while women use nets and fishing lines, and also glean the reef. Near shore coral reefs are the most heavily exploited with surveys revealing low numbers of food fish and invertebrates. More recently, the Institute of Applied Science and FLMMA introduced a logbook for fishing communities in 60 villages. The data show that nearshore fisheries in Fiji are threatened [5]. Of the two most common target fish, 74% and 88% of individual fishes taken were below size of maturity, meaning that they had not spawned before being removed from the reef. Additionally, these fisheries are becoming increasingly commercialized with 70% of the catch of fish and invertebrates sold [5]. Growing populations and improved fishing technology are leading to increasing pressure on fish stocks [2].

In terms of trade, commercial fisheries are Fiji's 4th largest export industry after tourism, garments and sugar [3]. Fresh tuna and trade in trochus shells (*Trochus niloticus*) are the highest sources of foreign currency from fishing. Fiji also has an active aquarium trade industry that exports small fish, invertebrates, corals and 'live rock' (coral rubble used in aquaria) collected mainly from the coast of Viti Levu [2, 3, 6]. The trade is subject to the CITES convention, and is monitored and assessed by the Fiji Ministry of Primary Industries. Fortunately, destructive fishing practices (bomb, cyanide, other fish poisons) are rarely used in Fiji [2, 3], although the traditional plant based poison extracted from the 'Duva' or '*Derris*' vine is still used to stun fish in rock pools [2, 3].

The **UNEP/SOPAC Environmental Vulnerability Index** [7] indicates that fishing poses some risk to Fiji's marine resources. The **Pacific Ocean Synthesis Report** [6] also indicates that commercial and subsistence fishing may pose severe threats to Fiji, and that collecting for the aquarium trade may pose a moderate risk.

Tourism is Fiji's main earner of foreign currency, and the largest non-extractive use of coral reefs. In 2004, more than 438 000 tourists visited Fiji [6] with 75% of these participating in some form of marine activity [2]. Surveys in 2005 showed that 12% of tourists dived with SCUBA while, 60% snorkelled during their stay. Recent estimates are that tourism generates FD $212 million (USD $115 million) annually [6]. The economic value of marine resource use by tourists may be worth between FD $74 million (USD $40 million) and FD $335 million (USD $181 million) a year, or equivalent to FD $171-778 per visitor per year (based on 2003 Tourist data) [8]. The main island, Viti Levu, caters for most tourists, but there are many resorts on smaller islands in the Mamanuca and Yasawa island groups. Many resorts and tourism operations in Fiji appear to be working towards improving their sustainability with all Fiji Islands Hotel Association members now working towards Tourism Fiji's 'Green Me' policy. The **UNEP/SOPAC** assessment [7] indicates that tourism does not appear to pose a risk to Fiji's marine resources.

Use of reef resources – EVIDENCE OF CHANGE (medium confidence)

There is some information available that suggests that human use of Fiji's coral reefs has depleted some resources, and may threaten the long-term sustainability of these extractive activities. The activities of most concern include subsistence and commercial fishing, and potentially collecting for the marine aquarium trade.

Factors affecting reef health and condition

The vulnerability of Fiji's coral reefs to external pressures has been assessed in a variety of ways. The 2011 global Reefs at Risk Revisited assessment estimates that about half of Fiji's reefs are under pressure from fishing and watershed pollution (sediment, nutrients and other land-based pollutants), and a third of Fiji's reefs are threatened by impacts associated by coastal development. A refined Reefs at Risk assessment for 15 locations in Fiji based on an analysis of local threats, including coastal development, pollution, sediment, overfishing, and destructive fishing (Table 1) suggests that land based pollution and overfishing are the main local threats facing Fiji's reefs, with the main islands, Viti Levu and Vanua Levu, being under the most pressure [2]. Fringing reefs on these islands including the Coral Coast have been affected by eutrophication caused by sediment and nutrient runoff, probably associated with agriculture, especially sugar cane [2, 3]. These factors may be driving the shift from coral-dominated to algal-dominated reefs in these areas, as well as seasonal algal blooms in the Mamanuca and Yasawa Islands [2]. These threats are also identified in the **Pacific Ocean Synthesis Report 2009** [6]. As mentioned above, Fiji's coral reefs are also affected by cyclones, outbreaks of COTS and warm water leading to coral bleaching events. Tsunamis have not caused major damage to coral reefs in Fiji in recent years.

INTEGRATED THREAT INDEX						
Reef Area	**Coastal Development**	**Pollution**	**Sediment Damage**	**Over-fishing**	**Destructive Fishing**	**Overall Threat Index Score**
Viti Levu, Suva	Medium	Very High	High	High	Medium	Very High
Viti Levu, Coral Coast	Medium	Medium	High	High	High	High
Viti Levu, Momi Bay	Medium	High	High	High	Medium	High
Viti Levu, Lautoka	Medium	Very High	High	High	Medium	Very High
Vanua Levu, Savusavu	Medium	Very High	High	High	Medium	Very High
Vanua Levu, Namena	Very Low	Very Low	Medium	Low	Very Low	Medium
Vatu-i-Ra	Very Low	Very Low	Very Low	Low	Very Low	Low
Lomaiviti	Low	Very Low	Medium	Medium	Low	Medium
Kadavu	Low	Very Low	Medium	High	Low	Medium
Beqa	Low	Very Low	Medium	High	Low	High
Mamanuca Is	Low	Medium	Medium	High	Low	High
Yasawa Is	Low	Low	Medium	High	Medium	High
Taveuni, Somosomo	Very Low	Low	Very Low	Low	Very Low	Low
Taveuni, Waitabu	Low	Very Low	Medium	Low	Very Low	Medium
Rotuma	Low	High	Medium	High	Medium	High

Table 1. An integrated threat index for 15 regions in Fiji (from Sykes and Morris 2009).

Fiji is expected to experience significant population growth which poses risks to Fiji's reefs. The **UNEP/SOPAC 2005** assessment listed Fiji's environment as **Highly Vulnerable**, mainly due to factors associated with the land-based pollution and runoff, population growth and density, and coastal development. This assessment also noted that spills of oils or other toxins, and the volume of international trade (which creates potential for introducing invasive species) also present risks to Fiji's marine environment. The 2011 Reefs at Risk Revisited assessment also notes that many of Fiji's reefs are projected to be threatened by warm water events and ocean acidification. By 2030, all Fijian reefs are estimated to be threatened by a combination of local and global pressures, with sea level rise being a potential issue for the islands and particularly for Fiji's mangroves [6].

Factors affecting coral reefs – EVIDENCE OF CHANGE (medium confidence)

Changes have already occurred in some reef areas of Fiji, based on available information on the many risks and their effects; some of these risks are increasing. The main factors are pollution and runoff from land-based sources, coastal development, with increasing pressure from population growth and the potential effects of climate change.

Governance and management

Fiji has a number of legislative measures such as the *Fisheries Act (1996)* and the *Environment Management Act (2005)*, which are administered by the Department of Fisheries and the Department of Environment respectively [2]. Fiji is also a signatory to the Convention on International Trade in Endangered Species (CITES) and the Convention on Biological Diversity, and management and planning instruments are in place to help Fiji meet its international obligations. The National Biodiversity Strategy and Action Plan forms the basis for future environmental protection [2]. There are also legislative acts and impact assessment processes to control and monitor pollution from development and ports [3].

Fiji has made a commitment that by 2020, 30% of the marine environment within its EEZ will be included in a comprehensive and ecologically representative network of Marine Protected Areas (MPAs) that is effectively managed and enforced [2]. Nevertheless, much of the actual management of marine areas and coral reefs is implemented through Locally Managed Marine Areas (LMMAs) or community-based management, with increasing interest and growth in community-based management of marine areas in the last decade [9]. Currently, Fiji has 410 *i qoliqoli* areas (traditional fisheries management areas) that together cover about 28 588 km^2 [9]. There are also 217 *tabu* areas which are another form of LMMA, 205 of which are within 114 of the *i qoliqoli*. LMMAs in Fiji cover 10 816 km^2 and have an average size of 9.6 km^2 [2, 9], and have a range of restrictions from no-take to species specific and seasonal closures [2].

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Reefs at Risk Revisited [10]*: Fiji*

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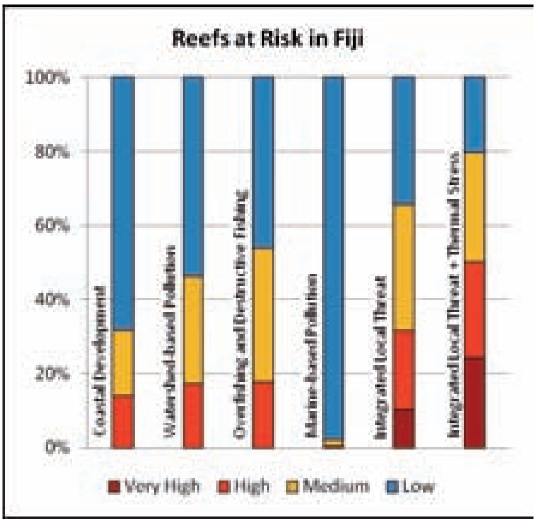
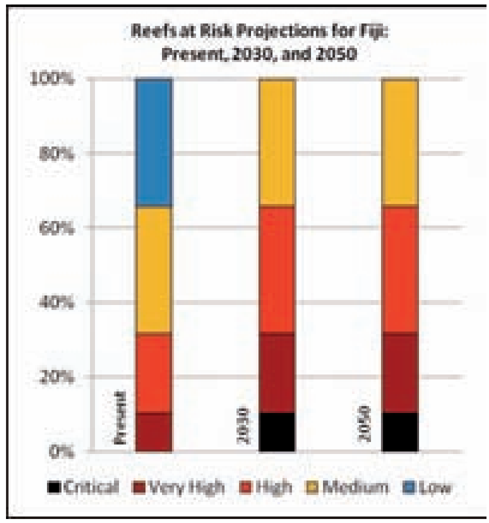
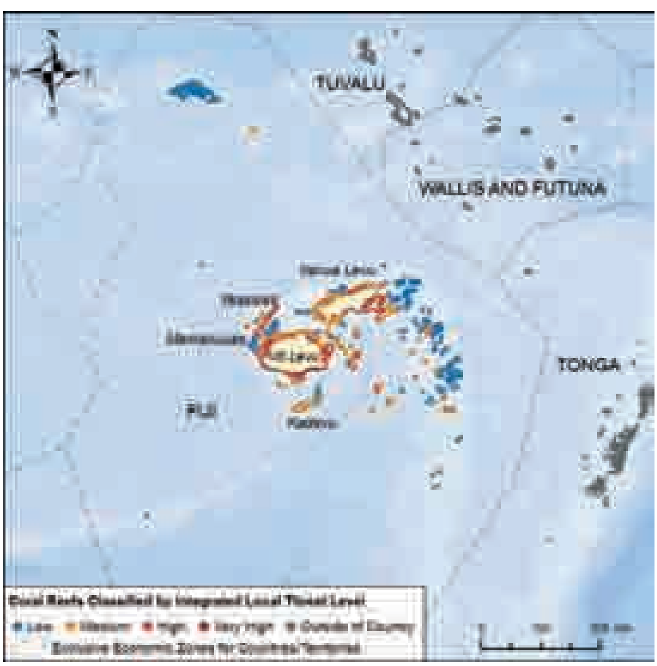
The *Reefs at Risk Revisited* analysis shows that currently, Fiji's coral reefs are most threatened by overfishing and the impacts of land based sediment and pollution, which threaten about half of Fiji's coral reefs. Coastal development threatens about a third of Fiji's coral reefs. The reefs around the two main islands of Viti Levu and Vanua Levu, and those in the Yasawa Islands are assessed as being most at risk (see map). When the recent impacts of thermal stress and coral bleaching over the past 10 years are integrated with local risks, almost 80% of Fiji's reefs are considered at risk. Future projections of thermal stress and ocean acidification (based on a business-as-usual scenario) and local pressures are that by 2030 all of Fiji's reefs will be threatened. The full report, methods and full size maps are on: http://www.wri.org/reefs.







Altogether, Fiji's LMMAs have 593 km^2 protected as no-take zones [9]. The 217 LMMAs are part of the FLMMA network, which is working towards improving coordination of these areas. While the LMMAs are not formally recognised through legislation, 171 have management plans that could be classed as Community Conservation Areas [9]. Government recognition of *i qoliqoli* is limited, but many LMMAs are recognised by local councils and traditional leaders [2]. In many cases, the community perceives benefits from LMMAs, and these community-based management systems have resulted in habitat recovery, increases in exploited fish and invertebrate populations and improved economic conditions such as in Waitabu [9] and Navakavu [6]. Unfortunately, there is little formal support and integration of LMMAs into national protection measures and this is a contentious issue. The *Qoliqoli Bill* was one of the factors leading up to the 2006 military coup [9]; the unstable political situation has slowed progress in Fiji's environmental management. *Reefs at Risk Revisited* data estimate that of the 32% of Fiji's reefs that are protected, management is effective for 0.3% of reefs, partially effective for 21%, not effective for 0.2%, with effectiveness levels unknown for the remaining 11%. Illegal fishing may be a problem in parts of Fiji, and there are limited resources and capacity for enforcement of fisheries regulations [6].

Governance and management – EVIDENCE OF CHANGE (low confidence)

While Fiji has a number of national planning and legislative acts, most management appears to be implemented through local community-based management. The growing number of LMMAs is a positive sign, as are efforts to improve coordination and to formalise these arrangements; however, there are ongoing challenges to management. Some LMMAs are perceived to be delivering benefits to the reefs and local communities. Reefs at Risk Revisited 2011 data suggest that management is partially effective in many managed areas. However, there are few detailed data on the effectiveness and enforcement of existing management arrangements, or their adequacy in protecting coral reef ecosystems and sustaining reef resources.

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Nauru

- Marine Area: 300 000 km^2
- Coastline: 19 km
- Land Area: 21 km^2
- Reef Area: 10 km^2
- Total MPAs: None
- Mangrove Area: 1 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 100%
- Population (2006 est): 9 233
- Population (2050 proj): 16 280
- Population growth (annual): 2.3% [(1)]
- Urban population (2003): 100% [(2)]
- GDP: USD $60 million (2005)
- GDP/Cap: USD $5 000 (2007)

Data from *ReefBase Pacific*, *Reefs at Risk Revisited* 2011 and the *SPC Statistics and Demography* database unless indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimate, proj = projected).

Overview

The country of Nauru consists of a single raised atoll island with a circumference of 19 km and a total land area of 21 km^2. The island is an ancient submerged volcano with a central plateau that forms 80% of the island. The remaining land area consists of a flat coastal terrace 300-1000 m wide, with a mean elevation of about 3 m above sea level. Nauru has no permanent freshwater and limited arable land. All land is held by private tenure with no public lands. The population density of 593 persons/km^2 is one of the highest of the Pacific islands. While it is a small island, Nauru has a very large EEZ of some 300,000 km^2, however the EEZ boundaries with Kiribati and the Marshall Islands have not been fully resolved. Nauru has approximately 10 km^2 of coral reef area and 1 km^2 of mangrove forest.

The oceanic fishery within this EEZ, specifically the access to revenue from foreign tuna vessels fishing, is the mainstay of the Nauru economy. Nauru is a Party to the Nauru Agreement (PNA) which aims to implement sustainable and precautionary transboundary management for this fishery [(4)]. Nauru's reef fisheries are minuscule by comparison as there is no real lagoon, but the reef and nearshore fisheries are extremely important in local subsistence nutrition.

The island had extensive phosphate deposits that have supported significant mining operations since 1906. Mining led to increasing affluence in the local community up to the mid 1990s when a decline in phosphate prices and financial pressures led to the collapse of the economy in 1999 [(5)]. Phosphate prices increased in 2007, leading to a limited resumption of mining, and a degree of economic recovery. However, phosphate mining has significantly altered the central plateau, leading to widespread losses and changes of vegetation and topsoil over 70% of the land area [(5)]. Since the economic collapse of 1999, subsistence fishing and agriculture have become increasingly important. Nauru is critically dependent on supplies from other countries, particularly Australia [(5)].

Status, health and resilience of coral reefs

In March 2000, a snorkeling, dive and manta tow survey covered 50% of the reef and showed relatively low coral diversity, with 80% of coral growth being *Pocillopora*, *Montipora* and *Acropora* species [(6)]. The highest coral cover was found on the northern side of the island while the western side had less coral and more algae. The north-east side, which is subject to strong hydrodynamic conditions, had the lowest coral cover and the substrate was dominated by sand and coral rubble [(6)].

In 2004, the Nauru Coral Reef Monitoring Network started monitoring using funding and support from the Institute of Marine Resources at the University of the South Pacific and the Canada-South Pacific Ocean Development fund [(7)]. Live coral cover at 7 sites ranged from 44% to 78% in 2004. In general, most reefs show high coral cover, although sites near coastal developments (Nibok and Yaren) show a higher percentage of dead corals and algal growth [(7)]. The 2004 surveys found the lowest abundance of finfish at Anibare Bay, a popular site for fishing, swimming and reef gleaning [(7)]. The **UNEP/SOPAC Environmental Vulnerability Index** indicates that Nauru's aquatic environments are at high risk due to disruptions in marine communities caused by fishing [(8)].

The SPC COFISH project survey in 2005, and a subsequent aquarium fishery assessment with COFISH methodology, also estimated coral cover and substrate type at numerous stations around the reef, and produced very detailed 'snapshots' of the abundance, density, size and species composition of reef fish and invertebrates [(1)].

Status of coral reefs – NOT CONSIDERED

Studies have not included sufficient information to identify trends in reef status. While initial baseline information has been collected, more information is needed to determine the status of these reefs.

Coral reef health and resilience – NOT CONSIDERED

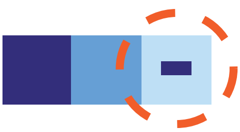
Similarly there is insufficient information to describe trends in reef health and resilience. Additionally, there is no information on long-term cycles of disturbance and recovery, community structure and composition, or about reef processes, to adequately assess the health and resilience of these reefs.

Use of reef resources

The main use of reef resources is through subsistence fishing, which has become increasingly important to Nauruans since the late 1990s. Fishing was also important to foreign mine workers in recent decades until these workers departed in 2007-2008 (T. Adams *pers. comm.*). People have a high consumption of fish (> 46 kg per person/year) [(5)], and fish are a vital source of protein [(9)]. Subsistence fishing is concentrated on the 50-300 m wide belt of coral reef around the island, and has significantly increased in recent years. Extensive social and economic surveys in 2005 showed an average of 3.7 fishers per household, with half the population being active fishers [(5)]. In 2005, about 420 tonnes of fish and 230 tonnes of invertebrates were harvested [(5)]. Harvested species include a variety of finfish, crustaceans, octopus, shellfish, sea cucumbers and other invertebrates, and algae. Most of the fish taken are for personal or family consumption and little is resold. Fishing patterns are changing with women, men and children all increasingly fishing. All sizes of fish are consumed, and a much wider range of species is now being harvested [(5, 9)]. Significant local SCUBA spearfishing began in the 1980s with noticeable effects on fish stocks (T. Adams *pers. comm.*)

There is little information on the status of reef fish stocks, but surveys in 1994 and 2005 combined with daily catch sampling by the Nauru Fisheries and Marine Resources Authority (NFMRA) indicate declines in fish stocks. The average size of fish also appears to be decreasing and the use of SCUBA, especially at night, is a significant concern [5]. Species showing evidence of over-exploitation include shallow-water snapper (Lutjanidae), rock cod and grouper (Serranidae), and coral trout (*Plectropomus* spp.), squirrelfish and soldierfish (Holocentridae), lined bristletooth (Acanthuridae) and large moray eels. Daily reef gleaning activities have led to over-exploitation of turban shell (or *emwari*), lobster and octopus [5]. Anecdotal reports suggest declining catches and fishers having to walk further to find fish [9]. Giant clams appear to have disappeared during the 1980s, and other commercially valuable invertebrates such as sea cucumbers were at low densities. Anecdotal evidence also suggests declines in lobster [5].

There is a small scale, nearshore fishery for tuna that involves local fishermen in powered skiffs who troll for skipjack and yellowfin tuna. Three fish attracting devices (FADs) have been maintained since 2005 to assist local fishermen increase their income during the economic downturn. However, increases in fuel costs prevented some fishers, except those fishing from canoes, from using these FADs. This has reduced the amount of pelagic fish available for local consumption [1, 5].

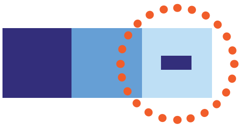


Use of reef resources – ALTERED (medium confidence)

While there are few trend data on catch and effort, and no fishery stock assessments, the 2005 socio-economic surveys covered a significant part of the population [1]. Ecological surveys suggest significant declines in targeted species from reef resource use, and patterns of resource use have changed, increasing pressure on Nauru's coral reefs.

Other factors affecting coral reefs

There is insufficient information on the stresses affecting Nauru's coral reefs to assess threats and effects [10]. Available information suggests that phosphate dust from phosphate mining has damaged corals near the main phosphate crushing and loading areas [7]. Reefs appear to be affected by effluent from sewerage and desalination plants, with little live coral near these sites [7]. The development of the airport and the Anibare boat harbour also damaged the reefs [5, 7]. There are anecdotal reports of significant coral bleaching during 1997/1998, and island wide bleaching was observed again in 2003 [7]. The **UNEP/SOPAC Environmental Vulnerability Index** rates Nauru's environment as being ***extremely vulnerable*** due to weather and climate change, small size and isolation, mining, vehicles, population density and population growth, and resource exploitation. Nauru's isolation will result in reduced recruitment of corals, fishes and invertebrates from other areas, increasing the vulnerability of resources to intensive exploitation [5] and disturbances. Because 39% of the population is under 19 there is significant potential for increased demand for land and resources. The coastal strip is low lying and potentially susceptible to sea level rise [10]. The *Reefs at Risk Revisited* report notes that marine-based pollution is a threat in Nauru, and rates Nauruan reefs as highly threatened with up to 80% of Nauru's reefs predicted to be at a critical state by 2030.

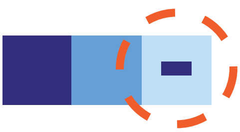


Factors affecting coral reefs – ALTERED (low confidence)

Information on trends in risk factors and their effects suggest that changes have occurred, and Nauru's small size makes localised impacts nationally significant. However, this information is patchy and anecdotal. Nevertheless, Nauru is exposed to numerous threats that can potentially alter the reefs, and there is clear evidence of increasing pressures from growing populations.

Governance and Management

Nauru's inshore marine resources are open access and there are no customary or community management regimes [5, 7]. Unlike oceanic fisheries legislation, NFMRA has inadequate legislation to protect and manage coastal marine resources since the repeal of the 1978 Marine Resources Act. There are plans, based on extensive consultations with each District to develop community-based fisheries and ecosystem management. There are no MPAs in Nauru, but the government has plans for their development within the next 5 years with assistance from the Global Environment Facility [11].



Governance and management – ALTERED (medium confidence)

While coastal management is currently under development, there are no indications that management had been finalized or implemented. Management faces serious challenges due to inadequate legislation, finances and capacity.

Reefs at Risk Revisited (12)*: Nauru*

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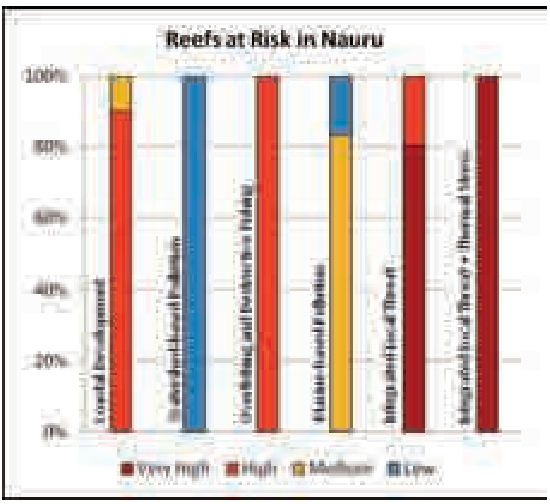
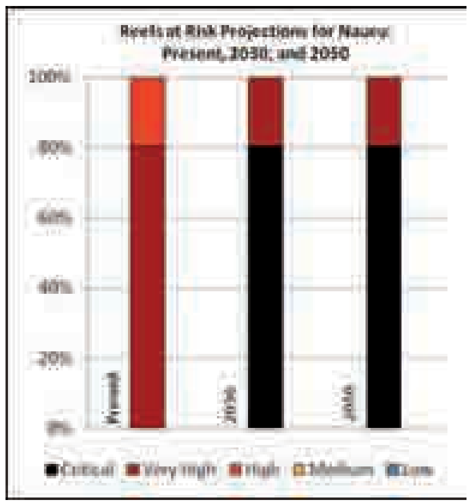
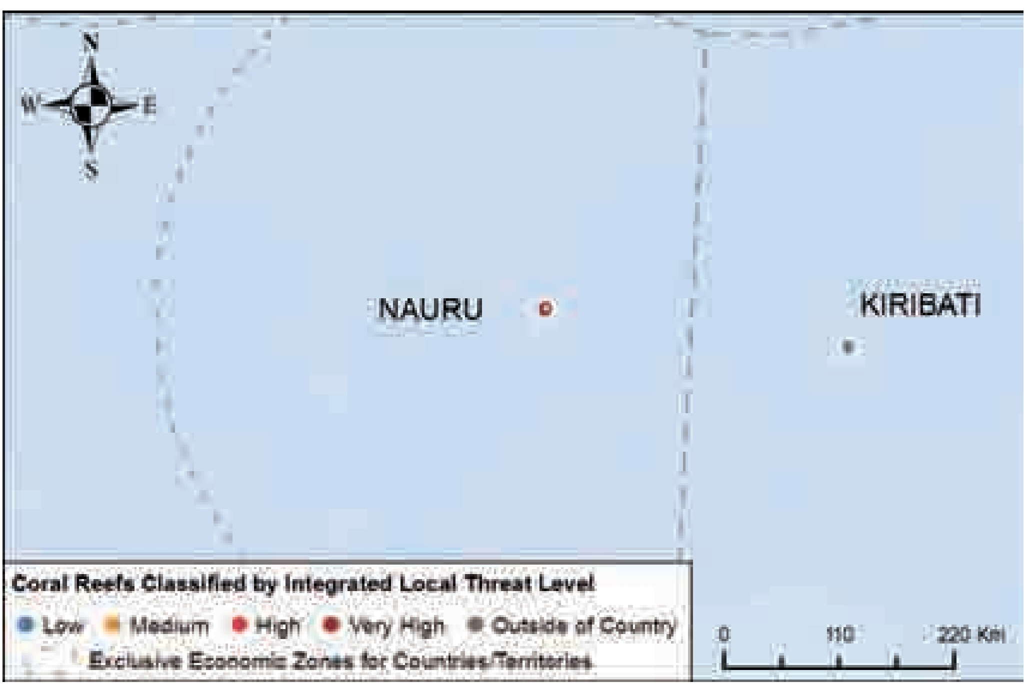
The *Reefs at Risk Revisited* analysis shows that Nauru's coral reefs are severely threatened, with the majority of the reefs at high risk due to overfishing and coastal development, with marine based pollution being an additional threat. When the local threats are combined, 100% of Nauru's reefs are threatened. By 2030, projections for the effects of thermal stress and ocean acidification together with local threats suggest that all of Nauru's coral reefs will be threatened, and up to 80% of reefs in a critical state. The full report, methods and full size maps are on: http://www.wri.org/reefs.







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New Caledonia

- Marine Area EEZ: 1 740 000 km^2
- Shelf area: 46 257km^2 [(1)]
- Coastline: 2 254 km [(1)]
- Land Area: 18 575 km^2
- Reef Area: 7 284 km^2 [(2)]
- Total MPAs: 13
- Mangrove Area: 456 km^2
- Reefs at Risk (local threats and thermal stress 2011): 57 %
- Population (2009 est): 245 000
- Population (2050 proj): 359 000
- Population growth: 1.5% [(1)]
- Urban population (2010): 57% [(3)]
- GDP (2003 est.): USD $3.1 billion
- GDP/Capita (2003 est): USD $1 500

Data mainly from *ReefBase Pacific*, *Reefs at Risk Revisited*, and the *SPC Statistics and Demography* database, unless indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

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Overview

The New Caledonia Archipelago is dominated by the main island of Grande Terre and smaller islands and atolls to the north including the îles des Bélep, the D'Entrecasteaux Reefs, Huon Atoll and Surprise Atoll; which are all surrounded by reefs. To the southeast of Grande Terre, the shelf continues to the île des Pins. Most of New Caledonia's islands and reefs sit on a shallow shelf platform ringed by the world's second longest barrier reef (1 300 km long), which encloses a large lagoon about 40 000 km^2 in area [(2)] with many platform reefs. Fringing reefs are also widespread in many areas. Due east of Grande Terre is the low-lying chain of the uplifted Loyalty Islands that includes Maré, Lifou and Ouvéa islands and their reefs, and to the north, the small atoll of Beautemps-Beaupré and the Astrolabe Reefs. About 550 kilometers west of Grande Terre are two very large shallow reef areas; the Chesterfield Islands which are coral cays on the perimeter of a large atoll (3 500 km^2); and Bellona Atoll which consists of shallow reefs and a few coral islands around the perimeter [(2)].

New Caledonia's population is concentrated in the southern province of Grande Terre (71% of the population), particularly in Nouméa with 40% of the population [(2)]. New Caledonia is a major global source of nickel which accounts for 90-95% of Nouméa's export trade [(2)].

In July 2008, the lagoons of New Caledonia were listed on the UNESCO World Heritage List, covering an area of 15 743 km^2 that includes 60% of New Caledonia's total reef area. The Listing recognized the outstanding value and diversity of the Lagoons, noting that these reefs were of global significance with many species: 350 hard corals; 650 other cnidarians (jellyfish and soft corals); 1 695 fishes; 841 crustaceans; 802 molluscs; 254 echinoderms (starfish, sea cucumbers, etc.); 220 ascidians (sea squirts); 203 worms; 151 sponges; 14 sea snakes; 4 turtles; and 22 marine mammals [4]. The World Heritage Area also contains 9 major reef types, including fringing reefs, single reef barrier reefs, very rare double barrier reefs, atolls with lagoons, raised atolls and coral islets. There are also extensive mangrove forests, and seagrass and algal beds, which contain 12 seagrass species and 322 recorded species of algae from 46 families [2, 5]. Recent studies conclude that New Caledonian waters include at least 401 species of scleractinian corals [6].

Status, health and resilience of coral reefs

Regular monitoring of New Caledonian reefs as part of the GCRMN began in 1997 using modified Reef Check methods, focusing on some reef fish species, commercially harvested species, invertebrates (such as giant clams, trochus, lobsters) and substrate and coral type. Six stations around Nouméa, the capital city, have been regularly surveyed since 1997, with a further 24 stations around New Caledonia monitored since 2003; the current total is 31 monitoring stations within 10 sites. As of 2006-2007, average live coral cover across these 10 sites was 27% [2] (range 5-48%) with some variation between sites. While some sites have shown changes in coral cover over time due to the impacts of crown-of-thorns starfish (COTS) and cyclones (i.e. Cyclone Erica in 2003), coral cover and fish and invertebrate density have remained stable at most sites.

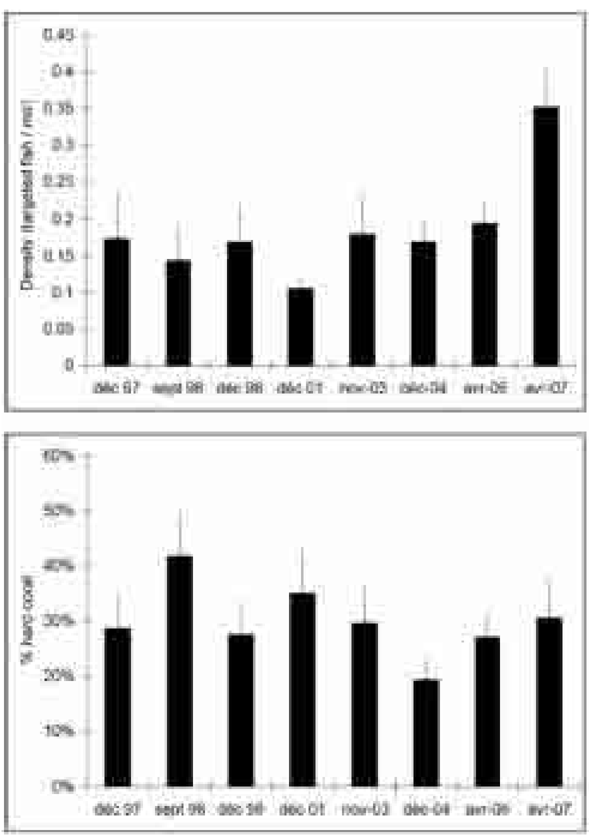

Fig. 1. Coral cover and the density of targeted fish species has remained relatively stable at sites around Nouméa. However, fish density increased in 2007. Figure from Wantiez et al. *2009.*

Hard coral cover around Nouméa (1997 to 2007), has generally remained relatively stable (Fig. 1). Corals declined at two stations (Ricaudy and Maitre) due to COTS, but by 2005 coral cover had increased. Fish densities generally remained stable but significantly increased in 2007 (mainly butterflyfish and parrotfish). Invertebrate density also showed some increase in 2007 [2].

For the other 9 sites around New Caledonia monitored between 2003 and 2007, overall live coral cover was similar to the long-term average with most stations and sites showing stable trends. However, coral cover decreased at Santal2, Hiengabat and Donga Hienga, while it improved at Qanono and Récif Intérieur [2].

A Rapid Biodiversity Survey of reefs in the northern province found that half were in 'very good' or 'good' condition. However, other reefs showed evidence of sediment related stress on coral reefs, and the first observation of white syndrome coral disease in New Caledonia [7]. A survey in 2009-2010 of coral and coralline algae diseases/lesions in the lagoon of New Caledonia was conducted under CRISP with funding from IRD in partnership with Hawaiian scientists. It found 23 types of lesions and diseases affecting 92% of surveyed reefs, but in low abundance. The most common were growth anomalies in *Porites* and white syndrome in *Acropora*. This first survey showed that the reefs in New Caledonia's lagoon had uniformly low (< 3%) prevalence of lesions [8]. Overall, the reefs were relatively healthy, based on the high scleractinian species diversity and general condition of corals.

The spatial patterns of coral communities and larval recruitment on reefs in southwestern New Caledonia varied between different habitat types. Community composition and coral abundance appeared to be driven by factors such as substrate type and recruitment processes [9]. There was little evidence of water quality or pollution damage, suggesting that these reefs were relatively healthy. However, recruitment rates appear to be reduced, which means that the capacity of these reefs to recover from disturbance events may be naturally quite low [9].

Status of coral reefs – STABLE (medium confidence)

Trends in coral cover and reef species are mostly stable, with some sites showing increases or decreases. There were no signs of widespread, long-term, persistent declines, however, long-term data from a wide range of sites are not available, reducing the confidence of this assessment

Coral reef health and resilience – STABLE (medium confidence)

While there are few data on spatial and temporal coverage, there are no worrying signs and many examples of recovery following disturbance. Coral health and resilience is reasonably good New Caledonia.

Use of reef resources

Three main types of fisheries occur in New Caledonia: commercial (small-scale); recreational; and traditional. The commercial fishery includes about 288 boats targeting inshore species across all provinces. Catches of reef fishes have been relatively stable since 1989, with 1 212 tonnes landed in 2001 [2]. Fish were the main catch (690.5 tonnes), followed by spiny lobsters and mud crabs [2]. Crabs provide significant income for fishers. The commercial fishery includes catching live fish for the aquarium trade, which landed 7 tonnes of fish in 2001 [2, 5], and the fishery is not currently regarded as posing significant threats for stock depletion or destructive fishing [2]. Catch data in 2003 for sea cucumber and trochus exports were respectively 69 tonnes (dry weight) and 100 tonnes (shells). Fishing trends from 2000-2003 appear fairly stable, but there are indications of increasing fishing effort further away from Grande Terre in the Chesterfield Islands, about 700 km from Nouméa [2]. The issues of greatest concern to commercial fishers appear to be reduced stocks of trochus and sea cucumber [5]. A Rapid Biodiversity Assessment of reefs in the Northern Province found extremely low densities of targeted sea cucumbers [7]. No destructive fishing (i.e. blast or poison fishing) has been reported in New Caledonia.

Recreational and traditional fishing is an important activity in New Caledonia with 50% of the population participating in fishing 1-3 times per week using hand lines and spear guns. While widespread declines in fish stocks are not evident, there are concerns about overfishing near urban centres; the expansion and development of mines and industrial activities in southern New Caledonia is increasing populations adjacent to the urban centres.

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The **2005 UNEP/SOPAC Environmental Vulnerability Index** suggested that fishing is not a major threat to New Caledonia's ecosystems [10], but more recently, the **Pacific Ocean Synthesis Report** identified that fishing could be an emerging issue for New Caledonia that requires attention [11]. Additionally, a Rapid Biodiversity Assessment of northern New Caledonia in 2007 found greater diversity and abundance of targeted fish, which suggests that fishing impacts were more pronounced on the more populated southern reefs [7]. However, fishing activity appears to be common on these northern reefs with 38% of surveyed reefs found with lost fishing gear [7].

Tourism is not currently a major economic activity in New Caledonia. In 2000, there were 100 000 tourist arrivals, which includes stop-over visits from cruise liners. Most reef related tourism occurs around Nouméa [2]. While tourism impacts across New Caledonia may be relatively small, there are localized impacts on some small islets of the southwest lagoon. Boat moorings have been installed in high-use areas to reduce anchor damage, but there is considerable damage in areas without moorings, especially on reefs near Nouméa and to a lesser extent, Bourail, Koné and Koumac [2]. The UNEP/SOPAC assessment indicates that tourism is not currently considered to be a major threat to New Caledonia's ecosystems [10].

A 2009 study of the economic value of ecosystem services from coral reefs in New Caledonia valued the services as US$ 250 to 420 million per year. The major contributions are: protection against erosion(67%); fisheries (22%); and tourism (9%). Reef fisheries values are shared between recreational (40%), subsistence (32%) and commercial (28%) fishing [12].

Data from the 1990s [13] suggest that New Caledonia's mangrove forests cover 539 km^2. Some mangroves are affected by coastal development, but there is increasing awareness for protection around Nouméa [5]. Mangroves are also damaged by sedimentation from mining activities in some estuaries, especially near old mines that have closed.

Use of reef resources – STABLE WITH SOME EVIDENCE OF CHANGE (low confidence)

The available information suggests that reef resource use is not causing widespread or significant damage to reef resources. However, there are concerns over trochus, sea cucumber and giant clams (*Tridacna* spp. and *Hippopus hippopus*). There was little detailed information about reef use trends in the sources used for this report, hence there is low confidence for this ranking.

Factors affecting coral reefs and condition

The coral reefs of New Caledonia are affected by a number of large-scale drivers and processes [2, 5, 10, 11]. Biological and geophysical factors include cyclones, outbreaks of COTS, and tsunamis. Human-related factors include population growth, coastal development, marine based pollution, and sediment runoff from coastal areas, especially from mining activities that includes closed mines that continue to act as pollutant sources. Areas of southern New Caledonia are considered to be especially at risk from nickel mining and agricultural pollution, as well as from localised impacts from tourism use and population growth. Prony Bay is particularly at risk from mining developments, although steps have been taken to mitigate these threats. Additionally, up to 24% of reefs surveyed in the less populated Northern Province appear to be affected by sediment runoff from mining activities [7]. The *Reefs at Risk Revisited* assessment suggests that land based pollution is one of the leading threats to New Caledonian reefs.

Coral bleaching has not affected New Caledonia in recent years, but is a potential threat in the future. Like all Pacific reefs, climate change may cause significant damage through changing temperature regimes resulting in coral bleaching, increasing ocean acidity and stronger storms and cyclones. The *Reefs at Risk Revisited* assessment predicts that by 2050, all of the coral reefs in New Caledonia will be threatened by a combination of local impacts and climate change, with about 35% of reefs at high, very high, or critical threat levels.

Like many Pacific islands, New Caledonia is expected to experience significant population growth, which will increase pressure on coral reefs [5, 10]. The **UNEP/SOPAC 2005** Environmental Vulnerability Index assessed New Caledonia's environment as being **Vulnerable**, mainly due to population growth, climate/weather changes and the threat to the ecosystem due to the loss (recorded extinctions) and potential loss (endangered species) of biodiversity from the development of nickel mining in the Southern province (Goro site) and the Northern province (Koniambo site).

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

The available information indicates that sediment runoff, pollution, and the potential for future impacts from increased population pressure and climate change can, and already are affecting coral reefs in New Caledonia.

Governance and management

The declaration of large areas of New Caledonian lagoon as serial World Heritage Sites is a positive sign for the future management of these coral reefs, with new requirements for assessment, reporting and management associated with the listing. A review by Govan (2009) found that New Caledonia is "within reach" of protecting 1.5% of their EEZ, which is the global average, and has more than 25% of continental shelf waters included in Marine Managed Areas (MMAs) [1]. In the Southern Province, where most of New Caledonia's MPAs are concentrat-

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ed, management capacity has increased from 5 rangers and 2 boats in 2007 (for managing 10 MPAs), to 16 persons and 6 boats in 2011 (for managing 24 MPAs and 2 marine parks). Regional offices of the environment department were established in 3 locations outside Noumea. The increase in the number of MPAs and the creation of 2 new parks increased the protected area to respectively 45 000 ha and 320 000 ha, representing 17% of the zone under the Southern province jurisdiction (up to 12 miles off New Caledonia's barrier reef; C. Chevillon pers. comm.). In the Northern Province, a significant positive trend was also evident with the finalisation of a new regulation for protecting iconic marine species such as marine turtles, sharks and sea cucumbers (holothuroids). A 'code for the environment' was developed in 2008 and a team of 11 rangers, equipped with 3 boats, was established in 2009 to monitor the entire provincial marine area. During the same period, 3 MPAs were established on the north-eastern coast (between Hienghene and Pouebo) with a combined areas of 11 455 ha (N. Cornuet, pers. comm.). Between 2009 and 2011, management committees for these MPAs were developed, and these embraced a community-based approach based on existing traditional Kanak (Melanesian) management systems, thereby incorporating the principles of community based MPAs within the MPA system (4, 14).

Governance and management – EVIDENCE OF CHANGE (low confidence)

The available information suggests an increasingly positive trend in marine management and governance in New Caledonia, with greater MPA coverage and investment in enforcing management arrangements. Discrepancies in the number and status of MPAs exist, partly due to the lack of a global and reliable assessment at the level of the country.

Reefs at Risk Revisited [14]: *New Caledonia*

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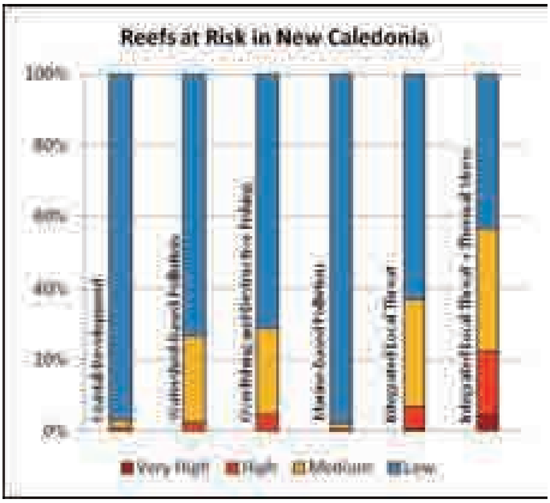
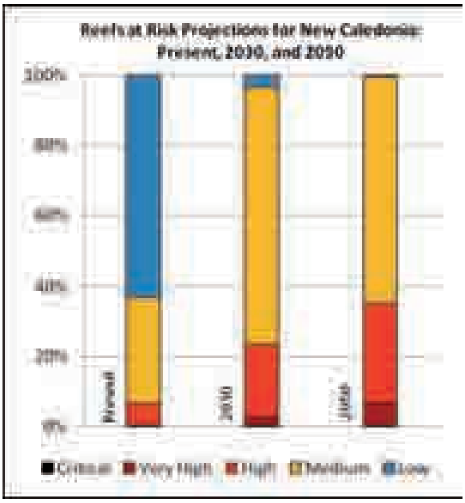
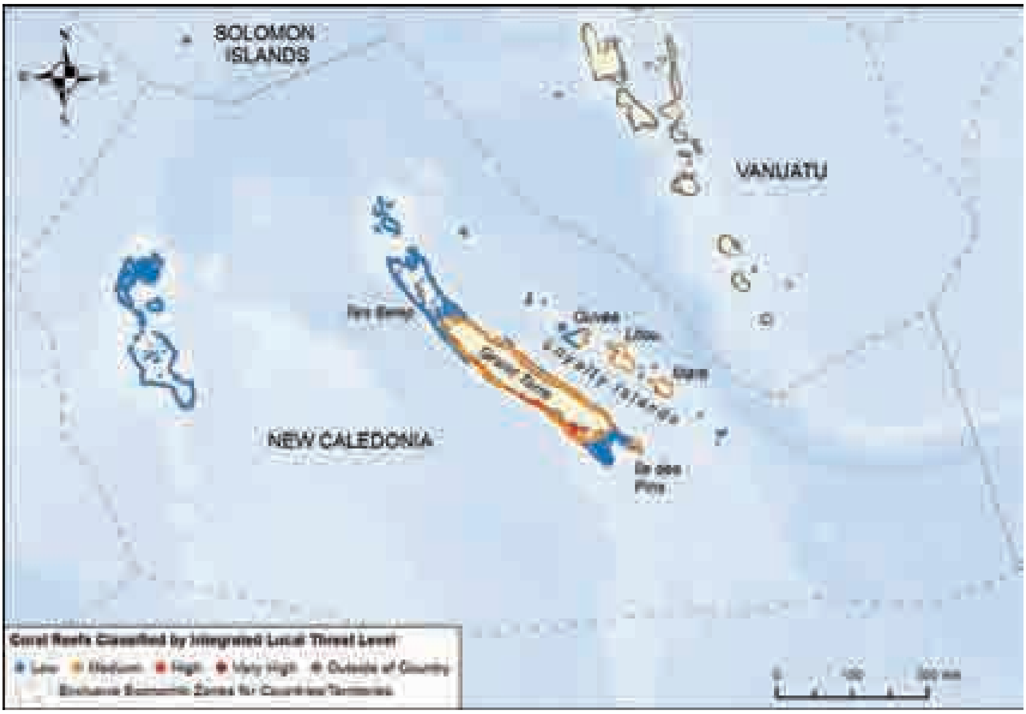
The *Reefs at Risk Revisited* analysis found that New Caledonian coral reefs are currently most threatened by overfishing and the impacts of land-based pollution. The reefs on the southwest and western coasts of Grande Terre are most at risk (see map). When the impacts of thermal stress over the past 10 years are integrated with local threats, nearly 60% of the coral reefs are currently at risk. By 2050, projections for thermal stress and ocean acidification suggest that all of New Caledonian reefs will be threatened, with about 35% at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.







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Papua New Guinea

- Marine Area: 3 120 000 km^2
- Coastline: 20 197 km [1]
- Land Area: 462 840 km^2 [1]
- Reef Area: 13 840 km^2
- Total LMMAs: 86 [1]
- Area of MMAs: 59.4 km^2 [1]
- Mangrove Area: 5 509 km^2 [2]
- Percentage of reefs threatened (local threats and thermal stress 2011): 78%
- Population (2007 est): 6 332 750 [1]
- Population (2050 proj): 13 271 000
- Population growth: 2.2% [1]
- Urban population (2003): 13.2% [3]
- GDP: USD $14.93 billion (2010 est) [4]
- GDP/Capita: USD $2 500 (2010 est) [4]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database and *Reefs at Risk Revisited* 2011 unless indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimate, proj = projected).

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Overview

Papua New Guinea (PNG) is the largest Pacific Island nation [5], and comprises the eastern part of the island of New Guinea and numerous smaller islands to the north and east. These islands and their reefs lie within the 'Coral Triangle' of biodiversity, which contains the highest marine biodiversity in the world. The smaller islands include Manus to the north of the main island, New Britain and New Ireland to the north east, and Bougainville to the east. PNG has a diversity of ecosystems including high alpine ranges and plateaus to lowland forests and swamps, and very rich biodiversity [6]. Much of the main island is very rugged and inaccessible, thus many areas are sparsely populated and isolated from government services [6]. Most of the people live on coastal land that is accessible and suitable for development; these populations are growing rapidly [6].

Most of PNG reefs are fringing reefs or patch reefs which dominate the northern coast and islands; barrier reefs occur along the south coast, the Louisiade Archipelago and around to East Cape on the eastern coast [6]. These reefs are extremely rich and diverse [6, 7], for example 860 species of reef fish and 400 species of hard coral have been recorded from Kimbe Bay (on the north coast of New Britain) [8]. Surveys in Milne Bay Province for Conservation International in 1998 reported more than 429 coral species, including 10 new species [6]. While few reefs have been surveyed, reports indicate that there are at least: 198 crustaceans; 700 corals; 950+ mollusks; 700 nudibranchs; 177 echinoderms; and 25 marine mammals [5].

The population growth rate is rapid at more than 2% per year, with most of the population being rural. Up to 85% of the population is reliant on subsistence agriculture, fisheries, forest harvesting and hunting to supply daily needs [5]. Customary tenure and management are very important with 97% of the land under private and customary ownership [5, 6]. The links between PNG people and their land are very strong, and land use and development must be approved by local governments and communities [6].

Status, health and resilience of coral reefs

Limited long-term reef monitoring in PNG has been carried out by NGOs [9]. The monitoring data reported by the Global Coral Reef Monitoring Network are largely from surveys conducted by The Nature Conservancy (TNC) and the Wildlife Conservation Society (WCS) at Kimbe Bay (New Britain), Madang (on the north coast of the main island), New Ireland and Manus. These surveys indicate that the coral reefs are generally healthy with 40% to 50% live coral cover and stable populations of corals and reef fishes [9]. Anecdotal evidence suggests that coral cover has declined from outbreaks of crown-of-thorns seastars (COTS) and coral bleaching, and then followed by recovery [8]. Reefs in specific locations have also been damaged by mining wastes, sedimentation, nutrient pollution and fishing [9].

New Britain

Monitoring in New Britain (Kimbe Bay) began in 1996 through TNC and includes nearshore fringing reefs. Live coral cover decreased at survey sites from 66% cover in 1996 to 7% cover in 2002, due to coral bleaching, COTS outbreaks and sedimentation [8, 9]; these reefs now appear to be recovering [8]. Fish biodiversity also decreased between 1997 and 2002, before almost full recovery by 2007 [8]. Some inshore reefs were also affected by coral bleaching in 2008, and sediment levels and macroalgal growth have been increasing at some sites over the last 10 years [8]. In contrast, anecdotal reports suggest that reefs further offshore in Kimbe Bay continue to be in good condition. Four Marine Protected Areas (MPAs) were established in Kimbe Bay in 1999 and appear to have contributed to an increased abundance of some reef fishes such as surgeonfish (Acanthuridae) [8]. The Rabaul Lagoon (also in New Britain) experienced a massive volcanic explosion in 1994 which devastated the coral reefs; the reefs are reported to be recovering [9].

New Ireland

The WCS and the PNG Locally Managed Marine Area (LMMA) network monitored some reefs in New Ireland province that showed declines in corals and reef fishes in preceding years. Live coral cover (averaged across 6 sites) declined from 40% in 2006 to 30% in 2007. In 2008, 3 sites showed a 20% decline in coral cover, while the cover of macroalgae increased [8, 9].

Manus Province

WCS monitoring sites at Andra and Ahus islands 5 km off the northern coast of Manus showed that coral cover has decreased slightly from 30% in 2004 [9] to about 25% in 2008 [8]. The cover of *Acropora* corals is low at Andra (~5%), probably due to coral harvesting to supply lime to the local markets and provincial capital for betel nut chewing [8].

Madang Province

This is on the north coast of the main island and includes the Madang lagoon, the largest and most ecologically diverse lagoon on the north coast. The reefs have been monitored since the mid-1990s by the Christensen Research Institute, Wetlands International, and recently by the World Wildlife Fund (WWF). Surveys (2004) recorded relatively high coral cover (35% to 40%), but there were signs of declines in some top predators such as sharks, and an increase in macroalgae [9].

Reef fishes

Surveys of marine fishes suggest increasing fishing pressure. Fish abundances of some reef fish appear to be higher in marine reserves in Kimbe Bay and New Ireland. Some surveyed reefs in New Ireland appear to have healthy populations of fishes such as bumphead parrotfish (*Bolbometopon muricatum*), humphead wrasse (*Cheilinus undulatus*) and reef sharks [8, 9], and high reef fish biomass is reported at sites in Madang [9]. However, there are also reports of declines in some species such as giant clam, bêche-de-mer (sea cucumbers), shellfish, and declines of sharks that are suspected to be due to fishing pressure from long-line vessels [8, 9].

Status of coral reefs – STABLE WITH SOME EVIDENCE OF CHANGE (low confidence)

PNG's coral reefs are biologically very rich and diverse, but long-term monitoring data are only available from a few locations. These data and anecdotal evidence suggest that PNG reefs are in good condition with effective recovery following disturbance events. However, some coastal fringing reefs show evidence of damage from sediment runoff, pollution and fishing.

Coral reef health and resilience – STABLE WITH SOME EVIDENCE OF CHANGE (low confidence)

The little information available suggest that damage from disturbance events is followed by effective recovery, indicating good reef resilience. However, some inshore reefs show signs of persistent stress such as increasing sediments and macroalgae cover. More information is required to better understand the resilience of these reefs.

Use of reef resources

Many communities in PNG are very reliant on natural resources for food security and income, with an estimated 85% of the population reliant on subsistence activities to meet daily needs [5]. Local communities in PNG have particularly strong ties to their surrounding environment, and this is often reflected in their use and management of natural resources [10]. Fishery resources provide the major source of animal protein for coastal populations and contribute to the staple diet and local economies [6]. PNG has commercial, artisanal and subsistence fisheries; the commercial focus is on harvesting tuna, prawns, lobsters, and sea cucumbers, with tuna being the main revenue earner [6, 10]. The government gains revenues from more than 300 licenses issued to foreign fishing fleets and from sale of fish products [10]. Stock assessments by the Secretariat for the Pacific Community (SPC) show cause for concern for yellowfin (*Thunnus albacares*) and

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bigeye tuna (*Thunnus obesus*) although the harvest of skipjack tuna (*Katsuwonus pelamis*) is probably within sustainable limits [10]. More information is needed on the catch and sustainability of these fisheries, including the content of bycatch [6]. Prawns and lobsters are trawled mainly from the Gulf of Papua. Collecting of sea cucumbers by commercial fishers and small scale artisanal fishermen occurs throughout coastal areas, and management plans have been developed to avoid collapses in stocks of these species [6, 10].

The subsistence and artisanal sectors operate in coastal and nearshore waters, and provide most of the fish for the domestic market, and for niche markets such as shellfish and sea cucumbers. Communities fish for pelagic and reef fishes from lagoons and fringing reefs, and there is also active reef gleaning at low tide [10]. Data on these fisheries is sparse, but estimates suggest an annual subsistence harvest of 70 000 tonnes [10]. Growing populations and demands are increasing pressure on these stocks, especially for valuable export species such as sea cucumbers and some shellfish, such as trochus and giant clams [6]. Declines have already been reported from Milne Bay with villagers reporting reduced stocks [9], and assessments indicate serious over-exploitation for some species of sea cucumbers in this region [6]. There are also reports of the collapse of sea cucumbers in New Ireland [8]. Declines in top predators, particularly sharks, have been reported in Madang and Lae; this is probably due to targeted long line fishing to supply the shark fin trade [9]. In New Ireland, there are reports that some fish stocks have declined with increasing fishing pressure to supply a processing plant in Kavieng [8]. Deepwater fisheries near the Lihir Island group are reported to be at risk of overfishing [11]. Collecting for the aquarium trade has also been suggested as posing some risk to coral reefs in PNG. Fortunately, destructive fishing practices (dynamite and cyanide) appear to be relatively uncommon although they still occur and some reef damage has been reported [5]. Corals are harvested around Andra island (Manus) to supply lime for betel nut chewing and this has led to significant loss of *Acropora* corals [9]. Mangroves have also been harvested for firewood near urban centres such as Port Moresby leading to loss of mangrove habitats [2, 5].

The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [12] indicates that fishing poses some risks to PNG. The **Pacific Ocean Synthesis Report** [11] identifies subsistence and artisanal fishing as posing a severe threat. The *Reefs at Risk Revisited* 2011 assessment suggests that about half of PNG's coral reefs are under threat from overfishing, with coastal and near-shore fisheries appearing to be under increasing threats of overexploitation [5, 6, 8, 9, 10, 11], but more information is needed to adequately assess these stocks and fisheries, and improve management [6].

Large-scale consumer tourism such as that seen in Vanuatu and Fiji does not occur in PNG, where tourism appears to be geared more towards snorkelling/diving and general sightseeing [10]. Diving may be the only tourism industry sector that is being well developed, and accounts for 68% of PNG's tourist visitors [5]. A number of challenges to developing tourism have been identified, including limited transportation, inadequate infrastructure and personal security [10]. The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [12] indicates that tourism is a low environmental threat in PNG, and impacts are believed to be negligible [5].

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

There is limited information (e.g. stock assessments, catch surveys) to assess the trends and effects of reef resource use. While many areas of PNG are remote and potentially near-pristine, anecdotal information or location specific surveys suggest that the pressure on reef resources is increasing and has caused declines in stocks in some areas. Some stocks (e.g. sea cucumbers and giant clams) have been seriously depleted as well as some finfish species and sharks; more information is needed for a definitive assessment.

Factors affecting reef health and condition

PNG's coral reefs are under threats other than from direct use. A major threat to the environment is from population growth which will increase resource exploitation, land use and pollution [10]. The **UNEP/SOPAC 2005** Environmental Vulnerability Index identifies population growth as the greatest risk facing the PNG environment [12].

The coral reefs are also threatened by land-based sources of pollution. Degradation of catchments and declining water quality and pollution were ranked as the top priority environmental issues in a 2004 national assessment [6], and are significant risk factors identified in the UNEP/SOPAC assessment [12] and the Pacific Ocean Synthesis Report [11]. The 2011 *Reefs at Risk Revisited* assessment indicates that approximately 25% of PNG reefs are threatened by land-based pollution, deforestation, logging and poor land-use practices resulting in increased erosion and sediment runoff in some areas. The inadequate disposal of sewage, and increasing use of toxic materials and wastes are also threats as these pollutants are frequently disposed directly into natural waters or inappropriate sites [6]. Solid wastes are not adequately managed and cause pollution [5, 6]. Mining has caused significant pollution in some areas with serious environmental impacts from erosion and sedimentation from mining activities, and direct pollution from mine discharges (tailings, slurry). These pollutants may contain toxic heavy metal contaminants [6]; examples include damage from the Bougainville Panguna copper mine, the Ok Tedi copper and gold mine, the Porgera gold mine [5], the Lihir gold mine, and Misima gold and silver mine. The disposal of mining wastes (tailings) into deep waters offshore has been promoted as a safer way to reduce mine pollution; however, significant concerns have been raised about the long-term environmental impacts in deep water habitats and pollution drift into shallow waters.

Collectively, these factors have caused localised damage to some of PNG's coral reefs. Increased sedimentation has been noted in inshore fringing reefs of Kimbe Bay, probably from oil palm plantations, mining activity and logging [9]. Oil palm plantations and sedimentation are also reported to have damaged some coastal fringing reefs in Milne Bay. Gold mining on Misima Island resulted in widespread coral mortality between 1989 and 1994, although the affected reefs are reported to be recovering well since mining ceased in 2001. Gold mining on Lihir Island (New Ireland) caused localised mortality on 7 km of surrounding reefs through sedimentation; the mine has introduced steps to reduce these impacts (9). As well as immediate impacts, there are concerns about heavy metal contamination and toxic pollutants such as cyanide which have killed marine life, bioaccumulation of heavy metals in food fish, and examples where pollution has severely affected subsistence fisheries.

Nevertheless, these reports are localised and there is a lack of information on the long-term affects throughout PNG; an integrated monitoring programme is required to evaluate the effects of these factors on PNG's coral reefs.

Volcanic activities and seismic events have also damaged PNG's coral reefs. The **UNEP/SOPAC 2005** assessment assessed PNG as being vulnerable to volcanic activity, and volcanic eruptions have been recorded to have previously damaged coral reefs (e.g. Rabaul in 1994).

Coral bleaching and COTS outbreaks have affected some coral reefs around PNG. Coastal fringing reefs were affected by outbreaks of COTS and coral bleaching between 1996 and 2003, but appear to have since recovered. COTS have also been recorded in New Ireland, as well as minimal coral bleaching and coral disease (8, 9). There is little information on the potential effects of climate change on PNG's coral reefs, although climate change is mentioned in several risk assessments particularly for inundation of low lying areas, increasing extremes of drought and flood, and increased severity of storm events (5, 10). Some communities in PNG have already been severely affected by rising sea levels and inundation, such as the community on Takuu Atoll (250 km north east of Bougainville). Climate changes may also affect fisheries and agricultural production, causing changes in resource use (10). The *Reefs at Risk Revisited* assessment indicates that by 2050, all of PNG's reefs may be threatened to some extent, with more than 40% at very high or critical threat levels.

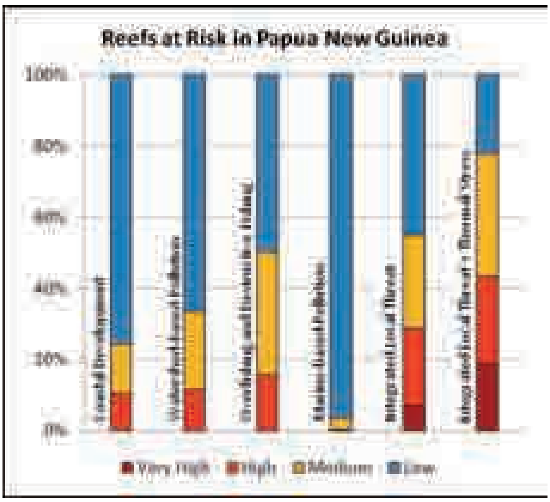
Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

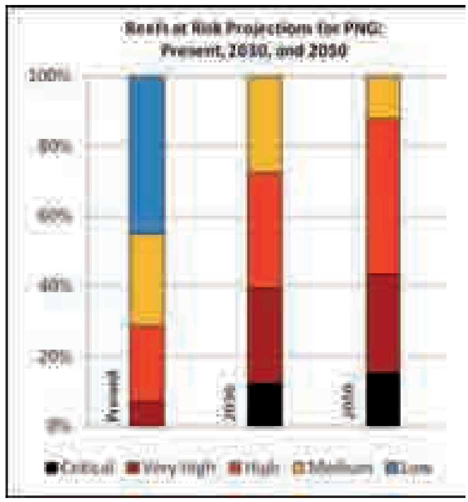
Anecdotal reports and risk assessments suggest various factors threaten the reefs, however, there is insufficient information on trends and demonstrated effects on the environment. This reduces confidence in describing these trends. The available information suggests that PNG's coral reefs have been affected by numerous risks and these risks are increasing or very likely to increase. There is some evidence that changes have already occurred in some areas. The main local factors of immediate concern include land-based pollution and sedimentation from poor land-use practices, mining, deforestation, and pressures from population growth.

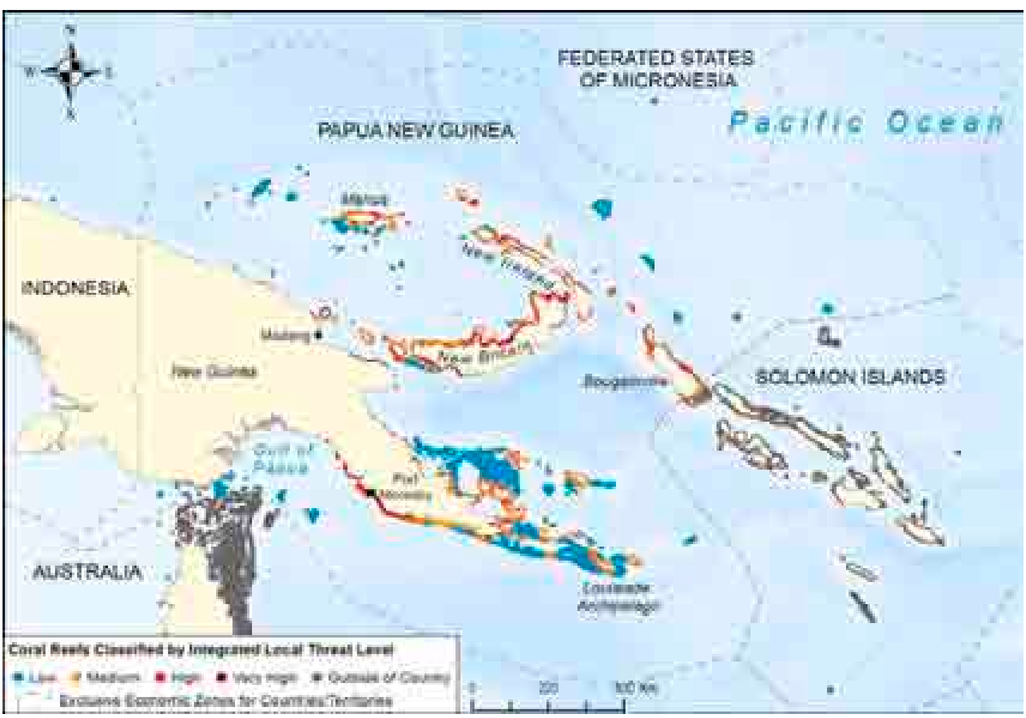
Reefs at Risk Revisited: Papua New Guinea (14)

WORLD RESOURCES INSTITUTE

The Reefs at Risk Revisited analysis indicates that PNG's coral reefs are currently most threatened by land-based pollution and overfishing. These factors threaten 33% and 51% of the reefs, respectively. While these percentages are significant, they are lower than many other Pacific island nations. When thermal stress over the past 10 years is integrated with local threats, about 78% of the reefs are threatened, and it is projected that by 2050, all of the coral reefs in PNG will be threatened by a combination of local human activities and climate change, with more than 40% at very high or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.







Governance and management

PNG has a number of legislative acts that provide for environmental protection and management; the main legislation for natural resource management is the *Environment Act (2000)* which became fully operational in 2004 [5]. This Act replaces three previous articles of legislation and is intended to streamline and strengthen environmental management [5, 10]. The Act covers planning, environmental impact assessment, development permits, and management of pollution and water quality. There are five separate acts focused on conservation to cover fauna protection, conservation areas, national parks, international trade and crocodile protection. The *Fisheries Act (1994)* regulates fishing activity through licensing and gear restrictions, and bans the use of explosives, and the *Forestry Act (1991)* manages and regulates forest resources [10]. While these acts cover some of the issues affecting coral reefs, there is no legislation specifically for coral reef management. There is little scope for direct government involvement in land-use management as 97% of the land is traditionally owned [5]. The *Organic Law on Provincial Governments and Local Level Governments (1996)* provides legally recognized pathways for local environmental management and has been used to establish traditional, community-based marine managed areas [1].

There are many challenges facing environmental management in PNG; while there is good legislation for environmental management, it is difficult to access remote areas to monitor compliance or undertake enforcement, and there is a severe lack of capacity and funds to implement and enforce legislation [5, 6, 10]. The Department of Environment and Conservation (DEC) lacks funding to conduct even the most basic regulatory functions [10]. A lack of government transparency and political will is reported in some areas to tackle major environmental issues [5, 9, 10]. Additionally, there is a lack of awareness and understanding in local communities that makes them vulnerable to unfair agreements to exploit their natural resources [5], or leads them to engage in poor resource use practices themselves [6]. There are reports of illegal and poor logging practices, as well as reports of illegal, unregulated and unreported fishing in PNG waters by foreign fishing vessels [5]. These logistic gaps have meant that NGOs play a far greater role in environmental management [5, 9, 10].

The reliance of local communities on natural resources means that environmental management is tightly intertwined with social and economic circumstances [5]. Traditional management and customary tenure are incredibly important in natural resource management in most areas of PNG; thus environmental monitoring, management and compliance are driven at the local government and community level [10]. However, there is a disconnect between environmental policy and actions at the local level [10]. Thus environmental management is regionally variable, depending more on the stakeholders involved (local communities, private companies, NGOs etc). There are an estimated 86 Community Conserved Areas (CCAs) with marine components. These can be considered as Locally Managed Marine Areas (LMMAs) [1], and frequently these include permanent or periodic 'tambu' (no-take) zones. The best known MPAs and LMMAs are in Kimbe Bay, Milne Bay, Kavieng, Manus and Madang. TNC is working with local communities and the local NGO Mahonia Na Dari to establish a network of MPAs in Kimbe Bay [9]. Reserves in Kimbe Bay and New Ireland have resulted in increases in abundance and biomass of some reef fishes [8]. Given the challenges to centralised government management, the ties between communities and their environment, and the practicalities of on-ground compliance and management, the most effective management of PNGs coral reefs may be through community based initiatives [9].

Governance and management – EVIDENCE OF CHANGE (low confidence)

PNG has a strong legislative base for environmental management for some issues affecting coral reefs, however, there are significant limitations in implementing this legislation and government compliance and enforcement appear to be extremely limited. Effective 'on ground' management relies on local-level initiatives which vary from place to place. A number of LMMAs are in operation and some display positive trends. Non-compliance and poor environmental management have reportedly resulted in damage to coral reefs in some areas. The increasing number of LMMAs point to positive progress, but more information is needed to determine the effectiveness of environmental management in PNG.

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Solomon Islands

- Marine Area: 1 377 100 km^2
- Coastline: 9 880 km
- Land Area: 28 370km^2
- Reef Area: 5 750 km^2
- Total MMAs: 127
- Area of MMAs: 1 380 km^2
- Mangrove Area: 642 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 82%
- Population (2010 proj): 549 574
- Population (2050 proj): 1 245 700
- Population growth (2007): 2.68% [(1)]
- Urban population (2003): 16.5% [(2)]
- GDP: USD $948 million (2007 est)
- GDP/Capita: USD $1 900 (2007 est)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* and Govan (2009) [(3)]. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimate, proj = projected).

Overview

The Solomon Islands archipelago is the third largest island nation in the South Pacific, with a land area of 28 370 km^2. The archipelago stretches 1700 km southeast to northwest between Bougainville to the east of Papua New Guinea and to the northern-most islands of Vanuatu. The 6 main islands are Choiseul, Santa Isabel, New Georgia, Guadalcanal, Malaita and Makira. These islands are volcanic in origin and rise steeply from the sea with high central peaks on each island; they periodically experience volcanic and seismic events, like the major earthquake and tsunami disaster of April 2007 [(1)]. The epicentre of that earthquake was near Gizo Island and measured magnitude 8.1; it generated a tsunami between 2 and 10 meters high. The Solomon Islands lie in the far east of the 'Coral Triangle' region, which contains the highest levels of marine biodiversity in the world. Surveys in the Solomons have recorded 497 species of hard corals, 1020 coral reef fishes, 10 species of seagrass and 26 species of mangroves [(4)].

The population of the Solomon Islands is largely rural with a relatively rapid population growth rate of 2.7% [(1)]. A large proportion (80%) of the population is coastal living mainly on the 6 main islands [(1)]. Solomon Islanders rely heavily on marine resources for subsistence as well as income, with one of the world's highest per capita consumption rates of seafood [(4)]. There is concern about the future health of coral reefs in the Solomon Islands due to pressures from other factors such as logging, mining and plantation development, [(1, 5)]. Ethnic tension in the early 2000s affected reef monitoring efforts [(1)], and had far reaching social and economic effects with losses of services, displacement of people and communities, and closures of businesses. However, security and stability have greatly improved since 2003 [(4)].

Status, health and resilience of coral reefs

Coral reefs in the Solomon Islands have been periodically monitored through independent surveys from the 1960s to the 1990s [4], and more recently through collaborative programs including NGOs such as The Nature Conservancy (TNC) and World Wildlife Fund (WWF) together with community and government organisations. The Solomon Islands Coral Reef Monitoring Network (SICRMN) was formed in 2002 and in 2003-2004 it established 5 permanent monitoring locations: 4 in the western province in the New Georgia Islands (Gizo, Munda, Tetepare, Marovo); and 1 in Isabel Province (Arnarvon Islands) [1, 4]. At each location, 4 stations (reefs) are monitored with 2 sites per station. Each site has 8 by 50 m transects on the reef slope; 4 at 3-5 m depth and 4 at 8-10 m depth [1]. Survey sites included fringing, barrier and patch reefs, although most reefs at Tetepare were fringing reefs [1]. Surveys are based on the standard Global Coral Reef Monitoring Network (GCRMN) monitoring protocols: substrate surveys use point intercept transects while fish are surveyed using underwater visual census (UVC). Substrate composition is recorded using 6 life form categories (*Acropora*, hard coral, soft coral, macroalgae, abiotic and other) based on the protocol developed by the Australian Institute of Marine Science [1]. These sites are part of the GCRMN and the data from 2006 to 2007 are reported here. Logistical constraints (costs and difficulty to access to survey locations) mean that surveys are dependent on assistance from local dive operators and these constraints, together with weather and events such as the 2007 tsunami, have reduced monitoring efforts [1]. In 2006, two temperature loggers were deployed at two sites in Gizo to provide temperature data at survey sites. Average live coral cover (pooled across monitoring sites) was 30%, with a range of 20% to 38% live coral cover [6]. However, long-term data are not available and the following descriptions provide 'snapshot' overviews of benthic cover and fish life at each of the 4 locations in the Western Province from 2006-2007. Monitoring in the Arnarvon Island sites was incomplete due to weather conditions, so these data are not reported here.

Gizo: In 2006, there was an average live hard coral cover of 43% on deep transects and 37% on shallow transects at the 4 monitored reefs in Gizo. The highest cover recorded was 61% [1]. Macroalgae covered 32.7% of the bottom. *Acropora* cover was low (< 5%) at most stations (except for Nijara with 22.8% cover), as was soft coral cover (< 10%). Major changes in the benthic community occurred after the 2007 earthquake and tsunami. Coral cover across deep sites decreased to 10%, *Acropora* cover dropped to 7%, and macroalgae decreased to 13%. In contrast, the amount of substrate covered by dead coral, coral rock and sand increased from 9% (shallow transects) and 16% (deep transects) in 2006 to averages of 37% (shallow transects) and 60% (deep transects) in 2007; this showed a significant loss of live benthic organisms [1].

Tetepare: In 2006, live coral cover was approximately 20-30% at most stations on Tetepare. *Acropora* cover ranged between 15% and 45%, and was generally higher at shallow transects. Hard corals and macroalgae were more prevalent at deeper transects compared to shallow transects. In 2007, overall *Acropora* cover and hard coral cover decreased slightly at some survey sites. Across all sites, *Acropora* cover ranged between 13% and 20%, with total hard coral cover ranging from 17% to 35% [1].

Marovo: In 2006, stations around Marovo were dominated by dead coral, coral rock and sand, ranging from 39% cover (shallow transects) to 29% cover (deep transects). Marovo had relatively high levels of live coral cover, from 34% (shallow) to 33% (deep), but *Acropora* cover was low with <5% across all sites. Macroalgal cover ranged from 21% to 45% early in 2006. In 2007 there were some changes in hard coral, *Acropora* and macroalgae. Hard coral cover increased at the Lumalihe and Muliana stations, reaching up to 50% cover. *Acropora* cover increased slightly at Lumalihe but was still low. Macroalgae showed an overall decrease across all sites, from a range of 21%-45% cover in 2006 to 12%-18% cover in 2007.

Munda: In 2006, hard coral and macroalgae were the main features at all 4 stations; coral cover reached 39% at shallow and deep transects, while macroalgae varied much more (from 15% to 43%). The cover of *Acropora* corals also varied between sites and transects, ranging from 4% to 19%. Non-living categories accounted for 8%-20% cover, but were generally higher on deeper transects [1]. The 2007 surveys recorded an increase in hard coral cover at some stations and decreases at others. Nevertheless, coral cover remained high across all stations ranging from 35% to 50%. Meanwhile, the cover of macroalgae generally declined across all sites, comprising between 4% and 19% cover.

Fish populations: Surveys of fish populations showed similar results amongst the 5 locations between 2006 and 2007. The most commonly recorded fishes included damselfishes (Pomacentridae), fusiliers (Caesionidae) and surgeonfishes (Acanthuridae). The abundance of food fishes such as snappers (Lutjanidae) and groupers (Serranidae) was relatively low, and there was a lack of large (>50 cm) parrotfish in the Gizo fish markets [4]. The 2007 earthquake and tsunami appear to have decreased abundances of fishes around Gizo, compared to 2006. Fishes tended to be larger in the Arnarvon Marine Conservation Area compared to other locations, especially bumphead parrotfish (*Bolbometopon muricatum*) and humphead (Maori) wrasse (*Cheilinus undulatus*). However, the abundance of bumphead parrotfish was highest at Tetepare. Across the Solomon islands, the abundance of algal eating parrotfish is estimated at 32 individuals per 100m^2 [6]. These herbivores play a crucial role in maintaining healthy coral ecosystems.

Status of coral reefs – STABLE (low confidence)

Information is only available for the Western Province for 2006-2007; this reduces the ability to assess reef status. The data from 5 monitored locations show relatively high coral cover; changes between 2006 and 2007 appear to be within the range expected from natural variation and the effects of the 2007 earthquake and tsunami. However, more monitoring is needed to adequately assess coral reef status in the Solomon Islands.

Coral reef health and resilience – NOT ASSESSED

Insufficient information is available to assess the resilience of coral reefs in the Solomon Islands; but the general health indicates potentially high resilience. Future monitoring of disturbed sites (such as those around Gizo) would provide information on the ability of coral reefs to recover and confirm this indication of strong resilience.

Use of reef resources

A large proportion of Solomon Islanders live in rural villages with high reliance on marine resources for food and income [1, 4]. The ethnic crisis between 1999 and 2002 resulted in the closure of prawn, pig, poultry and cattle farms, which increased pressure on marine resources [7]. Exploited marine resources include fishes, shellfish, lobsters, turtles and sea cucumbers (bêche-de-mer). Fish are collected by net and line, night diving, trolling; with high fishing pressure at some locations [1]. A survey of subsistence fishing in Vavanga village showed that the main component (by weight) of the catch was jacks (Carangidae), snappers (Lutjanidae), parrotfishes (Scaridae), sweetlips (Lethrinidae) and mullets (Mugilidae) [4]. While there is inadequate information on the impacts of fishing and effectiveness of management to assess the sustainability of these activities, there are reports of over-exploitation [4, 7, 8]. Some areas of the Solomon Islands have been fished for the live reef fish export trade, which included targeting spawning

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aggregations of groupers and coral trout (Serranidae). Declines in catch per unit effort, fish size, and scarcity of once-abundant species have been reported in Rovianna and Marovo [4, 8]. These concerns led to a suspension of live fish trade licenses in 1999, but the fishery was re-opened in 2000 following financial pressures from the ethnic tensions. However, the fishery stalled and no new licenses were issued up to 2003 [4]. In some areas, night spearfishing for bumphead parrotfish has reportedly decimated populations, and fish aggregations have also been targeted by subsistence and artisanal fishers, leading to declines of species such as groupers [4]. The Solomon Islands also have an active marine aquarium trade which accounted for 12% of all aquarium fish entering the international market between 1997 and 2002 [4]. While productivity appears to be stable, the aquarium trade has been assessed as a potential risk to fish stocks [9] and some tourism resort operators report localised depletions of anemone fish [8]. Destructive fishing practices (bomb fishing) are reported as being used by artisanal fishers who sell to local markets [4]. While this practice may have decreased [7], it still threatens some reefs [1, 4, 8]. Coral reefs in the Solomon Islands are also actively mined for coral lime, with an estimated 10 million kg of live *Acropora* corals taken per year for use with betel nut chewing [4]. In some areas, *Acropora* corals are severely depleted [4] and surveys show low levels of *Acropora* cover at monitored sites. Corals are also mined in some areas for building material and to maintain artificial islands. This coral mining poses a significant risk to reefs in the Solomon Islands [4, 8].

Marine resources (such as bait fish for tuna fisheries) are harvested from the shallow waters of mangrove forests, and the mangroves themselves are used for firewood and building material [4]. Mangroves have been cleared for development in some areas and this is a growing problem in provincial areas [7]. Commercial tuna vessels taking baitfish have been blamed for depleting baitfish and damaging coral reefs [8].

Sea cucumbers have been commercially harvested in the Solomon Islands since 1845. A stock assessment in 2000 showed that sea cucumber density was very low (5 individuals per hectare). Other studies also show low abundance of other valuable marine invertebrates such as giant clams, black lip pearl oyster and trochus [4]. There are reports of declining catch rates and changes in the diversity of sea cucumber species in Isabel Province due to over-exploitation.

Almost all commercially valuable crustaceans, echinoderms and molluscs have been depleted to the extent that the government has banned further commercial harvest, and the only allowable sea cucumber catch is artisanal [4, 8].

The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [10] indicates that fishing poses some risk to the marine resources of the Solomon Islands. The **Pacific Ocean Synthesis Report** [9] also identifies fishing as an issue of concern, with artisanal fishing potentially being a severe threat, and moderate threats posed by commercial fishing and the aquarium trade. The *Reefs at Risk Revisited* assessment found that up to 66% of coral reefs in the Solomon Islands as threatened by overfishing.

There is little information on the effects of tourism on the reef resources of the Solomon Islands, although the **UNEP/SOPAC** assessment [10] indicates that tourism is not a major threat.

Use of reef resources – ALTERED (low confidence)

The available information suggests that reef resource use has changed and is resulting in damage to the reefs and resource stocks. Social tensions and natural disasters in the last decade have increased pressure on marine resources such that some stocks (such as sea cucumbers) have been depleted. Densities of some fish and invertebrates are low or declining in some areas. The activities of most concern are subsistence and artisanal fishing, commercial fishing, coral mining, and collecting for the marine aquarium trade.

Factors affecting coral reefs

Assessments suggest that coral reefs in the Solomon Islands face a variety of pressures. The *Reefs at Risk Revisited* assessment reported approximately 72% of coral reefs as threatened by local factors with fishing and land-based pollution being the main factors. The risk assessment of the 5 SICRMN monitoring sites by Kere (2009) [1] showed similar trends with pollution, overfishing and destructive fishing as the key threats, followed by sedimentation and coastal development (Table 1). Logging, in particular, has been reported as a driver of sedimentation and increased turbidity that has caused coral reef damage. In Marovo Lagoon (New Georgia Islands), semi-permanent sediment plumes are attributed to logging activities and coral growth has declined. Fishers in the Isabel Province have reported difficulties in finding target species due to increased turbidity [4]. Erosion from deforestation is also considered as a significant threat to coastal waters, and land clearing for oil palm plantations is a major threat [8]. The 2009 **Pacific Ocean Synthesis Report 2009** [9] lists sediment increases as causing severe impacts to the reefs, along with runoff of untreated sewage, litter and rubbish, particularly around higher density urban settlements [4]. In 2007, a Canadian company was granted rights to 10 641 km^2 of the EEZ

INTEGRATED THREAT INDEX						
Reef Area	**Coastal Development**	**Marine Pollution**	**Sediment Damage**	**Over-fishing**	**Destructive Fishing**	**Overall Threat Index Score**
Gizo	Medium	High	Medium	High	High	High
Munda	Medium	High	Low	High	High	High
Tetepare	Low	Medium	Medium	Medium	Low	Medium
Marovo	Medium	High	Medium	High	Medium	High
Arnavon	Low	Low	Medium	Low	Low	Medium

Table 1. An integrated threat index for 5 locations in the Solomon Islands (from Kere 2009).

southwest of the New Georgia Islands to prospect for sea floor deposits of gold, silver, zinc and copper, and interest by foreign companies in mining land based minerals is increasing [8].

Natural disasters are significant factors that periodically affect coral reefs in the Solomon Islands. The **UNEP/SOPAC 2005** assessment regarded the Solomon Islands as vulnerable to volcanoes, earthquakes and tsunamis [10]. The April 2007 earthquake and tsunami had profound effects on many coral reefs. Corals were dislodged, overturned and broken and underwater landslides removed corals from some reef slopes [6]. This has reduced the area available for fishing and reef gleaning, although catches of fish do not appear to have been affected [6].

One of the biggest issues facing marine resources in the Solomon Islands is rapid population growth [4, 8] with one of the highest population growth rates in the world [4]. Population growth is assessed as a major risk factor in the **UNEP/SOPAC 2005** assessment [10]. Given the high reliance on marine resources for food and income, population increases are highly likely to result in greater pressures on these resources [4].

Coral bleaching and outbreaks of crown-of-thorns seastars (COTS) have been reported from some islands, with widespread bleaching reported in 2000 around Gizo, Marovo and Ngella. COTS outbreaks have also been reported in the western Solomon Islands, Guadalcanal and Malaita [7]. While widespread and persistent bleaching events or outbreaks have not been reported since long-term monitoring commenced. Projected increases in sea temperature and acidity are predicted to cause significant long-term damage to reefs throughout the region, and the *Reefs at Risk Revisited* assessment predicts that all coral reefs in the Solomon Islands will be threatened by 2050, with 85% at high, very high, or critical threat levels. Some areas of the Solomon Islands may also be highly vulnerable to sea level rise, which could submerge some low-lying islands and atolls [5, 9].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

Risk assessments and reports from various locations suggest that coral reefs in the Solomon Islands are affected by many risks, and that some of these risks are increasing or very likely to increase. Some changes have already occurred from the main factors of land-based pollution and the effects of population growth, and the potential effects of climate change.

Governance and management

At least 3 legislated acts provide an important legal framework for the management of Solomon Islands coral reefs. The *Wildlife Protection and Management Act (1998)* of 2003 is the primary mechanism to meet the requirements of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Fisheries resources are managed through the *Fisheries Act (1988)* and a draft management plan was produced in 2003 to manage the live reef fish trade in response to concerns over the impacts and sustainability of the trade [4]. Pollution and solid wastes are managed through the *Environment Act 1998* and other acts are pertinent to land development, management at the local government level, protection for rivers and birds, etc. [8]. There are also specific policies and guidelines, and agreements relating to logging, fishing, and protection of species such as turtles [4, 8]. Unfortunately, these laws are not fully effective because of inconsistent compliance and enforcement of legislation, and weak linkages between institutions, government and local communities [8]. Furthermore, management is affected by a lack of capacity, and natural resources have been “over used with little benefit to the country” [8]. Sulu *et al.* (2000) noted that legislation has seldom been enforced in remote areas in spite of government support and the best intentions [6]. Many problems remain regard-

Reefs at Risk Revisited [11]: *Solomon Islands*

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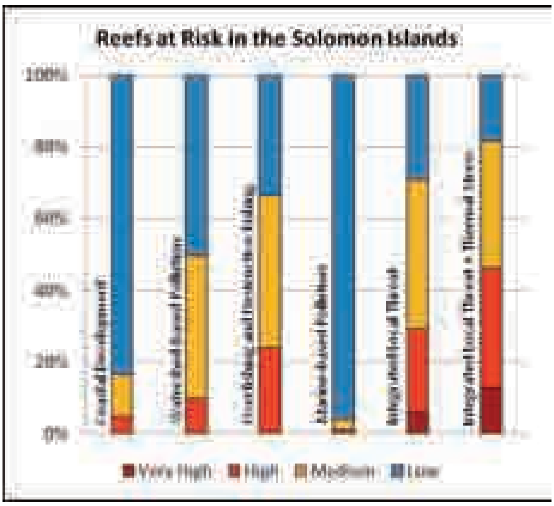
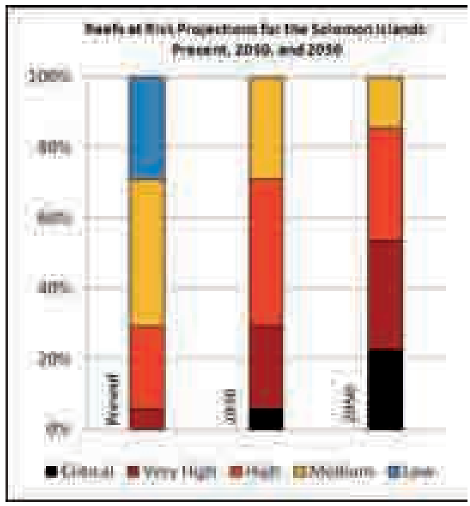
The 2011 *Reefs at Risk Revisited* analysis found the major issues facing the coral reefs of the Solomon Islands are overfishing and land based pollution (e.g. sediments). Together, these factors threaten more than half the coral reefs. The reefs around the central islands of Malaita, Guadacanal and San Cristobel are the most threatened. By 2030, projections for thermal stress and ocean acidification suggest that all coral reefs in the Solomon Islands will be threatened, with more than 70% at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.





ing financial investment, capacity and infrastructure[5]; for example, Sebetian and Afzal (2007) report many breaches of the logging code of conduct.

Traditional management arrangements of tenure and ownership are very important for coral reef management, and these traditional arrangements are acknowledged in the Solomon Islands Constitution [5]. Sulu *et al.* (2000) noted that the success of coral reef management and conservation measures depend largely on local communities, similar to many other Pacific islands [3]. Research suggests that customary management regimes could help reduce or halt overfishing of sea cucumbers and help identify alternative paths for local communities [9]. There are currently 127 Marine Managed Areas (MMAs) in the Solomon Islands: 22 are recorded on the World Database of Protected Areas [3]; 113 are Locally Managed Marine Areas (LMMAs) with about 90 being active; 109 LMMAs can be classified as Community Conserved Areas (CCAs); while the remaining 4 are co-managed with communities. There are an estimated 155 no-take areas within these LMMAs, but some may be periodically opened for extractive use. Two of the best know MPAs in the Solomon Islands are the Arnarvon Islands MPA and Tetepare, which is the largest uninhabited island in the South Pacific containing the last intact lowland tropical forests in Melanesia[4]. Tetepare is managed through the Tetepare Descendents Association together with the WWF, the Solomon Islands LLMA Network and the Solomon Islands Government [8]. Govan (2009) cites an increasing number of CCAs in recent years due to concerted efforts in the Western and Isabel Provinces.

Cultural and religious beliefs may also regulate the use of marine resources by specifying times of the year when certain foods are not eaten. In Ngella, it is believed that eating turtles leads to whooping cough and respiratory problems; while turtles are still eaten, consumption rates are much lower than elsewhere in the Solomon Islands [5].

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Governance and management – NOT CONSIDERED

While the Solomon Islands has national planning and legislative acts, there is little information on the effectiveness of these in managing coral reef resources. However, local reports suggest there are substantial challenges in enforcing management arrangements, with most direct management being implemented through LMMAs and community driven management. More studies are required on these traditional management arrangements because communities depend heavily on these resources.

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Tuvalu

- Marine Area: 757 000 km^2
- Coastline: 24 km
- Land Area: 26 km^2
- Reef Area: 872 km^2
- Total MMAs: 10 [(1)]
- Percentage of reefs threatened (local threats and thermal stress 2011): 31%
- Population (2002 est): 9 561
- Population (2050 proj): 13 800
- Population growth (2004-05): 0.5% [(2)]
- Urban population (2003): 55.2% [(2)]
- GDP (2002 est): US$ 14.94 million
- GDP/capita (2007 est): US$ 2 811

Data from *ReefBase Pacific*, *Reefs at Risk*, and the *SPC Statistics and Demography* database unless referenced with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated, proj = projected).

Overview

Tuvalu (formerly known as the Ellice Islands) is an archipelago of 9 islands, 5 of which are true coral atolls [(3)]. The islands have an average elevation of 3 meters above sea level and the low lying islands of the archipelago are at risk from rising sea levels [(2, 4)] and may be the first sovereign nation to become totally uninhabitable due to sea level rise [(4, 5)]. Of the 26 km^2 of land in Tuvalu, 20 km^2 is used for agriculture [(6)]. The most densely inhabited island is Funafuti with a population density of 1 610 people per km^2 [(3)].

Tuvalu's coral reefs include fringing reefs and platform 'patch reefs'. The fringing reefs are generally narrow and water depth rapidly increases to over 1000 m within a few km of the shore [(3)]. The outer slopes of the atoll lagoons are reported to have rich coral cover. There are also several seamounts which may reach within 30 m of the surface. Small stands of mangrove forest occur on 5 of the 9 islands, with 2 species of mangrove recorded [(5)]. Tuvalu's coral reefs and offshore waters have a rich biodiversity with some 532 species of fishes, 411 species of macro invertebrates (molluscs, decapods, arthropods, crustaceans), and 365 hard coral species recorded [(5)]. However, more surveys are needed to fully describe Tuvalu's marine biodiversity [(5)].

Status, health and resilience of coral reefs

Most of the coral monitoring has occurred around the main island atoll of Funafuti, with 6 sites at Funafuti started in 1995 in association with the establishment of the Funafuti marine reserve. These sites were re-surveyed in 1997 and 1999. In 2001-2002, Tuvalu became part of the Global Coral Reef Monitoring Network (GCRMN) and the sites were revisited by survey teams in 2002/2003 and 2007 [(3)]. Monitoring methods include belt transects and line intercept transects with surveys conducted at 3 depth zones – reef crest, reef slope and reef 'floor'. GCRMN monitoring is carried out by the Fisheries Department with assistance from the Funafuti *Kaupule*

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(Island Council) when opportunities arise, although logistical difficulties have hindered monitoring efforts [3]. Three sites do not have fishing pressure (Fualopa, Fuafatu and Tefala), while the other three sites are fished (Tepuka, Teafualiku and Fualefeke). Data from 2007 are not available for one site (Tefala).

The amount of live hard coral cover did not change significantly between 1997 and 2007; Poulasi (2007) [7] and (2009) [3] report average live hard coral cover (across all 3 depths and all 5 sites) at approximately 20% in 1997; 18% in 1999; 28% in 2002; 25% in 2003; and 23% in 2007. Data from 2003 and 2007 show that coral cover is highest on the slope with up to 74% cover in 2003, and 72% in 2007. However, significant coral cover declines occurred between 2003 and 2007 at Fualefeke and Teafualiku, on the reef crest, slope and floor. In 2007, bleached corals were recorded on the reef slope at Fuafatu, and at all habitats at Teafualiku. However, bleaching was very minor (1-2% of the live coral cover) and considered to be have been caused by coral-eating molluscs [3].

Fish surveys on Tuvalu focus on important food fish species such as unicornfishes and surgeonfishes (Acanthuridae), rabbitfishes (Siganidae), emperors (Lethrinidae) and snappers (Lutjanidae), and indicator species such as butterflyfishes (Chaetodontidae) that reflect coral reef health. Between 2003 and 2007, food fishes showed an increasing trend (across all sites) with the striped bristletooth *Ctenochaetus striatus* being the most common food fish observed. The humpback snapper (*Lutjanus gibbus*) is a particularly favoured food fish [3, 7], but was only recorded at relatively low numbers at 2 stations in 2007. Anecdotal information suggests declining catches of food fishes around the main island of Funafuti. The abundance of indicator fishes showed large increases between 2003 and 2007 at all sites except for Fualopa. The cause of this potential increase is not known, but could be due to factors such as variations in larval survey and environmental conditions [3]. The number of parrotfish in Tuvalu appears to be reasonably healthy compared to other locations in Melanesia, with densities of 36 parrotfish per 100 m^2 recorded [8].

Status of coral reefs – STABLE (low confidence)

While there is some information about Tuvalu's coral reefs, monitoring has been patchy and only occurs around the main island of Funafuti. These surveys show relatively stable coral cover, although potential declines at some sites should be monitored further. The information available shows little evidence of widespread and prolonged stress, damage or loss of live coral cover.

However, the limited time frame and spatial scale of monitoring mean that more work is required to assess the status of Tuvalu's coral reefs.

Coral reef health and resilience – NOT CONSIDERED

There is insufficient long-term trend data from sufficient sites about reef health, status of communities and community structure, or on cycles of disturbance and recovery to adequately describe reef resilience.

Use of reef resources

Tuvalu's population has a high dependence on marine resources, with a mean seafood consumption of 113 kg per person per year [(3)]. Most of the fishing is for subsistence, targeting a variety of finfish species, but there is also a small amount of commercial fishing for local consumption [(7)]. A 2001 census found that 900 families harvest and consume their own fish, while 140 households engage in commercial fishing [(7)]. Finfish are caught using gill nets and hand lines, although night spear fishing is common and may be driving populations of target food fish to very low levels [(7)]. Giant clams (*Tridacna* spp.) and spider shells are harvested for special occasions [(3, 7)], and there are reports of increasing harvest of turtles around Funafuti with anecdotal reports estimating that 15-20 turtles are taken per month [(3)]. Collecting seashells for sale is an important source of income for some families, and some reefs are over-exploited, especially those on Funafuti [(7)]. The government has concerns that changing attitudes and a change from subsistence use to a growing cash economy is putting increasing pressure on Tuvalu's natural resources [(9)].

Sea cucumbers have been harvested since 1978, but the main commercial fisheries closed in 1982 [(7)]. Recent reports suggest that sea cucumbers are again being harvested for export by fishers from the communities on Funafuti, Nukulaelae and Nukufetau; these stocks appear to be severely depleted [(3)]. The **Pacific Ocean Synthesis Report** [(4)] identifies subsistence fishing as a threat to marine resources on in Tuvalu.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

There is little long-term trend information on exploited resources and stock assessments have not been completed. However, anecdotal evidence strongly suggests that fishing has depleted stocks of some coral reef species, with significant declines in some food fish and sea cucumbers. Nevertheless, more information is required to adequately assess reef resource use in Tuvalu.

Factors affecting reef health and condition

Tuvalu's coral reefs are affected by various impacts and processes. Poor water quality and eutrophication have been reported around the island of Fogafale from pig and chicken farms [(3)]. The use of fertiliser to improve soils and sewage pollution have increased nutrient levels and degraded water quality around inhabited islands and in lagoons [(7, 10)]. There has also been pollution from landfills, and erosion and sedimentation damage resulting from coastal development. However, trials of dry sanitation techniques to protect groundwater have had some success, some substandard landfills and dumps have been closed, and other waste facilities improved [(2)]. Substantial amounts of sand and coral are also extracted for building material, exposing coastal zones to increased erosion. On Funafuti, construction of seawalls has apparently altered hydrodynamic patterns, leading to erosion elsewhere on the island [7]. These threats are echoed in the **Pacific Ocean Synthesis Report 2009** [4] and **2005 UNEP/SOPAC Environmental Vulnerability Index** [10] which note the risks posed by coastal development. The *Reefs at Risk Revisited* assessment also notes that coastal development along with fishing are the major pressures currently affecting coral reefs in Tuvalu.

Coral bleaching was observed in Tuvalu during 2002, but damaged corals appear to have recovered [7]. Tuvalu is extremely vulnerable to sea level rise [2, 4, 9, 10] with a rise of 2 mm ± 1 mm per year recorded between 1950 and 2001 [4]. The Tuvalu Government has announced contingency plans for climate change impacts including the evacuation of citizens [2]. Climate change impacts may also result in severe weather events such as cyclones and storm surge [4, 10].

Like other nations in the Pacific, Tuvalu is experiencing significant population growth. The limited available land area also means that population density will rise with increasing populations and urban drift, increasing pressures on Tuvalu's environment [9, 10]. The *Tuvalu National Strategy for Sustainable Development: 2005-2015* describes Tuvalu as one of the most environmentally vulnerable countries in the region. Key risks include: sea level rise (associated with climate change); rising population density in Funafuti; a decline in traditional resource management; unsustainable use of natural resources; and poor waste management and pollution control [9].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

The available information outlines many direct and indirect threats to Tuvalu's coral reefs, and indicates that these threats are likely to increase, especially as populations grow and the impacts from climate change become more prevalent. The other main threats are: pollution and run-off from land based sources and coastal development due to increasing pressure from population growth. However, more information is required to understand how these factors will affect Tuvalu's coral reefs.

Governance and management

Tuvaluan main legislative instruments for managing marine resources are the *Fisheries Act (1990)* for managing fishing activities and fisheries, and the *Falekaupule (Local Government) Act (1997)* that empowers local councils to regulate fishing and reef management on their islands [7]. However, the *Conservation Act (1999)* prohibits the killing of animals inside a reserve and thus, also provides some means for coral reef management [7]. On several islands, the council of chiefs (*Maneapa*) exercises powers that regulate fishing in their communities, including closures and restrictions. For example, the central lagoon of Vaitupu Atoll is closed to fishing for all species except for milk fish (*Chanos chanos*), and only one person designated by the chiefs is allowed to fish in this location with the proceeds going to the community [7]. The *National Strategy for Sustainable Development 2005-2015* lists a number of goals and policy directions for the governance and management of fisheries and the environment across different levels of government and legislation. Despite these management tools, there are reports that fishing continues to be largely unregulated and unmanaged [3, 7], along with concerns about the decline of traditional management arrangements [9].

The World Database of Protected Areas lists one Marine Managed Area (MMA) in Tuvalu, the Funafuti Conservation Area, which covers 35.95 km^2. This area is co-managed with the local community and can be considered a Locally Managed Marine Area (LMMA). A further 9 Locally Managed Marine Areas (LMMAs) have been recorded across other islands including the islands of Nukulaelae, Vaitapu and Nui [1, 3], bringing the total area of marine managed areas in Tuvalu

Reefs at Risk Revisited (11): *Tuvalu*

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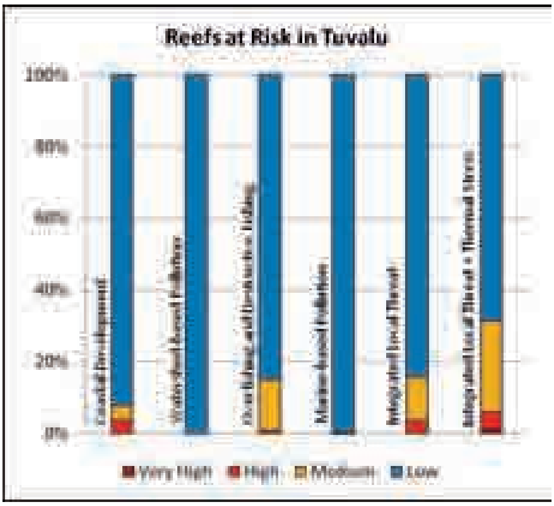
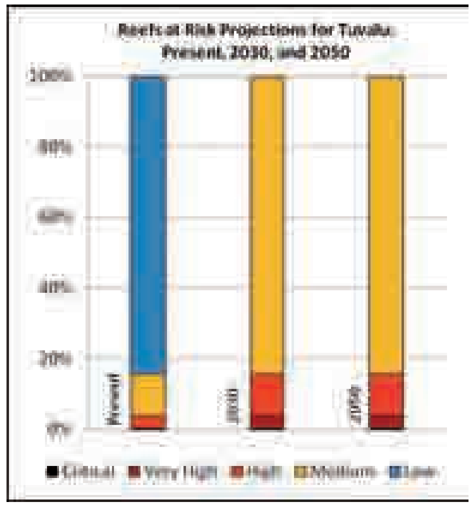
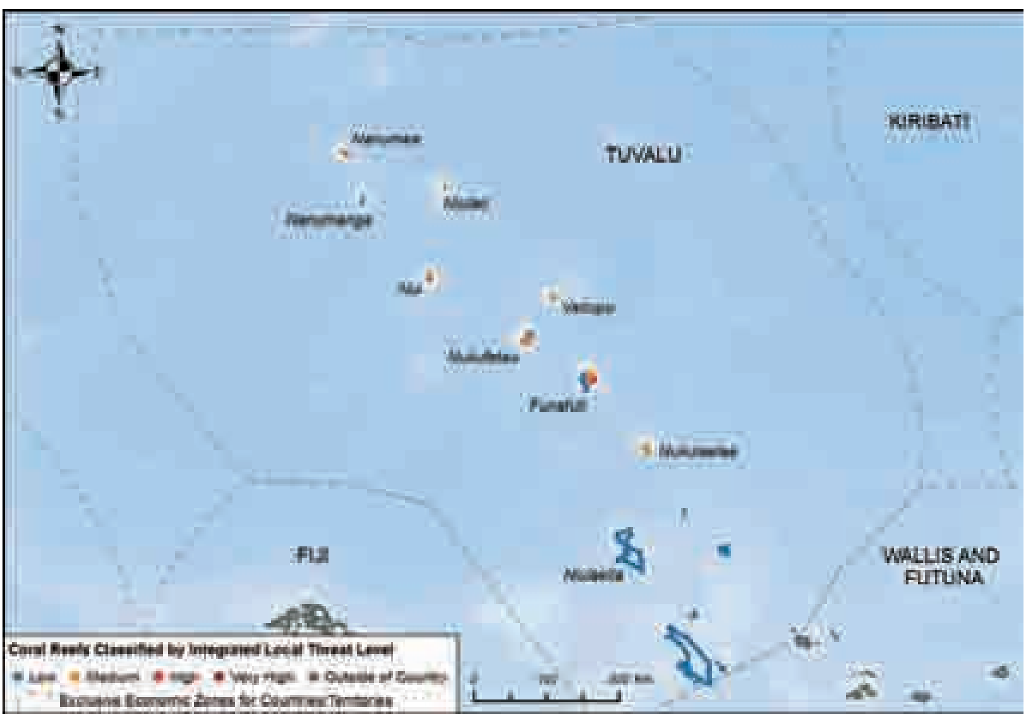
The *Reefs at Risk Revisited* analysis shows that Tuvalu's coral reefs are currently most threatened by over-fishing and coastal development. However, these threats appear to be quite localised (particularly around Funafuti) and most reefs are currently assessed as being at low risk. When the thermal stress over the past 10 years is integrated with local threats, the percentage of threatened reefs in Tuvalu increases from about 15% to more than 30%. By 2030, projections for thermal stress and ocean acidification suggest that all of Tuvalu's coral reefs will be threatened. The full report, methods and full size maps are on: http://www.wri.org/reefs.







to 75.6 km^2, with approximately 50 km^2 of this listed as no-take areas [(1)]. All the LMMAs are occasionally opened to harvesting for important ceremonies and events [(1)].

Governance and management – NOT CONSIDERED

Tuvalu has some legislation to protect and manage coral reefs; however, the extent to which this is implemented and the effects of management on the use and health of coral reefs is not known. There are reports of inadequate regulation and management of fisheries. The existence of traditional management arrangements and LMMAs are positive signs, but reports of declines in traditional management systems are a cause for concern, as are reports of over exploitation and declines of food fishes. More information is required to understand the effects of management on Tuvalu's coral reefs.

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Vanuatu

- Marine Area: 680 000 km²
- Coastline: 2 528 km
- Land Area: 12 190 km² [(1)]
- Reef Area: 4 110 km²
- Total MMAs: 55 [(2)]
- Area of MMAs: 1 380 km²
- Mangrove Area: 30 km² [(1)]
- Percentage of reefs threatened (local threats and thermal stress 2011): 92%
- Population (2009): 234 023 [(3)]
- Population (2050 proj): 538 707
- Population growth (2007): 2.3% [(3)]
- Urban population (2003): 24.4% [(3)]
- GDP: USD $1.137 billion (2009) [(3)]
- GDP/Capita: USD $510 (2009) [(3)]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database and *Reefs at Risk Revisited* unless indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated., proj = projected).

Overview

Vanuatu consists of 80 islands as a Y-shaped archipelago northeast of New Caledonia and west of Fiji, that continues northwards to the Santa Cruz Islands of the Solomon Islands; 12 are large islands and 67 are inhabited [(1)]. Geopolitically, Vanuatu is divided into 6 provinces that are largely self governing and able to manage the coastal waters (Provincial waters) to 6 miles from the coast [(1)]. Vanuatu lies on the western margins of the Pacific plate and is volcanically very active. Of Vanuatu's 16 volcanoes, 9 are active, and earthquakes and eruptions have occurred recently [(1)]. Vanuatu also lies within the tropical cyclone belt and is affected by two cyclones on average per year [(1)]. Seismic events and cyclones periodically cause significant damage to Vanuatu's coral reefs.

Vanuatu has a variety of reef types including fringing, platform and oceanic ribbon reefs, and volcanic atolls [(4)]. The reefs contain significant biodiversity with records of: 295 hard coral species; 469 reef fishes; 4 species of marine turtles; at least 4 species of marine mammals; and 18 species of sea cucumbers, as well as many other marine species (e.g. molluscs, crustaceans, algae, echinoderms) [(4)].

Vanuatu has one of the highest population growth rates in the Pacific (2.6% per annum) [(1, 2, 5)] with the population being predominantly rural. Most villages are on the coast, such that there is heavy reliance on agriculture and marine resources for subsistence and local income. The domestic fishery is very important to food security, supplying protein to 60% of households [(1)]. However, the urban population increased by more than 40% between 1999 and 2009 [(3)]. Monitoring of coral reefs and reef resources has been sporadic and numerous challenges to monitoring efforts exist [(1)].

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Status, health and resilience of coral reefs

Global Coral Reef Monitoring Network (GCRMN) activities were initiated in Vanuatu in 1998, but the first surveys did not occur until 2002 with funding and support from the Canada South Pacific Ocean Development program (CSPOD) and the University of the South Pacific [4]. Two monitoring sites were established on the main island of Efate in 2002, and more sites were added at Efate, and the islands of Epi and Espiritu Santo between 2003 and 2004 [1, 4]. The Vanuatu Coral Reef Monitoring Program is coordinated through the Vanuatu Fisheries Department (VFD) and in 2005, Reef Check Vanuatu was established in collaboration with the Peace Corps and funding from AusAID [1]. Surveys use modified Reef Check protocols that include target species such as rabbitfish and surgeonfish (which are taken for local consumption), and invertebrates such as turban shells, trochus, green snails and cowries [1]. Monitoring efforts are often limited by logistical constraints such as access to sites and SCUBA equipment, so most surveys are conducted by village-based Reef Check teams in shallow water (< 6 m depth) [1].

Between 2000 and 2007, some 57 sites in 11 regions were surveyed. While many of these sites were surveyed as single baseline surveys, some 33 sites are permanent sites that may be used for long-term monitoring [1]. Survey sites around the main island of Efate were established to monitor the effects of growing urban populations and development, fishing pressure, and especially the aquarium trade [4].

Between 2000 and 2004, sites surveyed around Efate showed varying levels of live hard coral cover that ranged from 58% at Bakura to 6% at Ifira, with a mean coral cover across all sites of 27% [4]. Surveys between 2006 and 2007 across 11 regions in Vanuatu reported a diverse range of coral cover: sites at North Efate showed 49% coral cover and Luganville had < 5% cover (Fig. 1) [1, 6]. Most of the substrate was recorded as hard substrate (rock, recently dead coral), with live hard coral cover averaging 26% and loose substrate being 20% [1]. North Efate had the highest coral cover, followed by Epi (40%); Malekula (37%) and Gaua (35%) [1].

There are indications that the coral reefs of Efate have experienced previous mortality events that could be due to coral bleaching or crown-of-thorns seastars (COTS) [1, 4]. However, the reefs appear to be recovering, and there are currently few signs of bleached corals and only low percentages of nutrient indicator algae recorded [1].

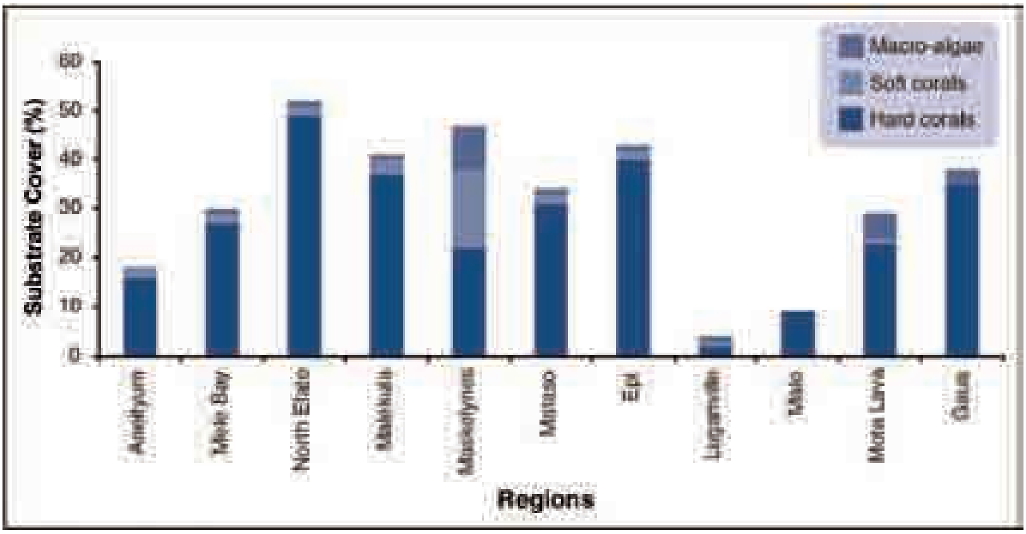

Fig. 1. Survey data from 57 sites in 11 regions of Vanuatu in 2006–2007 show that total live coral cover (hard and soft corals) varies considerably from less than 5% at Luganville to more than 50% at North Efate. The number of monitoring sites in each region is as follows: Aneityum (3); Mele Bay (3); North Efate (13); Malekula (7); Maskelynes (2); Mataso (2); Epi (3); Luganville (1); Malo (2); Mota Lava (3); Gaua (19); (Figure extracted from Morris and Mackay 2008 [6]).

Surveys between 2005 and 2007 show the probable effects of fishing on reef fishes and other valuable species. Butterflyfishes (Chaetodontidae) and surgeonfishes (Acanthuridae) were the most commonly observed fishes, while barramundi cod (*Cromileptes altivelis*), humphead (Maori) wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) were only observed at several sites [1]. Amongst the invertebrate species monitored, edible sea cucumbers had the highest recorded densities (38 per 100 m^2 at Aneityum). Triton and green snails were rarely observed. Surveys also detected COTS in 6 of the regions and at densities of > 0.2 per 100 m^2 which could indicate the potential for damaging outbreaks [1].

Status of coral reefs – NOT CONSIDERED

Trend information at permanent sites is only available for 2005-2007, many sites have only been visited once, and surveys are generally restricted to shallow water (< 6 m depth). While there is good coral cover on Vanuatu's reefs, the data are insufficient to determine long-term trends.

Coral reef health and resilience – NOT CONSIDERED

Insufficient information is available to assess the reef resilience in Vanuatu. While there is evidence of coral recovery in reefs around Efate, the extent of the initial decline and subsequent recovery are not known. Future monitoring of disturbed sites and monitoring of community structure would provide better information on resilience of Vanuatu's coral reefs.

Use of reef resources

About 80% of the population of Vanuatu is directly or indirectly reliant on marine resources for food and income [4]. Subsistence and artisanal fishing are the main fishing activities on the reefs. A 2006 census indicated that 72% of households in Vanuatu engaged in fishing activities [1] using a wide variety of fishing gear and techniques, including reef gleaning, hand lines, gillnetting, spear fishing, trapping, and in some areas, traditional fishing methods (bow and arrow, spears, traps and traditional poisons) (1). Destructive fishing practices (bombs, cyanide, coral breakage) are uncommon (1, 4). The subsistence fishery occurs mainly in the reef lagoons and inter-tidal zone, targeting a variety of finfish and shellfish (1, 4). Although consolidated national catch data are not available, some recent estimates show an average catch of 3.2 tonnes per km^2 per year (SD ± 1.4) in semi-urban areas (North Efate) (7). Subsistence fishing appears to be extremely important to local communities and is a major component of rural food security (4). Recent data suggest that the artisanal fishery mainly supplies products for domestic markets. The fishery extends from the foreshore to the 12 nautical mile zone. In shallower waters around reefs and reef lagoons, fishers target coral reef finfish and invertebrates such as trochus, green snail, sea cucumbers (bêche-de-mer), lobsters, giant clams and octopus, and collect live species for the aquarium trade (1).

Coral reef food fishes are coming under increasing pressures with the development of commercial exploitation, particularly around populated regions of Efate and Espiritu Santo (4). Over-exploitation may become a serious issue in all regions where commercial fishing is developing (e.g. close to urban centres and transport infrastructure) (Table 1). While stock assessments and catch surveys have not been completed, the data suggest that reef food fishes appear to be at moderate levels of abundance with the potential risk of future over-exploitation (4, 5, 8), especially given increasing local demand and improvements in fishing gear (1, 9). The government has invested in improved infrastructure and training to develop fisheries in order to meet growing urban demand (4). Trochus and sea cucumbers are the main export fisheries from inshore areas, but exports have been decreasing and stocks have been severely depleted in many areas (1). Giant clams have been taken for meat and for the aquarium trade, and some species are considered to be locally extinct. Export of clams for the aquarium trade was banned in 2000 (4). The harvest and export of green snail was prohibited in 2005, and harvest and export of sea cucumber was prohibited in 2008 for 5 years (1, 9). Coconut crabs are harvested in some areas of Vanuatu and are a traditional local delicacy, but significant amounts are also sold to hotels. Crab populations have been so seriously depleted in some areas that harvesting is now banned (4). Exports of aquarium species have increased dramatically since the fishery began in the early 1990s (Fig. 2), and this fishery is currently the largest earning export fishery from inshore waters (1). Exports are primarily ornamental fishes, corals, invertebrates and giant clams. While there are concerns that the aquarium fishery is depleting stocks (10), especially in reports from tourism operators and recreational divers, the trade generates over US$ 500 000 per year in export earnings and

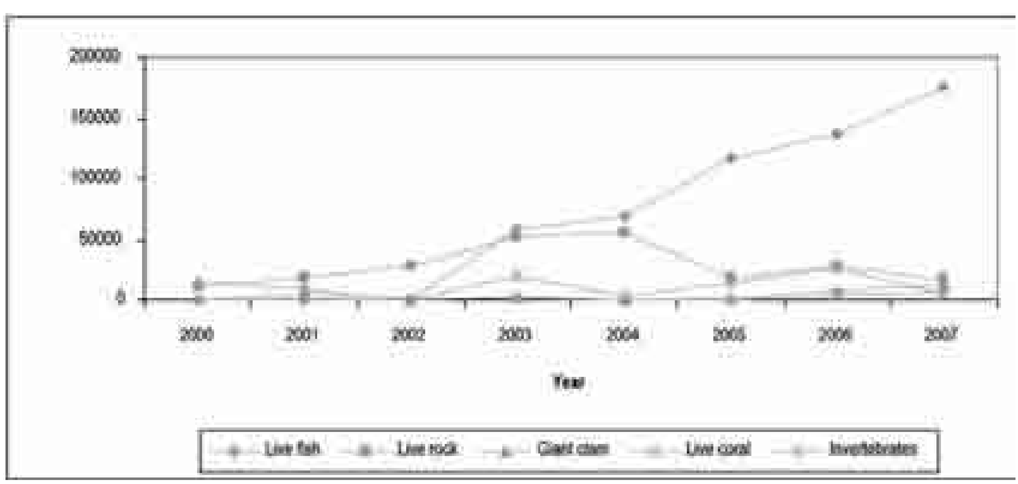

Fig. 2. Exports of specimens for the aquarium trade have dramatically increased from some 36 000 pieces in 2000 to 216 446 pieces in 2007 (Figure from Raubani 2009 (1)).

provides income for some local communities [1]. Preliminary assessments in 2004 indicate a high variety and density of non-food fish at different sites, however more information is required to adequately assess stocks of aquarium fishes [4]. Concerted efforts have been made to reduce the dependence on wild caught species through the development of aquaculture [4].

Most commercial fishing is in offshore waters targeting pelagic species such as albacore tuna (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*). This fishery is dominated by foreign long-line fishing vessels that provide Vanuatu with an average of US$ 1 million per year through licenses and access fees [1]. Vanuatu also has a deep-water fishery that targets valuable groupers and snappers ('poulet') for fish markets and hotels; however, the fishery has been sporadic over the years due to difficulties in processing and marketing the products [9]. Current commercial fishing effort is relatively small but is increasing [1], and catches appear to be sustainable, although there are concerns about the levels set for sustainable yield. More information is required [1].

Tourism is an important source of income for Vanuatu, and contributes up to 40% of the GDP [1]. Tourism activity is centered near Port Vila (Efate) and Luganville (Espiritu Santo), and coral reefs are among the main attractions [1]. Dive tourism is relatively small, but increasing numbers of divers are adding pressure to reefs, and this will require further attention to determine sustainable levels of access and ensure that benefits are shared with local communities [1, 4]. Local hotels and community guest houses can generate income in rural zones, but may also add pressures through increased waste, and demand for resources such as fish, lobsters and coconut crabs [1, 4]. However, tourism can also benefit local resource use; for example on Mystery Island, Aneityum, tourists pay access fees directly to support a marine reserve, which has shown increased abundance of stocks, including species that are scarce elsewhere [2]. There is little information on the overall effects of tourism on Vanuatu's reef resources, although the **UNEP/SOPAC Environmental Vulnerability Index** [11] indicates that tourism is not a major threat [1, 4, 12].

Mangroves are relatively sparse in Vanuatu and only cover some 30 km^2, most of which are in eastern Malekula [12]. However, mangroves are an important source of wood for fuel and building materials, for medicine, and as habitats for fish, crabs and shellfish, which are important in subsistence diets. While mangroves are not commercially exploited, firewood collection poses a threat and in Malekula and Efate, mangroves are threatened by tourism and infrastructure developments [1, 4, 12].

The **UNEP/SOPAC** assessment [12] indicates that fishing poses some risks to Vanuatu's marine resources. This is echoed in the **Pacific Ocean Synthesis Report** [10] which identifies subsistence, artisanal and commercial fishing as posing a moderate threat, while the aquarium trade is assessed as low threat. In contrast, the *Reefs at Risk Revisited* assessment suggests that more than 80% of Vanuatu's coral reefs are under threat from overfishing. The lack of data and subsequent uncertainty may account for some of these discrepancies.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

The limited information (e.g. long term stock assessments and catch surveys) is insufficient to assess the trends and effects of reef resource use; resource use has changed and may be causing negative trends. Some stocks (e.g. sea cucumbers, triton, green snail) have been seriously depleted and required bans on harvesting and export. Densities of some fish and invertebrates are low with declines reported in some areas. The activities of most concern include subsistence and artisanal and commercial fishing, coral mining, and potentially the collection for the marine aquarium trade.

Factors affecting reef health and condition

Vanuatu's rapid population growth and the dependence on marine resources are putting increasing pressures on reef resources and the environment [1]. Population growth is assessed as a major threat in the 2005 **UNEP/SOPAC Environmental Vulnerability Index** for Vanuatu [11].

Raubani (2009) evaluated threats to coral reefs within the 11 GCRMN survey regions and revealed similar trends to those found in *Reefs at Risk Revisited* (Table 1) [1]. This assessment showed that overfishing is the most significant issue, but that land-based pollution and sediments also pose threats to Vanuatu's coral reefs. The **Pacific Ocean Synthesis Report 2009** [10] also lists sedimentation as having moderate impacts on Vanuatu's marine environment. Activities such as agriculture and deforestation have altered the landscape such that landslides and floods resulting from heavy rains or earthquakes carry sediment and nutrients into waterways [1, 4].

Coastal development is also an issue near population centres. Port Vila and Luganville are areas for particular concern; water quality monitoring since 2001 shows serious water pollution near Port Vila, most likely due to inadequate sewage treatment [4, 5]. Disposal of solid waste is also an issue for many communities [5].

INTEGRATED THREAT INDEX						
Reef Area	**Coastal Development**	**Pollution**	**Sediment Damage**	**Over-fishing**	**Destructive Fishing**	**Overall Threat Index Score**
Aneityum	Medium	Medium	High	Medium	Low	Medium
Male Bay	High	High	High	High	Low	High
N. Efate	Medium	Medium	Medium	High	Medium	Medium
Malekula	Low	Low	Medium	Medium	Low	Medium
Maskelynes	Low	Low	Low	Medium	Low	Low
Matasso	Low	Low	Low	Medium	Low	Low
Epi	Low	Low	Medium	Medium	Low	Medium
Luganville	High	Medium	High	Medium	Low	Medium
Malo	Medium	Low	Low	Medium	Low	Medium
Mota Lava	Low	Low	Low	Medium	Low	Low
Gaua	Low	Low	Medium	Medium	Low	Low

Table. 1. A threat assessment shows that overfishing is the main threat across all Vanuatu's coral reefs, with land based pollution and sedimentation threatening some areas (from Raubani 2009 [1]).

Volcanic and seismic activities can also damage Vanuatu's coral reefs. The **UNEP/SOPAC 2005** assessment listed Vanuatu as 'vulnerable', with volcanoes and earthquakes posing significant risks [11]. There are uplifted coral reefs in Santo and Malekula, and an earthquake in 2002 caused severe landslides [4]. Other natural disasters such as cyclones, floods, landslides and tsunamis also pose threats to the people and the environment [5, 11]. In 1999, a 10 m high tsunami hit Pentecost Island causing considerable injury and loss of life [4]. Cyclones have caused significant damage to Vanuatu's coral reefs; Cyclone Danny (2003) damaged 80% of corals on exposed reefs on southwest Efate [4], and three cyclones have passed through Vanuatu since 2005 [1].

Coral bleaching and COTS outbreaks have affected some coral reefs around Vanuatu. In 2001-2002, warm water temperatures resulted in mass coral bleaching on several reefs around Efate, with some coral mortality [4]. Coral bleaching was also reported in 2004 [4] but no bleaching events have been recorded since then [1]. There are more recent reports of COTS outbreaks around Mele Bay and North Efate, with densities of 2 to 10 COTS per square meter [1]. As long-term monitoring of coral reefs has only recently begun, it is difficult to describe the impacts of COTS and coral bleaching across Vanuatu.

Vanuatu is particularly threatened by sea level rise as many roads and settlements are close to the coast [5]; 3 islands have already been submerged and at least one village (Lateu) has been relocated [10]. Projected increases in sea surface temperatures and acidity are predicted to have significant long-term effects on coral reefs throughout the region. The *Reefs at Risk Revisited* assessment predicts that all coral reefs in Vanuatu will be threatened by 2030, with more than 50% at very high or critical threat levels.

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

While there have been several risk assessments, long-term information is sparse on risks, and affects on the environment. Available information suggests that Vanuatu's coral reefs are affected by numerous risks and some risks are increasing or very likely to increase. There is some evidence that changes have already occurred in some areas. The main factors related to human activities include land-based pollution, increased sedimentation, population growth and sea level rise.

Governance and management

The *Fisheries Act No. 55 (2005)* and the *Environmental Management and Conservation Act (2000)* are the main legislative tools to manage Vanuatu's marine resources [1]. The *Fisheries Act* facilitates the establishment of marine reserves, the prohibition of fishing for marine mammals, bans on destructive fishing practises (bombs and poisons), and regulations on fishing gear [1]. There are also restrictions or bans on harvesting some species (e.g. green snails and sea cucumbers), live corals cannot be collected in designated marine reserves, and the export of wild collected live coral is banned. The *Environmental Management and Conservation Act* provides for the recognition and protection of Community Conservation Areas (CCAs), and assessment of coastal development [1, 2]. Vanuatu is a signatory to CITES, therefore coral exports are controlled. Wild collected corals cannot be exported and export of cultured corals requires a permit [1]. The

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Decentralization Act (1991) provides some powers to provincial authorities including management of marine resources; but unfortunately this act conflicts with the *Fisheries Act* and there have been problems working collaboratively between the fisheries department and local communities [4]. Additionally, a lack of resources is affecting the implementation of the *Environmental Management and Conservation Act* [5].

Traditional management and customary tenure are very important components of environmental management in Vanuatu [2, 5]. The World Database of Marine Protected Areas lists 26 MPAs in Vanuatu, including the well known President Coolidge and Million Dollar Reef Marine Reserve. Traditionally managed Locally Managed Marine Areas (LMMAs) or 'tabu' areas are recognized as being widespread, with estimates that as many as 80 villages manage marine resources through these traditional arrangements (the photograph above shows a tabu area marked with coconut fronds) [2]. The national constitution recognizes that each village has the customary tenure over their fishing grounds (from the shoreline to the edge of the reef) [14], and this is actively supported by fisheries officers, government organizations and NGOs [2, 5]. However, many more LMMAs and CCAs are unrecorded such that the current figures are likely to be underestimates. There is evidence that a number of LMMAs in Vanuatu have been effective [4, 7], with increased size and abundance of target species such as trochus, mullet and parrotfish within protected areas, and some records of spill-over effects into adjacent areas [2, 7]. A register of Protected Areas and Community Conserved Areas is maintained by the Environment Department, but is not currently available and concerted efforts at documenting MMA coverage are urgently needed [2].

The Vanuatu Fisheries Department has worked to rehabilitate areas depleted of reef species by supplying cultured trochus juveniles to communities. In turn, communities are required to meet several criteria including accepting fishing closures for trochus and size restrictions. These projects have resulted in increased harvests and have triggered the revival of traditional management in a number of communities and management of other marine resources [2]. The program is expanding to include more species such as green snail, sea cucumbers, lobsters and giant clams. The program has re-introduced the giant clam (*Tridacna gigas*) to Vanuatu, which was believed to have previously been locally extinct.

Governance and management – EVIDENCE OF CHANGE (low confidence)

Vanuatu has several national planning and legislative acts, but there is little information on whether existing management arrangements are effective in managing coral reef ecosystems and sustaining reef resources. Reports suggest there are substantial challenges in enforcing management arrangements. On-ground management appears to be dependent on local communities and LMMAs, and there are positive trends in some areas. Efforts to restore heavily exploited species are also reported to be positive. However, many resources remain under pressure and some species have not recovered from previous exploitation.

Reefs at Risk Revisited [13]: Vanuatu

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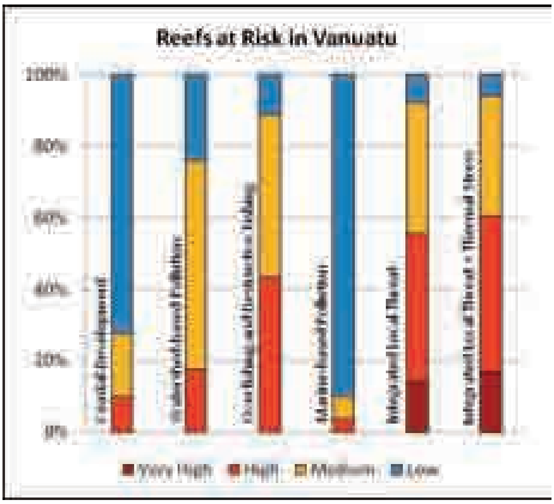
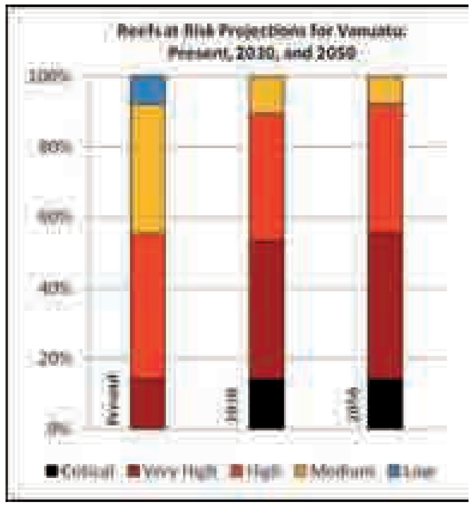
The *Reefs at Risk Revisited* report found that Vanuatu's coral reefs are currently most threatened by land-based pollution and overfishing. These factors threaten about 75% and 90% of Vanuatu's coral reefs, respectively. When past thermal stress is integrated with local threats, almost 95% of Vanuatu's coral reefs are threatened. Currently, the reefs most at risk are situated around Efate, Espiritu Santo and Malekula. By 2030, projections for thermal stress and ocean acidification suggest that all coral reefs in Vanuatu will be threatened, with more than 50% at very high or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.





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Commonwealth of the Northern Mariana Islands

- Marine Area: 1 823 000 km²
- Coastline: 1 482 km
- Land Area: 477 km²
- Reef Area: 102 km²
- Total MPAs: 9 [1]
- Area of MPAs: ?
- Mangrove Area: 7 km²
- Reefs at Risk (local threats and thermal stress 2011): 90%
- Population (2008 est): 86 616
- Population growth: ? (-4.0 [2]; +2.7 [3])
- Urban population (2010): 91% [2]
- GDP: USD $900 million (2000 est)
- GDP/Cap: USD $12 500 (2000 est)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimated; proj = projected).

Overview

The Mariana Islands are an archipelago of 15 islands stretching 480 km north to south. The islands are about 2 660 km east of Manila in the Philippines, and 2 100 km north of Papua New Guinea. The southern most island of the Mariana chain is Guam which is an independent US territory and is a separate political entity. The other 14 islands constitute the Commonwealth of the Northern Mariana Islands (CNMI) which has a combined land area of 477 km² [4]. There are also submerged banks, shoals and seamounts (e.g. Stingray shoal and Pathfinder Reef) along the Western Mariana Ridge on a north-south arc 145 to 170 km west of the main archipelago [1]. There are also several submerged banks closer to the islands such as Tatsumi Reef (2 km from Tinian Island) and Marpi Bank (28 km north from Saipan). Since 1976, the CNMI has been a self governed commonwealth in political union with the US, meaning it has a locally elected governor and legislature, but US federal law applies throughout the commonwealth [2]. Most of the population is urban and is concentrated at the southern end of the archipelago on the main islands of Saipan, Rota and Tinian [1, 4]. Saipan is the largest island (122 km²) and is the centre of government and administration [1].

The archipelago can be divided into two island groups: the 9 northern islands include (from south to north) Anatahan, Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and Farallon de Pajartos and are younger volcanic islands which are largely uninhabited [4, 5]. The 5 southern islands are Rota, Aguijan, Tinian, Saipan, and Farallon de Medinilla, and while these islands also have volcanic origins, they are older than the northern islands and are covered in uplifted limestone [4]. The southern islands have the oldest and most developed coral reefs, with the most extensive reefs on the western (leeward) side of the islands [4]. Approximately 256 species of corals from 56 genera and 41 octocorals in 20 genera have been identified in the CNMI [6]. Coral reef ecosystems are reasonably healthy across the whole of the CNMI [4], but there is evidence that human pressures have affected reefs around the populated southern islands [4]. Saipan has the greatest diversity of reef types and associated habitats in the archipelago but as the most densely populated island, these reefs are affected by human pressures [4]. The main issues facing the coral reefs of the CNMI include land-based pollution (sediments, nutrients etc.); over-exploitation of fish resources; coastal development (e.g. the expansion of military activities); and climate change and ocean acidification [1].

Status, health and resilience of coral reefs

Corals reefs in the CNMI have been periodically studied since the 1940s [1]. More recently, the reefs have been monitored by many organizations such as the US National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC) – Coral Reef Ecology Division (CRED), and CNMI agencies such as the Department of Environmental Quality (DEQ), Division of Fish and Wildlife (DFW) and the Coastal Resource Management Office (CRM) [1].

The PIFSC-CRED has monitored benthic and fish communities, and a range of environmental variables on coral reefs throughout the archipelago since 2003 as part of the Marianas Archipelago Reef Assessment and Monitoring Program (MARAMP) [1, 5]. This program surveys many sites across the archipelago and includes towed diver surveys at ~15 m depth on fore-reef slopes, SCUBA surveys on 25 m long transects from 10-20m depth, and collects temperature and salinity data [1, 5, 7]. The CNMI government monitoring programs are focused around the main populated islands: water quality is regularly monitored at 83 locations around population centres (Saipan, Tinian and Rota) by the DEQ; fish populations and benthic communities in marine reserves have been monitored every year by the DFW Fisheries Research Section since 2000; and fish, invertebrates and benthic communities have been monitored at 36 sites across Tinian, Saipan, Aguijan and Rota through the CNMI Marine Monitoring Team (MMT) with data reported from 2000 [1]. The MMT is a collaborative effort that involves staff from the CRM, DEQ and DFW [1, 8].Most of the MMT and DEQ monitoring programs are focused on Saipan Lagoon and near-shore coral reefs around Rota, Aguijan, Tinian and Saipan, while the NOAA MARAMP and reef mapping projects survey reefs across the entire archipelago [1].

The CNMI's coral reefs differ between the northern and southern island groups. The northern islands have lower coral diversity and colony surface area (62 species per site, colony size 206 cm^2) compared to southern islands (82 species per site, colony size 312 cm^2), but that coral density was similar between islands [1]. This suggests similar recruitment between regions, and factors such as wave exposure, volcanic ash and eruptions, bathymetry, water quality and the availability of suitable substrate heavily influence coral growth in the northern islands [1].

The MARAMP surveys of 2003-2007 showed varying levels of coral cover across the archipelago. Coral cover in 2007 ranged from 34% at Maug (northern islands) to 3.6% at Farallon de Pajaros (northern islands) [5]. The reefs of the northern islands have generally more variable coral cover, while southern islands showed similar coral cover between islands [5]. The northern reefs generally had higher coral cover and lower macro-algal [1, 5]; the *Archipelagic Benthic Condition Index* from towed diver surveys in 2005 and 2007 suggests that coral communities in the northern islands are 'healthier' compared to the southern, populated islands [5]. The reefs around Maug, Almagan, Gugan and Sarigan islands were the best in the archipelago, while the southern islands of Saipan, Tinia, Aguijan and Rota had low or decreasing coral cover between 2005 and 2007 [5] due to relatively high levels of stress [5]. There was more coral bleaching and coral disease, and higher densities of crown-of-thorns seastars (COTS) in the southern islands [5]. The relatively poor condition of the southern islands appears to be due to human impacts such as pollution and overfishing, but some trends may be driven by natural variation in environmental conditions between the islands [5]. Continued monitoring will provide a clearer indication of the health and resilience of these reefs [5].

The status and health of reefs in the populated southern islands has also been monitored by the CNMI MMT since 2000. COTS outbreaks caused the most significant damage on the reefs surveyed and resulted in a decline in coral cover on Saipan from about 32% in 2003 to <15% by 2004 [1]. These reefs are recovering with 20% coral cover in 2007. [1] On Rota, mean coral cover declined from about 13% in 2003 to 7% in 2004, and recovered to ~17% in 2007 [1]. Recovery has been mainly due to regrowth of fast growing *Acropora* and *Pocillopora* corals, however, trends vary between sites. For example, coral cover at Wing Beach on Saipan declined from ~30% in 2001 to ~20% in 2004, before recovering to ~37% in 2007 [1]. In contrast, Coral Ocean Point on Saipan declined from ~47% in 2001 to ~12% in 2006, with no recovery observed. The different recovery rates could be caused by differences in oceanography or impacts from sediments and pollution from adjacent watersheds [1].

Comparisons with earlier records suggest that human impacts have affected some coral reefs in the CNMI. DEQ water quality monitoring in 2006 identified degraded water quality at 37% of monitored locations, including 47% of Saipan's beaches [1]. In Saipan lagoon, there has been a decline from the data collected 50 years ago in the occurrence and extent of coral habitats (particularly *Acropora* staghorn corals) [1]. MMT data show that coral communities on reefs exposed to poor water quality (e.g. Lau Lau Bay on Saipan Island) exhibited worrying signs of decreased resilience such as decreased species richness and lower coral recruitment compared to healthy sites (e.g. Wing Beach on Saipan Island) [1, 8]. At degraded sites, *Montipora*, *Acropora* and *Pocillopora* corals are being replaced by more resilient *Porites* corals [1]. Meanwhile, the more remote, northern islands appear to have coral communities that are driven by natural processes [1].

The effects of human activities are also evident in data on reef fish populations and commercial fish landings collected through MARAMP and DFW surveys throughout the archipelago and at two sanctuary sites since 2000; the Managaha Marine Conservation Area (MMCA) on Saipan, and the Sasanhaya Bay Fish Reserve (SBFR) on Rota [1].

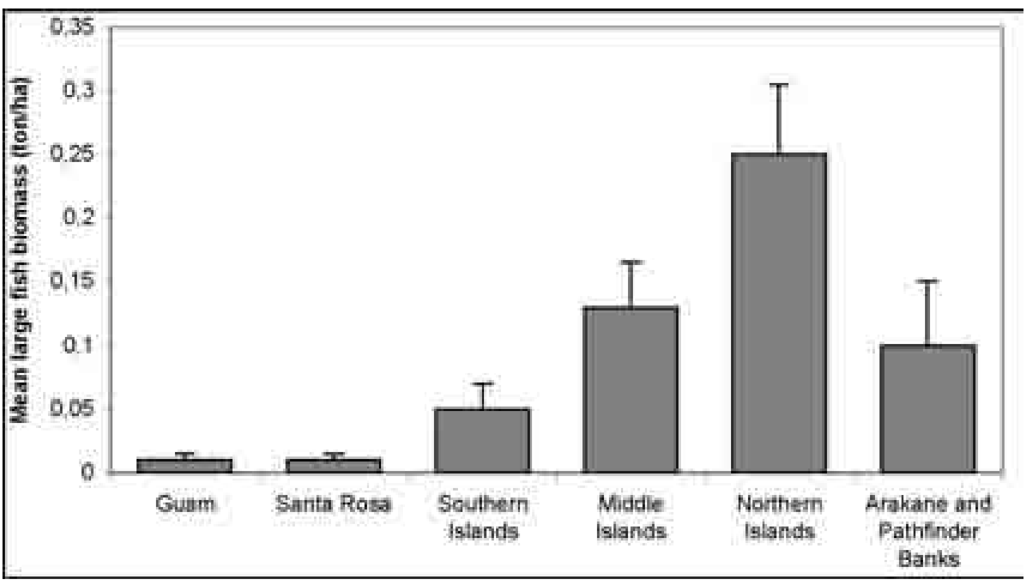
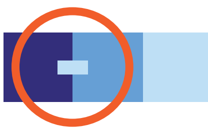


Fig. 1. The MARAMP surveys found that the biomass of large (> 50 cm long) fishes significantly increased with distance from the heavily populated southern islands. This pattern suggests that fishing pressure has reduced the abundance of large fish around populated islands (figure from Goldberg et al*. 2008).*

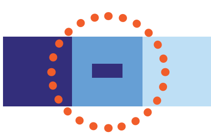
The greatest biomass of large fish (> 50 cm) was found in the northern islands and biomass decreased with proximity to the populated southern islands (Fig. 1). In 2005 and 2007, the highest biomass was recorded around the northern Farallon de Pajaros and Asuncion Islands [5]. The density of fishes targeted by fishers such as jacks (Carangidae), snappers (Lutjanidae) and groupers (Serranidae) was lower in the southern islands, especially for fish larger than 20 cm [1]. North-south differences across the entire archipelago (including Guam) were most evident in piscivore (fishes that eat other fishes) biomass in the northern islands (4.04 kg/100 m^2) being more than 13 times greater than in the southern islands (0.30 kg/100 m^2) [5]. Similarly, the density of sharks encountered was nearly 10 times higher around the northern islands with sightings of 174.5 individuals/km^2 compared to 17.6 individuals/km^2 in the southern islands [5]. These patterns of fish biomass and abundance may reflect human fishing pressures, which also occurs in other areas such as French Polynesia and the Marshall Islands.

Fisheries landings data from DFW suggest that localized depletion may have occurred, with a general decline in reef fish landings and CPUE since the 1990s [8], however, the landings data are not separated by species, making it difficult identify trends in fish populations [8]. Monitoring of the two sanctuaries shows positive results with increasing fish populations over time. Surveys also show positive effects of other management measures such as restrictions on fishing gear.



Status of coral reefs – STABLE/EVIDENCE OF CHANGE (high confidence)

While long-term monitoring of coral reefs commenced in the last decade, detailed surveys at many sites across the archipelago allow comparisons with historical data across human population gradients. Reefs in the north are healthier than the main populated southern islands, with signs of stress and decline including reduced cover of some coral species near population centres. Reef fish communities also show signs of fishing pressure with remote reefs showing greater biomass of larger fish than those near population centres, suggesting that the southern reefs have declined. Further data are needed clarify the extent of decline attributable to human factors compared to natural variability.



Coral reef health and resilience – EVIDENCE OF CHANGE (low confidence)

While CNMI's coral reefs show the ability to recover from disturbance events such as COTS outbreaks, there are signs that reef resilience may be declining. Changes in community structure and coral recruitment at degraded sites around Saipan suggest a decline of reef resilience in affected areas. Reefs in more remote areas of the archipelago appear to be functioning normally, nevertheless, further research and monitoring is required to fully describe reef resilience across the archipelago.

Use of reef resources

The coral reefs of the CNMI are an important natural resource, with those around Saipan valued at US$61.2 million per year [9]. Reef tourism on Saipan is valued at $42.3 million per year, fisheries at $1.3 million, coastal protection at $8 million, and diving and snorkeling at $5.8 million [9].

Fishing is the main extractive use of the reefs with three main fisheries operating: reef based; pelagic; and deep water bottom fisheries. Pelagic fish comprise the bulk of the commercial catch (by weight), followed by reef fish and then bottom fish [1, 10]. Tunas dominate the pelagic catch [10] while the bottom fishery mainly takes emperors (Lethrinidae), snappers, groupers and jacks [10].

Catch data collected by DFW suggest that landings of reef fishes have declined slightly from 68 060 kg and 90 750 kg between 1990 and 2002, to about 45 400 kg in 2006. Data from 2003 show that the main reef fish species include 'mixed reef fish' (32 450 kg), followed by rabbitfishes

(2745 kg) and parrotfishes (730 kg)[10]. Catch-per-unit-effort (CPUE) for reef fish has declined since 1994[8], and may be linked to localized depletion of fish stocks around the southern islands[8]. There have been 'considerable changes' to reef fish in Saipan lagoon between 1979 and 1996, indicating that localized depletion had occurred in the southern islands[8]. Changes in reef fishes are evident in populated southern islands compared to more remote northern islands. However, the introduction of new fisheries management arrangements around Saipan lagoon appear to be increasing fish stocks[1]. Collecting fisheries data is complicated by a lack of funding and capacity, the complexity of the target species and fishery and fishers, including a growing and diverse contract worker population[6, 8]. More information is needed to understand the status and trends in reef fisheries in the CNMI[9]. The 2009 Pacific Ocean Synthesis Report[9] identified commercial fishing as a severe threat to the coral reefs of the CNMI, while *Reefs at Risk Revisited* suggested that 90% of coral reefs are threatened (moderate risk or higher) by overfishing[11].

Reef invertebrates are also an important resource in the CNMI. The topshell (trochus) was introduced in 1938 by the Japanese, with specimens introduced to Saipan, Rota, Tinian and Agrihan. The shells provided income and the meat was consumed locally[6]; however over-harvesting lead to a moratorium on trochus harvest in 1983. There are also 9 species of edible sea cucumber in Saipan lagoon, these were harvested on Saipan and Rota between 1995 and 1996[6]., however catches also declined and the fishery was closed in 1997[9]. Destructive fishing methods (explosives, chemicals or poisons) are illegal in the CNMI; there is no evidence of explosives or electroshock devices, but poison has been reported but the prevalence is unclear[8]. The trade in coral or live reef species is banned and not considered a threat in the CNMI[1].

Tourism is a significant economic use of CNMI's coral reefs[9], and the CRM manages marine tourism activities through permits[1, 8]. There is evidence of damage to seagrass beds from tourism activities, and some hotel operators are seeking permission to remove seagrasses from designated swimming zones[1]. The 2005 **UNEP/SOPAC Environmental Vulnerability Index**[12] indicates that tourism poses a serious environmental risk to the CNMI.

Use of reef resources – EVIDENCE OF CHANGE (medium confidence)

Data on fisheries catch CPUE, fish populations across gradients of human pressure, and site specific studies indicate that some reef fishes have declined around the populated southern islands with decreasing CPUE and reduced biomass of large fishes. The commercial take of bêche-de-mer and trochus has been banned due to sustainability issues. Tourism is ranked as a serious threat although the available information is limited.

Factors affecting reef health and condition

The coral reefs of the CNMI are affected by numerous factors including pollution and sedimentation, coastal development, storms and cyclones, and COTS outbreaks. The Pacific Ocean Synthesis Report and *Reefs at Risk Revisited* suggested that coastal development, watershed pollution and marine-based pollution pose significant risks to the coral reefs and their dependent economies[1, 9]. While water quality throughout most of the archipelago meets the high water quality standards set by the DEQ[8], surface and ground water quality in populated areas has been polluted by point source and non-point sources[1]. The urban development boom of the 1980s and early 1990s led to overburdened and failing waste management systems, and increased sedimentation[1, 8]. Pollution sources also include failing sewage treatment, sedimentation from roads and construction activities, discharge from desalination plants and urban pollution[1, 9]. Marine water quality has declined near developed areas such as Garapan (the largest village on Saipan), and within marinas and around ports on Saipan [8]. Water quality monitoring around the main islands in 2006 showed that 37% of monitoring sites had excessive bacterial and nutrient levels [1].

Erosion and sedimentation has also damaged coral reefs around Saipan, resulting in changed reef communities and decreased resilience at affected sites [1, 9]. Sedimentation events are reported from construction works (e.g. the Nikko hotel and Lau Lau Bay resort on Saipan) that have damaged adjacent reefs [8]. Erosion on the southern coast of Rota is causing sedimentation problems on adjacent reefs [8]. In 2005, nearly all major hotels were found to be illegally discharging hypersaline and nutrient rich effluent into drains, affecting the water quality of Saipan Lagoon [1]. The US Environmental Protection Agency intervened and these systems are now discharging effluent into deep injection wells, resulting in short term improvement of water quality, but the long term effects of waste water injection are unknown [1]. Tourism and population growth could increase these pressures on coral reefs, however, there are conflicting data on population trends, potentially due to changing levels of emigration and immigration [2, 13] ; thus reliable predictions are difficult.

Erosion and sedimentation also affect coral reefs in the more remote central and northern islands. Over grazing and erosion from feral goats, pigs and cattle are a particular concern on Anatahan, Alamagan and Agrihan [8], and only Gugun and Farallon de Pajaros are completely free of feral animals [5]. The reefs at Alamagan are significantly less developed than those on nearby Gugun Island, potentially due to the effects of erosion and sedimentation [8]. The use of Farallon de Mendinilla by the US Navy as a bombing range has also reportedly increased erosion rates [8].

Anchor damage and ship groundings are also an issue at high use sites. There are 36 moorings around popular dive sites in Saipan, Rota and Tinian, with most of being installed and maintained by private companies; additional moorings are needed [1, 8]. Anchoring of naval and commercial ships on an extensive reef platform west of Saipan has been an issue since the 1990s, with surveys finding reduced coral cover in anchoring sites [8]. MARAMP surveys have identified high coral cover at sites proposed for new anchorages [1]. There are also some grounded and derelict ships that are moved by waves or storms, causing significant localized reef damage [8]. Of the 42 abandoned vessels assessed during a 2003 survey, 19 were identified as having a high priority for removal [1].

The coral reefs are also affected by volcanic activity, climate and weather and COTS outbreaks. Volcanic eruptions have damaged reefs in the northern islands, and volcanic ash may be a limiting factor in the development of some reefs [1, 8]. A major volcanic eruption on Pagan in 1981 required the evacuation of residents and damaged adjacent coral reefs [8]. The volcanic eruption on Anatahan in 2003 covered surrounding reefs with a layer of ash; the long term effects are unknown [8]. The Mariana archipelago also lies in an area of tropical storm activity sometimes referred to as 'Typhoon alley' [1]. The powerful waves damage coral reefs, and storm surge causes significant inundation of low lying coastal areas that increases erosion and washes pollutants and debris onto reefs. The 2005 UNEP/SOPAC assessment considered the CNMI to be extremely vulnerable to inundation [12]. The very heavy rainfall during cyclones increases erosion and runoff of sediments, pollution and debris, as well as adding low salinity water [1]. Coral bleaching from warmer than normal sea temperatures occurred during the La Nina phase of the ENSO cycle in the CNMI in 1994, and also in 1995, 1997, 2001 and 2003 [1, 8]. These bleaching events varied in severity and impact; the 2001 event resulted in coral bleaching to 18 m depth on reefs around Saipan, Rota and Tinian, with significant mortality of *Acropora* and *Montipora* corals [8]. However, there are no quantitative assessments available on the long-term impacts. Climate change could lead to increased frequency and intensity of coral bleaching and tropical storms, as well as increased ocean acidification [14]. The *Reefs at Risk Revisited* assessment predicts that rising sea temperatures and ocean acidification will threaten all of the CNMI's coral reefs by 2050 [11].

COTS outbreaks were recorded in late 1960s, the 1980s and 1990s, and control programs were established at some sites. As of 2005, COTS numbers appear to be relatively low, although 3 areas around Saipan and Tinian have persistent and dense COTS populations [8].

Factors affecting coral reefs – EVIDENCE OF CHANGE (medium confidence)

There is information the effects of pollution and sedimentation on coral reefs of the CNMI. Water quality and reef monitoring data show that pollution and sedimentation have damaged the reefs adjacent to human populations. The main factors affecting coral reefs in the CNMI are sedimentation and pollution, and the potential effects of climate change.

Governance and management

As a state in free association with the US, the coral reefs are managed through a range of organizations including US federal agencies and local government agencies, with participation by NGOs, community and industry groups. As a US territory, CNMI residents are US citizens and the islands are generally subject to US law, and the local government includes a locally elected governor, lieutenant governor and legislature [2]. CNMI capacity to effectively manage its coral reefs has significantly grown since 2001 through increases in resources, capacity and management tools [1]. The CNMI actively participates in the US Coral Reef Initiative through the CNMI Coral Reef Initiative which develops and coordinates strategies and actions to conserve coral reefs throughout the archipelago [1]. In 2010, the group listed 4 management priorities for coral reef management in the CNMI: addressing land-based pollution (sediments, nutrients etc); improving coral reef fish resources; monitoring and assessing the expansion of military activities; and monitoring and adapting to climate change and ocean acidification [15]. Interagency efforts to manage coral reefs in the CNMI are coordinated and implemented through the 2003 Local Action Strategy (LAS), which covers fisheries management, land-based pollution, public use and misuse, public awareness and coral reef management [15].

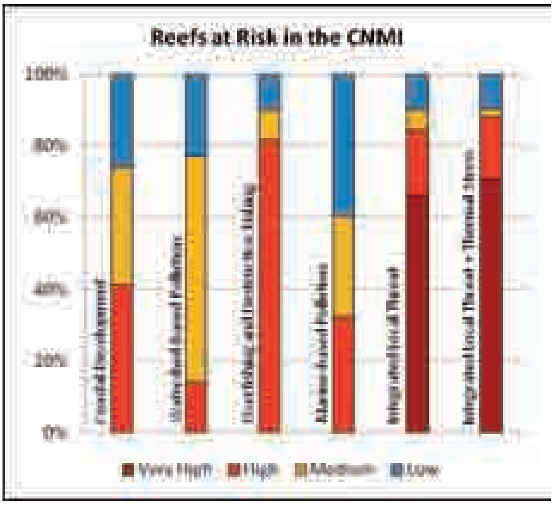
There are currently 9 MPAs in the CNMI: the Managaha Marine Conservation Area (MMCA) in Saipan Lagoon is the best known as it is a popular tourist area [1] and an important part of the traditional cultural history [1]. The reserve was established in 2000, but effective enforcement did not commence until 2002 with the provision of the necessary funds, staff and equipment, as well as education and awareness programs [1]. Surveys have shown increased size and abundance of fishes in the MMCA, except for snappers and unicornfishes (Nasinae) [1]. The no-take Sasanhaya Bay Fish Reserve (SBFR) on Rota is also well known, but there has been relatively little enforcement and management attention [1]. While surveys have revealed an increase in the abundance some reef fishes such as snappers, unicornfish, groupers (Serranidae), surgeonfish (Acanthuridae), goatfish (Mullidae) and parrotfish (Scaridae), fish size does not appear to have increased. These trends could be a result of differing levels of compliance and enforcement between the two reserves [1].

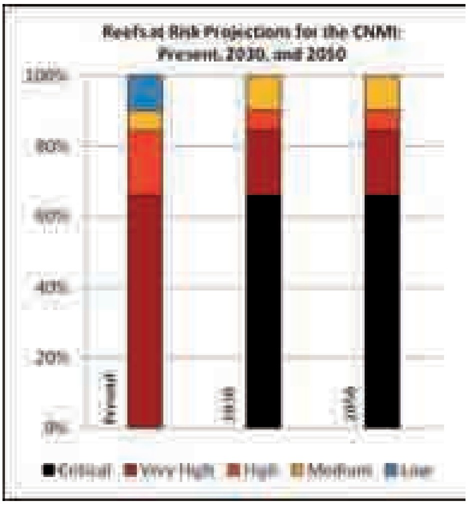
Some of the LAS strategies and programs address pollution and land use in priority watersheds [1]. In Talakaya (Rota Island), students, community volunteers and staff from the DEQ and Department of Lands and Natural Resources are revegetating 162 hectares (400 acres) with 25 000 grass and tree seedlings [1]. The entire watershed is now a conservation area and protected from extractive and illegal activities [1]. In Lau Lau Bay (Saipan), plans are underway to improve road crossings to reduce sediment runoff, and to revegetate eroded and degraded 'badlands' [1]. On Sarigan, the eradication of feral animals in 1997 and 1998 has led to dramatic recovery of vegetation which is reducing erosion [8]. On Obyan Beach (Saipan), there are plans to build settlement ponds to trap sediments in drainage waters before they reach the coast.

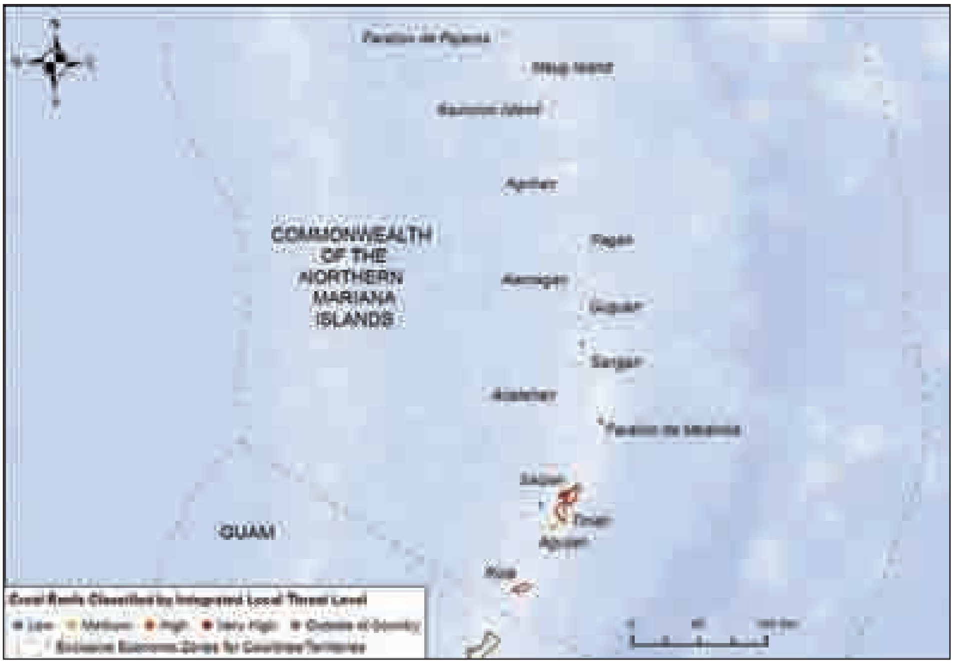
Reefs at Risk Revisited [11]*: Commonwealth of the Northern Mariana Islands*

WORLD RESOURCES INSTITUTE

Reefs at Risk Revisited reports that many of the coral reefs in the CNMI are assessed as threatened (medium risk or higher). Coastal development, watershed based pollution and over-fishing are all significant threats, and thermal stress from warm sea temperatures is an additional stress factor. When all these factors are combined, 90% of reefs are assessed as threatened. The reefs around the populated southern islands of Saipan, Tinian and Rota are most at risk. By 2030, projections for thermal stress and ocean acidification suggest that all coral reefs in the CNMI will be threatened, with 66% assessed as being in critical condition. The full report, methods and full size maps are on: http://www.wri.org/reefs.







Water quality monitoring by the DEQ will assess the effects of these local actions in improving water quality [1]. Campaigns to educate the community about environmental damage caused by driving off road (4X4) vehicles on beaches around Saipan have been successful [1]. The closures of two beaches to vehicle traffic has resulted in beach recovery and increased nesting success of green sea turtles [1]. The Commonwealth Utility Corporation is also upgrading and repairing sewerage infrastructure to improve water quality [1, 7].

Restrictions on some fishing activities have also resulted in increasing fish populations. Restrictions on the use of gill nets, drag nets and surround nets in 2003 appear to have contributed to increases in fish abundance in the MMCA, and probably throughout the entire Saipan Lagoon [1, 8]. The ban on spearfishing with SCUBA has also contributed to an increase in the number of target species such as emperors [1] which were heavily targeted by spearfishers. The trade on live corals and reef fishes is banned, as is the commercial harvest of trochus and bêche-de-mer [1].

The CNMI are also a signatory to the Micronesia Challenge which commits the islands to effectively conserve 30% of the marine resources and 20% of terrestrial resources by the year 2020 [1].

Governance and management – EVIDENCE OF CHANGE (low confidence)

Agencies and organisations in the CNMI have implemented coordinated actions and strategies to address issues facing coral reefs. The increase in research and monitoring, planning and management in the last decade is promising, and some positive trends result from these efforts (increased fish abundance, improved infrastructure, revegetation, pollution control). Nevertheless, long-term monitoring is required to determine the effectiveness of management measures. There is continuing concern that some reefs have continued to decline. Additionally, the reefs face increasing pressures from development and climate change which present considerable challenges.

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Federated States of Micronesia

- Marine Area: 2 980 000 km^2
- Coastline: 6 112 km
- Land Area: 702 km^2
- Reef Area: 14 517 km^2 [(1)]
- Total MPAs: 57 [(2)]
- Area of MPAs: 2 041 km^2 [(2)]
- Mangrove Area: 86 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 52%
- Population (2011 est): 106 836 [(3)]
- Population (2050 proj): unknown
- Population growth (2011 est): 0.3% [(3)]
- Urban population (2010): 23% [(3)]
- GDP: USD $238.1 million (2008 est) [(3)]
- GDP/Cap: USD $2 200 (2008 est)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

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The Federated States of Micronesia (FSM) lie to the north and northeast of Papua New Guinea, and south of Guam and the Mariana Islands. The Marshall Islands lie to the east, and Palau to the west. The FSM includes 607 islands and atolls spread across 2.9 million square kilometers of ocean, but the total land area is only 708 km^2. As part of the Compact of Free Association, the FSM and the United States have arrangements to share access, services and defense arrangements. The FSM is divided into 4 states: Yap; Chuuk (formerly known as Truk); Pohnpei (formerly Ponape); and Kosrae. Yap is the most western and borders the territory of Palau, and consists of 4 'main' volcanic islands and 19 inhabited 'outer' islands and atolls. The cluster of volcanic islands in western Yap ('Yap proper') is more heavily populated than the 'Outer islands' (predominantly atolls) which stretch east towards Chuuk [(4)]. Some islands of Yap were previously known as the Caroline Islands. Chuuk State has 290 islands consisting of the volcanic islands of Chuuk lagoon and 24 outer islands. Chuuk contains the most populated islands in FSM and the lagoon is a renowned SCUBA diving destination. Pohnpei State is to the east of Chuuk and consists of the large volcanic island of Pohnpei and 6 inhabited atolls. Pohnpei island has an area of 345 km^2 (almost half the total land mass of the FSM) and is the national capital of FSM. The eastern most state is Kosrae with only one volcanic island. Rainfall is extremely high on the high volcanic islands of Kosrae, Pohnpei and Chuuk, and can exceed 10 m of rain per year [(1)].

Each island group has its own unique language, culture, local government and traditional systems for managing natural resources, and islanders are heavily reliant coral reefs and marine resources [4, 5]. Fortunately, the coral reefs of the FSM appear to be generally healthy. However, reefs in some areas are affected by threats such as water quality, coastal development and destructive fishing practices [4].

Status, health and resilience of coral reefs

Several groups and organizations monitor the coral reefs of the FSM. Each state has two regulatory organisations that manage coral reefs, a Marine Resources Division (MRD) and an Environmental Protection Agency (EPA). In addition, many NGOs play important roles in monitoring and management, and include groups such as Yap Community Action Program (YapCAP), Chuuk Conservation Society (CCS), Conservation Society of Pohnpei (CSP) and Kosrae Conservation and Safety Organization (KCSO). Regional and international organisations such as SPREP, the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Palau International Coral Reef Center (PICRC) and NGOs (e.g. The Nature Conservancy and Peace Corps) also support coral reef research, monitoring and management [1]. Rapid Ecological Assessments (REAs) have been conducted in all 4 states, with surveys concluding in 2008.

The longest running long-term monitoring program is based in Kosrae state and has used Reef Check protocols to monitor corals, fishes and invertebrates since 1994. Other monitoring programs have commenced since 2000. Commercial fish stocks have been monitored in Kosrae since 2000; fish, corals and MPAs in Pohnpei have been surveyed since 2003; baseline coral reef data have been collected in Yap since 2006, and monitoring programs are being developed in Chuuk [1].

Kosrae has 5 permanent monitoring sites that are surveyed annually using Reef Check methods. Coral reefs in Kosrae are relatively healthy with high coral cover, ranging from 47% to 60% [1, 5]. However, these reefs are under pressure from coastal development and sedimentation [1]. Food fish recorded included blacktail snapper (*Lutjanus fulvus*), blackspot emperor (*Lethrinus harak*), multibarred goatfish (*Parupeneus multifasciatus),* bullethead parrotfish (*Chlorurus sordidus*), swarthy parrotfish (*Scarus niger*), blue banded surgeonfish (*Acanthurus lineatus*) and whitecheek surgeonfish (*A. nigricans*) [1]. A Rapid Ecological Assessment (REA) in 2006 indicated that some fish such as groupers (Serranidae), snappers (Lutjanidae), jacks (Carangidae) and emperors (Lethrinidae) were absent compared to previous surveys in 1986. A few humphead (Maori or Napoleon) wrasse (*Cheilinus undulatus*) were recorded, but no bumphead parrotfish (*Bolbometopon muricatum*). These two species are reported to be very rare in Kosrae [1].

In Pohnpei, grouper spawning aggregations, MPA effectiveness, benthic communities and sedimentation have been monitored since 2004. Benthic communities and sediment accumulation are monitored at 16 sites, with the data currently being analyzed [1]. However, preliminary analyses suggest that Pohnpei's coral reefs have been damaged by sediment runoff, dredging, and crown-of-thorns seastars (COTS) [1]. These factors have affected the species composition and structure of coral reef communities and hindered recovery [1, 5]. The abundance of target species of reef fishes such as emperors and snappers was low in many areas, indicating probable local overfishing [1]. Market-based analyses have also been conducted in Pohnpei to gauge fisheries management versus fishery practices [11].

In Yap, long-term surveys have revealed signs of coral bleaching, damage from COTS and destructive fishing from poachers, and physical damage from storms and ship groundings. Baseline surveys in 2005 at 5 MPA sites showed 11% to 56% live coral cover [1]. Long term monitoring sites were established at 6 sites in Yap in 2006, and REAs were performed at 47 sites at 3 atolls in 2007. Collectively, these surveys suggest that coral reefs in Yap are in relatively good condition, especially at remote Ngulu Atoll [1]. Humphead wrasse (*Cheilinus undulatus*) were observed at 50% of the survey sites, but estimated average total length for observed individuals was only

48 cm. Furthermore, fewer sharks than expected were seen at Ngulu Atoll which may indicate the presence of foreign fishers engaged in illegal shark-finning operations [1].

Status of coral reefs – STABLE/EVIDENCE OF CHANGE (low confidence)

Long-term monitoring has only recently begun and is restricted to a few sites. The limited data suggest many reefs are in relatively good condition, but some show signs of stress from sedimentation, especially around Pohnpei. Some reef fish communities also show signs of overfishing.

Coral reef health and resilience – NOT CONSIDERED

While there are independent studies that suggest that reefs around Pohnpei have declined, there was insufficient information available to describe the resilience of coral reefs across the FSM.

Use of reef resources

Marine resources are used for subsistence and commercial purposes, but in the last 30 years, there has been a shift from subsistence use to commercial use [1]. Coastal fisheries include inshore fisheries (in mangroves, reef areas, and lagoons), nearshore fisheries for larger pelagic species (including tunas) and bottom fisheries (for snappers, groupers and other demersal species) [6]. A variety of crabs, lobsters and other invertebrates such as sea cucumber (bêche-de-mer) and trochus are also harvested [6]. Targeted coral reef food fish include snappers, emperors, goatfish, parrotfish and surgeonfish. Surveys estimate the total coastal fishery production of Pohnpei Island to be about 1780 metric tonnes (75% reef/inshore, 25% pelagic). Of this, 780 tonnes were attributed to subsistence catch and 1000 to commercial effort [6]. The shift to fishing for income [6], a breakdown of traditional management systems and a growing population are putting increasing pressure on the FSM's marine resources [1, 6]. Overfishing from commercial and subsistence fishing is a severe threat to these coral reefs [1]. The 2009 **Pacific Ocean Synthesis Report** [7] identifies commercial and subsistence fishing as a severe threat to the marine environment of the FSM, while the *Reefs at Risk Revisited* assessment suggests that 30% of reefs in the FSM are threatened (medium threat or higher) by overfishing [8]. However, there are few available fisheries data and stock assessments [6].

In Kosrae, destructive fishing methods using locally-made poisons have reportedly killed large numbers of fish within the lagoon, but bomb fishing is uncommon [1]. Surveys at Kosrae in 2006 also noted the apparent absence of some fish species that had been recorded in surveys from 1986 [1, 5]. In Pohnpei, fishers mainly target unicornfish, snappers, jacks and parrotfish [1]. Market based analyses and biological surveys in 2006 suggest that current catch rates are unsustainable [1, 11], with over 4000 lbs (1800 kg) of reef fish taken every day from Pohnpei's reefs, including immature fish as 70% of the catch. Fishers also use spear guns and SCUBA gear at night; although a very efficient fishing method, this has led to serious declines in fish stocks in other Micronesian countries and has been banned in other countries [5]. Overfishing and bomb fishing have been reported on Chuuk as the greatest threats to coral reefs, especially near population centres [1]. In Yap, surveys showed that the average size of humphead wrasse was only 48 cm, and there were signs of shark-fin operations [1]. Yap has a smaller population and larger resource base as well as strong traditional management compared to other States. As a result, over-exploitation is not as severe as the other states. Nevertheless, stocks of giant clams and sea cucumbers have been seriously over-exploited in the past, especially near the state capital of Colonia [1]. This fishery was closed in the 1990s [9]. The 2007 REA at Yap found broken and dead corals at Ngulu which showed evidence of illegal cyanide fishing. The stock structure of the humphead wrasse observed suggested that this area had been fished illegally for the live fish trade [1].

Tourism is not a major economic activity in the FSM. Tourist visitation generally ranges between 15 000 and 20 000 visitors a year, and has remained stable between 2003 and 2006 [1]. Tourism development in the FSM faces numerous challenges including airline access, cost, and a lack of tourism infrastructure and services [6], and current tourism is limited to high end or boutique dive and snorkel tourism.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

The limited information on reef fisheries and their impacts on reef fish stocks suggest that some fisheries have declined, with some food fish becoming smaller and rare in some locations, and previous collapses of sea cucumber and trochus fisheries. While widespread fisheries declines have yet to appear, the data suggest that pressures on reef fishes are increasing and are unlikely to be sustainable in the long-term. Destructive fishing occurs in some locations, and fishing practices that are potentially very damaging to fish stocks are still permitted.

Factors affecting reef health and condition

The coral reefs of the FSM are affected by local factors such as coastal development, sedimentation and erosion. A development boom over the last 20 years has increased coastal development and dredging, land clearing and road construction [1]. Coastal development is the main source of erosion and sedimentation in Kosrae, and construction of a new road linking regional towns has exacerbated these threats [1]. Coastal development is also affecting reefs in Pohnpei, with more than 50 sites being dredged or cleared of mangroves. Sand mining and dredging are significant issues in some areas [6], and dredging associated with airport and port construction has destroyed some reefs [9]. In Yap, significant amounts of coral rock and sand were dredged for construction. Sedimentation and erosion also result from unsustainable agriculture and land clearing; already more than 70% of Pohnpei's natural forest has been cleared for agriculture [6]. Coastal development, erosion and sedimentation have affected coral reefs in all 4 states of the FSM [1], and the **Pacific Ocean Synthesis Report** and the **UNEP/SOPAC Environmental Vulnerability Index** consider sedimentation, pollution and coastal development are posing significant risks to the marine environment and coral reefs in the FSM.

Some coral reefs near population centres in the FSM are also affected by pollution from sewage effluent and solid waste; these are listed as significant threats to the marine environment [7, 10]. Runoff of effluent from pig farms and the poor location of sewerage outfalls have affected some reefs in Kosrae [1]. Solid waste management is also an issue, with mangrove forests converted into landfill sites. Inadequate waste management has resulted in accumulation of solid waste on shorelines and lagoons [1]. In Pohnpei, there is localized pollution at river mouths and estuaries [1]. Population growth and immigration, and the increased environmental pressures are significant issues for the FSM [6, 9].

The FSM lie in a tropical storm belt and experience frequent and intense tropical storms. Such storms cause physical damage to coral reefs through wave action, and associated heavy rainfall also increases sedimentation. Tropical storms and typhoons have damaged reefs in Pohnpei, Yap and Chuuk in the past, but there is little information on the direct effects [1, 9]. The lack of long-term monitoring data also means that the effects of other stress factors such as coral bleaching cannot be assessed. In 2004, coral bleaching was recorded in Kosrae (2004), and minor, localized bleaching was reported in Pohnpei; bleached corals on Pohnpei appear to have recovered by 2005 [1]. COTS have also been recorded in independent studies of coral reefs in FSM; an outbreak in 1994 caused coral mortality in western Kosrae. More recent surveys in Pohnpei found widespread COTS approaching outbreak densities [1]. The FSM has many low lying atolls and islands that are extremely vulnerable to inundation, flooding and storm surge which could severely affect coastal communities and their resource use [7, 10].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

There is little information on risks and their effects on coral reefs in the FSM. The information and risk assessments available suggest that the FSM is vulnerable to numerous risk factors, and that these have resulted in some reef decline. The main issues currently affecting the FSM's coral reefs, particularly those around populated islands, include sedimentation and pollution from land-based sources and coastal development. Increases in population, the demand for resources and climate change will place further pressures on the marine environment.

Governance and management

Coral reef management in the FSM involves a range of government agencies, community groups, regional organisations and NGOs, such as YapCAP, CCS, CSP, KCSO, The Nature Conservancy (TNC) and Peace Corps. As part of the Compact of Free Association, the FSM has close ties with the USA in access, funding and defence. While the national government sets national legislations, the 4 state governments implement local government laws and regulations. Each state has a Marine Resources Management (MRM) agency and an Environmental Protection Agency (EPA) [9].

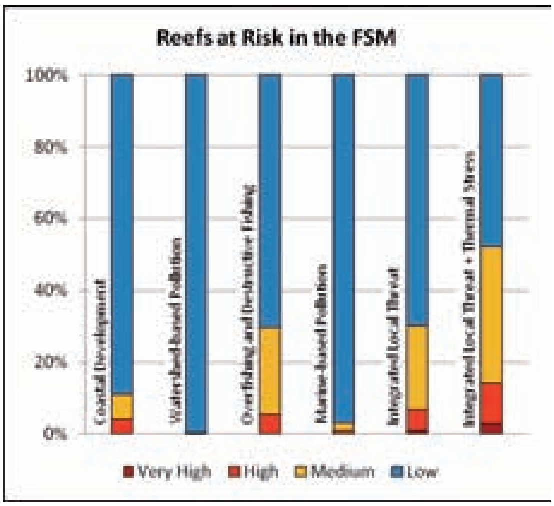
New initiatives and agreements have been developed in the last 10 years that lay the basis for significant improvements in coral reef management in the FSM. The National Biodiversity Strategy and Action Plan (2003) provides a 'blueprint' for sustainable management of the country's ecosystems and biodiversity conservation. The Plan identified 130 'Areas of Biodiversity Significance' (ABS) including 86 marine and coastal sites. The Plan also places a high priority on the development of a national network of protected areas [1]. Each State is at a different stage in implementing the Plan. The FSM is also a signatory to the Convention on Biological Diversity. In December 2004, state and national government agencies signed the National Implementation Support Partnership to establish a nationwide network of protected areas to help meet the FSM's obligations under the Convention [1]. The FSM is also a signatory to the Micronesia Challenge and has pledged to effectively conserve 30% of nearshore marine resources and 20% of terrestrial resources by 2020. Collectively, these agreements and initiatives have led to a range of capacity building, planning and coordination activities, projects and agreements which will strengthen management capacity in the FSM [1].

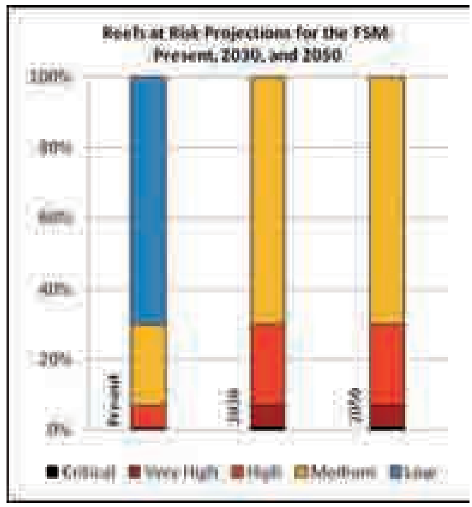
In Kosrae and Pohnpei, the State Marine Resources acts regulate marine resource use [1, 7]. Kosrae currently has 5 MPAs that are managed by the government or local communities. These areas have differing levels of protection with some protected as no-take reserves (e.g. the Utwe Biosphere Reserve), and others implemented to conserve specific habitats (mangroves) or commercially important species (trochus) [1]. Traditional lifestyles are still strong in Chuuk, and customary chiefs usually implement traditional management such as protecting turtle nesting beaches. Communities in Chuuk have begun conservation planning and programs to establish future MPAs, however more scientific information is needed to inform these efforts [1]; there is at least one traditionally implemented no-take area [1, 7]. In Yap, at least one MPA is managed by the local community and is considered as a Locally Managed Marine Area (LMMA). The Yap Community Action Program is working with other communities to establish two more LM-

Reefs at Risk Revisited [8]*: Federated States of Micronesia*

WORLD RESOURCES INSTITUTE

The 2011 *Reefs at Risk Revisited* report estimates that about one-third of coral reefs in the FSM are threatened by local pressures, particularly coastal development and overfishing and destructive fishing. Unusually warm sea temperatures over the past 10 years have added additional stress, increasing the number of threatened reefs to about 50%. The reefs around the most heavily populated islands of Pohnpei, Chuuk, Yap and Kosrae are most at risk. By 2030, projections for thermal stress and ocean acidification suggest that all FSM reefs will be threatened with about 50% at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.





MAs [1]. There are reported to be 20 MPAs in Pohnpei [6] with 9 of them being co-managed by communities forming the Pohnpei LMMA Network. Ant Atoll, on the other hand, became FSM's second UNESCO Biosphere Reserve in 2007. There are 4 core (no-take) zones in the Ant Biosphere Reserve, which were recognized into Pohnpei's Marine Sanctuary and Wildlife Refuge Act via executive order by Governor John Ehsa of Pohnpei State. This atoll is one of the most biologically significant areas in Pohnpei State, and Biosphere Reserve status provides additional protection for the atoll [1].

While these initiatives are promising, implementing management in the FSM faces significant challenges. A lack of capacity and resources means that management may not be implemented or effectively enforced. Compliance levels with current management are unknown [7]. Other challenges include conflicts between agencies, lack of data, poor awareness and understanding of the need to manage marine resources (which includes some staff in management agencies), and inadequate knowledge about engaging communities in community based management [6]. Additionally, it is difficult to describe the effects of these management initiatives given the limitations, and that coordinated long-term monitoring activities have only recently begun.

Governance and management – NOT CONSIDERED

There are some management initiatives in the FSM, and the recent initiatives to improve planning and management are promising. However, there are reports of significant challenges to implementing management 'on the ground'. There is little available information about the effects of coral reef and fisheries management, and whether these efforts are adequate to sustain and preserve the coral reefs of the FSM. The recent activity in monitoring and management may be able to provide some of this information in the future.

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Guam

- Marine Area: 218 000 km^2
- Coastline: 125.5 km
- Land Area: 560 km^2 [1]
- Reef Area: 183 km^2
- Total MPAs: 5 [2]
- Area of MPAs: 36.12 km^2 [2]
- Mangrove Area: 0.94 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 60%
- Population (2009 est): 182 207 [3]
- Population (2050 proj): 267 800
- Population growth rate: 1.9% [4]
- Urban population (2003): 93% [5]
- GDP: USD $2.5 billion (2005 est) [6]
- GDP/Cap: USD $15 000 (2007)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The island of Guam is a United States territory located approximately 2 400 km southeast of Tokyo and 2 400 km east of Manila [1]. Guam is the southern-most island of the Mariana Islands archipelago but as a US territory, it is politically distinct from the rest of the Mariana Islands. Guam has a land area of 560 km^2 making it the largest island in Micronesia. It is also the most heavily populated island in Micronesia, and has numerous urban settlements and a major harbour (Apra Harbour) [1, 5]. The island has a significant US military presence with air force and naval bases, and more land set aside for the US Department of Defense. Guam is surrounded by fringing reefs and a relatively narrow reef platform and lagoon (< 1 km wide) along the western/leeward shore, with a combined area of coastal reef and lagoon of about 108 km^2 [2]. Other marine habitats around Guam include patch, submerged and barrier reefs and mangroves [2]. However, mangrove habitats are restricted to Apra Harbour and only cover an area of 0.94 km^2 [2]. Guam is close to the Indo-Pacific centre of biodiversity and is one of the most species rich marine ecosystems amongst US jurisdictions, with about 5 000 marine species recorded from Guam including ~1 000 fish species and 300 corals [2, 7].

Tourism is a major activity that contributes up to 30% of the annual GDP and generates up to 15 000 jobs [2]. While population growth is lower than other Pacific islands such as Papua New Guinea or the Solomon Islands, Guam's population is projected to increase by about 38% over the next 10 years, to reach 230 000 [2]. Much of this is driven by immigration and the expansion of military infrastructure, with the number of military personal and dependents projected to increase by 160% from 15 000 in 2009 to more than 39 000 by 2020 [3].

The condition of Guam's coral reefs and reef resources varies considerably, and is affected by geology (northern Guam and southern Guam are very different), ocean circulation patterns and wave exposure, disturbance events (e.g. storms, coral bleaching, earthquakes, outbreaks of crown-of-thorns seastars (COTS)), human pressures (e.g. nutrient runoff and sedimentation) and resource use (e.g. fishing) [2, 3]. The top 5 human threats as identified by the Guam Coral Reef Initiative Coordinating Committee (GCRICC) include: overfishing; sedimentation/land-based pollution; lack of public awareness; recreational misuse and overuse; and climate change/coral beaching/disease [2].

Status, health and resilience of coral reefs

There is considerable coral reef monitoring data and research activity on Guam by a number of institutions, including the University of Guam Marine Laboratory (UOGML), the National Oceanic and Atmospheric Administration (NOAA) Pacific Islands Fisheries Science Center (PIFSC), the Guam Division of Aquatic and Wildlife Resources (DAWR), the Guam Environmental Protection Agency (EPA), the National Parks Service (NPS), and the US Fish and Wildlife Service (USFWS). Collectively, these agencies and organisations assess and monitor marine and coastal ecosystem resources around Guam, including coral reef fish populations and benthic communities (coral, algal, and macro-invertebrate components). Other programs include research and monitoring focused on marine park effectiveness, larval connectivity, sedimentation and its effects on reefs, monitoring fish and macro-invertebrate studies, Reef Check surveys and water quality surveys. Some programs, such as fisheries monitoring, have been operating for more than 20 years [2].

While Guam's coral reefs have been studied since the 1970s, regular long-term monitoring programs only began in 2003 [2]. Island wide ecological assessments were conducted in 2003, 2005, 2007, 2009, and 2011, as part of NOAA's PIFSC Coral Reef Ecosystem Division's ongoing Pacific Reef Assessment and Monitoring Program (RAMP) to collect data on benthic cover, coral stress and fish communities as well as environmental data such as temperature, nutrients and conductivity [3, 7]. Surveys include towed diver and SCUBA surveys on fore-reef slopes of islands and banks at ~15 m depth [3]. The UOGML also established a long-term monitoring program between 2005 and 2006 at 5 permanent sites of 4 x 50 m transects between 3 and 10 m depth and monitored using video transect surveys [2]. Since 2006, the UOGML has also monitored coral health (disease, predation, benthic composition, species richness etc.) at 10 reefs using 20 x 2 m belt intercept transects between 2 and 7 m depth, and also collect coral health and environmental data by diver observations, photographs and temperature loggers [2].

The current condition of Guam's coral reefs varies between different locations due to natural variations as well as human impacts [1, 3]. Surveys in 2005 showed an average live coral cover of 23% island wide, with similar levels of cover in the west/northwest, east/northeast, and east/southeast regions of the island (25%, 26%, and 26%, respectively) [2]. However, RAMP surveys in 2005 and 2007 show lower coral cover on south-western corner reefs (0-5%) compared to elsewhere; this could be due to stress from sediment and poor water quality and lack of suitable substrate [3]. Data from 5 UOGML permanent monitoring sites in 2006 also show varying levels of live coral cover of up to 80% at the Western Shoals site in Apra Harbour, while the Pago Bay site (on the central east coast) had less than 10% cover [2, 7]. The low coral cover in Pago Bay is probably due to COTS outbreaks over previous years [2]; cover at Fouha Bay (Southern Guam) was also low (~25%) compared to other sites, probably due to stress from land-based sediments and nutrients [2].

The long-term monitoring data on Guam's coral reefs shows evidence of declines in coral health and reef fish communities over the last 40 years [1, 7, 8]. Data from the 1960s reported coral cover on fore-reef slopes of around 50%, but by the 1990s this cover had declined to less than 25%, with only a few sites showing more than 50% cover [7]. This decline was attributed to degradation of water quality, chronic COTS outbreaks and low abundance of herbivorous fishes [7]. Coral recruitment also has declined on the leeward reefs over the last few decades, with recruitment rates falling from 0.53 recruits per settlement panel in 1979, to 0.004 in 1989, and 0.009 in

1992 [2, 9]. This decline could be due to sedimentation, freshwater runoff and algal overgrowth [9]. Sedimentation during heavy rain appears to have altered coral communities in Fouha Bay, with a decline in coral diversity from >100 species in the 1970s to < 50 in 2003 [2, 7]. Sedimentation rates in 2005 in Asan Bay (western Guam) was between 0.045 g/cm^3/day to more than 2.0 g/ cm^3/day; these are amongst the highest levels recorded in literature [7]. Coral disease may also be a localised issue in Guam; UOGML found relatively high incidence (> 10% prevalence) of coral disease at 3 of 10 sites [2]. While several types of disease were recorded, white syndrome was the most prevalent and caused the greatest tissue mortality [2]. Nevertheless, coral disease does not appear to be a widespread problem across all of Guam's coral reefs [8]; the long-term effects have yet to be determined.

There are long-term fisheries data (20+ years) from DAWR, and more detailed data on reef fish communities from RAMP surveys from 2003 to 2011 including UOGML surveys in 2006 [2]. The fisheries data reveal declining catch per unit effort (CPUE) in most inshore and offshore fisheries (gill net, cast net, hook and line, spear) [2, 7]. Small scale fisheries have declined by up to 86% since 1950 and creel surveys show that fisheries have not recovered from a sharp decline in the 1980s [7]. Fish larger than 25 cm were uncommon to rare in many areas and fishes greater than 50 cm were uncommon in most areas [2]. The biomass of large fish (> 50 cm) was higher on the northern reefs than elsewhere, but is still very low (0.01 tonnes ha^{-1}) compared to other islands in the Mariana Archipelago (0.13 to 0.25 tonnes ha^{-1}) with lower fishing pressure [2] (Fig. 1). Data from 2006 showed that major large target fishes, such as groupers (Serranidae), snappers (Lutjanidae), and emperors (Lethrinidae) were found in low numbers at most sites, and groupers were absent from one site [2]. These trends in CPUE, fish abundance and biomass suggest that overfishing is occurring on Guam's coral reefs. Nevertheless, RAMP surveys found that the abundance of some fishes, including snappers and emperors, appeared to be higher in MPAs [2], and fish biomass also appears to be increasing inside the 5 MPAs since enforcement began in 2001 [2, 7].

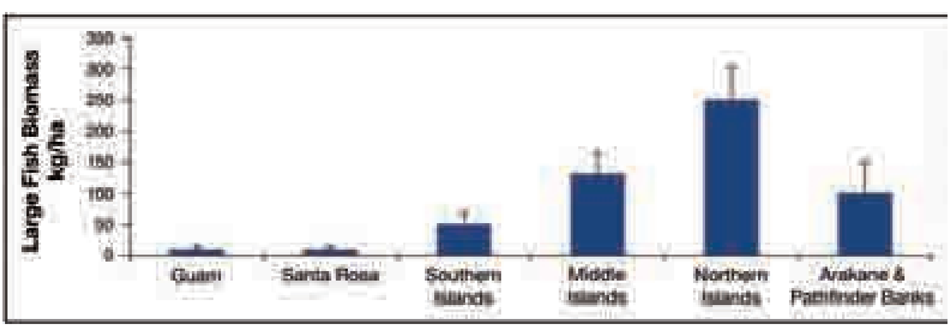

Fig. 1. Biomass of large fishes (> 50 cm total length) was substantially lower on the populated southern islands of the Mariana Archipelago such as Guam, compared to the more remote middle and northern islands (data from Burdick et al. 2008, Fig. from Goldberg et al. *2008).*

Status of coral reefs – EVIDENCE OF CHANGE (high confidence)

While long-term monitoring of coral reefs has only recently begun, surveys around Guam over the last 40 years report that while some reefs appear be in good condition, others show signs of stress and long-term decline, potentially from sedimentation, poor water quality and chronic COTS outbreaks. Reef fish communities also show signs of overfishing. Collectively, there is clear evidence that many of Guam's reefs are changing from conditions recorded in the 1960s.

Coral reef health and resilience – EVIDENCE OF CHANGE/ALTERED (medium confidence)

While Guam's coral reefs have shown the ability to recover from disturbances in the past, current data suggest a decline of reef resilience in some areas. Evidence includes long-term declines in coral cover, chronic stresses, altered reef fish and coral communities, and declines in coral recruitment. Coral disease could also have localized effects. Collectively, these trends suggest that the health and resilience of Guam's coral reefs is changing, and in some areas, has already changed.

Use of reef resources

Guam's coral reef resources are socially, culturally and economically important [2]. The local Chamorro community have traditionally taken finfish, invertebrates and sea turtles for food, and Guam's residents still use the marine environment for recreation and fishing. Reef fish, sea cucumbers (bêche-de-mer), sea urchins, crustaceans, molluscs and algae are consumed locally [2, 8]. A 2007 economic valuation indicated that Guam's coral reef resources are worth about US$127 million per year [2], with tourism accounting for about 75% of this value [2, 10].

Guam's reefs support a number of fisheries that use hook and line, cast net (talaya), spearfishing, gill nets (tekken), drag nets, jigging, spin casting and bottom fishing [2]. Target fishes include surgeonfishes (Acanthuridae), jacks/trevallies (Carangidae), rabbitfishes (Siganidae), goatfishes (Mullidae), snappers (Lutjanidae) and emperors (Lethrinidae) taken by shore-based fishing and from small boats (< 14 m length). Long-term catch data from the 1980s by DAWR surveys show declining trends in catch-per-unit-effort (CPUE) for most shore and boat-based fisheries, even with increased fishing effort and improvements in fishing gear [2]. The RAMP and UOGML surveys also report declining stocks, which is matched by the perception of long-time fishermen [2]. A survey of 400 Guam residents in 2005-2006 recorded that the most commonly cited concerns were declines in fish abundance and water quality [2]. Bottom fishing is the most popular gear used, but fishery CPUE has declined from levels recorded in 1982 [2]. In the mid to late 2000s, fishing effort also declined, potentially due to poor catches and rising fuel costs [2]. While the remaining fishers have reported a slight recent increase in CPUE, which is still much lower that 1982 levels [2]. Guam does not export aquarium fishes or live reef fish, but collection for local use does occur [2]. Various reef invertebrates including octopus and trochus are commercially targeted, with octopus being the primary target [2].

Reef fish are also harvested by spear fishers using SCUBA, with the main targets being large groupers (Serranidae), wrasses (Labridae) and parrotfishes (Scaridae). Spearfishing expanded to a major fishery in the 1990s, with very high CPUE (as high as 9 kg per hour) with harvest peaking at > 50 000 kg in 2000 [2]. This fishery has shifted to targeting smaller, faster growing species such as surgeonfish [2]; but the CPUE in this fishery has also declined [2]. Spearfishing with SCUBA and artificial lights and the continued use of gill nets are of 'particular concern'; these methods have been banned or heavily restricted in other countries in the Pacific such as Palau, the CNMI, the Cook Islands and American Samoa due to their impacts on fish populations [2]. Local fisheries biologists suggest that these fishing methods have given rise to a 'boom and bust' harvest of large humphead Maori wrasse (*Cheilinus undulatus*, 'tangisan' in Chamorro) [2] and the depletion of large groupers, as well as declines in the catch of other large wrasses, snappers and groupers in other fisheries [2, 7].

Overall, fisheries data and reef fish surveys suggest that fishing practices and the condition of Guam's fisheries resources have changed. The 2009 **Pacific Ocean Synthesis Report** [10] identified commercial fishing as a severe threat to Guam's marine environment, while *Reefs at Risk Revisited* suggest that 46% of Guam's coral reefs are threatened (moderate risk or higher) by overfishing.

There is also a sizeable tourist industry on Guam. In 2006, 1.21 million tourists visited Guam, with an estimated 300 000 SCUBA dives occurring on Guam's reefs [2]. Tourists and residents also go snorkelling, swimming, boating and use jet skis [2]. Reef use will increase with more military personal and their families moving to Guam [2]. While tourism and recreational use provide a sizeable economic contribution, there are concerns about the impacts in high-use areas. The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [11] indicated that tourism poses a serious environmental risk to Guam. Popular dive sites show evidence of physical damage from divers breaking and physically damaging corals, and many dive operators allow or encourage poor environmental practices such as touching or grabbing corals and fish feeding [2]. Tourism also contributes to coastal development with associated point and non-point sources of pollution [2].

Use of reef resources – EVIDENCE OF CHANGE (high confidence)

Long-term data on fisheries landings, effort and fish populations across a gradient of fishing pressure suggest declines in reef fish resources. Some fishing practices lead to rapid over-exploitation of fish stocks, shifts to different target species and adjusted fishing practices following declines in catches. Reef tourism could be a significant and sustainable use of Guam's coral reefs, but current visitation levels and practices are resulting at damage at popular dive sites. The increases in visitation and recreation will require careful management to protect dive sites and preserve the quality of tourist experiences and visitor satisfaction.

Factors affecting reef health and condition

Guam's coral reefs are affected by storms, sedimentation, pollution, marine debris, and COTS outbreaks. The most significant factors include pollution and sedimentation from land-based sources, and coastal development [2, 8, 10]. The Pacific Ocean Synthesis Report [10] and *Reefs at Risk Revisited* [12] analysis report that sedimentation, pollution and coastal development pose significant risks to Guam's marine environment and coral reefs. Coastal development such as construction of new roads, buildings, support infrastructure and the expansion of the harbour, will increase with the planned expansion of military bases [2, 8]. The increased population will increase pressure on Guam's environment, and the UNEP/SOPAC 2005 assessment lists population increases, population density and coastal development as major threats [11]. New tourism developments are planned alongside the Tumon Bay marine reserve [2], which will increase sedimentation of nearshore waters, and developments for Alpha, Bravo and Kilo wharves around in Apra harbour will include dredging of up to 12 hectares of coral reef habitat [2].

Severe upland erosion and the resulting sedimentation also pose a significant threat to the reefs. Sedimentation is most prevalent in southern Guam where steep slopes, underlying volcanic rock and exposed or degraded areas result in high sedimentation rates in coastal waters [2]. This particulate material combines with organic matter in coastal waters to form 'marine snow' which smothers corals and other sessile organisms. Erosion and sediment monitoring studies have found very high levels of sedimentation in parts of Guam. Illegal burning of vegetation by poachers (burning creates habitat for deer), deforestation, inappropriate road construction, recreational off-road vehicle use, and grazing by feral animals have accelerated erosion rates in southern Guam to the extent that they have now exceeded the sediment tolerance of coral communities in these areas [2, 10]. Surveys suggest that biodiversity and recruitment on these reefs has declined since 1979 [2].

Guam's reefs are also affected by sewage discharges, solid waste and marine debris [10]. Three sewerage outfalls are situated within 200 m of shallow reefs, and leaking and aging pipes allow more sewage to enter coastal waters during heavy rains [2]. This leads to increased nutrient inputs into local waters [10], with evidence that increased nutrients have lead to algal blooms [2]. Pollution from septic systems, animal wastes, chemicals, fertilisers and pesticides [8] in concentrations that exceed water quality standards occurs in springs and aquifers [2]. Additionally, there are residual contaminants remaining from World War II and the US Navy is restoring 15 sites around Guam [2]. Marine debris also affects Guam's coral reefs through physical damage (e.g. abrasion from lost fishing nets) and entanglement of marine animals [8]. While marine debris is not a major threat to Guam's reefs, it is a noticeable issue; a 2007 coastal clean up removed 12 tonnes of debris from around the island [2]. As a major port with a high volume of traffic, Guam's reefs are affected by ship groundings which cause localized damage; 3 ship groundings were reported between 2004 and 2008 [2].

Guam lies within an active tropical storm area and the reefs are periodically damaged by cyclones and storm waves. Cyclones can cause severe physical damage to coral reefs, and heavy rainfall increases erosion and runoff of sediments, pollution and debris onto reefs. Storm surges can increase wave heights by 40%, leading to inundation of coastal areas that also increases erosion and washing of debris and pollutants onto reefs [2]. Four major cyclones have affected Guam since 1994 and combined with other anthropogenic stresses, have triggered long-term declines in coral cover and biodiversity where degraded reefs are unable to recover [2, 10].

Climate change could lead to increased frequency and intensity of coral bleaching and tropical storms and cyclones, as well as increased ocean acidification [2]. While coral bleaching was observed in 1994, 1996, 2006 and 2007, Guam's reefs have escaped major coral mortality from coral bleaching [2, 8]. Guam has also been affected by widespread COTS outbreaks since 2004, with associated high levels of coral mortality [2]; the corals preferred by COTS such as *Acropora* and *Monitpora* were 'almost wiped out' in 2006 at some sites, and COTS had begun to consume less preferred corals such as *Porites* and *Goniopora* [2].

Factors affecting coral reefs – EVIDENCE OF CHANGE (medium confidence)

Information on risks and affects on Guam's coral reefs, including the magnitude and effects of these factors, indicate that many risk factors damage the reefs. These have increased and are likely to increase further, potentially resulting in long-term changes to Guam's reef habitats. The main stresses are sedimentation and pollution from land-based sources, coastal development and population growth. There is potential for damage from tropical storms, climate change and ongoing COTS outbreaks.

Governance and management

Management of Guam's coral reefs involves a broad range of organisations including government agencies (local and US federal agencies), NGOs, community groups and industry organisations. Projects are linked to the US National Action Plan to Conserve Coral Reefs (2000) and implemented through the Local Action Strategy Initiative (LAS) [2]. In 2002, the Guam Coral Reef Initiative Coordinating Committee (GCRICC) identified the top 5 threats: sedimentation/land-based pollution; overfishing; lack of public awareness; recreational misuse and overuse; and climate change/coral beaching/disease [2]. By 2003, LAS were drafted for each of these threats, and actions implemented through a range of programs and legislation [2].

Reefs at Risk Revisited [12]: Guam

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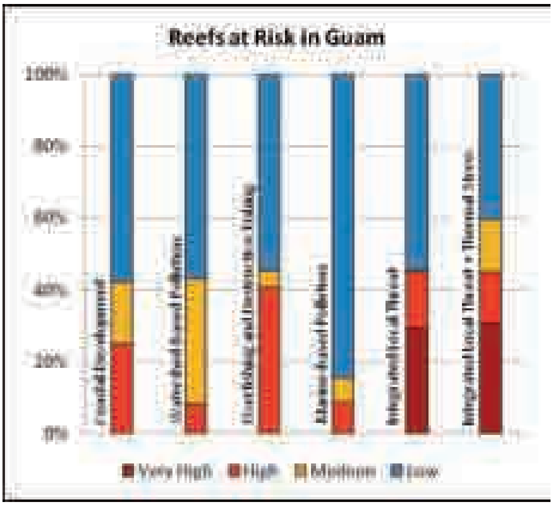
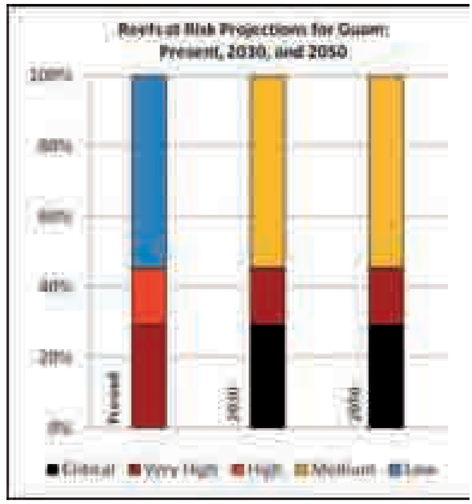
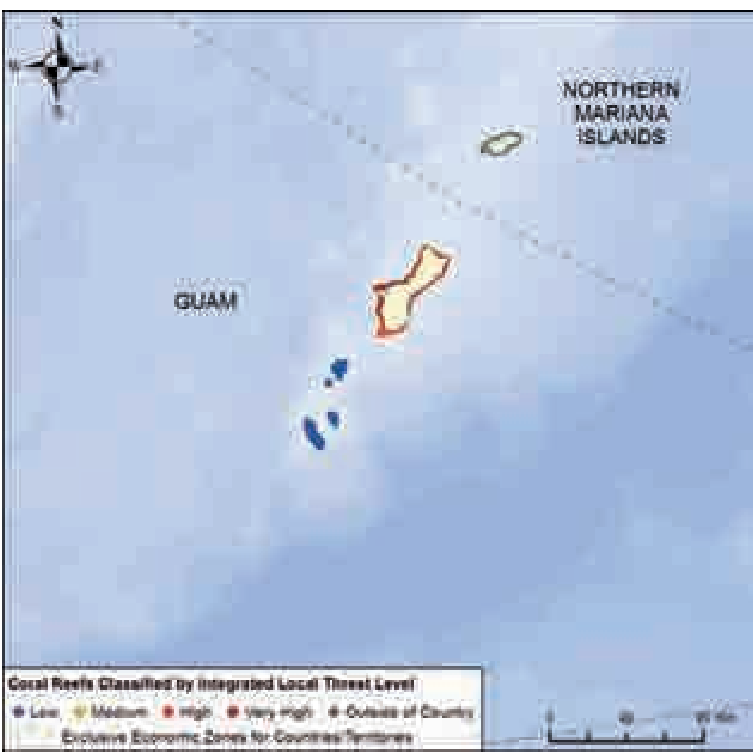
The *Reefs at Risk Revisited* analysis shows that almost half of Guam's coral reefs are threatened (medium risk or higher) by coastal development, watershed based pollution and overfishing. Thermal stress from warm sea temperatures adds additional stress, increasing the number of threatened reefs to about 60%. The reefs at the southern end of Guam are assessed as being most at risk. By 2030, projections for thermal stress and ocean acidification suggest that all of Guam's reefs will be threatened, including 29% of reefs assessed as being in critical condition. The full report, methods and full size maps are on: http://www.wri.org/reefs.







The LAS for sedimentation/land based pollution includes pollution control programs (Guam's Non-Point Source Pollution Control Program) under the US Coastal Zone Act, re-vegetation efforts, public and industry education campaigns and outreach programs, extension of sewerage outfalls, plans for a new municipal solid waste landfill and closing the old public dump [2].

The LAS for fisheries includes measures to improve compliance and enforcement; increase education and awareness; and to assess the effects of MPAs. New vehicles and jet skis for patrols have been purchased, legal capacity has been increased, statutory laws strengthened, and public information and outreach programs implemented [2]. Guam's fisheries laws and regulations (Title 16, Chapter 2) place restrictions on certain types of gear and fishing activities (e.g. prohibiting the use of gill nets or horizontal set long lines for commercial harvest), and limits on certain species such as trochus and lobsters. The take of giant clams is prohibited, as is the commercial take of gastropods other than trochus. Export of marine invertebrates is prohibited; however, other high risk fishing practices (e.g. spearfishing on SCUBA) are still permitted.

The lack of public awareness is being addressed through community 'Island Pride' events, community coastal clean-up days, a 'Guardians of the Reef' program, which was rolled out in local schools in 2007, and development of reef education programs in the school curriculum [2]. Public participation in Island Pride events has 'grown considerably in recent years', potentially indicting increased community environmental awareness and stewardship. Education and outreach programs are also being delivered to tourists and other reef users through information kiosks, in-flight videos and on-site projects [2].

The Recreational Misuse and Overuse LAS contains several initiatives to address the impacts of recreational activities such as SCUBA diving on Guam's coral reefs [2]. The Recreational Water Use Master Plan is being updated to improve management of personal water craft [2], and education programs have been launched to educate tourists and visitors about the natural values of areas such as Tumon Bay, and how to minimise their impacts [2]. The Coral Bleaching and Disease LAS is focused on research and monitoring of coral disease and coral bleaching to collect baseline information, and a coral bleaching response plan is being developed [2].

The military expansion on Guam will also pose a significant threat, and a LAS is being developed to help manage and mitigate the potential impacts [2]. Guam is a signatory to the Micronesia Challenge which makes a commitment to effectively protect 30% of near shore coastal resources by 2020; a major step towards management of Guam's coral reefs [2].

There is little published information on customary marine tenure in Guam [4]. Guam has 5 recognized MPAs covering 36 km^2 that were established in 1997 to restore fisheries resources [2]. In 2006, the government expanded the goal of these MPAs to include conservation purposes. These areas are now closed to all but certain types of fishing using specific gear or species, in certain areas and at certain times [2, 13]. Surveys indicate a significant increase in the abundance of food fish within the reserves, and research suggests that beneficial effects are being experienced outside reserve boundaries [2]. However, illegal fishing within these reserves has been reported, and education and enforcement activities have been implemented to improve compliance [2].

The Action Plans and Local Action Strategies have improved the management of Guam's coral reefs, and delivered some benefits. There has been an apparent increase in community participation and involvement in clean-ups and erosion control, and increasing public awareness [2, 7]. The increase in fish abundance in MPAs is also a promising sign, as are public works to relocate sewerage outfalls and improve management of solid waste. Nevertheless, management is hindered by a lack of resources and capacity; the limited resources are being further stretched by increasing pressures, developments and responsibilities, especially those related to the military expansion and effects of climate change [2, 7].

Governance and management – EVIDENCE OF CHANGE/ ALTERED (low confidence)

Guam has implemented plans and legislation to manage fisheries resources and coral reefs, including arrangements linking high-level policy to local actions. The increase in research and monitoring, planning and management efforts in the last decade is promising, as are the positive trends from these efforts (enforcement of MPAs, increasing fish abundance in MPAs, improved public awareness). However, some of Guam's reefs and resources have been degraded (e.g. coral reefs in southwest Guam), and pressures are growing which will require increased management efforts. Furthermore, some management measures are still being planned or implemented, thus the effectiveness is unknown.

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Palau

- Marine Area: 629 000 km^2
- Coastline: 1 519 km
- Land Area: 456 km^2 [(1)]
- Reef Area: 525 km^2 [(1)]
- Total MPAs: 32 [(2)]
- Area of MPAs: ~1 314 + km^2 [(3)]
- Mangrove Area: 47 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 94%
- Population (2008 est): 21 903
- Population (2050 proj): 22 400
- Population growth (2011): 0.36% [(4)]
- Urban population (2003): 68% [(5)]
- GDP: USD $1 24 500 000 (2004 est)
- GDP/Cap: USD $7 600 (2007)

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The Republic of Palau is the westernmost nation of Micronesia, located north of New Guinea and east of the southern Philippines. Palau includes more than 586 islands spread across 629 000 km^2 of ocean, that are volcanic in origin. The main island of Babeldaob (334 km^2) accounts for most of Palau's land area (total 456 km^2) [(1)]. The Rock Islands with iconic marine lakes and the raised platform island of Peleliu stretch southwest from Babeldaob's southern tip. Babeldaob and the nearby islands such as the Rock Islands, Peleliu and Kayangel comprise the main islands, and include the capital Melekeok. A group of small oceanic islets and Helen Reef atoll are known as the Southwest Islands, and are 339 to 599 km southwest of Palau's main islands. The islands are divided into 16 states that constitute the Republic of Palau [(6)].

Palau has a diversity of rich coral reefs which include fringing, barrier and atoll reefs; upwellings of cold deep oceanic water often occur, providing nutrient salts and calcium rich waters for reef growth [(1)]. Satellite imagery in 2007 classified marine habitats for 1,478 km^2 and estimated that coral reef and hard bottom areas cover 892 km^2 [(7)]. Palau has iconic reef lagoons, 'rock islands' and inland marine lakes [(1, 6)]. Palau's reefs have the most diverse coral reef fauna in Micronesia with 425 coral species, 1 700 fishes, 302 molluscs and 234 crustaceans recorded [(1, 8)]. This diversity of species and marine environments play an important part in Palau's economy, as tourism is a major component of the economy with more than 80% of Palau's visitors coming to dive on coral reefs [(7)]. These reefs are also important to a diverse mix of artisanal, subsistence and commercial fisheries [(7)]. Palau's coral reefs were severely affected by the 1998 coral bleaching event, and this served as 'a wake-up call' for an increased awareness and focus on coral reef conservation and management [(3, 6)].

Status, health and resilience of coral reefs

Several government agencies and organisations monitor coral reef environments in Palau. While ad hoc reef surveys have been conducted since the 1960s, the first comprehensive survey of Palau's coral reefs was the Rapid Ecological Assessment (REA) in 1992 [(9)]. Reefs were reported as being in generally "good condition with high coral cover" prior to the 1998 event when warm water temperatures and resulting coral bleaching severely affected coral reefs across all islands [(7, 9)]. Data from 'spot check' surveys between 2001 and 2003 were compared with the 1992 REA survey data to examine the effects of the 1998 bleaching event. This analysis suggested that the bleaching was very severe and reduced coral cover from 50%-70% to 14%-23% across survey sites [(9)]. Other surveys in 2001 showed similar high levels of bleaching and very high mortality (90% to 100%) of bleached corals [(8, 9)], especially of acroporid corals.

Most of the current long-term monitoring is conducted through the Palau International Coral Reef Center (PICRC) which began monitoring coastal ecosystems in 2001 [(7)]. There are currently 22 permanent monitoring sites around the main islands: Babeldaob; the Rock Islands; Peleliu; Angaur; and Kayangel (an atoll to the north of Babeldaob). Benthic composition is monitored using video transects while fish surveys use underwater visual census along five 50 x 5 m transects [(7, 9)]. PICRC monitoring has shown that Palau's reefs are recovering well from the 1998 bleaching event, with live coral cover increasing at ~2.9% per year from 2001 to 2004. At sites surveyed in all 3 years, mean live coral cover across all sites increased from 17% in 2001 to 26% in 2004 [(9)]. Surveys in 2006 and 2007 show continued increases in live coral cover [(7)] (Fig. 1). Coral recruitment was measured between 2001 and 2004 and found new coral recruits in all years, with density (recruits per m^2) varying between 3.6 ± 0.2 and 7.3 ± 0.5. Overall, Palau's coral reefs appear to be recovering well [(8, 9)].

Fish surveys also show increasing trends, with abundance (measured as numbers observed per 250 m^2 transect) of 21 surveyed species increasing at most sites between 2001 and 2005. Fish abundance totals are for all observed fishes, thus no species-specific trends are available [(7)]. The

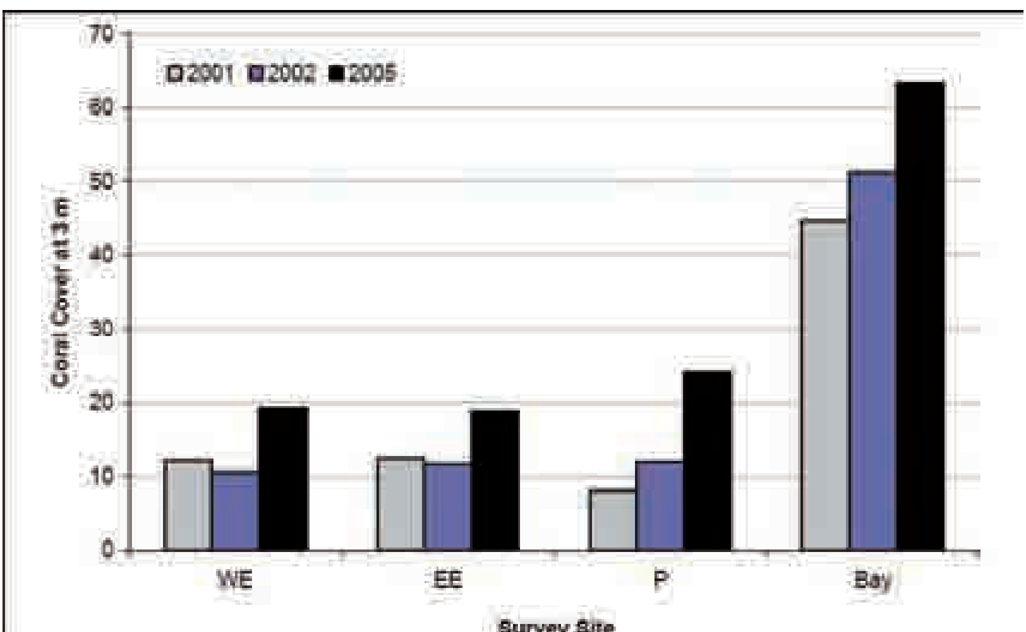


Fig. 1. Average coral cover at 3 m depth at western exposed reefs (WE), eastern exposed reefs (EE), patch reefs (P) and reefs around the rock islands (Bay) show continued recovery from the 1998 bleaching event from 2001 to 2005 (Figure extracted from Marino et al. 2008, original figure from Golbuu et al. *2007).*

lack of baseline data and long time series makes it difficult to interpret these trends, however, fishers have expressed concern that fish stocks are declining, and continued monitoring of reef fishes and species level analyses will be required to determine long-term trends [7].

Reefs at the remote Helen Reef atoll have also been surveyed, with periodic surveys in 1998, 2000 and 2002. These surveys, carried out by Hatohobei State and the community with support from the Community Conservation Network, form part of the Belau Locally Managed Area Network. The data show moderate live coral cover in 2002 (24% to 39%), which appears to be increasing since the 1998 bleaching event [10]. Many coral recruits were also observed which also suggests recovery. Large humphead (Maori) wrasse (*Cheilinus undulatus*) were also frequently observed. Bumphead parrotfish (*Bolbometopon muricatum*) were also observed but most were < 1 m in length. A number of invertebrates such as giant clams, trochus and sea cucumbers (bêche-de-mer) were also recorded. Unfortunately, changes in survey sites and methods have made it difficult to identify long-term trends; the 2002 surveys have been proposed as baseline data from which to continue long-term monitoring [10].

Status of coral reefs – EVIDENCE OF CHANGE (medium confidence)

There are some long-term data on Palau's coral reefs from different surveys focused on reefs around the main islands. These data show widespread declines during the 1998 coral bleaching event, followed by general recovery, suggesting that long-term coral cover across Palau is relatively stable, with little evidence of widespread, prolonged and consistent stresses, damage, or loss of live coral cover. However, changes in land-use are reducing coral cover and diversity on adjacent inshore reefs (see *below*). Trends in reef fishes are difficult to interpret.

Coral reef health and resilience – STABLE (low confidence)

Counts of coral recruits provide indication on the resilience of Palau's coral reefs. Substantial recruitment has followed disturbance events, such that coral cover has increased at most sites since 1998. These trends suggest that Palau's reefs have the resilience to recover from disturbance. While these signs are promising, more information about recruitment and community structure are needed to fully describe the resilience of the reefs, and to determine whether resilience is changing over time.

Use of reef resources

Palau has diverse fisheries including subsistence, artisanal and commercial fishing, however, there is limited information on fishing effort, catch, and status of exploited stocks. Fisheries production between 1989 and 1998 was estimated at 2 155 metric tonnes, 19% of which was exported and 81% consumed locally [7]. The Bureau of Marine Resources collects fish export data and landings at local markets. Unfortunately, nearly a third of the species are lumped into an 'assorted fish' category, making it difficult to determine species-specific trends [7]. Data from 2000 to 2005 show that reef fishes dominate fisheries landings, with tuna and mackerels, crabs, lobsters and trochus recorded in smaller amounts. Between 1992 and 2005, bumphead parrotfish, (*Bolbometopon muricatum*; 'kemedukl'), groupers and rabbitfish (*Siganus fuscescens*) were the top commercial species [7]. However, bans on the catch of bumphead parrotfish and seasonal closures on the catch of groupers and rabbitfish have resulted in a change of fishing effort towards unregulated fishes such as the bluespine unicorn fish (*Naso unicornis*). This species has been the top commercial species over the last 10 years and inspections of landings have revealed many undersized fish [7].

Palau has also experienced commercial ‘pulse fishing’ where large scale commercial ventures intensively fish one area before moving onto another. Pulse fishing for live reef fish at Helen Atoll (Hatohobei State) over a two year period resulted in a ‘drastic drop’ in fisheries production [4]. The local community also perceived changes occurring from impacts of foreign fishing and poaching between 1970 and 2000 [10]. In response to these concerns, Hatohobei State stopped the operation [4]. Helen Reef was declared as a State Marine Protected Area in 2001 with bans on all forms of fishing [10].

Fisheries landings data show reducing yields from 9 states between 1992-1997 and 1998-2001. These declines are attributed to large scale pulse fishing, coral bleaching, habitat loss and sedimentation. The declines could also be explained through changes in the fishery due to increased management [4, 7]. Patterns of resource use also appear to be changing. Fishers are using newer and more effective fishing gear, use is shifting from subsistence fishing to fishing for income [4], and most fishers are reported to have abandoned traditional methods that tended to limit catches. Surveys suggest that fishers are concerned about the status and use of many fish resources including reef fish, especially bluespine unicornfish, humphead wrasse, bumphead parrotfish, sea cucumbers, sea urchins, crabs, giant clams, tunas, and aquarium fish [4, 7]. The community perceived that catches are at least 3 times less than a decade ago. Total landings of the top shell, *Trochus niloticus* have dropped by 72% [4]. Destructive fishing practices (e.g. bomb and cyanide) appear to occur less frequently than in past decades, but are still an issue of concern about occasional destructive fishing [11].

The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [12] indicates that fishing poses some risk to Palau’s marine resources. Likewise, the 2009 **Pacific Ocean Synthesis Report** [13] identifies fishing as an issue of significant concern in Palau, with both commercial and artisanal/subsistence fishing potentially being a severe threat. Like many other nations, the report also indicates some concerns about the impacts of collecting for the aquarium trade [13].

Tourism makes the largest contribution to Palau’s GDP and is a vital economic activity [4, 7]. In 2005, more than 80 000 tourists (mostly from Japan and Taiwan) visited Palau and tourism appears to be growing [7]. The majority of tourists dive and snorkel on coral reefs and visit the iconic Rock Islands [7]. Communities on the main island of Babeldaob have opened a new road to develop land-based tourism. In 2007, a river boat tourism operation began, and visits to waterfalls and other historic sites have increased [7]. Sharks are an important dive attraction and the value of sharks to the Palauan economy has been estimated as US$18 million per year, accounting for approximately 8% of the gross domestic product of Palau. Each individual shark had an estimated annual value of US$179 000 and a life-time value of US$1.9 million to the tourism industry [14].

Nevertheless, increasing tourism could pose a threat to Palau’s coral reefs [7]. In 2006, Peleliu State installed mooring buoys to reduce anchor damage at dive sites. The introduction of a sea anemone into Jellyfish lake in 2003 prompted Koror State to implement spatial management zoning for the Rock Islands and establish a new fee schedule to help manage tourism sites [7]. The 2005 UNEP/SOPAC Environmental Vulnerability Index [12] indicates that tourism could pose some risks to Palau’s environment.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

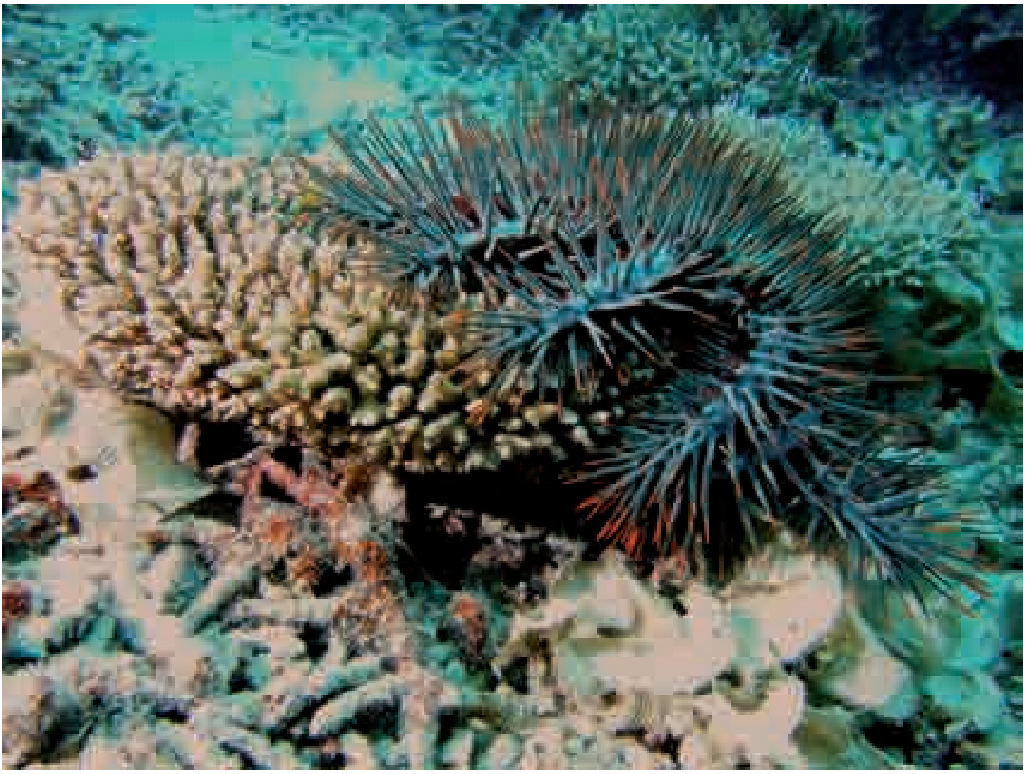
While there are good data on fisheries landings, long-term data on catch composition, fishing effort and stock assessments are not available. Nevertheless, fisheries landings data, many risk assessments, anecdotal reports and community surveys suggest declines in some marine resources including reef fish and invertebrates. The main risks include subsistence and commercial fishing, and potentially collecting for the marine aquarium trade, although increases in tourism could also lead to significant impacts. More data are required to fully understand current patterns and trends of reef resource use.

Factors affecting reef health and condition

Several factors other than direct use (i.e. fishing and tourism) also affect Palau's coral reefs. These include coastal development and land runoff, land-based pollution, tropical storms and climate change. The *Reefs at Risk Revisited* assessment suggests around 30% of Palau's reefs are threatened (medium threat or higher), mainly from fishing and coastal development [15]. Historically, most coastal coral reef areas around Babeldaob's main watersheds (which have steep slopes and soil that is prone to erosion) have experienced increased sedimentation [16]. In the 1940s, agriculture and mining were the main sources of sediment pollution, however development since the 1980s and 1990s has accelerated sedimentation [16]. More recently, changes in population distribution, construction, road building and land-use have also affected the coastal environment [7]. Many of these activities are associated with the recent move of the central government from Koror to Babeldaob, and the construction of a new road (the 53 km 'Compact Road') encircling the island [4, 7]. These activities have required development of infrastructure and land to support these changes, resulting in increased erosion and sedimentation [7]. Some mangrove areas have also been cut and filled for development [4]. Land and forests are also being cleared in Airai (the southernmost state on Babeldaob) for roads, farms and housing developments, leading to sedimentation of coastal waters [7]. Poor farming practices also contribute to sediment pollution. Studies indicate large sedimentation rates in many areas, resulting in buried coral reefs, altered coastal and estuarine habitat profiles and affected coastal marine resources [16]. Overall, sedimentation is considered to have a significant impact on Palau's coastal habitats [7, 13, 16].

There are also numerous point sources of pollution including discharges from fishing companies (brine, oil, trash) and hotels [7]. The Koror landfill is also leaching pollution into nearby waters [7]. Additionally, the sewerage system is old and has deteriorated due to a lack of maintenance, and sewage overflows are regularly reported [7]. This contaminates adjacent waters with bacteria and increases nutrient loads. The **2005 UNEP/SOPAC Environmental Vulnerability Index** lists treatment of waste and sanitation as moderate to high risks to Palau's environment [12].

Other threats also affect Palau's coral reefs; debris is commonly found on beaches around Palau as well as discarded or lost fishing nets and lines. Given that Palau imports a large amount of material, it is difficult to determine if this debris originated locally or from outside Palau [7]. Invasive species have also been recorded in Palau, mostly invertebrates that were probably introduced on ship hulls or in ballast water. While these species appear to have only had low impact in Palau thus far [7, 13], invasive species can become a series threat and more information is required [7]. The UNEP/SOPAC 2005 assessment lists invasive species as a high risk [12], and the spread of the invasive anemone *Aiptasia* sp. into Jellyfish Lake is of particular concern [7]. Many ship groundings have occurred in Palau causing physical damage to the reefs and contamination with toxic anti-fouling paint. These events have caused localised damage [7].



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Palau's coral reefs are also affected by tropical storms which cause significant physical damage; however, there have been no direct studies on long-term effects of storms [7]. As evident from the 1998 bleaching event, Palau's reefs are vulnerable to above-average sea temperatures which have caused significant bleaching and mortality. Elevated seawater temperatures and coral bleaching have also affected fisheries and tourism, with reductions in visitor numbers and visitor satisfaction [13]. Increasing storms and warm water events arising from climate change could increase the impacts from these factors, with the *Reefs at Risk Revisited* assessment suggesting that all of Palau's coral reefs will be threatened by 2030.

There is little information available on the effects of crown-of-thorns seastars (COTS) on the reefs. Surveys conducted between 1969 and 1979 identified outbreaks in many areas [17]. According to Idip (2007), early COTS control programs were initiated in several places but no further data were available until coral reef surveys began in 2000. Also in 2000, a local dive operator began a control program at popular dive sites around the southern end of Babeldaob and the Rock Islands [17]. While there appear to be significant numbers of COTS at a few areas, Idip (2007) does not report widespread outbreaks or serious impacts around Palau.

While there are controls on immigration and efforts are being made to manage population growth [4], Palau is expected to experience significant population growth which will increase pressure on the environment. The **UNEP/SOPAC 2005** report assessed Palau as being highly vulnerable to population growth [12].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

There is some information on risks and their affects on Palau's coral reefs, which suggests that changes have occurred on some coral reefs, and some risks are increasing. The main issues are sedimentation and pollution from land-based sources, coastal development and population growth. There are also the potential effects of climate change. However, better information is needed to fully describe the long-term trends in these risk factors.

Governance and management

Palau has a number of legislative acts and initiatives to manage and protect coral reefs. The Ministry of Resources and Development has overlapping jurisdiction with the 16 State Governments in waters out to 12 nautical miles from the high water mark [7]. The national and state governments, as well as NGOs and other institutions, have implemented plans and programs to address issues such as fishing, land-use and sediment pollution [7]. Palau is a signatory to several international agreements such as the UN Convention on the Law of the Sea, the Ramsar Convention on wetlands and the Convention on Biological Diversity [4]. Palau is also a signatory to the Micronesia Challenge that aims to effectively conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources by 2020 (see Micronesia Challenge Case Study). Palau also has many management plans for fisheries such as tuna [4]. The *Marine Protection Act* (1994) was introduced to manage fisheries and includes bans on the harvest of species such as mangrove crabs and some species of sea cucumbers. There are also regulations on catching groupers (Serranidae), rabbitfish (Siganidae), bumphead parrotfish, humphead wrasse, lobsters, coconut crab, clams, trochus, blacklip pearl oyster, dugong and marine turtles [4, 7]. Taking fish using SCUBA or hookah diving, or destructive fishing practices (e.g. explosives) are all banned, and there are restrictions on fishing nets [4]. In 2009, Palau declared that it was a shark sanctuary and protected all sharks within its EEZ from fishing [14].

Like many other Pacific Island nations, Palau faces numerous management challenges, these include: insufficient capacity and resources to implement management and enforce plans at both the state and national levels; inconsistencies between state and national government management; and a lack of cohesive information network between agencies [4]. Illegal fishing and poaching have been reported, including poaching from foreign fishing vessels [4]. Legislative attempts to implement total bans on harvesting certain species and extend moratoriums of endangered species have been met with limited success [7]. Community surveys of the Ngelukes conservation area revealed that some community members perceive that poaching still occurs, although they were aware of the difficulties in enforcing the closure [3].

Palauans have a long history of traditional management of marine areas, and current management is implemented through a mix of customary, state and national authorities [3]. There are 28 MPAs in Palau, but only 2 are recognised as national marine parks [3]. Almost all MPAs in Palau have been established for local resource management and were not designed to form a comprehensive, inter-connected national network of MPAs. The *Protected Areas Network Act* came into effect in 2003 and provides for government administration and coordination of Palau's MPAs. Under these arrangements, on-ground management is delivered at the state and community level, with support and coordination from the national government [3, 4]. Surveys of local communities suggest support for MPAs with perceived benefits such as increased fish abundance within the MPAs, and evidence for spill-over effects [3]. Surveys of reef fishes in 2003 and 2004 also reported increased fish abundance [3, 7].

Reefs at Risk Revisited [(15)]: *Palau*

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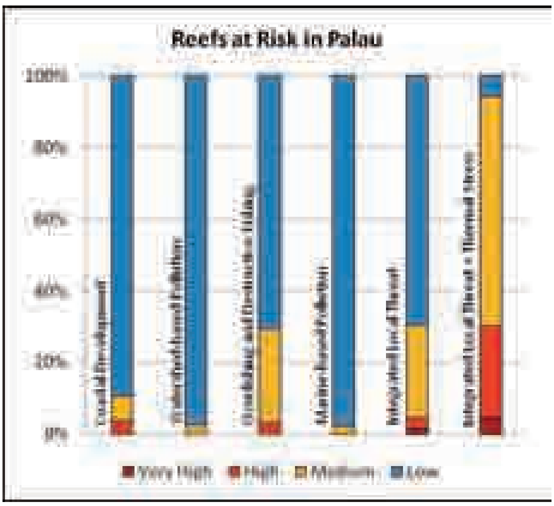
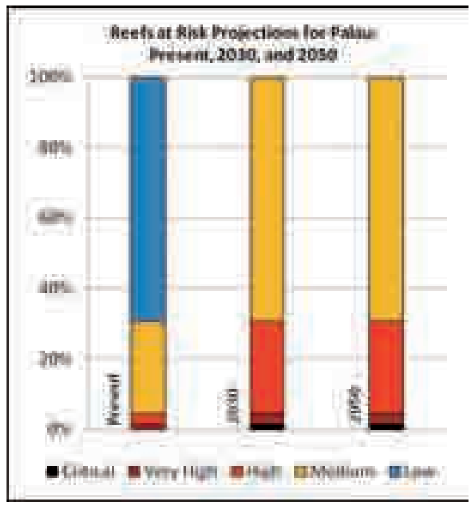
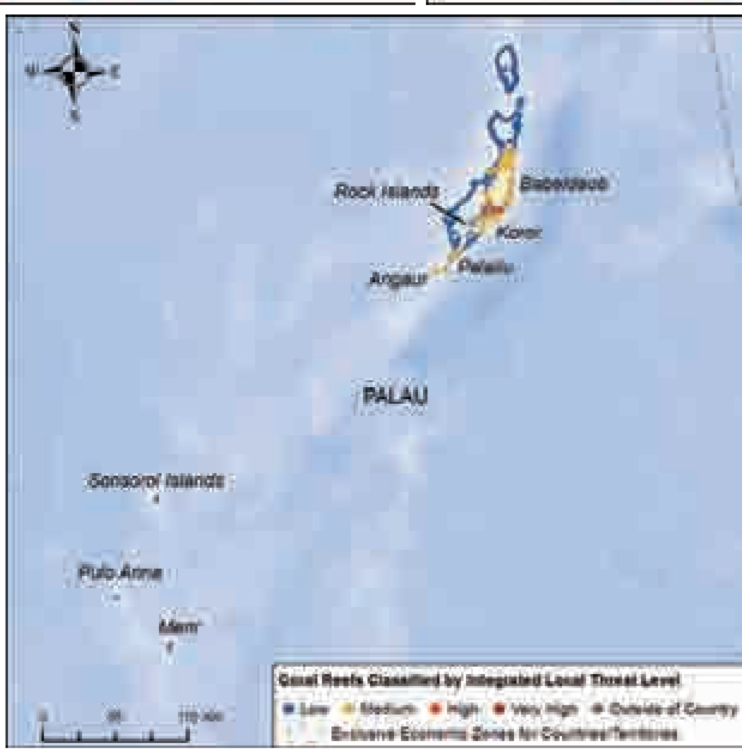
The *Reefs at Risk Revisited* analysis found that about a third of Palau's coral reefs are threatened by local pressures, with the greatest pressures posed by overfishing and coastal development. When thermal stress over the past 10 years is included, 94% of Palau's reefs are threatened. The reefs at the southern end of Babeldaob around Koror are assessed as being most at risk. By 2030, projections for thermal stress and ocean acidification suggest that all of Palau's reefs will be threatened, with about 35% at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.







Governance and management – EVIDENCE OF CHANGE (low confidence)

Palau has many legislative tools for managing fisheries resources and coral reefs, including measures to coordinate management efforts. Palau is also committed to continued environmental management which is a positive sign. Some MPAs are perceived to be delivering benefits to coral reef ecosystems and local communities. However, many challenges to effective management have been identified including limited capacity, funding and enforcement issues. Poaching has been recorded. More information is needed to fully describe the effectiveness of existing management arrangements in protecting coral reef ecosystems and sustaining reef resources.

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Republic of the Marshall Islands

- Marine Area: 2 131 000 km^2
- Coastline: 370.4 km
- Land Area: 181.3 km^2
- Reef Area: 1 995 km^2
- Total MPAs: 41 [(1)]
- Area of MPAs: 5 892+ km^2 [(1)]
- Percentage of reefs threatened (local threats and thermal stress 2011): 29%
- Population (2011 est): 67 812 [(2)]
- Population (2050 proj): No Data
- Population growth (2011 est): 1.9% [(2)]
- Urban population (2010): 72% [(2)]
- GDP: USD $133 millions (2008 est) [(2)]
- GDP/Cap: USD $2 500 (2008 est) [(2)]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The Republic of the Marshall Islands (RMI) has been an independent state since 1986, but maintains close ties with the USA under the Compact of Free Association which provides for joint access, services and defence agreements. The Marshall Islands host the US Army Kwajalein Atoll Reagan Missile Test Site, a key installation in the US missile defense network [(2)]. The islands are approximately 3 800 km southwest of Hawaii and 4 500 km southeast of Tokyo. The RMI consists of 1 225 small islands and islets. The islands are grouped into 29 coral atolls and 5 low-lying coral islands which lie in two island chains: Ratak (sunrise) chain in the east and Ralik (sunset) chain in the west [(3)]. The isolated atolls of Enewetak and Ujelang are to the west of these main chains. Wake Atoll is approximately 1 430 km to the north northeast of Majuro, the main island, but is administered by the USA. Two thirds of the population live on Majuro and Ebeye. The atolls are narrow strips of land enclosing large central lagoons, and only about 2 m above sea level [(4, 5)]. The 1 000 islands and islets are very small such that the RMI total land area is only 181 km^2, or only 0.01% of the EEZ.

Bikini and Enewetak atolls were used as nuclear test sites in the 1940s and 1950s, and the local communities were relocated. The long-term effects of these tests are still unknown [(4)]. Since nuclear testing ceased, there has been minimal human use of the affected atolls, resulting in significant increases in some fish groups such as sharks and jacks (Carangidae); therefore they are amongst the most pristine reef communities in the region [(6)].

The coral reefs of the RMI support a diverse assemblage of marine and coral reef species including: macroalgae, 222 species; seagrasses, 3; mangroves, 5; corals, 362; molluscs, 1655; crustaceans, 728; echinoderms, 126; and reef fishes, 860 [(4)]. The coral reefs are generally in excellent condition, and most reefs are less affected by overfishing, pollution and disease than other reefs in SE Asia and the Pacific [(5)]. However, there are increasing localised pressures from fishing, pollution and coastal development on reefs around population centres. Additionally, climate change will present significant challenges to the reefs and people of the RMI [5].

Status, health and resilience of coral reefs

Since 2000, monitoring has been conducted by the College of the Marshall Islands (CMI), the Marshall Islands Marine Resources Authority (MIMRA), the Secretariat of the Pacific Community (SPC), NGOs and several Australian universities. Many of these were specific Natural Resource Assessment Surveys (NRAS) as snapshots of reef diversity and health at various atolls [5]. These data provide valuable baseline data for future monitoring. Long-term monitoring began in 2006 and 2007 at Rongelap, Ailuk, Likiep, Majuro and Arno Atolls [5].

The NRAS surveys between 2000 and 2007 at 7 atolls (Likiep, 2001; Bikini, 2002; Rongelap, 2002-2003; Mili, 2003; Namu, 2004; Majuro, 2004; and Ailuk, 2006), included timed swims, belt and line intercept transects using SCUBA, and quadrats [5]. The NRAS surveys also included baseline data on fishes, sharks, corals, invertebrates and marine algae. Data reported below note that 6 of the atolls have generally healthy reefs with relatively high coral cover.

Atoll	Year surveyed	No. of reef sites	% live coral cover	Range in % coral cover on reef sites
Bikini	2002	6	25.7	6.03 – 40.6
Rongelap	2002-03	7	40	26.4 – 59.2
Mili	2003	6	29	11 – 54
Namu	2004	6	23.3	13.7 – 50.6
Majuro	2004	7	54.1	44.3 – 73
Ailuk	2006	6	29.5	15.9 – 44.1

Table. 1. Live coral cover (% average across all reef sites) at 6 atolls surveyed during the NRAS surveys between 2000 and 2007. Surveys showed relatively healthy reefs with relatively high levels of coral cover (data from Beger et al. *2008).*

In general, coral reefs on the outer islands and atolls have not experienced major mortality events or degradation [5, 7]. Rongelap at the northern end of the Ralik (western) chain has been largely uninhabited since residents were relocated in the 1950s due to atomic testing (Rongelap is due east of Bikini Atoll). Surveys at Rongelap Atoll found large fish, healthy corals and abundant megafauna such as turtles and humphead (Maori) wrasse (*Cheilinus undulatus*). Surveys at Rongelap also found a new Scleractinian coral species, and recorded range extensions for a further 7 coral species. Mili Atoll was also in excellent condition with abundant fish, corals and algae [5]. Namu Atoll had a high abundance of fish and sharks [5]. Bikini Atoll also had high coral cover, showing relatively healthy communities and their ability to recover from disturbances. However, a number of coral species appear to have become locally extinct on Bikini, most likely due to the effects of atomic testing [8]. At Bikini Atoll, the nuclear tests created craters up to 73 m deep and altered sediment movement patterns [5]. Other atolls also showed signs of human impacts. While Majuro still had high overall coral cover, some sites have been affected by coral disease such as white syndrome and coral lethal orange disease (CLOD), as well as outbreaks of crown-of-thorns seastars (COTS) [7]. Goldberg et al. (2008) reported that 30-50% of the corals in the lagoon have recently been devastated by a COTS outbreak, and that 30% of Majuro's oceanic reefs suffered high disease related mortality [7]. Some reefs around the main atoll of Majuro have also been directly affected by dredging, coral mining, sedimentation and pollution [5, 7]. There are limited data on trends over time as there has been no long-term monitoring.

NRAS surveys show a rich and diverse fish fauna across the Marshall Islands. Rongelap had high abundance of food fishes such as surgeonfish, snappers, wrasses and groupers, and relatively high abundance of large coral trout (Serranidae) compared with other atolls [5]. Most RMI atolls and reefs appear to have healthy populations of top level predators such as sharks, although some localised declines have been reported [5, 9]. Rongelap and Bikini support higher shark abundances compared to other atolls in the RMI [5]. Fish populations are considered to be decreasing in Majuro from surveys by local residents. However, fisheries data are limited and the status of fish populations is unknown [7].

Status of coral reefs – STABLE (low confidence)

Although there are valuable baseline data, more surveys are needed to identify reef status, long term trends and coral health. Nevertheless, the data available do suggest that many atolls in the RMI have high coral cover and abundant food fishes, especially on more remote atolls such as the uninhabited Rongelap and Bikini atolls. However, localised pressures have caused degradation of reefs around heavily populated atolls such as Majuro; this will require more monitoring to identify the long term effects of human activities.

Coral reef health and resilience – NOT CONSIDERED

There was insufficient information to describe the resilience of coral reefs. More information on long-term trends in status and recovery, community composition and ecological processes is needed to adequately describe the resilience of these reefs.

Use of reef resources

Artisanal fishing, including small scale commercial fishing, is still very important to the Marshallese and current regulations allow fishers to use all non-destructive forms of fishing apart from gill netting [7]. There is also an active aquarium fishery [6]. However, most commercial fishing is by foreign fishing vessels licensed to target tuna in RMI waters. The RMI Ministry of Resources and Development has fishing agreements with Japan, Korea and Taiwan, and fishing licenses are a significant source of foreign income; and a fish processing plant on Majuro provides additional income and economic development [5]. Although these fisheries target pelagic fish resources, they can also affect coral reefs. Many reef sharks are taken by long-line vessels in the RMI, even though long-line fishing for sharks is prohibited [5, 9]. Sharks are likely targeted to supply shark fin to Asian markets [7]. There have been reports of illegal shark fishing using traps and long lines in Likiep and Mili atolls [9], and NRAS surveys in 2003 reported low numbers of sharks on Mili Atoll where locals had previously reported high shark numbers [5, 9]. Shark numbers at Mili were also notably lower than at more remote atolls such as Rongelap and Bikini, even though these remote atolls have been affected by some fishing. For example, a single spate of long line fishing caused a significant decline in the population of grey reef sharks at Shark Pass, an iconic dive destination on Bikini Atoll [5]. These anecdotal reports indicate that shark populations may be affected, and better monitoring of fisheries catch, effort and of shark populations is needed to determine the extent of shark fishing and its effects in the RMI.

Fisheries data are very limited and there are no data on fisheries catch and effort, stock assessments or fishery surveys [7]. Targeted reef fish species include the big nose unicornfish (*Naso vlamingii*), big eye emperorfish (*Monotaxis grandoculis*), forktail rabbitfish (*Siganus argenteus*), peacock groupers (*Cephalopholis argus*) and giant coral groupers (*Plectropomus laevis*). Abundance of these fishes is higher at more remote atolls such as Namu compared to populated atolls like Majuro [5], and anecdotal evidence also suggests that fish populations have declined around populated atolls such as Majuro and Arno [7]. The current take of grouper, reef shark, and humphead wrasse may not be sustainable [3].

Some species of giant clams have also become more rare in RMI waters [5] although some outer atolls have healthy populations of clams (*Tridacna gigas*) that may be subject to some poaching. There are few giant clams near human population centres such as Majuro. Green turtles may be taken for subsistence use. There are healthy populations of sea cucumbers (bêche-de-mer) in some areas although they are not exploited around Majuro [7].

An active aquarium fish trade exports tens of thousands of live fish every year, especially the prized flame angelfish (*Centropyge loricula*) [7]. Wild caught aquarium fish are mostly taken from reefs around Majuro, Arno and Mili [5]; however, declines in aquarium fish have been reported such that some businesses support the establishment of no-take marine reserves to protect breeding stocks [7]. There are small aquaculture farms focused on clams (for the aquarium trade), pearl oysters and trochus [6], and coral fragments are also cultured for the aquarium trade [5]. The MIMRA operated aquaculture ventures on Majuro, Likiep, Arno and Mili are probably the most successful operations [5].

The 2009 Pacific Ocean Synthesis Report [10] identifies commercial fishing as potentially posing a severe threat to the Marshall Island's marine environment, with some threat also posed by aquarium collection and artisanal/subsistence fishing. The 2011 *Reefs at Risk Revisited* assessment indicated that 23% of coral reefs in the Marshall Islands are threatened (medium risk or higher) by fishing activities.

Tourism is fairly limited compared to other Micronesian islands such as Guam, Saipan and Palau. About 1 200 tourists visit the RMI each year, mostly from the USA and Japan, with most visiting for SCUBA diving, sport fishing, or to visit historical sites from World War II [5]. Coral reef related tourism is focused around Majuro's northern lagoon which has small-scale resorts and dive shops. Bikini Atoll was once a renowned SCUBA diving destination due to the collection of wrecks and Shark Pass which had a large population of sharks [5]. Long-range SCUBA diving operations take divers on expedition trips to dive Bikini. However, difficulties in accessing the atoll reduce opportunities for general tourism. A new resort is also being developed on Rongelap Atoll which has been virtually inaccessible since the nuclear tests in the 1950s. While the more remote atolls have renowned SCUBA diving sites, their remoteness presents a significant challenge to developing tourism in these locations [5]. The 2005 UNEP/SOPAC Environmental Vulnerability Index [11] indicates that tourism could pose some risks to the RMI's marine environment.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

There are few data on human uses and resulting impacts on the coral reefs of the Marshall Islands. Anecdotal evidence and comparisons of fish populations between populated and remote atolls indicate that some fish species are declining, including top predators such as sharks. Risk assessments also suggest that commercial fishing and collecting for the marine aquarium trade pose medium to severe risks to the reefs. Nevertheless, more data are needed about fisheries catch and effort, and long term monitoring at both exploited and pristine sites needs to be maintained to understand levels of use, impacts and sustainability.

Factors affecting reef health and condition

The coral reefs of the RMI are also affected by storms, volcanic activity, pollution and climate. The 2011 *Reefs at Risk Revisited* global assessment suggests that about 26% of reefs in the

Marshall Islands are threatened (medium risk or higher), mainly from fishing and coastal development. Some reefs around Majuro are affected by sediment runoff and pollution from coastal development. The demand for coral rock and sand for construction is resulting in ongoing dredging in Majuro lagoon, as well as small-scale sand mining on other beaches [7]. Coastal erosion is ongoing with significant amounts of beach area lost in the southern lagoon area of Majuro [7]. While recovery has been observed in some quarry areas, other areas have filled with loose sediments that prevent coral settlement. Quarrying and dredging has also altered water flow, resulting in severe erosion at places around Majuro [5]. The use of drag-line dredging was banned by the RMI Environmental protection Agency (EPA) in 2008, and has been replaced by suction dredging of deeper lagoon sediments.

Majuro's coastal waters have been affected by pollution from municipal landfills and sewage. The breakdown of waste collection and sewage treatment between 2004 and 2007 resulted in dumping of rubbish and sewage directly on the shoreline [5]. The lack of a seawall allowed solid waste to escape from the municipal landfill directly into coastal waters, blanketing down-current reefs with garbage [5]. The solid waste landfill is nearing capacity, and leachate continues to enter coastal waters from the fill. Waste management was placed under the control of a single authority in 2007 which has fortified the seawall and stabilised the landfill with sand from the lagoon. However, waste management and pollution continues to be serious environmental issues in the RMI [5, 11]. The UNEP/SOPAC 2005 Environmental Vulnerability Index lists land-based pollution, wastes and coastal development as the major risk factors [11]. In addition to domestic waste, the RMI receives a large amount of marine debris from sources as far away as Central and South America. Some reefs have significant levels of accumulated plastic rubbish and debris from local and foreign sources [5]. Like many other Pacific islands there is a high population growth rate on the Marshall Islands; while 2050 projections are not available, increases in population are likely to put more pressure on the environment and resources, such as fisheries. The UNEP/SOPAC 2005 Assessment indicates that the RMI is highly vulnerable to population growth [11].

The islands and atolls of the Marshall Islands are extremely vulnerable to sea level rise because they are only few meters above sea level [5]. The projected rise in sea level of 80 cm could inundate two thirds of the islands [10]. This would cause immense changes to the coastline, threaten water supplies, severely disrupt agriculture, and destroy coastal development and infrastructure [10]. The resulting changes would severely affect coastal communities, resource use and potentially, jeopardise traditional history and culture. The effects of rising sea levels are already evident in the RMI during extreme high tides, and the national government is very concerned about predicted sea level rises associated with climate change [5]. The UNEP/SOPAC 2005 assessment and the Pacific Synthesis report suggests that the Marshall Islands are extremely vulnerable to sea level rise and the resulting effects from flooding, inundation and storm surge [11].

The reefs of the Marshall Islands have not experienced the widespread and severe coral bleaching events seen elsewhere in Micronesia. However, coral bleaching has been observed on many occasions around Majuro, usually in shallow intertidal depths. However, coral bleaching down to 10 m depth occurred in 2003; in 2006 extensive bleaching and mortality of *Acropora* corals were recorded down to 3 m depth [5]. While bleaching is rarely reported from other reefs, monitoring at these sites is limited so the actual frequency and severity of bleaching events is unknown [5]. Nevertheless, most bleaching recorded to date has been of shallow corals and has not significantly lowered the relatively high coral cover on most reefs. Coral disease has been recorded in the RMI, particular on reefs around Majuro. The incidence of disease appears to be linked to warm sea water temperatures, and disease has caused significant mortality of some corals around Majuro [5, 7].

The RMI is periodically affected by typhoons. The low elevation of the islands makes them particularly vulnerable to typhoons and tsunamis, and recent events have devastated parts of

Majuro, Mili, Arno, Jaluit, Likiep and other atolls [5]. A severe storm in 2007 destroyed infrastructure around Majuro and damaged reefs. Storm waves also exacerbate erosion which is already a significant issue around Majuro [5].

Several outbreaks of crown-of-thorns seastars (COTS) have been recorded on reefs in the Marshall Islands. In the 1970s, a large COTS outbreak led to the development of a COTS control program. In 2004, several large, dense aggregations of COTS were observed at some reefs around Majuro. These outbreaks caused significant impact with 90% mortality of *Acropora* corals, and in some areas, up to 75% mortality of *Porites* corals. These observations indicate that the outbreak was severe; many of the *Porites* corals were up to 100 years old and *Porites* are generally not preferred food for COTS [5]. Outbreaks have also caused significant coral mortality in Ebon lagoon during the 1980s and 1990s [5].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

There are many reports and observations of factors affecting the coral reefs of the RMI, but there are insufficient long-term data to quantify the impacts on coral reefs. Nevertheless, the available information suggests that changes have occurred on some coral reefs, and that the factors driving these changes are increasing, or are likely to increase. The main issues identified are coastal development, waste management and pollution from land-based sources, as well as population growth, erosion, sea level rise and storm activity.

Governance and management

The Marshall Islands have a wide legislative basis for managing resource use and protecting coral reefs. As part of the US Freely Associated States, coral reef management in the RMI involves both Federal US law and local regulations, as well as Federal US agencies, local government agencies, NGOs and community groups. The Compact of Free Association includes a pledge between the USA and the RMI to "promote efforts to prevent or eliminate damage to the environment and biosphere and to enrich understanding of the natural resources of the Marshall Islands" [4]. The compact obliges the RMI to develop and enforce environmental management standards comparable to those of the USA [4]. The US laws enforceable in the RMI include the *Marine Mammal Protection Act*, the *National Environmental Protection Act*, the *Coastal Conservation Act* and the *Planning and Zoning Act*. These laws contain provisions for species protection, research, enforcing regulations to preserve the environment, and managing coastal development [4]. Local laws and management tools include provisions in the RMI constitution to recognise traditional tenure, and the *Public Lands and Resources Act* (1988) aims to protect mangroves and beaches. The *Marshall Islands Marine Authority Act* (1988) regulates foreign fishing and vessel activities in RMI waters, regulates domestic fisheries (e.g. fishing licenses, prohibition on gill nets and destructive fishing methods), and protects some marine species such as marine turtles [4]. The *Marshall Islands Marine Resources Authority Act* prohibits the use and possession of drift nets in RMI waters, and regulates the harvest of top shell (*Trochus*) through closed seasons, size limits and access to the fishery. The RMI Environmental Protection Agency has regulations on construction and development activities, coastal development, sedimentation and erosion, waste management and water quality [4]. In addition to these Federal and national laws, local laws exist on atolls that regulate the take of marine resources and protect turtles. The RMI is also a signatory to the Micronesia Challenge which commits the RMI to effectively conserving 30% of marine resources and 20% of terrestrial resources by 2020. An action plan for the systematic protection of marine areas was completed by the national government in 2008 [7]. Nine atolls and one low reef island have been nominated for World Heritage listing [7].

Reefs at Risk Revisited [(12)]: *Republic of the Marshall Islands*

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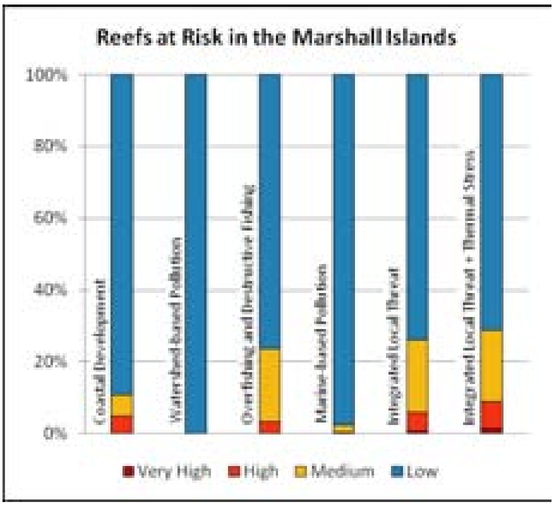
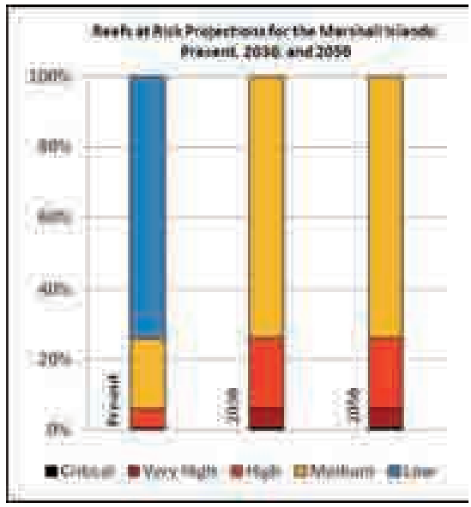
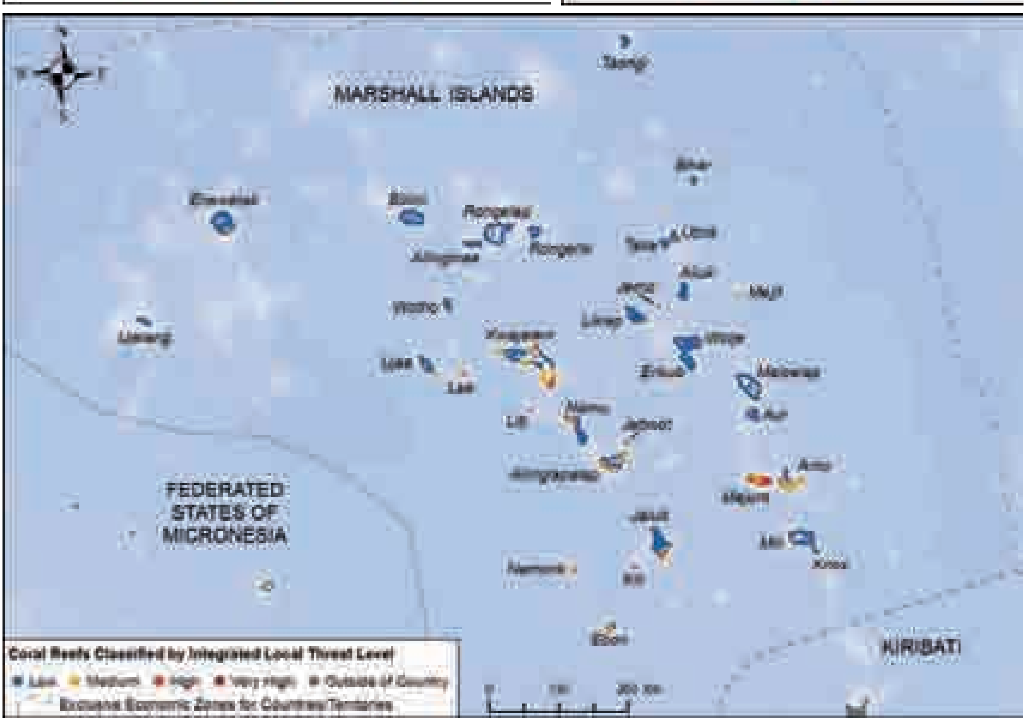
Reefs at Risk Revisited reports that about 25% the coral reefs of the Marshall Islands are threatened by local pressures, primarily by overfishing and coastal development. Unusually warm sea surface temperatures over the past 10 years have caused some additional stress, increasing the proportion of reefs currently threatened to nearly 30%. The reefs around the population centres of Majuro and Arno are most at risk. Projections for thermal stress and ocean acidification from climate change suggest that by 2030, all coral reefs in the RMI will be threatened, with about a quarter at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.







While these management tools provide a management framework, there are few detailed regulations to manage fisheries such as catch and effort limits, size limits, protected species; and there is little monitoring of fisheries [7]. While gillnets and destructive fishing are banned, all other forms of fishing, including night spearfishing on SCUBA, are still permitted [7]. This form of fishing has caused significant declines in exploited stocks in many other locations of the Pacific. Some aquarium collection businesses support the creation of no-take marine reserves to protect stocks, but the government processes have stalled [7]. Additionally, enforcement of regulations is difficult and costly due to the size of the RMI and the remoteness of many atolls and fisheries resources [5, 7]. Enforcement agencies in the RMI do not have the capacity and resources needed to police RMI waters. There are many reports of illegal fishing activities at various atolls, particularly of illegal shark fin fishing [5, 7].

The Marshall Islands have a long history of traditional marine resource management. Customary chiefs had powers to establish a '*mo*', a traditional marine reserve where fishing was restricted or banned to preserve marine resources [5, 13]. Traditional management also included seasonal closures and restrictions. For example, there was a minimum size limit imposed on the harvest of coconut crab on Wotje Atoll [5]. Unfortunately, these traditional arrangements have been significantly eroded during 150 years of colonization [5] and further eroded at some atolls by the forced movement of people during nuclear testing [4]. Erosion of these practices has been increased with the transition to a modern cash-based economy and globalization [5]; thus some natural resources have declined as a result [5]. Nevertheless, traditional *mo* appear to still be active on some atolls, and some local communities have asked for assistance in re-establishing *mo* and other traditional fisheries management practices [5]. Since 2000, several national and atoll level plans and strategies have been developed to help manage marine resources, and coordinate management activities between different government departments, organisations and the community [5]. MPAs have been established in Bikini, Ailuk, Ailinginae, Rongelap and Rongerik atolls under local government ordinances, and fisheries and/or management plans for Mili, Likiep, Arno, Ailuk and Majuro atolls are being developed [5]. There are many MPAs across the RMI and these operate as co-managed areas between agencies and local communities. Most of these MPAs are small and intended to protect habitats and enhance food security, but unfortunately, these MPAs are not currently being monitored [1]. In 2003, Jaluit was declared as a Ramsar wetland conservation site [5] and Bikini Atoll became the Marshall Island's first World Heritage site on 31 July 2010. The RMIEPA, CMI and various local agencies and traditional organisations are working closely with the Pacific Islands Marine Protected Area Community in MPA planning [5]. These measures are promising developments but efforts will need to be maintained to complete management plans, to effectively implement them, and to monitor their effectiveness.

Governance and management – NOT CONSIDERED

The Marshall Islands have a substantial legislative basis for managing marine resources, however, there is insufficient information available on whether these are adequate and effective. Some marine resources are reported to have declined and there is poaching and illegal fishing, particularly in remote locations. Fisheries management arrangements need to be assessed and where necessary, revised to prevent degradation of fisheries resources. Monitoring is being strengthened and the RMI government and communities have made commitments to improve environmental management, including reviving traditional management systems and establishing MPAs. While these are positive signs, significant challenges remain due to limited capacity, funding and enforcement. More information is needed to adequately describe the effectiveness of management in protecting coral reef ecosystems.

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American Samoa

- Marine Area: 390 000 km^2
- Coastline: 116 km
- Land Area: 200 km^2 [(1)]
- Reef Area: 220 km^2 [(1)]
- Total MPAs: 19 [(1)]
- Area of MPAs: 174 km^2 [(1)]
- Mangrove Area: 57 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 95%
- Population (2011 est): 67 242 [(2)]
- Population growth (2011 est): 1.2% [(2)]
- Urban population (2010): 93% [(2)]
- GDP: USD $575 million(2007 est) [(2)]
- GDP/Cap: USD $8 000 (2007 est) [(2)]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

American Samoa consists of a group of 5 volcanic islands and 2 atolls (Rose Atoll and Swains Island) located about 4 200 km south of the Main Hawaiian Islands. American Samoa is a Territory of the USA and thus falls under US federal law and administration. The local government consists of an elected governor, senate and a house of representatives [(2)]. The main island of Tutuila is the largest island (138 km^2) and houses the centre of government, along with 60 000 residents, which is most of the American Samoan population [(2)]. The islands of Ofu, Olosega and Ta'u (collectively called the Manu'a Islands) are to the east of Tutuila, and Rose Atoll is further east from the Manu'a Islands [(3)]. Swains Island is very remote, approximately 350 km north northwest of Tutuila. The atolls are small and low lying; Rose Atoll has an area of 4 km^2, Swains Island is 2 km^2.

American Samoa's reefs consist of shallow fringing reefs growing around the volcanic islands, and atoll reefs which are less expansive and have steeply sloping sides [(4)]. Approximately 2 705 marine species have been recorded from reefs around American Samoa; this is probably a significant underestimate [(5)]. There are currently 276 species of hard coral, 700 molluscs, 167 crustaceans and 945 fishes recorded from reef and shore habitats [(5)].

American Samoan coral reefs have experienced major disturbances in recent decades including coral bleaching, outbreaks of crown-of-thorns seastars (COTS) and cyclones. In September 2009, a tsunami struck American Samoa causing severe damage to some coastal areas and loss of life; damage was reported to some reefs around Tutuila [(6)]. There are also reports of damaging fishing practices and coral disease, erosion and sedimentation, degradation of coastal habitats, and pollution from solid and hazardous wastes [(3, 4)]. In spite of these disturbances, many reefs show strong ability to recover, which indicates that they are relatively resilient [(4, 5)]. Nevertheless, some data suggest that coral cover is lower now than recorded in the 1970s [(5)].

Status, health and resilience of coral reefs

A wide range of monitoring programs operate in American Samoa, some programs covering several decades. Benthic cover and coral communities from the shore to the reef crest along the Aua Transect in Pago Pago harbour have been periodically monitored since 1917. Benthic cover, coral reefs and fisheries have also been monitored with fisheries surveys recording fish landings since 1978, and long term monitoring of corals from 1982 (on Tutuila and Manu'a) and 1985 (at Fagatele Bay, Tutuila). A further 9 programs began between 2002 and 2007 monitoring beaches, water quality, marine parks, coral reefs and reef fisheries at weekly to yearly intervals [(5)]. The combined efforts of these surveys mean that all of the islands of American Samoa have several sites that are regularly surveyed.

These surveys have recorded numerous cycles of disturbance and recovery on the coral reefs. Those in late 1970s recorded an average live hard coral cover of 40% to 63%, with reef communities primarily composed of *Acropora* corals [(5)]. Soon after, American Samoan reefs were affected by a severe COTS outbreak (1978) resulting in significant coral mortality. Further disturbances included hurricanes (1987, 1990, 1991, 2004, 2005 and 2011), coral bleaching (1994, 2002 and 2003), and extreme low tides (1998, 2005 and 2006). Recent surveys (2005-2007) show that many reefs are recovering from these disturbances, with 28% live coral cover at sites around Tutuila (Fig. 1). Coral cover on the other islands in 2006 varied from 18% (Rose Atoll) to 42% (Swains Island), with the Manu'a Islands having around 30% live coral cover [(5)]. Surveys also showed high levels of crustose coralline algae, which play a critical role in stabilising the substrate and providing a good surface for new coral settlement. The recent surveys also show that the dominant coral community has shifted from *Acropora* to encrusting and massive corals such as *Montipora*, *Pavona* and *Porites* [(5)]. In summary, reefs in American Samoa appear to have recovered from many disturbances to reach levels of about 30% live coral cover. However, coral cover has not reached the levels reported in the 1970s, and coral communities have changed from reefs with high cover of *Acropora*, to reefs dominated by encrusting and massive type corals [(5)]. However, a recruitment pulse of *Acropora* corals was reported at several sites around Tutuila in 2007, which could result in increased cover of *Acropora* corals and total coral cover in the future [(5)].

Some monitoring programs in American Samoa have been established for long enough to identify long-term changes in coral condition. The Aua transect in Pago Pago harbour has recorded changes in coral communities over 90 years [(4)]. In 1917, the transect showed high cover of branching corals from the shore to the reef slope. But urban development after World War II, including dredging and industrial pollution, caused coral cover to decline. Surveys in 1973 reported that the reef flat had been reduced to coral rubble. However, after effluent outfalls from tuna canneries were moved further offshore, corals began to recover. While the inner reef flat is still predominantly rubble, some corals have begun growing there and coral cover on the reef flat and slope is between 18% and 53%. Species richness has also increased [(4)].

Surveys of fish communities at various locations around American Samoa have recorded major changes in the communities. Reef fish communities around the main island of Tutuila are currently dominated by herbivores and detritivores such as surgeonfishes (Acanthuridae), small parrotfishes (Scaridae), and damselfishes (Pomacentridae) [(5)]. While the abundance of fishes does not appear to have changed over the last 30 years [(5)], biomass has significantly declined. Fish populations around Tutuila have changed since the 1970s such that surgeonfish now have higher biomass than parrotfish. SCUBA spearfishing could be responsible for this shift. The fishery, which targeted parrotfish at night, operated from 1994 until night-time SCUBA spearfishing was banned in 2001 [(5)]. Surveys of reef fishes across American Samoa in 2002, 2004 and 2006 showed that fish biomass was higher at sites further away from the main populated islands, suggesting negative impacts from nearshore fishing. Fish biomass was highest at the remote Swains Island and Rose Atoll (1.3 to 1.4 tonnes per hectare), compared to only 0.5

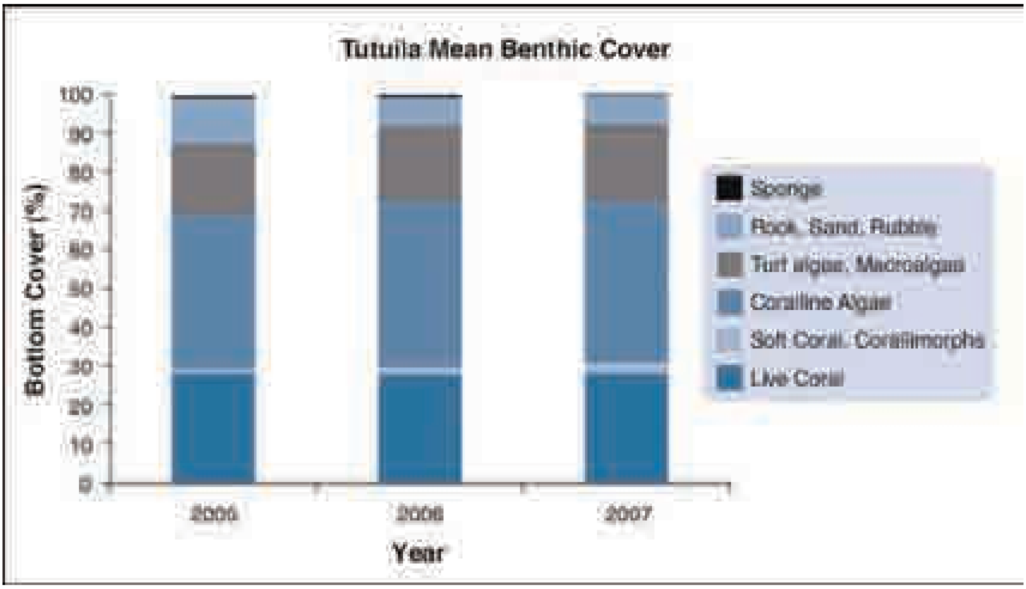
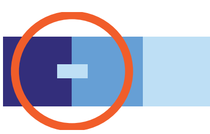


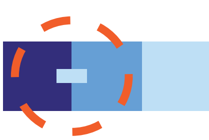
Fig. 1. Coral communities around the main island of Tutuila appear to have recovered from recent disturbances, with total live coral cover (hard and soft coral cover combined) remaining at about 30% between 2005 and 2007. However, cover is still lower than historically reported levels (From Goldberg et al. *2008)*

tonnes per hectare in Tutuila [5]. This decline was greatest for large fish (> 50 cm). More recent surveys between 2008 and 2010 in 5 areas of American Samoa found significant differences in the size structure of reef fish communities between populated and remote areas, with remote reefs having around double or more biomass of groupers, snappers, jacks, and of fish size classes larger than 40 cm in length [7].



Status of coral reefs – STABLE/SOME EVIDENCE OF CHANGE (high confidence)

There are reliable long-term data indicating that the status of coral reefs in American Samoa is relatively stable (decade plus time scales), with disturbances followed by recovery. Nevertheless, coral cover and communities have not returned to levels recorded in the 1970s, and declines have been recorded in a few shallow reef flats in some parts of Tutuila. These trends indicate some level of decline.



Coral reef health and resilience – STABLE/EVIDENCE OF CHANGE (medium confidence)

Surveys show that reefs have made some recovery from a series of severe disturbance events between 1987 and 2005. The recent recruitment pulses of corals and fish observed could further enhance recovery, indicating strong reef resilience. Nevertheless, coral and fish communities have changed in some areas, with changes in size structure and community composition. The abundance of large fish has declined around more populated islands.

Use of reef resources

The coral reefs of American Samoa are important for commercial and subsistence fisheries. Several types of fishing techniques and fishing gear are allowed, although there are restrictions and limitations on some gear types (e.g. size of gill nets and limits on SCUBA spear fishing). There is no trade in live aquarium fish in American Samoa [5]. Data about fishing and fisheries include fishery-based catch surveys and data from in-water surveys of reef fishes. Long-term fisheries catch data (> 30 years) show that commercial landings have varied greatly. Declines in the early 1990s were likely due to hurricanes which caused significant damage to coral reefs, but also to fishing boats [5]. The introduction of SCUBA spearfishing in the mid 1990s led to sharp increases in catch and over-exploitation of parrotfish, especially the bumphead parrotfish, resulting in declining catches by the late 1990s [5]. Night spearfishing on SCUBA was banned in 2001. Overall, fish landings and fishing effort in both the commercial and subsistence fisheries has declined since the 1980s, in spite of continuing population growth [4, 5]. Part of this trend is due fishers changing from subsistence to cash-based fishing [5]. While fishing is still regarded as an important part of culture and tradition, many American Samoans now purchase locally caught or imported fish [4, 5]. In addition some fishers have changed from subsistence to cash-based fishing [5].

Catch records suggest that fish landings are closely linked to fishing effort, and that fish densities do not appear to have significantly declined over the last 30 years, in spite of fishing activities and natural disturbance events [5]. However, recent surveys and reports suggest significant fishing impacts in American Samoa. Official catch statistics have been found to under-report catch, and reconstructed catches reveal declining catches since the 1950s [8]. While density may not have significantly changed, fish biomass has declined. While populations of small and medium sized fish appear to be relatively healthy, larger fish (> 50 cm) are now uncommon to rare, including species such as sharks, the humphead (Maori) wrasse (*Cheilinus undulatus*), the bumphead parrotfish (*Bolbometopon muricatum*), the giant grouper (*Epinephelus lanceolatus*) and the giant trevally (*Caranx ignobilis*) [5]. The relatively low standing stocks and size structure of fishes on the main island of Tutuila compared with the more remote Rose Atoll and Swains Island are further evidence of fishing impacts [4]. Additionally, recent surveys (2008-2010) show significant differences in the numbers of some large fish between populated and remote areas of American Samoa, suggesting significant impacts of fishing on these communities [7].

The Pacific Ocean Synthesis Report [9] and the 2005 UNEP/SOPAC Environmental Vulnerability Index [10] identify commercial and subsistence fishing as posing low to moderate threats to American Samoa. However, recent assessments and the Local Action Strategy suggest that overfishing is a significant issue in American Samoa. The 2011 *Reefs at Risk Revisited* assessment found that 86% of coral reefs in American Samoa are threatened (medium risk or higher) by fishing activities. This information suggests that fishing has caused changes to reef fish communities, but more data are needed to understand what these changes mean for the long term health of the reefs and fisheries.

There is little tourism in American Samoa, with 7 027 to 7 762 tourists visiting in 2005 and 2006. Most tourists are from the USA or New Zealand. The 2005 UNEP/SOPAC assessment [10] indicates that tourism could pose some risks to American Samoa's marine environment.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

Recent data suggest that some fish populations in American Samoa have been significantly affected by fishing, especially through the use of SCUBA. There are documented changes in fish populations between populated and remote islands, with declines in biomass of large fishes (> 40 cm), and declining catches. There has been over-exploitation due to spearfishing which has been banned. More data are needed to determine the ecological significance of these declines, and whether current fishing levels are sustainable.

Factors affecting reef health and condition

Coral reefs in American Samoa are affected by many other factors such as coastal development, poor land-use practices, pollution and severe storms and waves. The major concerns are focused on coastal development and pollution. These high volcanic islands have very steep slopes that erode during heavy rainfall. Fortunately, most of the dense vegetation is intact [5], and flushing by oceanic currents generally provides good water clarity [11]. However, cleared land areas are prone to erosion, and result in increased sediment flows into coastal waters. The main island of Tutuila has only 26 km^2 of flat land in the coastal fringe which is densely populated [5]. The Department of Marine and Wildlife Resources (DMWR) monitored sedimentation rates at 12 sites on Tutuila from 2006 to 2007 and found that sedimentation rates were highest at stream sites, where sediments are transferred to the coral reefs. Sedimentation rates within the bays and headlands caused moderate to slight effects on coral reefs as the sediment is quickly dispersed [5]. However, sedimentation causes more damage in sheltered bays with less flushing. The American Samoan population is growing rapidly; 40% of the population is under 14 [2]. This population growth is placing increased demands for land, development and resources, which are adding pressures in the coastal zone. Population growth has been identified by the American Samoa Coral Reef Advisory Group (CRAG) as a very serious issue facing resource management.

Non-point source pollution (i.e. runoff from the land and other diffuse sources) is a primary issue facing coastal waters in American Samoa, with pollution from pig farms, septic tanks, sewage, and contaminated sediments. There are over 1000 piggeries in American Samoa with an estimated 9 000 pigs; approximately 82% of these piggeries channel high nutrient effluent into inadequate treatment systems which then discharge pollution into wetlands and waterways [5]. The waters of Pago Pago harbour periodically experience high bacterial loads during heavy rains, and the public are advised against eating fish from the inner harbour due to heavy metal and chemical contamination [5]. The Pacific Ocean Synthesis Report lists coastal development and pollution as severe threats to American Samoa [9]. Fortunately, pollution is generally restricted to specific parts of the heavily populated islands. Solid waste, including marine debris, has not been reported as a serious environmental problem for the reefs [5], but litter and marine debris do accumulate in some areas (T. Clark, *pers comm.*)

In September 2009, a tsunami hit American Samoa causing severe damage to the southern parts of the Territory and loss of life. A rapid assessment of 13 reefs (mostly reef flats) around Tutuila found varying levels of damage [6]; half the sites had 'high' to 'major' levels of damage, with overturned corals and broken corals. Future monitoring will identify the long-term impacts of the event [6].

Coral reefs in American Samoa have also been affected by climate change and storms. Several cyclones have passed through the islands in the last 20 years resulting in significant impacts on coral reefs [5]. The El Niño-Southern Oscillation (ENSO) periodically causes significant changes in wind, currents and upwellings, and brings cooler water temperatures during El Niño cycles, and warmer water temperatures during La Niña cycles [5]. Mass coral bleaching was recorded in American Samoa in 1994, 2002 and 2003, and localized bleaching regularly affects small pools in the sheltered reef lagoon around Tutuila where water temperatures get higher. While these events have not caused widespread coral mortality, corals exposed to regular bleaching may be experiencing chronic stress [5]. Future changes in climate and ocean acidification may cause significant long-term damage to coral reefs throughout the Pacific, including reefs in American Samoa [5, 12].

Other potential stressors to reefs in American Samoa include coral diseases and outbreaks of some species. Coral disease appears to be widespread and diverse throughout American Samoa, but only appears to affect a few corals at each of these locations [5]. Outbreaks of ascidians have overgrown large patches of reef in Swains Island [4] but disappeared within 2 years. Outbreaks of COTS have caused significant damage to many reefs in American Samoa, but many of these reefs have largely recovered.

Factors affecting coral reefs – STABLE/EVIDENCE OF CHANGE (low confidence)

Some factors have damaged coral reefs in American Samoa. The available information suggests that pollution and sedimentation cause localised damage to some islands and reefs, however, most reefs have largely recovered from disturbance events and are currently in relatively good health. There is insufficient information to fully describe trends and long-term impacts on affected coral reefs. The greatest human impact to the reefs has been overfishing; coastal development and pollution, population growth, storm activity, and the potential effects of climate change are the other major current threats.

Governance and management

As a US territory, coral reefs and marine resources in territorial waters of American Samoa fall under territorial management with federal assistance (almost all coral reefs are in territorial waters). Specific legislation and policies have been enacted through local government legislative codes and Local Action Strategies, and the Department of Marine and Wildlife Resources (DMWR) is responsible for marine resources, including fishing regulations. American Samoa has laws governing water quality standards, land-use, waste disposal, fisheries, habitat protection, endangered species, protected areas and pollution [11]. The American Samoa Coral Reef Advisory Group (CRAG) has a mandate from the Governor of American Samoa to help plan and coordinate management efforts between different agencies such as the DMWR, the American Samoa Environmental Protection Agency (EPA), the US Department of Commerce (which includes NOAA), the American Samoa Community College and the National Park of American Samoa which is managed by the National Park Service within the US Department of the Interior [5].

CRAG has developed Local Action Strategies for population pressures, fisheries management, land-based pollution and climate change, but has no power to enforce these. There have been some successes in addressing pollution; for example, the EPA implemented programs to educate communities and improve pig farm operations, resulting in significantly reduced the levels of nutrient entering coastal waters, with bacterial contamination decreasing by 90% in one watershed [4, 13]. Community programs run by NGOs have helped some villages reduce the use of high phosphate detergents and improve waste water treatment, resulting in significantly reduced localized pollution and prevention of chronic algal blooms [13]. Importation of high phosphate detergent was banned in 2007, but this has not been enforced by Customs [13].

The American Samoa Administrative Code contains fishing regulations on the use and configuration of fishing gear such as gill nets and fishing with SCUBA, and on fishing zones. The Code places restrictions on spearfishing on SCUBA including banning SCUBA spearfishing at night. It is illegal to collect or harvest living corals in shallow waters, or to harvest sea turtles or marine mammals. There are also restrictions on the take of giant clams (Tridacnidae), mangrove and coconut crabs and ornamental shells. While these programs and management tools provide a management framework, there appear to be few detailed regulations for managing fisheries, such as catch and effort limits or species specific size limits.

While agencies have announced the intent to protect particular species such as the humpead wrasse, the bumphead parrotfish, the giant grouper, the giant trevally and sharks [4], these intentions have not been implemented several years after the announcement.

American Samoans have strong traditional ties to marine resources and some communities are actively engaged in marine management. Many villages have retained virtually all their traditional marine and land tenure systems [5]. The DMWR coordinates a Community-based Fisheries Management Program whereby the agency and communities develop joint management plans for use of marine resources. The program includes 10 community-based marine reserves [1] which are intended to support continued extraction and use of living resources, such as fish and shellfish. Reserves may include no-take areas, but these may be periodically opened to fishing at times agreed by village elders and set out in the management plan. The DMWR is discussing the options for establishing long term or permanent closures with communities [5]. The village of Fagamalo is establishing a permanent no-take area which will be the first on an inhabited island (D. Fenner, *pers comm.*). Some communities have also played an active role in enforcing restrictions on SCUBA spearfishing, with local authorities successfully monitoring fishery catches and reef fish populations [9]. The DMWR has also drafted a compendium of village by-laws that regulate the use of a village MPA to help improve enforcement [5].

As well as the community based MPAs, there are a further 9 MPAs in American Samoa including the Rose Atoll National Wildlife Refuge, the National Park of American Samoa, 3 special management areas, 2 National Natural Landmarks, a territorial marine park and the Fagatele Bay National Marine Sanctuary [1]. These MPAs bring the total number in American Samoa to 19 MPAs with an area of 173.5 km^2 [1]. Rose Atoll was the first no-take area in American Samoa and covers 159 km^2, but its remote location makes enforcement difficult. The other MPAs are much smaller and have varying arrangements that allow different levels of use. The 2004 Local Action Strategy sets a target for establishing an MPA network that covers 20% of the territory's coral reef ecosystems, and an MPA Network Strategy was released in 2007.

While American Samoa appears to have a broad legislative basis for managing coral reefs, enforcement is an issue. Violations have been detected and prosecuted, but enforcement is not widespread and problems persist [11]. The 2004 Local Action Strategy clearly stated that enforcement was lacking, and there appears to be little information on the effectiveness of management arrangements. It is hoped that this information will become available as new management initiatives, such as the establishment of a national MPA network and revised fisheries management arrangements come into force, and monitoring activities continue.

Governance and management – EVIDENCE OF CHANGE (low confidence)

American Samoa has legislative basis for managing marine resources, and there are instances where management appears to have delivered tangible benefits (e.g. pollution reduction). However, management needs to be improved in order to ensure the protection and sustainable use of marine resources. There are relatively few regulations for reef-based fisheries, and enforcement of some environmental policies is lacking. Management is difficult to implement at remote locations where some marine resources appear to have declined, and there are isolated reports of illegal fishing. More information is needed to adequately describe the effectiveness of management arrangements to protect coral reef ecosystems and resources.

Reefs at Risk Revisited [(12)]: *American Samoa*

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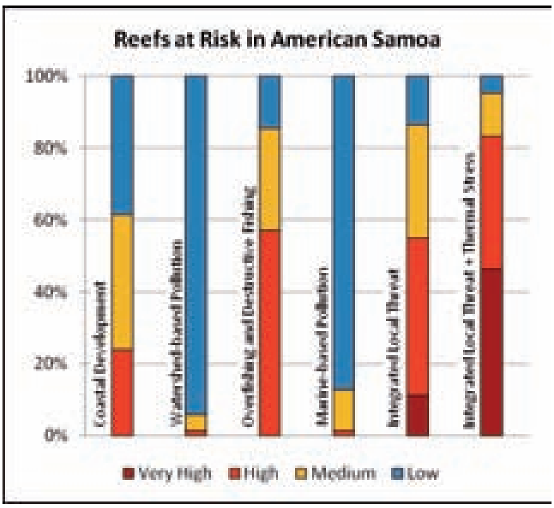
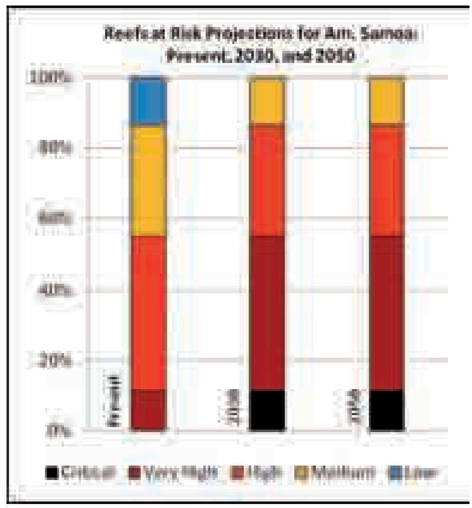
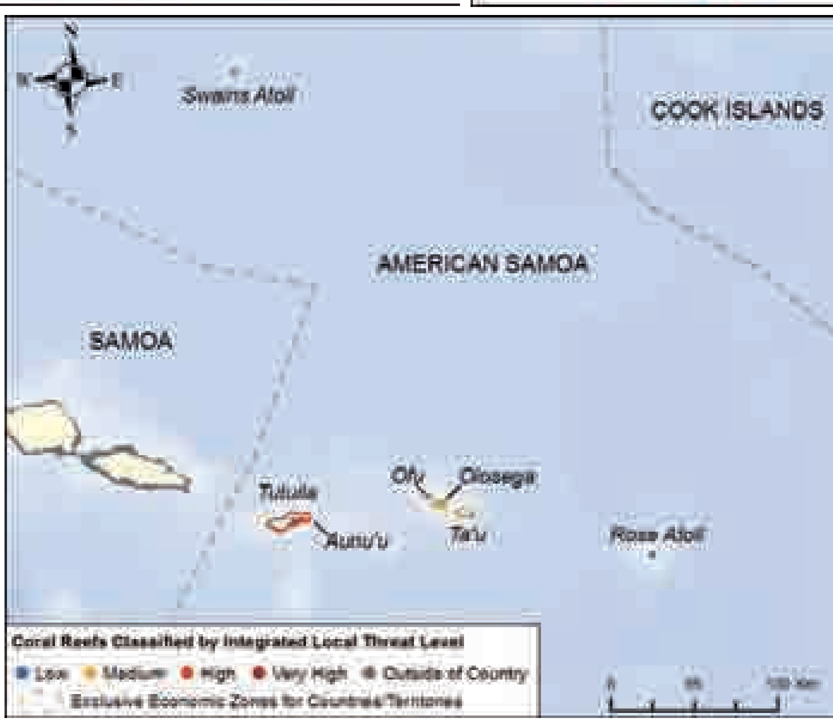
The *Reefs at Risk Revisited* assessment found about 87% the coral reefs in American Samoa are threatened by local stressors, especially overfishing and coastal development. Thermal stress from unusually warm sea surface temperatures over the past 10 years has added to these local stressors, increasing the percentage of threatened reefs in American Samoa to about 95%. The reefs around the main island of Tutuila are assessed as being most at risk. Projections of thermal stress and ocean acidification from climate change suggest that by 2030, all coral reefs in American Samoa will be threatened, with around 10% in critical condition. The full report, methods and full size maps are on: http://www.wri.org/reefs.







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Cook Islands

- Marine Area: 1 830 000 km^2
- Coastline: 120 km
- Land Area: 237 km^2
- Reef Area: 220 km^2 [1]
- Total MPAs: 24 [1]
- Area of MPAs: 18.9 km^2 [1]
- Mangrove Area: 0 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 61%
- Population (2011 est): 11 124 [2]
- Population (2050 proj): ?
- Population growth (2011 est): -3.2% [2]
- Urban population (2008): 75% [2]
- GDP: USD $183.2 million (2005 est) [2]
- GDP/Cap: USD $9 100 (2005 est) [2]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The Cook Islands consist of 15 islands spread out across an extensive EEZ of 1.8 million km^2; however the total land area is only 237 km^2. The volcanic high island of Rarotonga is the centre of government and commerce, and comprises 28% of the total land area. The islands are particularly remote being approximately 3000 km northeast of Auckland, New Zealand, about 4500 km south of Hawaii, 1130 km to the west of Tahiti, and 1000 km east of Niue.

There are two groups in the Cook Islands: a northern group of 5 islands; and a southern group of 9 islands, which includes the main islands of Rarotonga and Aitutaki. The main industries in the Cook Islands include tourism, pearl aquaculture and tuna fisheries. The Cook Islands has been self-governing since independence from New Zealand in 1965, but Cook Islanders still retain New Zealand citizenship. Cook Islanders are Maori of Polynesian descent, and the language is Maori but English is widely spoken. The Cook Islands' population has been declining since 1965 due to emigration (mostly to New Zealand and Australia), with some islands experiencing population declines of 30% between 1996 and 2002 [3].

There are between 550 and 600 species of finfish in the Cook Islands, about 1500 invertebrates including 11 species of sea-cucumber (*rori*), and 100 kinds of seaweed [4]. Recent published reports list 178 species of hard corals, 70 molluscs, but the diversity of crustaceans, hydrozoa and other invertebrates is unknown [5].

Status, health and resilience of coral reefs

Coral reefs around Rarotonga have been surveyed since 1995 [6]. Outbreaks of crown-of-thorns seastars (COTS) were recorded between 1995/96 and 2001 which caused a 'shift towards a coral depauperate state' [6], compounded by coral bleaching in 1991 and 1994 which reduced coral cover [6]. Surveys between 2001 and 2009 for the Cook Islands Environment Service found low live coral cover, with < 5% cover between 2001 and 2005, < 2% cover on fore-reefs in 2006, and an average of 5% cover in 2009 [6]. Data published in Global Coral Reef Monitoring Network (GCRMN) status reports indicate that the outer reefs around Rarotonga's reefs appear to be declining, due to COTS predation and cyclones [7, 8], and live coral cover has declined from about 40% in 2000 to 15% in 2003 [7]. When the GCRMN 2004 report was published, coral cover and diversity were low at survey sites, but there was little recent coral mortality and COTS numbers were also relatively low, presumably due to a lack of available food. Nevertheless, recovery appeared to be slow [7], and subsequent surveys around Rarotonga show an apparent phase shift from coral dominated reefs to algal dominated communities. The abundance of sea urchins has significantly increased with the proliferation of algae since 2003, but numbers are now declining with a decline in algal cover [8].

Recent surveys show that these reefs are in the early stages of recovery, with increases in the cover of soft corals and coralline algae, and larger populations of herbivores. Most corals are small with 86% of colonies on the fore-reef slope being new recruits [8]. Moreover, 82% of these recruits were species that are more resilient to coral bleaching and storm damage. This early stage recovery contains few of the bleaching sensitive corals [8].

Long-term monitoring was established in 2008 on the outer slope of west Rarotonga by the CNRS (French National Centre for Scientific Research) and the IRCP (Institute for Pacific Coral Reefs) through the French Polynesian CRIOBE (Centre for Island Research and Observatory of the Environment) in collaboration with the Cook Islands Ministry of Marine Resources. They monitor 20 permanent photographic quadrats for corals and 50 m x 4 m transects for fish communities as part of the Polynesia Mana GCRMN node; they recorded only 4% coral cover.

A shift in reef fish communities occurred around Rarotonga between 1999 and 2006, with a general decrease in the abundance of planktivores and corallivores, an increase in herbivores, and a general increase in omnivores [8]. The most recent CRIOBE surveys confirmed this, with fish biomass in 2009 and 2011 dominated by herbivores (mainly surgeonfish and parrotfish) and omnivores.

While these surveys have provided some information, the lack of survey data, monitoring programs and monitoring capacity was identified as a problem [9].

Status of coral reefs – EVIDENCE OF CHANGE (low confidence)

There are some long-term data, but most is limited to survey reefs around Rarotonga, which appear to be recovering from declines caused by COTS outbreaks in the late 1990s. Trends in reef fishes appear to reflect changes in benthic cover (corals and algae), but are difficult to interpret. There is insufficient information to adequately describe the condition and trends of reefs in the Cook Islands.

Coral reef health and resilience – NOT CONSIDERED

The appearance of recruits in more recent coral reef surveys suggests that the reefs around Rarotonga are showing signs of recovery. However, there is not enough information available to describe the resilience of coral reefs in the Cook Islands.

Use of reef resources

Cook Islanders have a long tradition of harvesting marine resources, based on inshore fisheries (reef fish and invertebrates), offshore fisheries harvesting tuna, wahoo and flying fish, and deep water bottom fisheries especially targeting snapper [4, 5]. Subsistence fishing is an important activity, especially in the northern islands. Similarly subsistence and artisanal fishing on Rarotonga and Aitutaki supply urban populations and tourist resorts [4]. Some islands have no commercial fishing. Seafood is an important part of the diet with Cook Islanders consuming an average of 47 kg of seafood per person per year [4]. Many different fishing methods are used, including nets, traps, hooks and lines, and spears. A wide variety of reef fish are eaten including parrotfish (Scaridae), surgeonfish (Acanthuridae), squirrelfish (Holocentridae), rabbitfish (Siganidae), mullet (Mugilidae), bonefish (Albulidae) and milkfish (*Chanos chanos*) [4]. The Cook Islands have high incidence of toxic ciguatera fish poisoning, especially in large predatory fish such as groupers (Serranidae). Further offshore, vertical long-lines and fish aggregation devices (FADs) are used to fish for tuna [4]. Destructive fishing techniques (poison and bombs) were used in the past but have since been banned [4].

There is limited information on trends in fishing and fisheries, but there is cause for concern. Some inshore fish species have been heavily exploited, especially through the use of small mesh gill nets [4]. A major decline in parrotfish populations has been reported on many islands including Rarotonga, Aitutaki and Palmerston islands [4], and the mean size of fish decreased between 1998 and 2007, indicating that harvesting is 'unsustainable' [5]. Increasing demand and use of modern, more efficient fishing gear and methods have increased fishing impacts on Rarotonga [4]. There are reports from Penrhyn Island that it is becoming harder to catch black trevally (*Rui*), and there are concerns about fishers targeting spawning aggregations of grouper [4].

Invertebrates are also an important marine resource. Trochus are harvested in Aitutaki for export, giant clams (*pa'ua*) are considered a delicacy by many island communities, and the culture of black lip pearl oyster (especially on Manihiki Atoll) is the second largest industry after tourism [4]. Cook Islanders also take coconut crabs (*Birgus latro*) and lobsters for domestic consumption. Over-harvesting of giant clams has been reported from Aitutaki in previous decades, with stocks greatly depleted compared to 25 years ago [5]. However, some populations may be recovering due to reserves, and aquaculture and hatchery operations [4]. Reduced stocks have also led to bans on taking clams in Manihiki and Tongareva [5]. Trochus populations on Penrhyn, Manihiki, Rarotonga and Palmerston Islands also appear to be increasing and approaching 'harvestable' numbers [4]. Nevertheless, populations of clams and mussels appear to be declining on Rarotonga. Coconut crabs also appear to have declined in many areas, especially on heavily populated islands [4]. The 2005 UNEP/SOPAC Environmental Vulnerability Index [10] and the 2009 Pacific Ocean Synthesis Report [11] both identify fishing as posing a low level of risk to the Cook Islands.

Tourism is a very important economic activity in the Cook Islands. The number of visitors to the Cook Islands grew by 6.3% per year on average between 1987 and 2000 [3]. The contribution of tourism to annual GDP grew from 27% to 51% during the same period. Between 1997 and 2000, an estimated 60 000 tourists visited the Cook Islands [9]. Tourism is centered on Rarotonga and Aitutaki, but there are plans to expand tourism to other islands. While SCUBA diving is a very popular activity, there is little information on the use of marine resources by the tourism industry [9]. Nevertheless, the 2005 UNEP/SOPAC assessment [10] indicates that tourism and associated pressures and resource use could pose some risks to the Cook Islands.

Use of reef resources – NOT CONSIDERED

There is little information on trends in resource use and the status of resources in the Cook Islands. Some species are under increasing pressure, with declines of parrotfish and giant clams. However, fishing and fisheries data, long-term monitoring and survey data, and risk assessments are not available. Accordingly, trends in marine resources and resource use are not described here, and more data are required to understand current patterns and trends of reef resource use.

Factors affecting reef health and condition

Coral reefs in the Cook Islands are affected by coastal development, run-off of sediments and nutrients from coastal watersheds and solid wastes (4, 5, 9). The development of tourism infrastructure and resorts is a major cause of degradation and erosion of foreshore environments on Rarotonga (5, 9). Specific problems associated with these developments include clearing of coastal vegetation, building too close to the sea, and disposal of sewage and waste from piggeries (5). Demand for land has also seen some coastal wetlands around Rarotonga reclaimed (9). The construction of seawalls has altered lagoon hydrological patterns and caused fore-shore scouring and long-shore drift in some areas (5).

The disposal of solid and liquid waste is also an issue. Currently, all 12 inhabited islands lack adequate facilities for solid waste disposal (9). The problem is compounded by the increase in the consumer culture and demand for imported goods. On Mauke, Mitiaro, Atiu and Mangaia islands, solid waste is discarded into limestone pits, while on other islands, waste is discarded into coastal wetlands or excavated pits on the foreshore (9). Frequently this solid waste, especially plastics, flow into marine habitats and coral reefs. Liquid waste management systems are also lacking. For example, septic tanks are used but there are improper designs, construction and maintenance (9). These could cause eutrophication and contamination of adjacent waters. However, coastal water quality monitoring has only recently started, so the environmental risks have not been quantified. Nevertheless, villagers in Takitumu Lagoon (south Rarotonga) perceived that lagoon water quality had deteriorated, with suspected algal blooms, high levels of ciguatera toxins in some lagoon fishes, and increased sediment and mud that has smothered corals and benthic habitats, and made the lagoon shallower (12). Other pollution sources such as pig effluent, agriculture, septic tanks and sediment runoff were the suspected causes of these problems (8, 12).

Development on sloping land can also lead to soil erosion and pollution of coastal waters; this is a significant problem on Rarotonga and the southern islands (9). This erosion stems from agriculture (e.g. pineapples, fruit trees, coconuts), residential developments on sloping land and road construction and drainage. Poor land-use practices and cultivation techniques, the improper use of heavy machinery and poor maintenance has resulted in increased erosion (5, 9). Fern forests are sometimes burnt and vegetation cleared for agriculture and development, and excess fertilisers in sediment runoff has lead to eutrophication of coastal waters, especially in lagoons (9).

While these issues do affect coastal water quality and coral reefs, there are insufficient data to quantify the trends, or assess their effects on the marine environment. The 2011 *Reefs at Risk Revisited* assessment suggests that coastal development only threatens 14% of reefs in the Cook Islands, and that watershed-based pollution is not a major issue. The 2009 Pacific Ocean Synthesis Report (11) suggests that wastes, and pollution from nutrients and sedimentation are also low-level threats, although coastal development was assessed as a moderate threat.

Climate change could have significant effects on the reefs, islands and marine resources of the Cook Islands. Seven cyclones affected the Cook Islands between 2001 and 2010, and severe damage was caused by some (e.g. in February 2010 Cyclone Pat severely damaged 90% of the houses on Aitutaki). There are also many low lying areas in the Cook Islands which are vulnerable to sea level rise, increased erosion, inundation of coastal foreshores, and salt water intrusion into inland taro [(5, 11, 13)]. Changing environmental conditions could also affect the pearl culture industry and agriculture [(13)]. The *Reefs at Risk Revisited* 2011 analysis suggests that thermal stress from rising sea temperatures, and ocean acidification, will double the number of threatened reefs in the Cook Islands to nearly 90% by 2030. These effects could also change patterns of resource use, thus increasing pressure on the marine environment.

There are enormous quantities of manganese nodules in deep waters (around 5000 m) around the Cook Islands [(4)]. These nodules contain cobalt, nickel and copper, with cobalt being most valuable mineral. Mining of these is not currently viable, but could be extracted in the future [(4)], however, the potential impacts on the coral reefs are not known.

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

There are many factors damaging the coral reefs of the Cook Islands, such as poor land use, coastal development, erosion and waste management. Surveys indicate that environmental conditions have declined in Takitumu Lagoon on Rarotonga, and global pressures (i.e. climate change) are likely to increase. However, information is insufficient to describe trends and effects on the marine environments. The reefs are also affected by storms, COTS, and are at risk to the potential effects of climate change.

Governance and management

There are a number of environmental policies and acts of legislation to manage marine resources and the environment in the Cook Islands, but these can vary amongst the different islands. The Cook Islands *Environment Act* (2003) empowers each island to develop its own regulations and by-laws for environmental management, and recognises the unique traditions and situation of each island. The National Environment Service administers the Act and works closely with the *Aronga Mana* (traditional tribal councils), the Island Councils and NGOs. For example, government agencies, local councils, NGOs and the community developed the Takitumu Lagoon Management Plan which addresses issues affecting the lagoon [(12)]. In 2006, government agencies and the community finalised a management plan for the Takuvaine watershed, a major watershed on Rarotonga that supplies drinking water [(15)]. In Rarotonga, the Public Health (Sewage) Regulations (2008) provide the basis for improving water quality in the lagoon [(5)]. There are also island-specific management plans for tuna fisheries, managing black-lipped pearl oysters, and on Aitutaki, a plan to manage the emerging bonefish or *Kiokio* (*Albula glossodonta*) for the tourism industry has been submitted to the government [(5)].There are also acts to regulate waste disposal, land development, marine pollution, fisheries and pesticides [(9)]. The Cook Islands are also a signatory to the Convention on Biological Diversity [(3)] and have established plans and policies to conserve biodiversity [(5)].

Under these arrangements, each island may have specific laws regarding fishing and harvesting. For example, Aitutaki has restricted the use of gill nets and has size and catch limits on trochus [(4)]. Palmerston Island has placed short-term bans on harvesting parrotfish, and communities on Pukapuka have banned the take of groupers by spearfishing, and placed restrictions on the take of coconut crabs and seabirds [(4)]. SCUBA spearfishing has been banned on most islands, but there are fewer controls on the use of gill nets [(4)].

There are reports of significant problems in implementing environmental management; development activities are neither adequately monitored nor enforced [(9)]. The lack of support, funds and capacity for environmental monitoring are restrictions for effective environmental management, as agencies do not have the capacity to monitor and assess activities under their control [5, 9]. There is only one patrol boat, therefore large areas of the EEZ are open to illegal fishing [5]. Environmental and biodiversity conservation plans have not been translated into effective implementation on the ground [5].

Many communities in the Cook Islands practice traditional forms of management, which include traditional marine reserves known as *ra'ui* [1, 5, 9]. In 1998, the *Aronga Mana* of Rarotonga and Aitutaki established 5 marine *ra'ui*, with 2 more declared on the islands by 2000. *Ra'ui* also manage the take of clam (paua) on Mauke Island, and manage commercial stocks of trochus on Aitutaki [9] which includes a permanent trochus reserve [5]. Currently, there are approximately 39 marine managed areas in the Cook Islands of which 24 appear to be active [1]. Most of these are Locally Managed Marine Areas (LMMAs) or *ra'ui*, although there are state national parks such as the Suwarrow National Park. These *ra'ui* LMMAs may impose total bans on access to particular resources, but are usually periodic closures. However, traditional management systems may be eroded by changing community attitudes on islands such as Aitutaki [4]. Nevertheless, the lack of systematic data means that there could be other MPAs that have not been identified [5].

Governance and management – NOT CONSIDERED

The Cook Islands has a mix of national and island specific management arrangements for the environment and fisheries resources. There are also many traditionally managed marine areas; however, many problems have been reported. There is little information available about the adequacy of these measures or their effectiveness, thus trends in governance and management are not described.

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Reefs at Risk Revisited (14): *Cook Islands*

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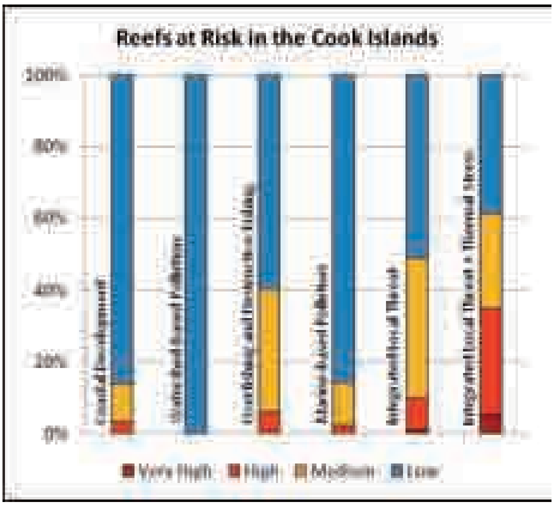
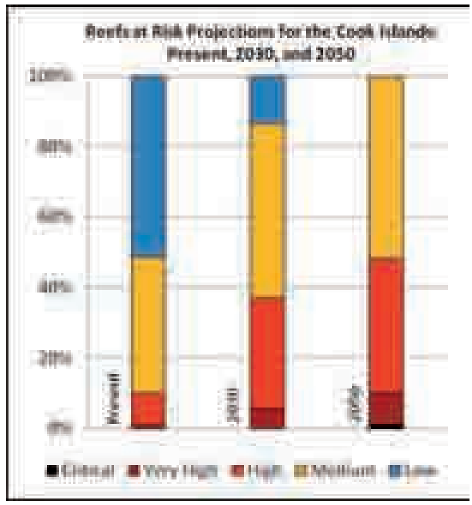
The *Reefs at Risk Revisited* analysis found the main threats currently facing coral reefs in the Cook Islands are overfishing and coastal development. When all local threats are combined, approximately 50% of reefs are at risk. Integrating these threats with observed thermal stress over the past 10 years, increases the percentage of threatened reefs to more than 60%. The reefs around Rarotonga and Rakahanga are currently most at risk. By 2030, projections for thermal stress and ocean acidification suggest nearly 90% of reefs in the Cook Islands will be threatened, with more than 35% at high, very high, or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.





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French Polynesia

- Marine Area: 5 030 000 km^2
- Coastline: 2 525 km
- Land Area: 3 660 km^2
- Reef Area: 6 000 km^2 [(1)]
- Total MMAs: 10 [(1)]
- Area of MMAs: 2 837 km^2 [(1)]
- Percentage of reefs threatened (local threats and thermal stress 2011): 33%
- Population (2011 est): 294 935 [(2)]
- Population (2050 proj): No Data
- Population growth (2011 est): 1.2% [(2, (3)]
- Urban population (2010): 51% [(2)]
- GDP: US $4.718 billion (2004 est) [(2)]
- GDP/Cap: US $18 000 (2004 est) [(2)]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless otherwise indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimated, proj = projected).

Overview

French Polynesia consists of 118 islands scattered across a vast ocean area of over 5 million km^2 [(4)]. While 84 of these islands are low-lying atolls, most of the land area in French Polynesia is concentrated in the high volcanic islands [(4)]. The 118 islands are clustered into 5 main island groups or archipelagos. The Society Islands lie in the centre and include the main high islands of Tahiti and Moorea in the Windward group and Bora Bora and Raiatea in the Leeward group. A few atolls such as Tetiaroa also belong to the Society Islands. Papeete on Tahiti is the capital city and centre of government, and is approximately 6 100 km east of Sydney, 4 100 km south of Hawaii, and about 8 000 km west of Santiago, Chile. The Austral islands are mainly high islands and approximately 650 km south of Tahiti, while to the east are the numerous atolls of the Tuamotu archipelago (300 km east of Tahiti). The remote Gambier archipelago is 1 600 km south southeast of Tahiti, while the Marquesas archipelago is 1 300 km northeast of Tahiti.

While 76 islands are inhabited, about half the population lives in a few urban centres on the main islands of Tahiti and Moorea (75% of French Polynesian population; with 34% in Papeete) [(3)]. Most of the people on the other inhabited islands live along narrow coastal strips on volcanic high islands or on coral atolls [(4)]. The population has increased over the past few decades, but the growth rate has slowed from 1.9% between 1988 and 2002 to 1.2% between 2002 and 2007 [(3)]. French Polynesia is a French Territory but has autonomy in all areas except for police and justice, monetary policy, tertiary education, immigration, defense and foreign affairs [(2)]. Consequently, environmental management is the responsibility of the territorial government.

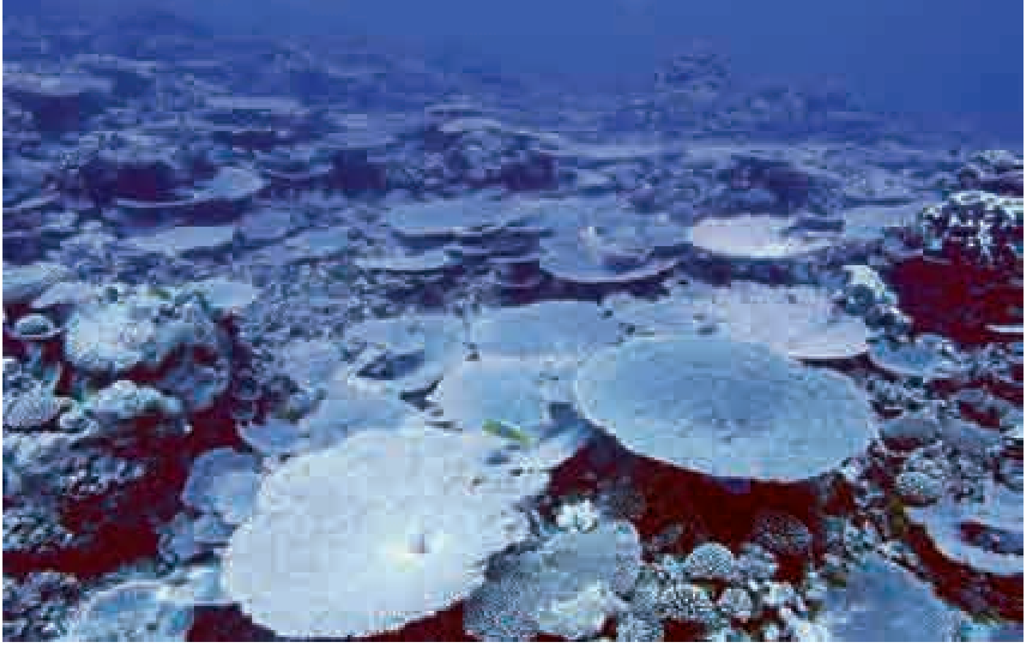
French Polynesia has fringing, lagoonal and outer barrier reefs, and these have lower levels of biodiversity than reefs to the west in the Pacific; there are about 500 species of molluscs, 170 corals, 800 fish species, 346 species of algae and 30 echinoderms [(4)].

Status, health and resilience of coral reefs

The coral reefs of French Polynesia have been studied over many years, with many coral reef research projects carried out by scientists working from institutions such as the Antenne du Muséum National d'Histoire Naturelle et de L'École Pratique des Hautes Études (Antenne Museum-EPHE), and the Moorea based Centre de Recherches Insulaires et Observatoire de l'Environnement - École Pratique des Hautes Études (CRIOBE-EPHE). More recently, scientists from the University of California at Santa Barbara and at Berkeley, along with other U.S. universities have established the Long Term Ecological Research (LTER) site at the Gump South Pacific Research station on Moorea. Reef Check has also established survey sites. Most reef studies have been around Moorea and Tahiti (Society Islands), but there have been studies on many other islands in the 5 archipelagos [4, 5]. The Tiahura Outer Reef Sector (TORS) on the north coast of Moorea has been monitored since 1971. The Tiahura sector is one of the oldest long-term reef monitoring sites in the world and includes shallow (0-5 m) and deeper reef slope sites (10-70 m) [6]. In contrast, the coral reefs of the Gambier, Marquesas and Austral archipelagos are less studied [4], but recent efforts like CORALSPOT, a CRIOBE program, are bridging knowledge gaps in remote areas. The CRIOBE-EPHE monitoring program of Polynesia Mana has monitored sites at 14 locations across French Polynesia since 1992, including sites at 5 locations in the Society Islands; 5 locations in the Tuamotu Archipelago; 2 in the Gambier Archipelago, and one each in the Australs and Marquesas. Reefs are monitored using permanent 1 m^2 photo-quadrats, landscape photographs and at scales > 100 m using 'manta tows'. Reef fish communities are surveyed using underwater visual census (UVC) on 200 m^2 belt-transects. Environmental parameters (temperature, pH, dissolved oxygen, salinity, sea level and wave activity) are also recorded on automatic loggers.

The French Polynesian coral reefs experience frequent disturbance events, and several cycles of disturbance and recovery have been recorded. Between 1979 and 2009, northwest Moorea was affected by 11 disturbance events including outbreaks of crown-of-thorns seastars (COTS) from 1979-1986 and 2006-2009 [5]; cyclones in 1983, 1991 and 2009, and coral bleaching in 1983, 1987, 1991, 1997, 2002 and 2003 [6]; a disturbance event every 2.7 years [7]. These events have had differing effects on coral cover at these sites. COTS outbreaks have caused the greatest coral loss [7] and reduced live coral cover from ~49% (in 1979) to ~12% (in 1982) [6, 7]; a cyclone in 1991 reduced coral cover on reef slope sites from 50% to 24% [7]. While there has been an overall decline in coral cover at Tiahura from 49% in 1979 to 17% in 2009 [7], the current level of coral cover reflects the effects of the most recent COTS outbreak, and these reefs are expected to recover as they have in the past. However, there are signs of long-term changes in the Tiahura coral community, with a decline in *Acropora* species and increased dominance of *Pocillopora* and *Porites* corals [7]. This shift could indicate disruption of the coral community by frequent disturbances that have exceeded the reef's capacity to recover over this time.

Other coral reefs across French Polynesia have also experienced periodic bleaching events, cyclones and COTS outbreaks. Coral bleaching in 1991, 1994, 2003 and 2007 has caused significant coral mortality at a range of geographic scales [8]. A COTS outbreak killed corals on many reef slopes and lagoons from 1978-1982, and a new outbreak has been reported on reefs in the Society Islands since 2006 [8]. As of 2008, major COTS outbreaks were reported at Huahine, Bora Bora, Tahaa, Raiatea and Tahiti (Society Islands), and on Rurutu in the Australs [9]. However, there has been good coral recovery on some reefs on Moorea and Raiatea (in the Society Islands) from previous COTS outbreaks [9]. Monitoring and research suggest that coral reefs in French Polynesia have an optimum coral cover of about 50-60%, although this may be reduced to less than 10% by disturbance events [8]. In most cases these disturbances were followed by the recovery of many of the damaged outer reef slopes [6, 10]. In the absence of more frequent disturbances, French Polynesian coral reefs should recover in about 12 years [8].



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Coral recruitment has been studied at 9 locations on Tiahura, Vaipahu and Haapiti (on Moorea) between 2000 and 2003, and showed that trends in recruitment were largely driven by seasonal patterns and by the community composition and health of surrounding reefs [(11)]. However, coral recruitment has been relatively low on these reefs indicating that post-disturbance recovery may be slow [(11)].

Overall, most reefs in French Polynesia are in relatively good condition [(8, 9)], especially those in the more remote Tuamotu, Gambier and Marquesas archipelagos [(9)], where anthropogenic stresses are much lower, although climate change continues to be a major threat [(9)]. Trends in coral cover on most reefs appear to be driven by large-scale disturbance events, but there is evidence of impacts from human pressures in some areas, especially on reefs around the most populated islands of Tahiti and Moorea [(8, 9)], and particularly on fringing reefs [(5)].

Reef fish communities in French Polynesia have been monitored at 14 locations since 2003 by CRIOBE-EPHE for the GCRMN Polynesia Mana Node, although some locations have been monitored over longer time scales. Reef fish surveys at Tikehau (in the Tuamotu Archipelago) began in 1987 (a joint program with Institut de Recherche pour le Développement) and showed decreases in reef fish density and diversity between 1987 and 2003, with the greatest decreases occurring near villages linked to fishing pressure [(12)]. The fish community shows an increasing dominance of small, site-attached species such as damselfishes (Pomacentridae) with a parallel decrease in target species, such as surgeonfishes (Acanthuridae), groupers (Serranidae), parrotfishes (Scaridae) and wrasses (Labridae) [(12)]. Similarly, reef fish communities along a gradient of fishing pressure in the Society Islands show decreases due to fishing. A comparison between Tahiti and Moorea (higher fishing pressure) and Raiatea and Maupiti (lower fishing pressure) found that the density, biomass and mean size of commercially valuable fishes decreased with fishing pressure [(13)]; reef fish communities have also changed.

Status of coral reefs – STABLE (medium confidence)

Reliable long-term data are available for many coral reefs in French Polynesia; however, many remote areas are relatively poorly known. This reduces the confidence in describing the condition of all reefs. Nevertheless, available information suggests that French Polynesian reefs are in good condition, with decreases in coral cover in some areas, stable trends in other areas, and increasing coral cover elsewhere after disturbance events. There is little evidence of widespread and prolonged stress, damage, or loss of coral cover. However, fringing reefs show damage from localised stresses around Tahiti and Moorea.

Coral reef health and resilience – STABLE/EVIDENCE OF CHANGE (medium confidence)

The high quality, long-term data from French Polynesia suggest that most reefs are generally healthy and show resilience (i.e. reefs have consistently recovered after disturbance). Coral recruitment reflects normal seasonal and spatial patterns, and does not appear to be reduced. Nevertheless, there are signs of alterations to some reef communities, with changes in coral assemblages in Moorea, and altered reef fish communities due to fishing pressure. The trends appear to be restricted to the populated islands.

Use of reef resources

French Polynesian reefs have been exploited for coral mining, commercial, subsistence and artisanal fishing, and collection of aquarium fish for many decades [5, 8]. The coral reefs, islands and reef lagoons support tourism and the culture of black pearls, both of which are French Polynesia's main economic resources and are vital sources of income [8, 9, 14]. In 2006, French Polynesia produced 6.4 metric tonnes of black pearl worth USD $100 million [9]. The pearl industry also employs up to 5 000 people across more than 50 islands [9].

Subsistence and commercial fishing are particularly important with the main fisheries targeting lagoonal species and pelagic tunas [4, 5]. The total fish catch has fluctuated between 10 000 and 15 000 tonnes per year since 1997. Annual landings of coral reef fishes are reported to be around 4 000 tonnes, of which 3 500 tonnes are kept for domestic consumption, while the remainder is sold [4, 5]. In 2006, the total reef fish catch was estimated at 4 300 tonnes consisting of: coral reef fishes, 3 400 tonnes; small pelagic fishes (captured in lagoons), 700 tonnes; and other coral reef resources such as molluscs, crustaceans, and echinoderms, 200 tonnes. The Tuamotu archipelago supplied 38% of total reef fish catch; followed by 27% from the Windward Islands in the Society Archipelago (where most people live); 17% from the Leeward Islands; 10% from the Australs; and 8% from the Marquesas. Commercial fishing in the Tuamotu Archipelago appears to be stable for the past 20 years at around 1 200 tonnes per year. The atolls of Tikehau, Kaukura and Arutua (in the Tuamotu Archipelago) supply about 80% of the commercial catch that is the sole income source for many communities [4, 5]. The distinction between subsistence and commercial fishers is hard to define, but it is estimated that 3 000 to 4 000 people

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fish regularly on coral reefs. Reef fish consumption varies from 50 kg/person/year in Tahiti to 150 kg/person/year in Tikehau, among the highest fish consumption rates in the Pacific [5].

Fishing is a major component of the local culture, and techniques include spearfishing, handlines, nets, cages, and fish traps (102 fish trap licences reported for 2006). The main targets are Carangidae (jacks), Lethrinidae (emperors), Lutjanidae (snappers), Mullidae (goatfishes), Acanthuridae (surgeonfishes), Holocentridae (squirrelfishes and soldierfishes), Scaridae (parrotfishes) and Siganidae (rabbitfishes) families. Other exploited resources are the trochus shell (*Trochus niloticus*) and green snail (*Turbo marmoratus*), which were introduced from Vanuatu in the late 1950s and 60s [4]. These shells are used to make jewelry and provide alternative income to some outer island communities [4]; the flesh is also eaten. The black pearl oyster (*Pinctada margaritifera*) is also exploited for its shell, and exports increased dramatically from 1998 to 2005 (850 to 2 878 tonnes). Conversely, the mean shell price has decreased by 30% due to over-production of pearls and pearl oysters. Giant clams (*Tridacna maxima*) are a traditional delicacy, and have been increasingly harvested to meet an ever-increasing demand. East Tuamotu and the Australs supply most of the giant clam flesh to Papeete (70 tonnes in 2006) [4, 5].

Fishing has affected reef fish communities in some locations, with evidence of declines in diversity, biomass and size of target fishes in tandem with increasing fishing effort. In Tikehau, the human population increased by 23% between 1988 and 2002, which together with increasing tourism, has increased the demand for fish [12]. Additionally, fishers have changed from passive, non-selective fish traps to selective spearfishing and hand line fishing [12], which may explain the disappearance of the grouper *Epinephelus microdon* from the Tikehau lagoon [12]. Shark finning is also a recent issue with reports of rapid and drastic declines in reef shark populations at several atolls; this has led to protests from dive and tourism centres. As a result, the government has passed legislation protecting all sharks from fishing, except the Mako shark (Arrété du 28 avril 2006, Code de l'Environnement de la Polynésie Française). The **UNEP/SOPAC Environmental Vulnerability Index** [15], **Reefs at Risk Revisited** [16] and the **Pacific Ocean Synthesis Report** [14] indicate that fishing poses moderate risks to French Polynesian's environment.

Over-exploitation of trochus and snail shells has threatened populations [4]; while these were regularly fished between 1990 and 1994 (up to 355 tonnes of trochus and 50 tonnes of snails in 1990), the fisheries were closed in 2000, with occasional openings by the Fisheries Service. Stocks of *Tridacna maxima* are close to collapse in many lagoons of the Society Islands [4, 5].

Tourism is a well-developed and important economic activity in French Polynesia. Visitor numbers reached a peak of 222 000 international visitors in 2006, and although numbers have recently declined, tourism remains a major activity with 160 000 international visitors arriving in 2009 [17]. There are many tourist resorts on Tahiti, Moorea and Bora Bora in the Society Islands, where visitors use reef resources; for example, shark watching at a feeding site on Moorea brings in USD $5.4 million per year [18]. However, these activities may alter shark and ray behaviour and the long-term implications are unknown [19, 20]. The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [15] indicates that tourism could pose risks to the environment, most likely through coastal development for tourism infrastructure.

Several social and economic assessments have been made of non-extractive uses of the coral reefs. Moorea is the one of the most densely populated island (15 000 inhabitants) and tourism and recreation account for 58% of the total 'goods and services' provided by the reefs, with aesthetic values being 28% and coastal protection 7%. Only 2% of the value was attributed to fishing; this highlights the economic importance of non-extractive use [9].

Use of reef resources – STABLE/EVIDENCE OF CHANGES (low confidence)

Reef resource use has had localised effects on some reefs in French Polynesia with the most significant impacts being changes in reef fish communities from increased fishing pressure, and lesser effects from tourism. The immense size of French Polynesia suggests that direct use damage to reef resources across the territory is probably low, with localised impacts in a few areas. Nevertheless, patterns of resource use are not well documented on remote reefs, which reduces confidence in describing these trends.

Factors affecting reef health and condition

There are many direct and indirect pressures on the reefs and lagoons of French Polynesia, including pollution and sedimentation, poor land-use practices, storms, outbreaks of destructive species and the emerging threats of climate change. The two main categories are: broad-scale factors that affect many locations (e.g. coral bleaching); and more localised impacts, mainly from human activities, at specific locations and islands.

Broad-scale factors include episodic disturbances such as storms and cyclones, COTS outbreaks and coral bleaching events. Such events have caused significant damage to coral reefs in French Polynesia, but impacts vary between reef communities and locations. For example, mass coral bleaching damage in Moorea in 2002 varied with depth, the types of corals and the location of the reef relative to the island [(21)]. In most cases, affected reefs have recovered from these disturbances, however, climate change is an emerging issue that could magnify disturbance effects and lead to long-term reef degradation. Climate change is predicted to change the frequency and severity of cyclones and coral bleaching events, and increase ocean acidity; all of which will result in significant changes to reefs throughout the Pacific [(8, 14, 16)]. By 2050, projections are that 98% of French Polynesian reefs will be threatened by increasing sea temperature and ocean acidification [(16)].

While most reefs and atolls in French Polynesia are relatively free of human impacts, reefs have been damaged around the more heavily populated islands of Tahiti and Moorea due to coastal development, coral mining, pollution from sewage, and run-off from the land [(4, 8, 9)]. Coastal development boomed in the 1950s and 1960s around Moorea and Tahiti and included development of Faaa airport and Papeete harbour [(4)]. Development booms were also associated with nuclear testing programs on Mururoa and Fangataufa (in the Tuamotu Archipelago) during the 1960s. Other developments included dredging and coral mining, and the construction of seawalls, resorts and airports [(4)]. Hotel construction of bungalows and jetties in lagoon waters, or reclamation of the lagoon itself have added to the damage [(4)]. By 1999, about 50% of the shoreline of the main Society Islands had been modified [(4)]; seawalls and reclaimed land covered 33% of the coast in 1993, but increased to 53% in 2009, and 12% of the beaches in 1993 have since vanished [(4, 22)].

Pollution has also damaged some reefs as effective sewage treatment is not available in all places. Systems range from private septic tanks to small-scale sewerage plants for apartment blocks and hotels [(4)]. Although hotels and resorts are required to treat wastewater and sewage, studies on Moorea in the early 1990s found that nutrients still reached the lagoon [(4)]. Eutrophication of coastal waters near Faaa airport on Tahiti was shown to have increased algal cover and the abundance of sea urchins in 1998. These urchins greatly reduce survival rates of coral recruits, which in turn, leads to gradual erosion of the fringing reef [(4)]. Disturbance from dredging and construction was linked to outbreaks of the toxic benthic dinoflagellate *Gambierdiscus toxicus* in the Gambier Archipelago between 1965 and 1974 [(4)] which resulted in ongoing ciguatera poisoning. Water quality is still considered to be poor around the main populated islands [(9)], and studies of ciguatera outbreaks in Tahiti in 2005 suggest a link between algal blooms and local ciguatera poisoning [14].

Coastal waters around Tahiti and Moorea are also affected by sedimentation and pollution from land-based runoff. Land clearing and development on the slopes of the volcanic high islands has led to increased soil erosion, with about 1 000 tonnes of sediment estimated to wash into Tahiti's lagoons every year [4] carrying pesticides and fertilisers [4, 5]. For example, pesticides have been detected in mussels around Tahiti [4]. Sediment cores from Papeete harbour (the most polluted area in French Polynesia) show 10 to 20 times increases in organic carbon, nitrogen and phosphorus since the 1960s, as well as increases in heavy metals and hydrocarbons [4].

The developments, pollution and land-based runoff have affected fringing reefs around the main populated islands. While the outer slope reefs around Moorea appear to be relatively healthy, significant changes have been reported on inshore reefs between 1971 and 1992, with inshore reefs shifting from coral-dominated communities to those dominated by macroalgae [10]. Reports from 1998 indicate that 20% of fringing reefs near Tahiti (about 15% of the coastline) had been destroyed [4]. In the rest of the Society Islands, about 6% of fringing reefs in the Leeward Islands have been destroyed, and a further 17% damaged by coral extraction and reclamation. On Bora Bora, up to 75% of fringing reefs were reported to be moderately to severely disturbed [4] .

While these are localised examples of damage, they illustrate the potential threats to reefs around heavily populated islands such as Tahiti, Moorea and Bora Bora [10]. The 2011 ***Reefs at Risk Revisited*** assessment found that 13% of French Polynesia's coral reefs are threatened by coastal development, and both the **UNEP/SOPAC Environmental Vulnerability Index** [15] and the **Pacific Ocean Synthesis Report** [14] list coastal development as a significant threat to the marine environment. Furthermore, the impacts from coastal development and pollution may increase with population growth and increased tourism [15].

Two atolls and surrounding reefs of Mururoa and Fangataufa (southeastern Tuamotu Archipelago) have been affected by nuclear testing. Short half-life radioactive elements are not detectable and levels of longer half-life elements are 'very low' [9].

Factors affecting coral reefs – STABLE/EVIDENCE OF CHANGE (medium confidence)

Broad-scale factors such as cyclones and coral bleaching are part of a normal cycle of coral reef disturbance and recovery in French Polynesia. However, global climate change is predicted to increase the frequency and severity of these events, resulting in long-term degradation of coral reefs. Most reefs are remote and unlikely to be exposed to human impacts such as coastal development, sedimentation and pollution. However, these impacts are damaging coastal fringing reefs near population centres, particularly in the Society Islands. These pressures are likely to increase with future population growth.

Governance and management

As an autonomous French Territory, the territorial government is responsible for environmental management. In 1985, the 'Délégation à l'Environnement', now known as the 'Direction de l'Environnement', was formed and is responsible to the Minister of Environment [4]. However, other departments that manage tourism, research and land management, have environmental responsibilities that affect coral reefs [4]. Several international conventions and agreements also apply including the Ramsar Convention on wetland conservation, the Convention on International Trade in Endangered Species (CITES), the Bonn Convention on migratory species

Reefs at Risk Revisited (16)*: French Polynesia*

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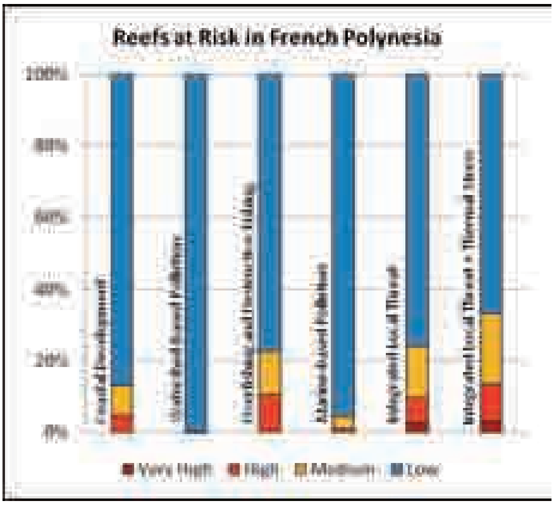
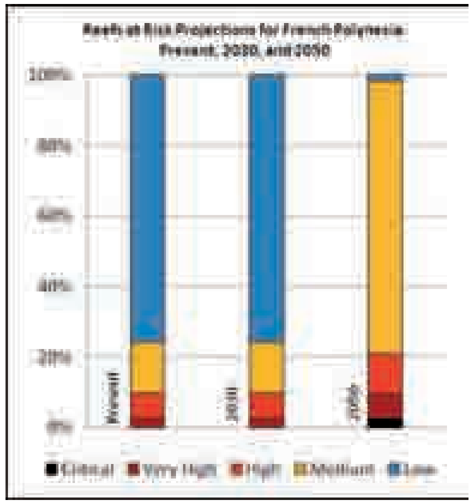
The Reefs at Risk Revisited analysis found that relatively few reefs in French Polynesia are currently threatened due to their remoteness, and the most threatened reefs are around the populated Society Islands. Local threats affect nearly 25% of French Polynesia's coral reefs, with the primary local pressures being overfishing and coastal development. When observations of thermal stress over the past 10 years are combined with these local threats, approximately 33% of French Polynesia's reefs are at risk. While projections of thermal stress and ocean acidification illustrate little near-term effect in this territory, these threats escalate significantly by 2050, such that 98% of coral reefs will be threatened by this decade. The full report, methods and full size maps are on: http://www.wri.org/reefs.





and the Rio Convention on biodiversity. French Polynesia is also party to regional conventions such as the *Convention on the Conservation of Nature in the South Pacific* (the Apia Convention 1990) [4].

The reef, lagoon, and shorelines of French Polynesia are well-covered by management; for example, the Plan de Gestion des Espaces Maritimes (PGEM) covers spatial planning of lagoons, while regulations (Deliberation No. 95-257 AT of December 14th 1995) cover conservation planning. These latter regulations provide for the creation of protected areas and protection of fauna and flora. Protected areas correspond with the IUCN protected areas categories and include Nature Reserves, Wilderness areas, Monument areas, Territorial Parks, Management areas for habitats and species, Marine or Terrestrial Landscapes, and Management areas for natural resources [23]. A PGEM management plan is being developed for Bora Bora to manage marine activities [4], and another is under discussion for Raiatea and Tahaa.

Some species are protected in French Polynesia under the local act 'Arrêté N°1300 CM du 30/08/2007' and national law 'N° 2008-3 du 06/02/2008', as well as international and regional agreements. Protected species include black coral, marine turtles, seabirds, invertebrates and crustaceans [4] and come under different levels of protection: species in Category A (vulnerable to endangered species), include 4 molluscs (*Charonia tritonis*, *Cassis cornuta*, *Cypaecassis rufa*, *Atrina vexillum*), manta rays and the sea turtles (*Lepidochelys olivacea* and *Caretta caretta*). Marine mammals and sharks belong to Category B (rare species or species of special interest). The local act 'Arrêté N° 622 CM du 13/05/2002' declared French Polynesia's waters a sanctuary for marine mammals. Whale watching activities are also closely regulated. Sharks were specially added to Category B under the local act 'Arrêté N° 396 CM du 28/04/2006'.

Environmental Impact Assessments are required for development projects; and 'some progress' has been made towards improving land-use practices and management of pig effluents, which has improved river water quality [4]. However, the 2006 Status of the Environment Report [5] underlines that these issues still require close attention. Reef restoration projects have been implemented at sites in Bora Bora, Tahiti and Moorea [4], especially at hotel sites or in coral dredging areas, with variable success rates.

The French Polynesian government has improved planning and management of high-biodiversity areas and threatened ecosystems since the early 1970s, especially on Tahiti, Moorea, Huahine, and Raiatea in the Society Islands [10]. The numbers and sizes of MPAs varies [1]; previous GCRMN reports suggest the following numbers:

Two MPAs established in 1971 in the western reaches of the Society Islands at the uninhabited Manuae (Scilly) and Motu One (Bellinghausen) atolls [4, 10];

Four MPAs established in 1971 in the more remote Marquesas Archipelago at Eiao, Hatutaa, Motu One and Mohotane islands [10];

In 1977, Taiaro atoll in the Tuamotus was declared as a UNESCO 'Man and Biosphere' reserve [4, 10]; and expanded to include 7 atolls (including Taiaro) covering 2 564 km^2 [1] and known as the Fakarava Biosphere Reserve with 1 098 km^2 of no-take zones [1]; and

Reserves and MPAs established for Moorea's reefs and lagoon (the PGEM - Plan de Gestion de l'Espace Maritime de Moorea, Polynésie française) and implemented to resolve user conflicts and manage use of the reef [9]. There are 5 'no-take' areas, and another 3 MPAs where fishing is regulated in the PGEM, in an area of 9.38 km^2 [1].

Traditionally managed marine areas in French Polynesia are known as *rahui* [1], and 5 *rahui* are integrated into the Fakarava Biosphere Reserve in the Tuamotus [1]. These *rahui* cover 430 km^2 although it is likely that other *rahui* exist (particularly on Rapa in the Australs), and there are efforts to revive additional *rahui* [1]. The total of French Polynesian marine managed areas (including formal marine parks as well as *rahui*) is 2 837 km^2; but, this is a relatively small area of the expansive EEZ, and the reserves "do not adequately cover the diversity of coral reef habitats present in the region" (4).

There is evidence that some of these marine reserves are having positive effects on fish communities. A comprehensive monitoring program to explore the effects of the PGEM in Moorea found increased density and abundance of commercially-exploited fishes in 2004 and 2006 at 7 of the 8 monitored locations (24). These benefits, however, may be threatened by poaching as enforcement effectiveness of these areas has been extremely variable over time.

Despite the many management initiatives, numerous challenges remain including the enormous distances that make monitoring and enforcement difficult. Similarly, enforcement of protected species is 'unsatisfactory' in MPAs at Manuae (Scilly) and Motu One (Bellinghausen) atolls (4).

Governance and management – EVIDENCE OF CHANGE (low confidence)

French Polynesia has management systems and legislative acts in place that provide a strong basis for managing coral reefs. The establishment and expansion of MPAs and the Moorea PGEM are positive signs; as are positive trends in fish populations within MPAs. However, enforcement is lacking in some areas. There are few long-term data to quantify the effects of management programs and MPAs across French Polynesia, other than on Moorea; it is unknown whether current management is sufficient to ensure sustainable use and preservation of coral reefs across the territory. These factors reduce confidence in describing trends in governance and management.

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Republic of Kiribati

- Marine Area: 3 600 000 km^2
- Coastline: 1 143 km
- Land Area: 811 km^2
- Reef Area: 1 967 km^2
- Total MPAs: 14
- Area of MPAs:
- Percentage of reefs threatened (local threats and thermal stress 2011): 95%
- Population (2011 est): 100 743 [(1)]
- Population 2050 (proj): 163 200
- Population growth (2011 est): 1.25% [(1)]
- Urban population (2010): 44% [(1)]
- GDP (2010 est): USD $619.5 million [(1)]
- GDP/Cap (2010 est): USD $6 200 [(1)]

Data are from ReefBase Pacific, the SPC Statistics and Demography database and *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The Republic of Kiribati (pronounced *Kiri-bas*) consists of 3 island groups that straddle the equator. Kiribati's EEZ covers some 3.6 million km^2 of ocean, making Kiribati the largest atoll nation in the world. The western Gilbert Islands group has 17 islands with Tuvalu to the south, and the Marshall Islands to the north [(2)]. An estimated 96% of the population lives in the Gilbert Islands group [(3)]. Tarawa is the main island in the Gilbert group, and the city of Bairiki on South Tarawa is the Republic's centre of government and administration. South Tarawa is the most populated location in Kiribati and houses 43% of the national population [(2)]. The Phoenix Islands are the central group with 8 islands and 2 submerged reef systems, forming a mostly uninhabited archipelago several hundred kilometres long. The area is covered by an expansive marine protected area (410 500 km^2) [(4)] which contains some of the world's most isolated and pristine tropical marine environments. The eastern Line Islands group consists of 9 islands and a submerged reef; they are divided into the Northern Line islands and the Southern Line Islands. Kiritimati Island (also known as Christmas Island) is in the northern Line Islands and like South Tarawa, functions as a centre of government and administration for the Phoenix and Line Islands [(2)]. Three of the islands of the Line Islands (Palmyra, Kingman and Jarvis) are US dependencies and not part of Kiribati [(5)].

Almost all of Kiribati's islands are low lying coral atolls that are rarely more than 3 m above sea level [(2)]. Additionally, most of the islands are very narrow and consequently, Kiribati is vulnerable to coastal erosion, storm surges, tsunamis and sea level rise [(2)]. The geography of the islands also means that Kiribati has limited land, near-shore and shallow lagoon resources, but has a vast expanse of deep oceanic waters which are difficult to use and manage [(2)].

The coral reefs of Kiribati grow mostly around atoll rims, which then drop down to depths of 4000 to 6000 meters [(5)]. Surveys have identified 115 coral species in Tarawa and Abaiang atolls in the Gilbert Islands [(5)]. Marine biodiversity in the Phoenix Islands includes more than 200 coral species, 520 fish species, 18 marine mammals and 44 birds. Large numbers of top level predators (e.g. sharks and jacks) and threatened reef fish such as humphead (Maori) wrasse (*Cheilinus undulatus*) also occur [4].

Status, health and resilience of Coral Reefs

The coral reefs and atolls of Kiribati have been studied by various organisations since the 1950s [6]. The Atoll Research program supported by the University of the South Pacific is located in Tarawa, and the Fisheries Division also conducts surveys [5]. More recently, reefs and biodiversity have been surveyed in the Phoenix Islands by Conservation International, the New England Aquarium and the Kiribati Government, and in 2005, long-term monitoring sites were established on Tarawa as part of the Global Coral Reef Monitoring Network (GCRMN) [4, 7]. In 2010, a long-term monitoring site has been implemented on the outer slope of the west coast of Kiritimati (Christmas Island) by the CNRS (French National Centre for Scientific Research) and the IRCP (Institute for Pacific Coral Reefs) through the CRIOBE (Centre for Island Research and Observatory of the Environment) based in Moorea – French Polynesia, in collaboration with the Kiribati Fisheries Division. Twenty permanent quadrats are photographed for coral and benthos monitoring, and total reef fish communities are monitored along 50 m x 4 m transects. This site also belongs to the Polynesia Mana GCRMN node.

Surveys from the 1970s and 1980s generally recorded moderate levels of live coral cover, with half the sites on Tarawa (in 1982) showing 26% to 50% coral cover, and the other sites 0% to 25% [5]. Surveys from the Phoenix Islands in 1978 reported that most reefs had 25% to 50% cover [5]. Surveys in the early 2000s using line transect and manta tow methods at 3 m and 9 m depths found moderate to high levels of coral cover, with a third of the sites on Tarawa and Abaiang having 51-75% live coral cover, and most remaining sites having 21-50% coral cover [5].

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However, these surveys noted that coral cover and diversity was lower at sites in the southern portion of Tarawa Atoll which is the most densely populated region of Kiribati [6]. Recent monitoring in Kiritimati through the CRIOBE found live coral cover percentages of 54%.

Gilbert Islands

Six long-term photoquadrat monitoring sites at 6 m depth were established in the Gilbert Islands in 2004 (2 on Kuria, 3 on Tarawa and 1 on Abemama) [8]. There were varying levels of coral cover: 13% and 31% live coral cover at the 2 sites on Kuria; 48% cover at the Abemama site; 21% cover at 'Hospital site' (South Tarawa), 22% at Teaoraereke (South Tarawa), and 55% at North Tarawa [8]. The South Tarawa and Kuria sites had lowest coral cover and the highest dead coral 'pavement', although there was little recently dead coral. These sites appear to have been affected by human activities [8]. Similar to findings from surveys in the early 2000s, the cover of faster growing but more vulnerable *Acropora* corals was low across all sites in the Gilbert Islands [5, 8].

There was coral bleaching on Tarawa Atoll in late 2004; the North Tarawa site was the only site significantly affected of the three Tarawa sites, declining from about 55.2% coral cover to 30.9% [7]. While the North Tarawa site appears to be 'recovering' [4], coral cover was similar to the South Tarawa sites and coral community composition has changed with a decrease in *Pocillopora* corals, and *Porites* corals being the dominant species [4]. The sites at South Tarawa (Hospital site and Teaoraereke) are close to population centres and are affected by coastal development, pollution, eutrophication, sedimentation, and over harvesting [6, 9], while the degraded site at Kuria may be affected by the blasting of a channel [8]. Fish have not been surveyed at the GCRMN monitoring sites, but some fish monitoring was performed as part of the SPC PROCFish program [8].

Phoenix Islands

The first comprehensive surveys of the Phoenix Islands in 2000 and 2002 found that reefs were near-pristine, probably due to their isolation. The reefs at Kanton Island (also known as Canton or Abariringa Island) were described as having 'probably the most highly developed *Acropora* species community in the world' [4, 6]. Other reefs were dominated by encrusting and massive corals. The reefs surveyed had 20% to 40% live coral cover, and there was considerable physical breakage and coral rubble. However, this is highly likely to result from wave action and not human impacts [6]. Fish populations in the Phoenix Islands contained large numbers of predators such as jacks (Carangidae) and snappers (Lutjanidae), sharks, and other targeted reef species such as surgeonfish (Acanthuridae) and parrotfish (Scaridae) [6]. In 2002 and 2003, reefs in the Phoenix Group were affected by coral bleaching; surveys in 2004 at Kanton Island reported massive coral mortality with the only living corals being a patch of *Pavona* corals [4]. However, subsequent surveys reported 'exceptional recovery' [4].

Status of coral reefs – EVIDENCE OF CHANGE (low confidence)

Long-term monitoring of coral reefs in Kiribati only began in the last decade, and repeated surveys are only available from Tarawa and the Phoenix Islands. While some reefs appear to be generally healthy, reefs close to population centres of South Tarawa have been significantly degraded. Coral bleaching has also affected reefs in North Tarawa and the Phoenix Islands with significant declines in coral cover and changes in community composition. No data from Kiribati's Line Islands have been reported.

Coral reef health and resilience – NOT CONSIDERED

The lack of long-term monitoring data from Kiribati makes it difficult to describe reef health and resilience. The start of monitoring in the Gilbert and Phoenix Islands is a positive sign, particularly as these will collect data on coral recruitment and community composition. Continuation of these surveys over longer time scales will help describe reef resilience.

Use of reef resources

Marine resources are incredibly important to the Kiribati people. The economy is based on marine products, and the poor soil fertility means that most protein is sourced from the sea [2, 5]. The people have some of the highest levels of seafood consumption in the world; whole fish consumption of 656 g/person/day on rural atolls and 320 g/person/day on urban South Tarawa [5]. All non-toxic fish over a few centimeters in length are eaten, as well as many species of shellfish [5]. Other marine products such as shells and teeth are used for handicrafts or cultural purposes [2]. Kiribati also has active aquaculture of resources such as seaweeds for both domestic consumption and for export [6]. There are also efforts to culture black pearl oysters and trochus [2].

The main fishing activities in Kiribati include subsistence and artisanal inshore/lagoonal reef fisheries, offshore fisheries, aquarium fisheries and aquaculture. Between 300 and 400 finfish species have been reported from Kiribati [2], and the main finfish species taken in inshore and reef fisheries include snappers (Lutjanidae), cods and groupers (Serranidae), coral trout (*Plectropomus* sp.), emperors (Lethrinidae), goatfish (Mullidae), mullet (Mugilidae), milkfish (*Chanos chanos,* although there are several milkfish farms supplying fish), trevallies (Carangidae), bonefish (*Albula glossodonta*) and herrings [2, 6]. Fishing gear includes hook and line, reef gleaning, gill nets for schooling fish (e.g. bone fish and mullet), spearfishing and trolling [6]. However, fishing gear is being modernised with the introduction of improved fishing tackle, outboard motors and ice boxes, particularly around South Tarawa [6]. Other reef resources harvested include marine turtles, crabs, shrimp, lobsters, bivalves, gastropods, sea cucumbers (bêche-de-mer) and molluscs [6]. Offshore fisheries target deep water species such as snappers, flying fish and billfish, and pelagic species such as tunas (Scombridae), wahoo and trevally [6]. Sharks are also reported to be an increasingly important resource for export of shark fin, and sea cucumbers have been a lucrative export fishery [2]. Kiribati's EEZ is reported to have 'considerable potential' to further develop pelagic fisheries for tuna, flying fish, and to a lesser extent, for deepwater fish, sharks and deep water corals [2].

Several species of grouper, coral trout and wrasse are also targeted for live fish export to Asian markets. Exports declined from about 80 000 fish in 1996 to just over 10 000 fish in 1998 [2]. Surveys in early 2000 found only low numbers of the target species at 3 Line Islands with high levels of live fish exports from Tabuaeran, Teraina and Kiritimati [5]. Surveys at targeted islands in the Gilbert Islands showed similar trends [2, 5]. At Onotoa atoll (in the Gilbert Islands), numbers of target species had decreased to the extent that local fishers voluntarily reduced fishing effort due to their concerns over declines in fish stocks [2].

Kiribati also has an active aquarium fish trade that began in the 1980s in South Tarawa but was relocated to Kiritimati to access markets in Honolulu. The main export species include angelfish (Pomacanthidae), damselfish (Pomacentridae), wrasse and butterflyfish (Chaetodontidae) [6]. The number of fish exported from Kiritimati increased from around 15 000 in 1996 to more than 100 000 in 1998 [6], and increased further to more than 160 000 fish in 2003 [2]. Over half the numbers of fish exported are the highly prized flame angelfish (*Centropyge loricula*) [2]; now there are concerns that the aquarium fishery is depleting stocks of some species, and that fishers use destructive and damaging fishing techniques such as crowbars to collect fish [6]. The

Fisheries Authority has been monitoring exports and checking aquarium fish divers to improve management of the fishery [6].

Fishing pressure on reef resources is intense in some areas. Subsistence fishing harvests are several times larger that artisanal and small-scale commercial reef fisheries [5], with harvests between 6 and 25 tonnes per km^2 per year [3]. The take of reef fishes and resources from South Tarawa is substantially higher than on other islands in Kiribati [3]. High population density and pressures, and improved fishing technology such as cold storage, communications and mechanisation [5] appear to have contributed to over-harvesting of species [3]. Data from 1977 to 1993 suggest that bonefish have been depleted with long-term evidence of declining CPUE and sizes, particularly around Kiritimati (Line Islands), and of over-exploitation of sardines, clams, finfish, coconut crabs and shellfish, particularly around South Tarawa [2, 6]. Species such as goatfish and mullet appear to have 'disappeared' from South Tarawa lagoon, and reef fish such as snappers (*te morikoi*), were less abundant in this area than in the more exposed western lagoon [6]. Several species of small baitfish such as the goldspot herring have 'become rare'. These declines are considered to be driven by fishing pressure, mainly from the overpopulated South Tarawa, but the effects of coastal development also need to be considered. Over-harvesting is considered to continue to affect other already depleted stocks such as: bonefish, paddletail (*Lutjanus gibbus*), spangled emperor (*Lethrinus nebulosus*), lobsters and sea cucumbers (mainly the white teat fish *Holothuria fuscogilva*) [6]. The giant clam *te kima* (*Tridacna gigas*) is almost locally extinct in some areas and other clams are rare [6], and the coconut crab is probably extinct on Teraina (or Washington) Island in the Line Islands [5]. Sea cucumbers also appear to have been depleted in some areas, with harvests peaking in the early 1990s but then significantly declining by 1996 [6]. The Fisheries Division of the Ministry of Natural Resources Development is currently engaged in efforts to 'regenerate heavily fished bêche-de-mer stocks in atoll lagoons' [2]. Destructive and damaging fishing practices are also used, such as the use of crowbars to extract crustaceans from corals [5], as well 'frequent uses' of poisons and explosives, fishing of spawning aggregations, and the use of very small mesh gillnets that capture small and undersized fish [2]. In contrast, more distant villages, deeper waters and locations with strong wave action are not exploited to the same extent, and outbreaks of ciguatera may lead to these locations being left unfished for several years [5]. The Phoenix Islands appear to be relatively untouched by harvesting and fishing and marine resources there appear to be relatively pristine [4].

Both the **Pacific Ocean Synthesis Report** [10] and the **UNEP/SOPAC Environmental Vulnerability Index** identify fishing as posing a threat to Kiribati's marine environment, while *Reefs at Risk Revisited* suggest that 71% of coral reefs are threatened (moderate risk or higher) by fishing.

Tourism is still developing in Kiribati with relatively small visitor numbers (1 712 visitors to Kiritimati, 1 471 visitors to Tarawa in 1999) [5]. Some locations such as the Phoenix and Line Islands have gained a reputation for being pristine marine ecosystems which could attract visitors [5]. Reef tourism also attracts visitors to North Tarawa [2], and sport anglers from the United States and Japan visit Kiritimati specifically to catch and release bonefish [6]. The 2005 **UNEP/SOPAC** assessment [11] indicates that tourism currently poses a low threat to Kiribati's environment.

Use of reef resources – EVIDENCE OF CHANGE (medium confidence)

There are some fisheries catch data and resource surveys that show declines in marine resources around populated atolls of South Tarawa and Kiritimati. Declining stocks include sea cucumbers, some fish species targeted for live export, and other fish species. There is increasing pressure due to destructive fishing practices to collect aquarium fishes. Some species are considered to be close to local extinction. This suggests that reef resources around Tarawa and Kiritimati have changed due to human use, whereas, other areas such as the Phoenix Islands are in relatively pristine condition.

Factors affecting reef health and condition

Kiribati's coral reefs and marine environment are affected by pollution, waste disposal and coastal development; these habitats are also at risk from the long-term affects of climate change [2, 5, 6]. Pollution is a significant issue around populated regions such as Tarawa. There are real concerns over bacterial contamination of near-shore waters of Tarawa lagoon [(2, 6)], and poor sanitation has led to high incidence of illness and disease in the population, including outbreaks of cholera [(6)]. In 2000, 54% of households across Kiribati had inadequate sanitation, and about half the population is reported to use beaches as lavatories [(6)]. There is a sewerage system that services some households on Tarawa, however, the system requires urgent maintenance to repair leakage of raw sewage. Impact assessments have found that sewerage outfalls have caused localised changes in coastal habitats, including reef degradation [(6)] in areas such as the Hospital outfall on southeast Tarawa. The existing sewerage outfalls were inappropriately designed and sewage can wash back into the lagoon [(6)]. Lagoon reef flats have high levels of bacterial contamination which exceed standards. Studies in the early 1990s found that shellfish collected with 25 m of shore were not safe to eat [(6)]. Lagoon waters can also be polluted by effluent from pig farms on the coastline of South Tarawa, and from inadequate storage and disposal of chemical waste [(6)]. Further offshore, there are concerns over pollution from radioactive sources [(2)]; atmospheric nuclear testing occurred over Kiritimati and Malden islands after WW II [(5)].

Coral reefs and coastal habitats are also affected by coastal development such as dredging and blasting of boat channels, mining of sand and coral for construction, building of causeways and sea walls, land reclamation and development projects [(2, 5, 6)]. There is evidence that coastal erosion has increased in areas of South Tarawa where coral mining has occurred [(2, 6)]. Coral mining has also directly damaged some coral reef habitats [(6)]. The causeways that link the atoll islands and islets have altered lagoon water circulation patterns and blocked fish movements [(5)]. In Cutaritari and Tarawa, causeways have obstructed recruitment of larval fish from the ocean into the lagoon, and may contribute to declines of goatfish and mullet [(5, 6)]. Land reclamation, channel blasting and poorly designed seawalls have also altered coastal hydrodynamics and caused increased erosion [(2, 3)]. Mining of sand and gravel, and dredging and construction of ports and increased shipping may also result in increases in sedimentation of coastal and lagoon habitats [(5, 6)]. Coastal vegetation and mangroves have also been cleared around urban areas for new construction. Ballast water from visiting ships is also considered to have introduced an alien species of catfish [(2)].

Waste disposal problems have '… increased at an alarming rate' in Kiribati, especially in South Tarawa [(6)]. The increase in imported goods and growing population has led to large volumes of solid and liquid waste, and waste management systems are inadequate. Around large villages, waste is deposited along roadsides (often without adequate containers) for collection by local councils, but in the rest of South Tarawa and Kiribati, waste is burnt, buried or dumped at sea [(6)]. Collected waste is dumped at designated dumpsites along the coast [(6)]; but these sites are periodically inundated at high tide with waste washing into lagoons and onto beaches [(6)]. There are no waste disposal facilities for potentially hazardous substances, such waste oil. These wastes are stockpiled in drums until they can be exported [(6)], increasing the risk of chemicals leaching into ground water and coastal habitats. There are also no facilities for disposing of, or exporting, batteries.

Pollution and coastal development may result in increases in ciguatera poisoning [(5)]. In Marakei Island (Gilbert Islands), ciguatera has become 'common' since a causeway altered circulation patterns in the lagoon, and the first reported cases of ciguatera on Maiana Island occurred after a boat channel was excavated [5]. Interviews with local communities found that many locals believe that ship wrecks, sewage, dumping and reef damage contribute to ciguatera poisoning [5]. There was a massive fish kill in some atolls of the Gilbert Islands in November 2003 [4]. Fish included small herbivores to large carnivores, moray eels and even some dolphins. A toxic algal outbreak was suspected, but not confirmed [4].

The Pacific Ocean synthesis report and the 2011 *Reefs at Risk Revisited* analysis suggest that coastal development threatens about 37% of Kiribati's coral reefs, and animal waste from farms, poor sanitation and sewage are listed as a serious environmental threats in the 2005 **UNEP/SOPAC Environmental Vulnerability Index** [11].

Kiribati is threatened by the effects of climate change such as coral bleaching and sea level rise [2, 5, 6, 11]. The low lying atolls are extremely vulnerable to storm surge, inundation and flooding [2, 6]. Tidal data from Kiribati show sea level rises of 4 mm per year [6]. Climate change is also predicted to have serious effects on coral reefs, and the *Reefs at Risk Revisited* analysis suggest that almost all of Kiribati's reefs will be threatened by 2030. Increased storm surges and sea level rise could increase erosion, inundate land and damage the limited agricultural lands [6], which in turn, could increase pressure on the marine environment from sedimentation and fishing [6].

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

The major risks facing Kiribati's coral reefs are unsustainable development (e.g. causeways, pollution), overfishing and coral bleaching; however, most of the information is from Tarawa. The lack of information reduces confidence in describing these trends. Pressures on coral reefs around Tarawa and South Tarawa have increased damage to coral reefs and coastal habitats. Pollution and coastal development are the main issues across Tarawa, while climate change is an emerging issue.

Governance and management

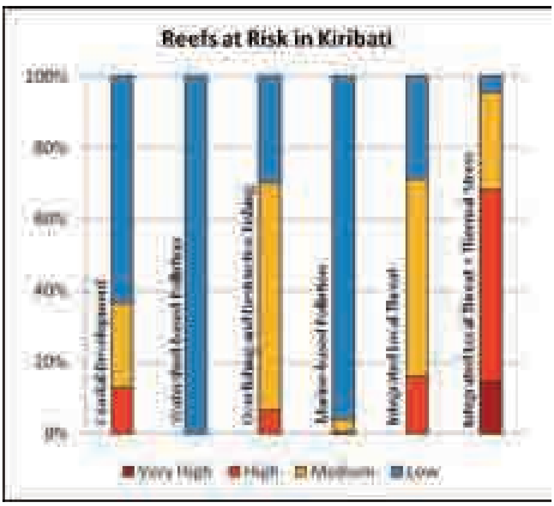
Kiribati has some legislation and planning instruments to manage the marine environment; the *Environment Act* (1999) controls development and pollution, and there are ordinances and local laws covering issues such as protected species, fishing, and marine reserves. The *Fisheries Ordinance* (1957) prohibits the use of explosives and poisons [5], but different atolls and local councils have differing laws on environmental management and harvesting marine resources [6] and there is no overarching environmental policy to coordinate environmental management across different government departments or policies [2]. Kiribati is a signatory to the Convention on Biological Diversity which requires the Government to take steps to conserve its biodiversity, this stimulated the implementation of Kiribati's National Biodiversity Strategy and Action Plan (NBSAP) in 1999 [6].

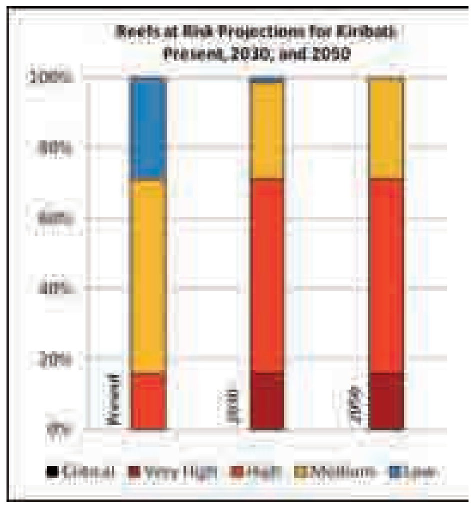
Coastal development and pollution are managed through the *Environment Act* and various planning policies. Some plans and research projects have been completed to tackle issues such as coastal erosion and destruction of coastal habitats [2]. The use of coral to construct walls is now illegal in Tarawa [6]. There are public awareness campaigns to reduce the amount of sewage and rubbish entering coastal waters, minimise waste generation and increase recycling [2, 6]. There are also plans to relocate sewerage outfalls further offshore and to repair elements of the sewerage system [6]. However, many plans and recommendations have yet to be implemented, for example, plans to modify causeways to re-introduce natural water circulation patterns have been too expensive to implement [6]. Enforcement of pollution controls and regulations is hampered by a lack of funds and capacity, resulting in poor management of land-based pollution and 'uncontrolled' coastal development [6].

Reefs at Risk Revisited: Republic of Kiribati

WORLD RESOURCES INSTITUTE

The *Reefs at Risk Revisited* analysis found that about 70% of Kiribati's coral reefs are currently threatened by local activities, particularly coastal development, overfishing and marine-based pollution. Watershed-based pollution is not a significant issue due partly to the limited agriculture on the islands. Thermal stress from increased sea-surface temperatures in the past 10 years has caused additional stress, increasing the percentage of threatened reefs to about 95%. The reefs around Tarawa, Beru, Teraina and Kiritimati are most at risk. Projections for thermal stress and ocean acidification suggest that by 2030, about 99% of Kiribati's reefs will be threatened. The full report, methods and full size maps are on: http://www.wri.org/reefs.





There are few provisions in the *Environment Act* that specifically protect or direct sustainable use of biodiversity [2]. Under the NBSAP and fisheries policy, the Fisheries Division is monitoring fish catch and exports (especially for the live fish trade), and has introduced restrictions on the mesh size and the number of nets fishers can purchase [6]. The Department has instigated public awareness programs about destructive fishing, and is continuing fish monitoring programs including fish surveys and fisheries research. Coral trading has been banned, as has fishing using SCUBA equipment, and the use of cyanide, explosives and fish traps [6].

Fisheries and environmental protection in Kiribati face numerous challenges. The different local by-laws can introduce confusion and limit effectiveness. For example, targeting spawning runs of bonefish has been banned in the North Tarawa Conservation Area, but these restrictions do not apply to fishers in adjacent South Tarawa [6]. Kiribati had traditional management systems such as 'te mwaneaba' and 'te unimwane' but these have deteriorated since colonization by the British who introduced the concept of 'open access' to fisheries and marine resources [2, 5]. Around South Tarawa, the open access arrangements have led to over-exploitation by subsistence and commercial fishers [2]. Nevertheless, some communities and atolls have retained some local laws and customs which limit fishing season, gear and catch [5]. For example, Abemama prohibits the taking of giant clams by visitors, Nikunau limits fishing close to villages and Tamana banned fishing by visitors on inter-island boats [5]. The Kiribati Government is actively promoting the involvement of local communities in marine management [2].

There are at least 14 marine protected areas (MPAs) in Kiribati; with most established between 1960 and 1980, and most are relatively small (< 100 hectares). The exceptions being Kiritimati and Starbuck (in the Line Islands) and Phoenix Islands [6]. Many of the MPAs were established to protect and enhance stocks of important marine species to preserve food security and fishing activities. However, the Line and Phoenix Islands are relatively pristine areas of high conservation value and in 2008, the Phoenix Islands Protected Area (PIPA) was declared. This covers 410 500 km^2 and is one of the world's largest MPAs [4], and also the world's largest UNESCO World Heritage Site. PIPA includes 8 atolls, 2 submerged reef systems, underwater seamounts and deep water habitats, and a wide range of terrestrial and marine biodiversity. Commercial fishing is banned, but subsistence fishing is allowed for the few inhabitants of Kanton Island [4]. Kiribati's loss of potential revenue from fishing licenses in the Phoenix Islands is being offset by an endowment fund established by the New England Aquarium, Conservation International and the Kiribati Government. The fund will also support costs of managing PIPA [4, 5].

The Kiribati Government and other partners are also exploring aquaculture ventures. Seaweed culture is an important activity in Kiribati, and efforts are being made to culture sponges, pearl oysters and sea cucumber. Aquaculture could provide alternative income streams and help restore and reduce pressure on wild capture fisheries [2]. Coral restoration projects are also being trialed [2].

Governance and management – EVIDENCE OF CHANGE (low confidence)

Many of the plans and management tools have not been implemented, and there is a need for a more coordinated approach to environmental and fisheries management. There are problems with enforcement due to limited funding and capacity, with many knowledge gaps about marine resource status and use. The effectiveness of management on resource use, behaviour and habitat status has not been assessed. Nevertheless, the establishment of PIPA is a very significant step in improving management and conservation of Kiribati's coral reefs. Continued monitoring of PIPA, other MPAs and fished areas could provide the necessary information on effectiveness of management arrangements.

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Niue

- Marine Area: 390 000 km^2
- Coastline: 64 km
- Land Area: 260 km^2
- Reef Area: 170 km^2 [1]
- Total MMAs: 3 [1]
- Area of MPAs: 31 km^2 [1]
- Percentage of reefs threatened (local threats and thermal stress 2011): 100%
- Population (2011 est): 1 311 [2]
- Population growth (2011 est): -0.03% [2]
- Urban population (2010): 38% [2]
- GDP: USD $10 million (2003 est) [2]
- GDP/Cap: USD $5 800 (2003 est) [2]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The small island nation of Niue consists of a single uplifted coral atoll that reaches up to 70 m above sea level. With an area of 260 km^2, the island is probably the largest uplifted atoll in the world [3]. Niue is surrounded by a reef platform up to 5 km wide, which then drops off to more than 1000 m depth [4]. There is another reef system, Beveridge Reef, 200 km southwest of Niue, which sits atop a large seamount with a permanent sand cay but no vegetation.

Niue lies approximately 2500 km northeast from New Zealand, and about 4500 km south south-east from Hawai'i. Tonga is to the west of Niue, while the American Samoa and Samoa are to the north, and the Cook Islands are to the east. Niue is a self governing state in free association with New Zealand, and residents have New Zealand citizenship although the majority live in New Zealand [2, 3]. The capital of Niue is Alofi, but most people in Niue live outside the main city in settlements along the coast. Niue's population has declined due to emigration and while this reduces some population pressures, these declines make it difficult to maintain infrastructure required for sustainable development [5]. Fishing and tourism are important economic activities in Niue with commercial fishing focused mostly on offshore and pelagic species (i.e. tuna). However, agriculture, fisheries and forestry are important for sustaining local communities [5]. There are concerns about over-fishing of inshore stocks, pollution, sedimentation, and a lack of data on resource condition, use and sustainability [5].

Little is known about the marine biodiversity of Niue. There are reported to be 2 species of marine reptiles, 243 fish and 25 marine macro-invertebrates, and 45 coral genera [3, 4], although these figures are almost certainly underestimates.

Status, health and resilience of coral reefs

There is limited information available on the coral reefs of Niue. Spalding (2001) reported that coral cover on Beveridge Reef was reported to be 'high' and fish populations 'diverse and unfished'. Spalding also reported that Cyclone Ofa struck Niue in 1990 and 'caused considerable damage to coral reefs, particularly on the western coast'. A coral bleaching event in 2003 also damaged Niue's reefs although details were sparse [(6)].

In January 2004, Cyclone Heta passed by Niue and caused significant damage to coral reefs. Surveys were conducted 3 weeks after the cyclone at 11 sites on the north and west coast. These surveys documented significant reductions in live coral cover to less than 10% from anecdotal levels of up to 70% before the cyclone. The waves reduced exposed reefs to bare coral 'pavement' [(7)]; however, reefs in more sheltered locations had less damage, with 2 survey sites still showing up to 75% coral cover [(7)].

In 2005, reef monitoring sites were established on Niue for the Global Coral Reef Monitoring Network (GCRMN) through the support from SPREP, CNRS (French National Science Research Centre), IFRECOR (the French coral reef initiative) and AFD (the French development agency). Reefs were surveyed using random photo quadrats at 6 m depth, and by permanent photo quadrats along a 20 m long transect on the reef slope at 10 – 13 m depth [(6)]. Photos were analysed to document community composition and change over time. Four sites (Tavala, Makefu, Tamakautoga and Avatele) were established as long-term monitoring sites, and to also document recovery from Cyclone Heta. Monitoring in 2005 and 2006 showed little change in live coral cover between years, and cover was still very low in 2006, ranging from 13% cover at Tamakautoga, to 1% at Makefu [(8)]. However, there are signs of recovery at some sites such as the decrease in filamentous green algae and turf algae, and increases in coralline algae which provide a good foundation for coral recruitment and recovery [(8)]. Nevertheless, recovery at these sites has been slow [(9)].

Status of coral reefs – EVIDENCE OF CHANGE (low confidence)

There were significant decreases in live coral cover in Niue after Cyclone Heta; there are some indications of recovery with new coral settlement, but full recovery is not evident. Monitoring only started 5 years ago on the west coast, and continuation and expansion is necessary to provide good information on the status and trends of Niue's coral reefs.

Coral reef health and resilience – NOT CONSIDERED

There is currently insufficient information to describe the health and resilience of these coral reefs. Monitoring after Cyclone Heta will provide good baseline to document recovery.

Use of reef resources

Niue does not appear to have abundant reef fisheries resources [(4, 10)]. The narrow reef flat descends to 1000 m depth within 5 km from shore, restricting habitat for reef species, however, this fringing reef does provide molluscs, fish, seaweed and other resources which are mainly harvested by women [(10)]. Reef fishing is usually for subsistence with the catch either consumed or sold locally [(10)]. Fishers collect reef species using spears, hook and line and by reef gleaning, but in more recent years, male fishers have began commercial fishing for deep sea snapper and pelagic fish [(10)]. Fish aggregations devices (FADs) were installed in near-shore habitats to attract fish [11]. Reef fishing occurs mainly on the western side of the island where there is easier access to fishing grounds. The Niue Department of Agriculture, Forestry and Fisheries (DAFF) has expressed concern about the increasing improvement in fishing technology and fishing effort, and subsequent increases in fishing pressure on inshore marine resources. There is evidence of over-harvesting of lobsters, giant clams, turban shells, sea urchins, sea cucumbers (bêche-de-mer), octopus and some species of crab [10]. There are also reports from the early to mid 1990s of destructive fishing practices and illegal export of corals [5]. Concerns about over-harvesting, ciguatera poisoning and a lack of data about fisheries resources have also been repeatedly expressed since the early 1990s [5].

There is very little available information about reef fisheries and fishing activities. The 2011 *Reefs at Risk Revisited* analysis suggests that 96% of Niue's coral reefs are threatened by overfishing (moderate risk or higher), and the 2005 UNEP/SOPAC Environmental Vulnerability Index [12] suggests that fishing poses some threat. Nevertheless, the lack of information increases uncertainty and more information is needed in order to describe the current status, trends and sustainability of Niue's reef fisheries.

Tourism is limited in Niue, but plays a significant role in the national economy [5]. At the time of publication, Air New Zealand had a weekly service to Niue. Tourism marketing is directed towards diving, fishing, sports, people and culture, and eco-tourism, primarily for visitors from New Zealand and Australia [5]. The 2005 UNEP/SOPAC assessment [12] indicates that tourism poses a low environmental risk to Niue.

Use of reef resources – NOT CONSIDERED

There is little information on trends in reef resource use, effects on species and habitats, or sustainability. There are concerns of over-exploitation over the limited resource area, but more information is needed.

Factors affecting reef health and condition

The factors damaging coral reefs in Niue include pollution and sedimentation from land-based sources, inadequate waste management and contamination of water sources with agricultural chemicals [5]. There were reports that coral reefs in the vicinity of Alofi harbour (west coast of Niue) were being affected by sedimentation in the early 1990s, and concerns about oil spills and pollution from the harbour [5]. There are also accounts of poor agricultural activities, damage from the use of heavy machinery, poor use of herbicides and pesticides, impacts from the construction of 'bush roads', loss of soils and land clearing and deforestation dating from the 1960s, throughout the 1990s and up to 2001 [5]. These activities can lead to increased sedimentation and pollution of adjacent coastal waters. Pollution and contamination of some water sources from inadequate septic tanks and piggeries have also been reported [5]. Additionally, concerns have also been raised about the disposal of municipal waste (including problems with waste generated by increasing imports of goods) with inadequate landfills and the potential for coastal fills to contaminate coastal waters.

An increase in severe storms associated with climate change could increase erosion of the coastline and damage coastal infrastructure, and cause significant damage to coral reefs [5]. Impacts on crops and livestock from droughts or floods could increase pressure on marine resources. Climate change could also directly affect fish stocks and potentially, increase the risk of ciguatera poisoning which has been linked to reef disturbance [5]. The 2011 *Reefs at Risk Revisited* assessment indicates that most Niue's reefs are threatened by the potential effects of increasing sea temperatures and ocean acidification, with all reefs listed as threatened (medium risk or higher) by 2030.

Factors affecting coral reefs – NOT CONSIDERED

The factors affecting Niue's coral reefs are similar to those damaging other areas of the Pacific. Nevertheless, few data are available to quantify these risks and measures their effects.

Governance and management

Niue has several acts of legislation, plans and policies for managing the marine environment. These include the *Environment Act* (2003), the *Coastal Management Policy* (2008), the *Forest Policy* and *Forest Bill*, the *Integrated Coastal Management Plan*, the *National Waste Management Plan* and the *National Tuna Fishery Management and Development Plan* [4]. The *Niue Domestic Fisheries Regulations* (1996) include size and catch limits on a few marine species such as giant clams, lobsters, and coconut crab, and prohibit the take of marine mammals, moray eels, rays, live corals and 'giant wrasse'. There are also plans to reduce pollution, protect water resources, develop tourism, and combat land degradation and drought [4]. There is also a National Biodiversity Strategic Action Plan which encompasses all terrestrial and marine biodiversity on Niue [4]. These plans provide recommendations and some legislative level controls that could promote the health of Niue's coral reefs. There are some promising signs of improving agricultural practices with better control of pesticides and shifts to more suitable crops and farming methods [5]. This could reduce soil loss and subsequent coastal sedimentation.

There are currently 3 marine managed areas in Niue with a combined area of 30.5 km^2. Most of this consists of the marine component of the Huvala Forest Conservation Area [1, 3]. The Anono Marine Reserves was established in 1998. Traditional marine management systems in Niue include *fono* or *tapu* which are closures that restrict harvest. In 2004, the SPREP International Waters Program embarked on a pilot project to establish community based marine reserves in the villages of Makefu and Aklofi North [11]. Four temporary closures were established and are being monitored to assess effects on fish stocks [1]. There are also reports that the Alofi North community was considering tighter controls over netting and spear fishing, methods which significantly reduce fish stocks [11]. It has also been reported that Beveridge Reef is a 'declared' protected area, although its legal status is unclear and there is no active management [3].

While legislation, planning and marine reserves exist and are promising signs, there are few data available on the effects of management. There are concerns that management is not coordinated, with reports of a significant lack of trained staff to implement management [5]. Delays in finalising the *Environment Bill* and *the Environment Planning Act* are making it difficult to coordinate environmental management [5]. There is also a lack of monitoring and information [5], and the lack of data on fishing effort and harvest pressure is a significant challenge in making informed management decisions [11].

Governance and management – NOT CONSIDERED

The planning instruments and management tools to establish MPAs with communities are promising signs, however, there is insufficient information to determine their effectiveness. Continued monitoring and future work will help to document the effects of these management actions.

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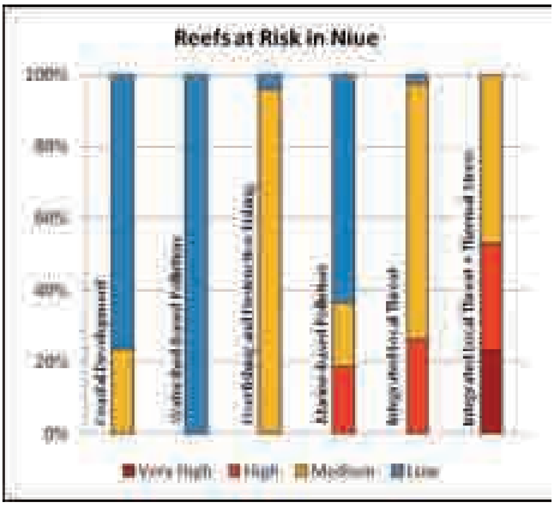
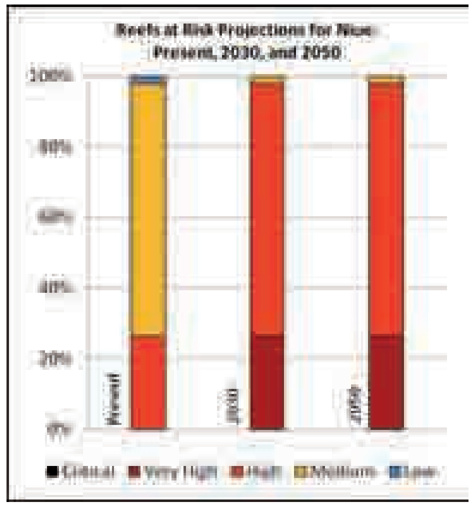
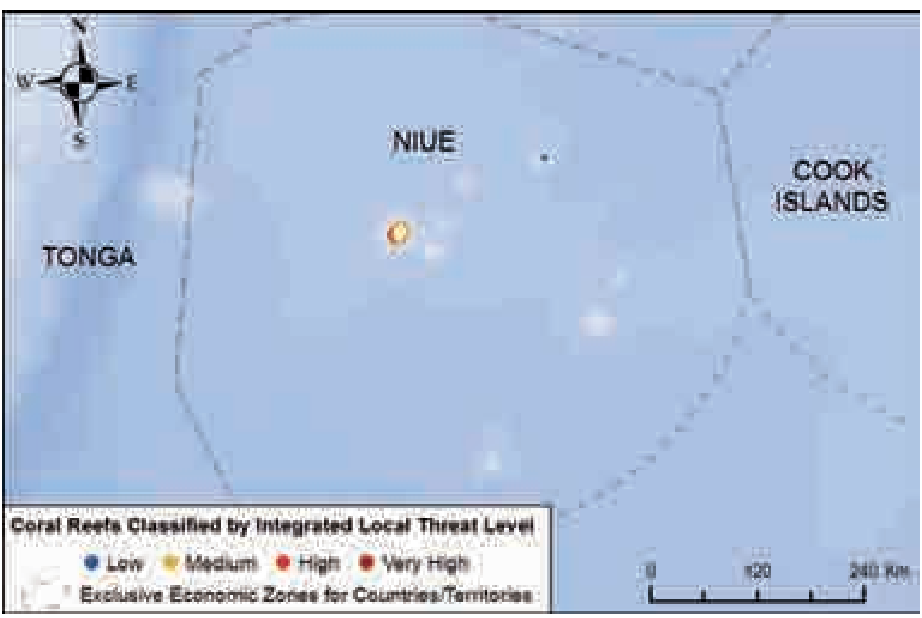
Reefs at Risk Revisited found that nearly all of Niue's coral reefs are currently threatened, mainly from overfishing, coastal development and marine-based pollution. Unusually warm sea surface temperatures over the past 10 years have caused additional stress, increasing the number of threatened reefs to 100%. The reefs on the western side of Niue are most at risk. By 2030, projections for thermal stress and ocean acidification suggest that the number of reefs under high, very high, or critical risk will increase from 30% (current) to 99%. The full report, methods and full size maps are on: http://www.wri.org/reefs.







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Samoa

- Marine Area: 120 000 km^2
- Coastline: 403 km
- Land Area: 2 934 km^2
- Reef Area: 490 km^2 [1]
- Total MMAs: 84 [1]
- Area of MMAs: 209 km^2 [1]
- Mangrove Area: 7 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 100%
- Population (2011 est): 193 161 [2]
- Population (2050 proj): No Data
- Population growth (2011 est): 0.6% [2]
- Urban population (2010): 20% [2]
- GDP: USD $1.002 billion (2010 est) [2]
- GDP/Cap: USD $5 200 (2010 est) [2]

Data from *ReefBase Pacific*, the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless otherwise indicated with a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimated, proj = projected).

Overview

Samoa (previously known as Western Samoa) consists of the 2 volcanic high islands of Upolu and Savai'i, and a few smaller islands nearby. Samoa's coral reefs are mainly fringing reefs that surround the islands, and extend to 3 km off the northwestern coast of Upolu [3]. Samoa is approximately 4000 km south southwest of Hawaii, and 100 km to the west of American Samoa. The Samoan population is more dispersed than American Samoa with only 20% living in urban centres. The population of the capital Apia was about 36 000 in 2009 [2]. Agricultural production (e.g. copra, coconut cream, coconut oil) employs two thirds of the workforce and comprises 90% of exports [2], although tourism is a growing sector.

The diversity of Samoa's coral reefs has yet to be extensively studied [3]. Surveys have recorded up to 124 hard coral species, 991 fish species, 287 algae species, 5 turtle species, 4 giant clam species, 3 mangrove species and 2 seagrass species [3]. Coral reefs in Samoa have been monitored since the International Year of the Reef in 1997, and also as part of the Global Coral Reef Monitoring Network (GCRMN) since 2002 [3, 4]. Reefs in Samoa are affected by events such as cyclones and outbreaks of crown-of-thorns seastars (COTS), but are also affected by human impacts such as fishing, pollution and coastal development, and outbreaks of introduced invasive species.

Status, health and resilience of coral reefs

Samoa's coral reefs have been assessed and surveyed since the mid 1980s by various agencies and organisations [3]. The main monitoring programs currently operating in Samoa include: annual monitoring of marine protected areas (MPAs) set up through Samoa's community-based management program run by the Samoan Fisheries Division (FD); annual surveys of coral reef


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benthos and communities at 10 GCRMN long-term monitoring sites since 2002 (these sites are part of the community based fisheries MPA sites monitored by the FD); and monitoring of permanent transects in multi-use MPAs in the Aleipata and Safata districts as part of a IUCN and Samoan Government project [3, 4]. Benthic cover is surveyed using point intercept transects every 2 m along a 50 m line transect. Fish communities are surveyed using visual counts of fish within a 50 m x 3 m transect [4]. Monitoring is restricted to the back reef (lagoon, reef flat) at depths between 2 and 5 m. Data from 8 sites (4 on Savai'i and 4 on Upolu) between 2003 and 2007 are reported here.

Trends in coral cover are dominated by recovery from Cyclone Heta which slightly affected some reefs around Samoa in 2004 [3], and monitored reefs have shown some recovery since then. Between 2003 and 2004, coral cover (mean across all sites) was 34.4% [3], rising to 39.6% in 2006 and 42.7% in 2007 [4].

Most of the monitoring sites show similar trends in coral cover. Between 2004 and 2007, average live coral cover remained relatively stable at most sites, but increased at two sites: Papa i Puleia increased from 36% to 56% cover; Saleapaga increased from 16% to 30%; and decreased at Suifaga from 28% to 20%. In 2007, the highest live cover recorded at the Fagamalo site on northwest Savai'i (80% cover) [4], and lowest at the Suifaga site on north Savai'i (19.9%). This site has had the lowest coral cover over the previous surveys (Fig. 1). *Acropora* species are the dominant hard corals at most sites except for Safa'atoa (south Upolu) [4]. Minor coral bleaching was observed at Fagamalo, Papa i Puleia and Vaisala but this was attributed to exposure of elevated portions of some corals during low tides [4].

Coral cover at the Palolo Deep (north Upolu) and Suifaga sites have probably been affected by human impacts, especially poor water quality. The Palolo Deep site is near the Vaisigano river which delivers significant amounts of nutrient into coastal waters [4]. Suifaga has been a dredging site for many years and may be affected by these activities [4]. Nevertheless, the coral reefs of Samoa appear to be in generally good condition, with relatively stable levels of live coral cover and no significant degradation or declines reported.

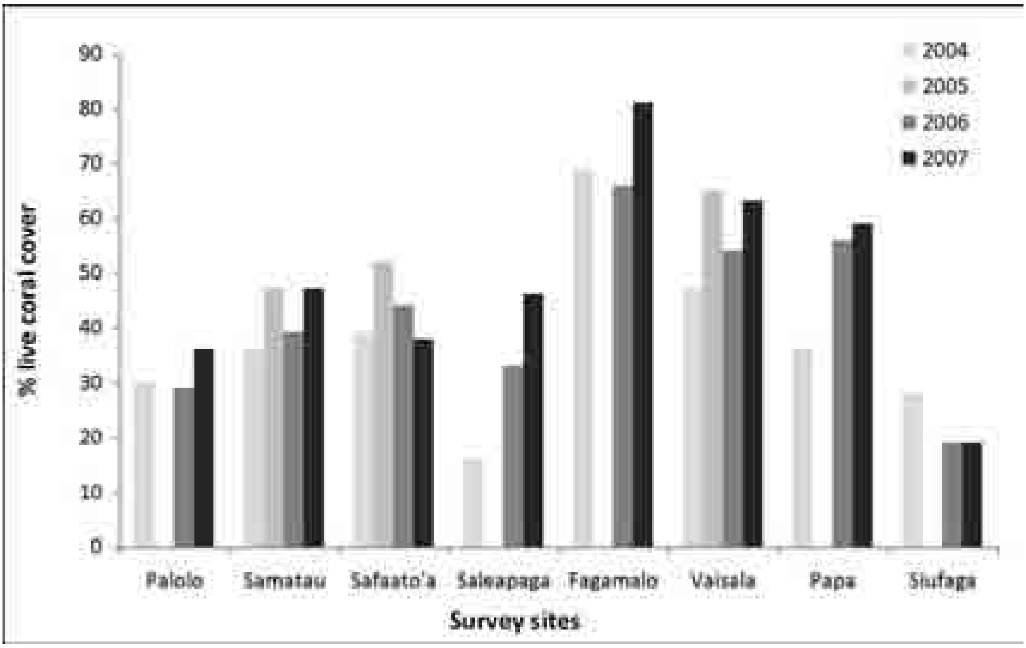

Fig. 1. Percent live coral cover recorded at 8 sites around Samoa from 2004 to 2007. Most sites had relatively high coral cover with little change over the years (Fig. from data in Samuelu and Sapatu 2009.

Fish surveys record the abundance of several species, including species that are indicators of reef health or are targeted food fish. These species include butterflyfish (*Chaetodontidae*), damselfish (*Pomacentridae*), rabbitfish (*Siganidae*), surgeonfish (*Acanthuridae*), parrotfish (*Scaridae*), triggerfish (*Balistidae*), goatfish (*Mullidae*), groupers (*Serranidae*), emperors (*Lethrinidae*) and wrasse (*Labridae*) (4). Surveys between 2003 and 2007 show that the most abundant reef fish are damselfish, surgeonfish, wrasse and parrotfish (3, 4). Most fish observed were reported to be juveniles, and large fish such as snappers (*Lutjanidae*), emperors and groupers were only observed in low numbers and had an average size of about 30 cm (5). Surveys suggest that fish abundance and diversity are higher on more exposed outer slopes (5).

Status of coral reefs – STABLE (low confidence)

The information available suggests that Samoa's coral reefs have moderate to high levels of live coral cover, and that they are recovering from damage experienced during Cyclone Heta in 2004. There is little evidence of widespread and prolonged stress, damage, or loss of live coral cover. However, systematic long-term monitoring of coral reefs in Samoa is relatively new with few available data; this reduces the confidence of this assessment.

Coral reef health and resilience – NOT CONSIDERED

There is insufficient information to describe the health and resilience of Samoa's coral reefs. Further monitoring of reef processes (e.g. recruitment, reproduction) is required on disturbance and recovery, and trends in coral cover and community composition.

Use of reef resources

Subsistence and artisanal fishing in inshore areas is a very important activity [4], with more than 70% of villages located on the coastal fringe [5]. In 2006, a socioeconomic survey by the Samoan Fisheries Division of 939 households in 49 villages with 7778 individuals documented the importance of fishing for income and food security. Fishing comprised 41% of the mean household income, and over 20% of households were heavily dependent on fishing for income. Average finfish consumption was about 60 kg per person per year (163 g per day); substantially higher that the world average of 12 kg per person per year [3]. People in villages with fisheries management plans tended to have higher consumption of fish. This could indicate some successes in Samoa's Community Based Fisheries Management Program (CBFMP) with participating villages experiencing higher catch per unit effort and increased quality of fishing [4]. Villages closer to Apia (the capital of Samoa) ate less fresh fish than those further away.

The Fisheries Division also conducts weekly monitoring of fisheries landings at selected outlets [3]. Finfish are the dominant group harvested and include species such as unicornfish (*Ume*), parrotfish (*Fuga*), surgeonfish (*Pone, Alogo*) and mullet (*Anae*) [3]. There has been a slow change from subsistence to artisanal fishing with the growing cash economy, and this has increased pressure on inshore fisheries resources through overfishing and destructive fishing practices [4]. However, subsistence fishing still accounts for the vast majority of the catch, with 13 666 metric tonnes landed in subsistence fisheries in 2006/07, compared to 126 tonnes landed and sold for domestic consumption [4]. Increased public awareness has reduced the incidence of destructive fishing, however there are isolated cases of destructive fishing (use of bombs and Derris poisons) reported amongst subsistence fishers [4]. Samoa also has a history of exporting wild-caught aquarium fish, live corals, live rock and other reef organisms for the aquarium trade, particularly between the late 1980s and mid 1990s. In 1992, more than 65 000 aquarium fish were exported [5], however, exports have declined with only 183 fish exported in 1996 [3] and the aquarium fishery is currently not active [4].

Surveys in the 1990s reported reduced fish biomass in more heavily fished areas, and dramatic declines of fisheries stocks, attributed to habitat destruction, overfishing, destructive fishing and improved fishing technology [5]. Many of the fish were very small, with the most of the predator species from reefs and lagoons being between 16 and 20 cm in length, these are below the minimum legal size set by fisheries regulations [5]. As previously discussed, more recent surveys show that most fishes appear to be juveniles and many are also relatively small in size. The 2006 socioeconomic surveys reported that 66% of respondents felt that there were fewer fish than 10 years ago [4]. There is also an apparent long-term decline in species such as giant clams (*Tridacna* spp.), milkfish (*Chanos chanos*), mullet (*Mugil cephalus*) and giant triton (*Charonia tritonis*) [3]; many other species are considered threatened by over-harvesting [6]. This information suggests that Samoa's fisheries resources have changed significantly. The UNEP/SOPAC Environmental Vulnerability Index [7], *Reefs at Risk Revisited* and the Pacific Ocean Synthesis Report [8] indicate that fishing poses a significant threat to Samoa's marine environment and coral reefs. Unsustainable fishing in many areas has threatened to undermine nutrition and standard of living in villages [9].

Tourism in Samoa is increasing, with tourist numbers increasing by 7.5% in 2005 and by 20% in 2006, potentially due to increased airline access [9]. In 2007, tourism generated a record US $108 million and is a sector that has significant potential for future economic growth [4, 9]. The UNEP/SOPAC assessment [7] indicates that tourism could pose some risk to Samoa's marine environment, most likely through coastal development for tourism infrastructure.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

The available information suggests that Samoa's marine resources have degraded due to direct human use, especially fishing. Fish abundance and diversity is lower, and fish sizes are relatively small. Villagers perceive that the resource has declined; however, fish consumption is relatively high indicating that fishing is still a viable activity. Community-based fisheries plans may improve sustainability, however, more information is needed on trends in fishing activities, production and sustainability.

Factors affecting reef health and condition

Samoa's coral reefs and marine environment are affected by indirect pressures including pollution, poor land-use practices, invasive species, storms and climate change. The vulnerability of reefs has been assessed through focused risk assessments developed in Samoa (Table 1), which identified coastal development as the main issue at 5 sites, with land-based pollution and sedimentation affecting some sites [4]. The major coastal developments include construction of sea walls intended to reduce coastal erosion, reclamation for business and residential developments, road construction, and development of hotels, resorts, and other tourist infrastructure [3, 4]. The development of a new marine slipway could affect the Aleipata MPA [6]. Reclamation and development has damaged seagrass beds and coastal vegetation, wetlands and other natural ecosystems [3]. Mangroves have been cleared and damaged though dumping of rubbish, land reclamation and pollution [4, 6]. Sand mining and coral dredging occur nationwide to supply building material [3], and uncontrolled sand mining is a concern [9].

While 48% of Samoa's main islands remain forested, deforestation and habitat degradation have increased soil erosion in many areas [4, 6, 9]. The widespread dieback of coral on northern Upolu between 1970 and 1985 was likely due to sedimentation and eutrophication [3]. Poor land-use practices associated with agriculture, forestry, housing and road construction are causing eutrophication near river mouths and in lagoons. The Vaisigano River is a major source

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Table 1. Integrated Threat Analysis for 5 sites around Samoa shows that coastal development is the major issue affecting these sites. Note that fishing pressure is low as these sites are all marine reserves; (Table from Samuelu and Sapatu 2009).

OVERALL: INTEGRATED THREAT INDEX						
Reef Area	Coastal Development	Marine Based Pollution	Pollution and Sedimentation	Artisanal Over-fishing	Destructive Fishing	Overall Threat Index Score
N Upolu	Medium	High	High	Low	Low	Medium
SE Upolu	Medium	Low	Low	Low	Low	Low
SW Upolu	Medium	Low	Medium	Low	Low	Low
N Savaii	Medium	Low	Low	Low	Low	Low
SE Savaii	Medium	Low	Low	Low	Low	Low

of nutrients and bacteria (3), and sewage and wastewater are persistent issues of concern in Apia (9). Drainage and waste treatment systems are inadequate, with many households using poorly maintained septic tanks (4). The disposal of municipal waste is unsustainable, with some communities continuing to burn waste or to discard it into the surround area, directly into waterways, wetlands or into coastal waters (3, 4). Chemical waste and runoff of pesticides and fertilisers threaten to contaminate coastal waters (3, 4, 9). Collectively, these pollutants comprise a significant threat to Samoa's marine environment. The 2005 UNEP/SOPAC Environmental Vulnerability Index (7) suggest that farming, fertilisers, coastal development and population density and significant threats to Samoa's environment. This is echoed finding in the 2011 *Reefs at Risk Revisited* assessment.

Samoa's coral reefs are also affected by cyclones, outbreaks of crown-of-thorns seastars (COTS), coral disease and warm water leading to coral bleaching events. There were 12 cyclones between 1950 and 2004 which affected 42% of the population (9). Cyclone Heta affected 13% of Samoa's coral reefs in 2004 (3). COTS outbreaks have also previously damaged reefs around Samoa but there have been no recent widespread outbreaks. However, the spread of introduced invasive algae (*Codium arenicola* and *C. prostratum*) from Apia harbour into nearby reef-slope environments is a cause for concern (4, 9). Samoa's coral reefs have not experienced widespread coral bleaching in recent years; however, climate change predictions indicate more frequent and intense bleaching events, strong winds and storms, rainfall and drought, and sea level rise. Many Samoans and their economic activities are concentrated in narrow, low lying coastal areas that are vulnerable to flooding and sea level rise (7, 8).

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

Many indirect factors threaten Samoan coral reefs, and some of these risks have increased recently or are likely to increase in the future. Some coral reefs have been damaged, principally from overfishing, coastal development, pollution and run-off from land-based sources; however, the information is insufficient to quantify trends.

Governance and management

Samoa has several legislative acts, policies and programs to manage and sustain marine resources. The National Parks and Reserves Act (1974) provides for the establishment of parks and reserves and regulates the use of those areas. The Fisheries Act (1988) regulates fishing activities as well as marine pollution, and the Lands, Surveys and Environment Act (1989) covers

Reefs at Risk Revisited: Samoa

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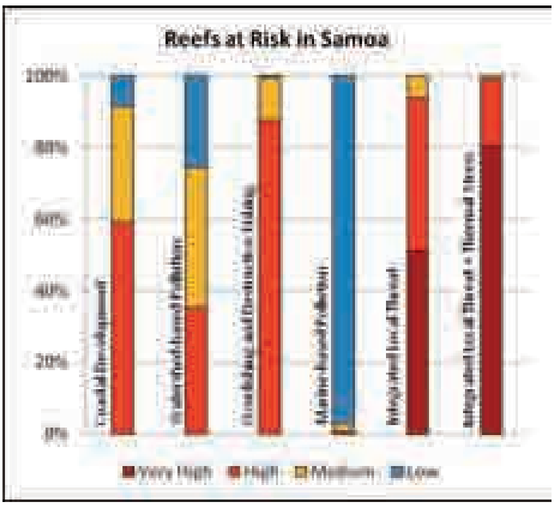
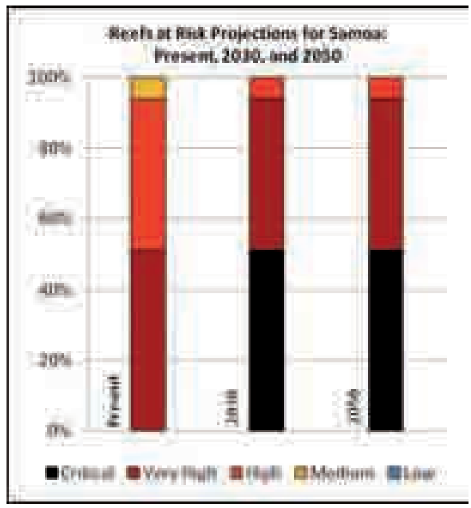
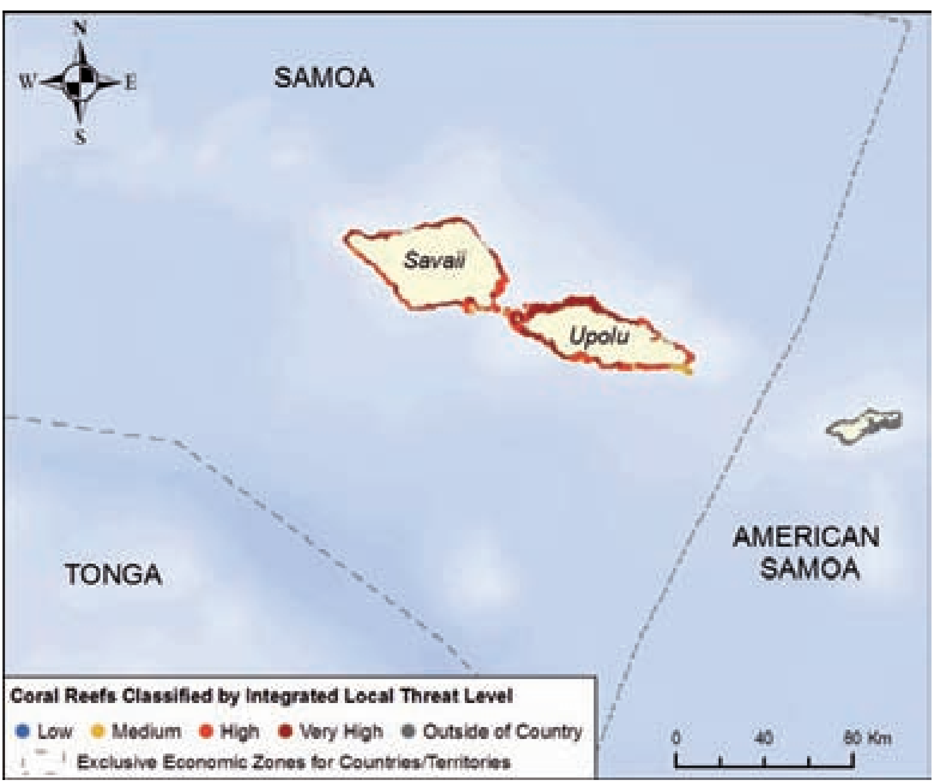
The Reefs at Risk Revisited analysis found that almost all of Samoa's coral reefs are threatened, primarily by overfishing, land-based pollution and coastal development. When adding in thermal stress over the past 10 years, 80% of reefs are very highly threatened. Projections for thermal stress and ocean acidification suggest that pressures will increase to the extent that half of Samoa's reefs will be in a critical state by 2030. The full report, methods and full size maps are on: http://www.wri.org/reefs.







environmental impact assessment, environmental planning and policy, pollution control and conservation of natural resources and the environment [3]. Samoa is a signatory to the Convention on Biological Diversity [6] and in 2002, Samoa declared its EEZ as a sanctuary for all whales, turtles and sharks [6].

In 1995, the Community Based Fisheries Management Program (CBFMP) was launched to address concerns over declining fisheries. This a collaborative effort between the Fisheries Division and local communities that assists villages in effectively managing and protecting their marine resources [4]. Under the program, each village develops a fisheries management plan that is tailored to the needs of the community. The CBFMP now includes 89 villages from across Savai'i and Upolu, and constitute more than 25% of all the villages in Samoa [9]. These villages have by-laws that are legally recognised by Samoa's legal system [3, 4]. The program has established 51 community based MPAs with a combined area of 38.8 km^2, include 50 no-take zones that cover 9.4 km^2 [1]. The Samoan Department of Environment and Conservation (DEC) recognises a further 8 MPAs including the Aleipata and Safata Marine protected Areas which cover 81.1 km^2 [1] and includes 20 villages [4]. The remaining 6 protected areas include MPAs covering approximately 89 km^2 but this could be an overestimate [1]. Both the FD and the DEC aim to improve collaboration and establish more MPAs in Samoa.

Villages that have developed fisheries management plans through the CBFMP are reported to have substantially higher fish catch and consumption, such that the CBFMP is viewed as a crucial management tool in supporting sustainable livelihoods for the rural population [4, 9]. However, long-term monitoring and survey data are not readily available for all MPAs and monitoring has only recently begun for some. Thus trends in management of land use and pollution are difficult to determine. Some achievements have been reported (for example, improved compliance with dumping and pollution regulations by vessels at the Fisheries Wharf [3]), but monitoring and enforcement is difficult due to limited resources and difficulties in regularly accessing more remote areas [3]. Non-compliance with the ban on destructive fishing has been reported, and concerns have been raised about the adequacy and effectiveness of environmental impact assessment processes [9].

Governance and management – EVIDENCE OF CHANGE (low confidence)

Samoa has several planning instruments and legislative acts to manage the marine environment, and the community based program is reported to be improving the status of fisheries through a strong commitment to maintain and expand these MPAs. However, there are few long-term data available that quantify the status and trends of fish populations and management effectiveness, although monitoring is now being expanded.

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Tokelau

- Marine Area: 290 000 km²
- Coastline: 101 km
- Land Area: 12 km²
- Reef Area: 97 km²
- Total MPAs: 3
- Area of MPAs: 1 km²
- Percentage of reefs threatened (local threats and thermal stress 2011): 71%
- Population (2011 est): 1 384 [1]
- Population (2050 proj): No Data
- Population growth (2011 est): -0.01% [1]
- Urban population (2010): 0% [1]
- GDP: USD $1.5 million (1993 est) [1]
- GDP/Cap: USD $1 000 (1993 est) [1]

Data from ReefBase Pacific, the SPC Statistics and Demography database**,** *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated; proj = projected).

Overview

Tokelau consists of 3 small coral atolls within an expansive EEZ of some 290 000 km². The central atoll, Nukunonu, is the largest with an area of 4.7 km² [3]. Atafu atoll is 92 km northwest from Nukunonu; and the southern atoll, Fakaofo, is 64 km southeast of Nukunonu. The atolls are only 3-5 meters above sea level, making Tokelau very vulnerable to the effects of climate change [3]. These coral sand atolls do not support food crops apart from breadfruit, coconut, pandanus, banana and giant swamp taro, although banana and taro are rarely cultivated now [3].

Tokelau is a New Zealand Territory and Tokelauans have New Zealand citizenship with the nearest neighbour being Samoa, 480 km to the south. These islands are isolated and transport to Tokelau is by ships departing from Samoa. There are 4 villages in Tokelau, one each on Atafu and Nukunonu, and two on Fakaofo. Tokelau's population is only 1 466 permanent residents. Atoll level administrative and legislative powers reside with the 3 *Taupulega* (Village Council of Elders) while national interests reside with the General *Fono* (parliament). Through these arrangements, the majority of key public services remain with national level administration, which is based in Samoa [3].

The little available information on Tokelau's coral reefs indicates that the reefs are periodically affected by outbreaks of crown-of-thorns seastars (COTS), cyclones and coral bleaching [3, 4]. The potential effects of climate change are a growing and significant concern to Tokelau [3].

Status, health and resilience of coral reefs

Tokelau's coral reefs have been surveyed periodically since the 1960s. Brief surveys in 1969 and 1971 reported that coral growth in the lagoons was limited to the upper portions of old coral massifs. There are anecdotal reports of COTS being present during the late 1960s but few COTS were observed during surveys in 1971. Extensive coral mortality in reef shallows around Nukunonu was reported in early 1983 due to a sudden drop in sea level of about 60 cm, which may have been associated with an abnormal El Nino event [4].

Surveys of the effects of Cyclone Tusi on the 3 atolls in 1987 noted that coral growth was diverse, but not 'luxuriant' at unaffected sites before the cyclone [4]. There was widespread coral damage by massive storm waves on outer reef slopes at exposed sites. Coral mortality varied between sites, but was up to 90% in some areas. No damage was evident in Fakaofo lagoon although large quantities of rubbish were deposited by the cyclone; the other 2 lagoons were not inspected [4]. Surveys at Atafu before the cyclone (and also in 1987) reported 90-100% coral mortality on the north-western outer reef slopes; this was probably due to the grounding of a Korean ship which was subsequently 'blown up' with explosives in 1981 to remove it [4].

Long-term monitoring sites were established in 2003 by the Secretariat of the Pacific Regional Environment Programme (SPREP), and recorded a mean live coral cover of 66% on the reef-slopes at 10 to 12 m depth [2]. In 2005, 3 long-term monitoring sites on Fakaofo atoll were established as part of the Polynesia Mana node of the Global Coral Reef Monitoring Network (GCRMN), with support from SPREP, CNRS (French National Sciencific Research Center), IFRECOR (the French coral reef initiative) and AFD (the French development agency). The reefs were surveyed using random photo quadrats at 6 m depth [2]. This method was chosen in recognition of the limited capacity and logistical constraints for monitoring by community members in Tokelau [2].

Three survey sites were selected in 2005 in consultation with the Fakaofo *Taupulega*: the 'shipwreck' site; the Fakaofo conservation area; and 'Graveyard Motu'. Live coral cover was low at all 3 sites, ranging from 30.3% to 12.0% cover (Table 1). The surveys showed high incidences of coral disease, with diseased corals outnumbering healthy corals at 2 of the 3 sites [2]; the reason for high disease prevalence was not clear [2]. Many feeding scars on live corals were also observed, probably from the coral eating snail *Drupella* sp. The 2003 SPREP surveys found evidence of coral bleaching in the previous 2 years. No recovery was evident in the 2005 surveys and coral bleaching is reported to have become an annual event in the lagoons and on the outer reefs, and damaging fish communities [3]. Concerns have also been noted about the spread of black algae from the shipwreck site [2].

Table. 1. Benthic composition of sites surveyed in 2005 showed low coral cover and a high incidence of coral disease. Algal cover was dominated by coralline algae which are a good settlement platform for new corals (data from Vieux 2005 [2]).

Sites surveyed in 2005	% live coral cover (total)	live coral cover (healthy or diseased)	% cover algae	% cover dead coral	Comments
Shipwreck	14.7	4.7% cover healthy 10% cover diseased	24.2	59.0	Almost all algae were pink coralline algae; dead corals were not recent
Fakaofo conservation area	30.3	11.5% cover healthy 18.8% cover diseased	22.0	44.0	Almost all algae were coralline algae; dead corals were not recent
Graveyard motu	12	7.6% cover healthy 4.4% cover diseased	51.0	35.0	Almost all algae were coralline algae; dead corals were not recent

Status of coral reefs – NOT CONSIDERED

There are reports of past damage to Tokelau's coral reefs from cyclones and COTS. There are particular concerns about climate change and coral bleaching, however, recent long-term monitoring is insufficient to describe coral reef status and trends. Continued monitoring will provide better information on status and trends.

Coral reef health and resilience – NOT CONSIDERED

Monitoring is insufficient to describe the health and resilience of these coral reefs. More monitoring is required to determine reef recovery from disturbances.

Use of reef resources

Tokelau's coral reefs and marine environment are very important for food security, especially since poor soil quality limits agricultural production [3]. In 2003, 75% of the households across the 3 atolls were surveyed [5] with surveys showing that almost all were actively involved in fishing, demonstrating the high dependence of Tokelauans on marine resources. People fish on the reef and lagoons using gill nets, spearfishing, diving, reef gleaning and bait fishing. Fishing outside the reefs was by trolling for pelagic fish (e.g. tunas) or bottom fishing [5]. Fishing effort is divided fairly evenly between the reef lagoons and outside for pelagic or deepwater species. The surveys found that fishers have changed from canoes to aluminum dinghies with outboard motors which is improving efficiency and expanding catches [5].

Tokelau gains significant revenue through agreements with foreign fishing vessels to catch tuna in its EEZ [3]. However, there are concerns over the effectiveness of existing management arrangements for this fishery [3]. There are also concerns about the loss of traditional skills and fishing methods, more recent 'aggressive' fishing practices, and threats such as COTS that could threaten the sustainability of fish resources [3]. Advances in fishing technology such as powered dinghies, mono-filament gill nets, steel fishing hooks and fish aggregation devices, could greatly increase fishing efficiency which could threaten sustainability [6]. There have been reports of declines in the number of turtles, giant clams, black pearl oysters and coconut crabs [4, 6, 7]. Surveys in 2003 also revealed community concerns over perceived declines of fish such as *atule* (yellow-tail scad), *maeava* (rabbitfish), *tonu* (red coral trout), *uluakata* (giant travally) and *atu* (skipjack tuna) [3]. Communities also believed that declines in fish stocks may be linked degradation of coral reef habitats from pollution [3]. However, fish are generally still reported to be abundant, with people catching fish for sport, or to feed to pigs [7]. The unnecessary wastage of caught fish was raised as a concern, with reports that large amounts of fish were 'thrown away' [7].

There are few data available on fishing and fisheries in Tokelau, which introduces significant uncertainty in describing the status and trends of reef resources. The 2009 Pacific Ocean Synthesis Report [8] did not assess fishing in Tokelau, the 2005 UNEP/SOPAC Environmental Vulnerability Index [9] identified fishing as a relatively minor risk while the 2011 *Reefs at Risk Revisited* report suggests that 45% of Tokelau's reefs are threatened (medium risk or higher) from fishing activities.

There is very little tourism in Tokelau due to limited access and infrastructure [3]. However, effects of any potential tourism (such as coastal development, pollution, and increased demand for marine resources) and development will need careful management [3]. Small-scale, low impact, boutique ecotourism is being considered for further development of the tourism industry [10].

Use of reef resources – NOT CONSIDERED

The few data on fishing and fisheries report declines, and improved fishing technology could dramatically increase fishing efficiency; the potential effects of this on sustainability in Tokelau are unknown. More information and monitoring is required.

Factors affecting reef health and condition

Tokelau's environment and coral reefs may be affected by several factors. The main issues of concern are climate change, sea level rise, droughts, cyclones, tsunamis, pollution and waste management [3, 10]. As a small country, disasters can cause proportionally greater damage on a national scale than to larger countries [10] and particularly change the availability of marine resources. Cyclones are a significant factor, with 3 cyclones affecting Tokelau in the late 1980s and early 1990s (Tusi 1987, Ofa 1990 and Val 1991), with Cyclone Ofa being the worst in living memory. These cyclones and storm surges cause coastal erosion, damage freshwater supplies, increase soil salinity and destroy crops [10]. The 2005 UNEP/SOPAC assessment [9] lists Tokelau's isolation and the low lying topography as severe environmental risks.

Climate changes are reported to be affecting Tokelau's environment, with reports of increased frequency of cyclones and storm surges with more intense impacts. These have reportedly eroded coastal areas, some small islets have disappeared, and some species of plants have disappeared due to increased soil salinity [3]. Corals are declining from regular coral bleaching and warm temperatures, which have also caused changes in the quantity and quality of fish caught in the lagoons [3]. The 2011 *Reefs at Risk Revisited* suggests that by 2030, rising temperatures and ocean acidification could threaten all of Tokelau's reefs.

Pollution is also an issue in Tokelau; in 2002, more than half the households in Tokelau had 'sea latrines' with sewage disposed directly into the lagoon, and other households had septic tanks. Drainage is inadequate so chemicals such as bleach, disinfectant and detergent are discharged directly into the ground, and able to flow directly into adjacent reef lagoons. The lack of a jetty means that cargo from supply ships is offloaded over water into small dinghies, including chemicals and oil drums which sometimes, are 'floated' between the ship and beach. This exposes these reefs to spills of oil and other chemical pollutants [3, 10]. A significant pesticide spill in 1969 killed all the corals in a 2 km section along Motu Te Kakai in Nukunonu lagoon, and there had been little coral recovery by 1975 [4]. Furthermore, the reef lagoons have low exchange rates with the ocean and consequently, solid waste, sewage and pollution remain in the lagoon for extended periods, exacerbating their effects on the marine environment [3]. There are also concerns that pollution from the 20 year old rusting shipwreck of the *Ai Sukula* on Fakaofo is contributing to algal blooms and increasing ciguatera poisoning [2, 3, 7]. However, there are no quantitative studies or data to establish this link [6].

Disposal of solid waste is also an issue [3, 7, 10]. While organic waste is often composted, other garbage is burnt or buried in secluded locations on the atolls and islets, but waste is sometimes dumped into the lagoon [10]. There are no adequate facilities to dispose of chemical or hazardous waste. The increase in imported goods from Samoa also introduces non-biodegradable waste to the atolls.

Coastal development in Tokelau has included reef-blasting to build boat channels to provide deep water access to the 3 atolls [4], and the construction of sea walls near villages to mitigate the storm surges and rising sea levels [3]. Sea wall construction is reportedly driving unsustainable sand and coral mining [3]. The Pacific Ocean Synthesis Report lists coastal development, oil spills and chemical pollution and sea level rise as threats to Tokelau's marine environment [8]. Coastal development is also listed as a potential threat in the *Reefs at Risk Revisited* analysis and the UNEP/SOPAC assessment.

Factors affecting coral reefs – STABLE (low confidence)

The factors affecting Tokelau's coral reefs include those associated with climate change (sea level rise and coral bleaching), pollution, and coastal development. However, there is insufficient information to quantify these risks.

Governance and management

Tokelau has some legislation and planning to protect and manage its marine resources and coral reefs. However, the judicial system is not fully developed [3] and authority rests largely with the village leaders (*Taupulega*) on each atoll. Inshore coastal management plans were developed for each village, and a national waste management plan was finalised in 2007 which led to each village developing its own waste management plan [3]. An agreement with Samoa was also finalised to send recyclable material to Samoa [3]. Nukunonu has a rubbish collection service which has helped to reduce the amount of waste entering the marine environment [10].

The need for additional management has been identified. There is a push to improve management of tuna fisheries in Tokelau's EEZ [3], and communities have expressed interest in adding specific fishing regulations to existing by-laws [7]. Legislation is also needed to prevent further damage from indiscriminate sand and coral mining, and to regulate imports of non-biodegradable goods to reduce the amount of solid waste [3].

Composting toilets have been trialled to replace sea latrines and septic tanks. These could reduce seepage of nutrients into the lagoon, conserve rainwater (by replacing flushing toilets), and produce much needed natural fertiliser [10].

Most of the land and sea in Tokelau is under customary tenure and there are *lafu* in place, which are traditional bans or closures on the take of marine resources [7, 11]. *Lafu* have been incorporated into community-based fisheries management plans developed in 2004 [7]. There are currently 3 managed *lafu* areas in Tokelau, which cover 1.7 km^2 [11]. These could be considered as locally managed marine areas that rely on community engagement and enforcement.

There are indications of inadequate enforcement and compliance with fisheries regulations and *lafu* in Tokelau. Communities have expressed concern that restrictions on the mesh size of gill nets are not enforced, and there is a lack of awareness about fishing rules and regulations [7]. However, communities on Nukunonu felt that there was good compliance with their *lafu,* which had many giant clams and showed signs of 'regeneration' [7]. One of the challenges to management identified by communities and the Tokelau government is the lack of resources and capacity. There are more Tokelauans living overseas than on the islands, and a lack of skilled personnel in fisheries and marine resource management is a significant problem [3, 7]. Tokelau also has a limited capacity to manage its EEZ, exposing Tokelau's waters to illegal commercial fishing [3].

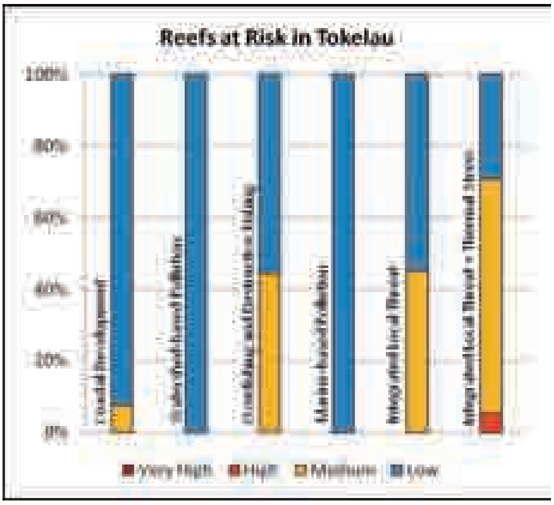
Governance and management – NOT CONSIDERED

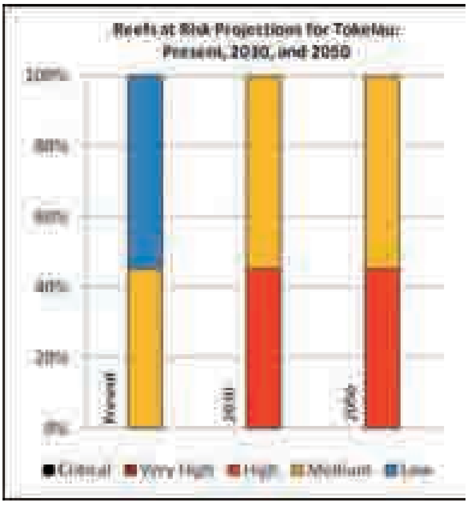
Tokelau has some legislation and regulations to manage marine resources and protect coral reefs, but the need for additional management is evident. Management relies heavily on community commitment to implement and enforce rules and regulations, with evidence of inadequate compliance, enforcement, and capacity in marine and fisheries management. However, there is currently insufficient information to assess the effectiveness of existing management.

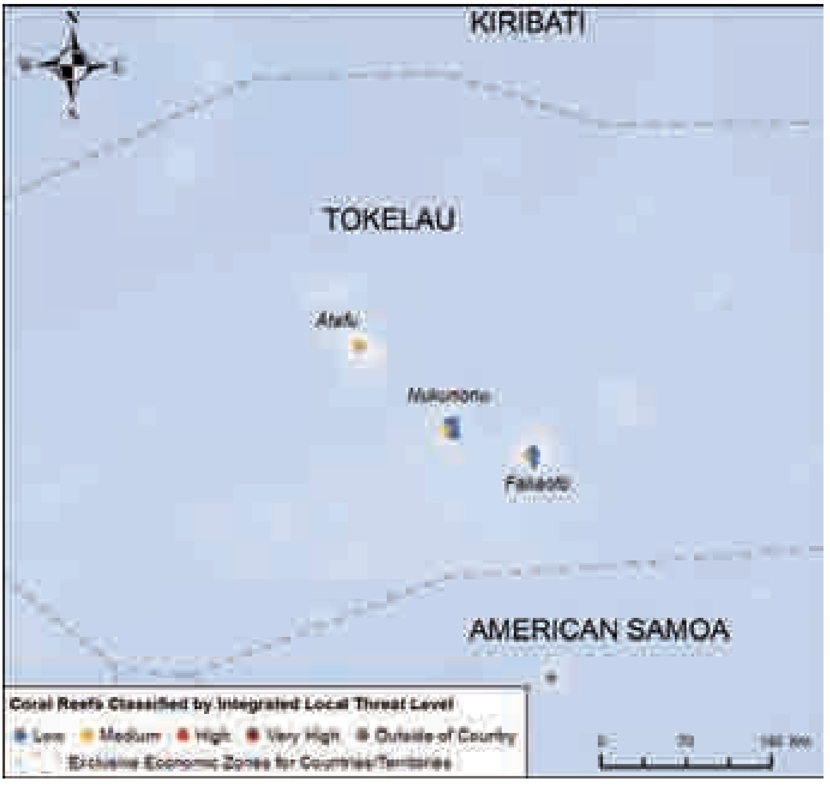
Reefs at Risk Revisited: Tokelau

WORLD RESOURCES INSTITUTE

The Reefs at Risk Revisited assessment estimates that about 45% the Tokelau's coral reefs are threatened by local factors, primarily overfishing and coastal development. Thermal stress over the past 10 years adds to these local stressors, increasing the number of threatened reefs in Tokelau to about 70%. Projections for thermal stress and ocean acidification from climate change suggest that by 2030, all coral reefs in Tokelau will be threatened. The full report, methods and full size maps are on: http://www.wri.org/reefs.







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Tonga

- Marine Area: 700 000 km^2
- Coastline: 419 km
- Land Area: 718 km^2
- Reef Area: 1 500 km^2 [1]
- Total MMAs: 18 (6 active) [1]
- Area of MMAs: 10 009 km^2 [1]
- Percentage of reefs threatened (local threats and thermal stress 2011): 75%
- Population (2011 est): 105 916 [2]
- Population growth (2011 est): 0.2% [2]
- Urban population (2010): 23% [2]
- GDP: USD $767 million (2010 est) [2]
- GDP/Cap: USD $6 300 (2010 est) [2]

Data from *ReefBase Pacific,* the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used; (est = estimate, proj = projected).

Overview

The Kingdom of Tonga consists of 174 islands spread over 4 main island groups: Tongatapu; Ha'apai; Vava'u; and Niua. Although 37 islands are inhabited, most of the population lives on the island of Tongatapu where the capital Nuku'alofa is located [3]. Most of the population is engaged in subsistence farming and fishing. Tonga's islands include both volcanic, including active volcanoes, and uplifted coral islands and reefs which emerge from two submarine ridges than run north northeast from Tongatapu towards Samoa [3]. Fiji lies about 740 km to the northwest, and Niue is approximately 600 km to the northeast. The Tongan archipelago contains fringing, barrier and submerged patch reefs. Although the coral reefs extend along the fringes of all the islands, there has been little scientific monitoring and assessment of most reef areas and many islands have not been mapped and surveyed [3].

Surveys of 11 reefs from around Tongatapu recorded 192 hard coral species, and 1993 surveys in marine parks around Tongatapu recorded 229 species of fin fish from 39 families, the most common being wrasses (Labridae) and damselfish (Pomacentridae). Some 55 species of bivalves, 83 gastropod species, and 13 sea cucumbers (bêche-de-mer) have also been recorded [3]. These figures are probably underestimates, with probably more than 300 coral species considered to occur in Tonga [4].

Tonga's coral reefs and marine ecosystems face numerous pressures including pollution and sedimentation from land-based sources, over-harvesting of marine resources, destructive fishing, loss of mangroves and wetlands and marine based pollutants [4].

Status, health and resilience of coral reefs

There is limited information on Tonga's coral reefs [3]. Previous studies from 1996 and 1997 report coral cover ranging from 2% at Mounafe reef to 50% at Hakaumama'o reef reserve. Surveys in 1996 found a mix of healthy, degraded and recovering coral communities from 36 sites sampled around Vava'u. The presence of crown-of-thorns seastars (COTS) was evident from feeding scars [3]. The 2004 Global Coral Reef Monitoring network (GCRMN) status report noted efforts to establish monitoring programs to collect baseline data and review existing information in several areas [5]. GCRMN surveys were conducted in conjunction with the Environment Department, with 3 transects established at each of 2 sites in Vava'u in 2005. These preliminary surveys found relatively low live coral cover, with a mean cover of 15% near Tefisi Village, and 13% near Toula Village [6]. Several other monitoring sites were recommended for Tongatapu to monitor trends in reefs that could be affected by coral harvesting for the aquarium trade and tourism, and to monitor marine protected areas (MPAs) [6].

In 2009, a new long-term monitoring site was established on the outer slope of the west coast of Tongatapu, at Ha'atafu, by the CNRS (French National Centre for Scientific Research) and the IRCP (Institute for Pacific Coral Reefs) through the CRIOBE (Centre for Island Research and Observatory of the Environment) based in French Polynesia, in collaboration with the Tongan Ministry of Fisheries. Twenty permanent quadrats were photographed for coral and benthos monitoring, and total reef fish communities are monitored along 50 m x 4 m transects. This site also belongs to the Polynesia Mana GCRMN node. This survey found relatively low percentages of coral cover (14%) and high cover of soft corals (31%).

Some reef monitoring data are also available from socio-economic surveys conducted between 2002 and 2008 by the SPC Reef Fisheries Observatory PROCFish program. This program surveyed 6 locations in Tonga during 2001 and 2002, and 4 locations around Tonga in 2008. These locations were Ha'atafu and Manuka on Tongatapu (12 transects in each location), and Koulo and Lofanga on Ha'apai (13 transects in each location) [7]. Comparisons of sites surveyed in both 2002 and 2008 showed increasing coral cover at all sites: Ha'afatu (increased from 17% to 28%); Manuka (21.4% to 28%); Koulo (16% to 32%); and Lofanga (16% to 25%) [7].

However, these surveys also highlighted significant concerns over the status of reef fish and invertebrates, with severe drops in abundance identified for several species [7]. Finfish resources were poor to very poor at Ha'atafu, Manuka and Koulo, but better at Lofanga, although values here were still lower compared to regional values. Herbivores, especially surgeonfish (Acanthuridae) were the dominant fish group, followed by parrotfish (Scaridae) although these were at much lower density and biomass than surgeonfish. Similar observations were made on the outer reef-slope during the surveys by CRIOBE in 2009. Fish communities were dominated by small fish, with mean sizes of several fish families below 50% of the maximum values, indicating significant fishing pressure [7]. Fish size and biomass has decreased in some areas since 2002. Size, biomass and abundance of predators such as emperors (Lethrinidae) and groupers (Serranidae) were especially low. Two to four species of giant clams were recorded, but some species such as the bear claw or horse clam (*Hippopus hippopus*) appear to have become locally extinct since the mid 1970s [7]. Giant clam distribution across the study sites was noticeably irregular, with very few clams close to sites such as Ha'atafu. Sea cucumber numbers were variable, with moderate numbers of some species such as the leopardfish or tigerfish (*Bohadschia argus*), but very few of other species such as the black teatfish (*Holothuria nobilis*), in spite of the complete ban on commercial harvesting of holothurians for 7-10 years [7].

Coral bleaching was reported in Tonga around Tongatapu and the Ha'apai group in February 2000 [3]. Bleaching was widespread on the reef slopes and lagoon, and was reported to be similar to that observed in Fiji with corals showing varying levels of bleaching. In the lagoons, the dominant *Montipora* coral showed only minor bleaching, while species such as *Goniastrea retiformis, Platygyra sinensis* and *P. daedalea* showed 80-100% bleaching [3]. On the reef slopes, corymbose *Acropora* corals were the most affected while tabulate corals were not seriously affected. Fortunately, there was little coral mortality (< 5%) from this bleaching event [3]

The few available data are from a small number of sites and years, thus trend estimates in coral cover are difficult due to the paucity of data. For example, the 2010 report on Tonga to the Convention on Biological Diversity reports that coral cover is declining across Tonga [(4)] (page 36), contradicting the ProcFish survey findings. No coral cover data for Tonga were reported in the 2008 GCRMN status report.

Status of coral reefs – NOT CONSIDERED

There is limited information available for Tonga, with the only data being from 4 sites which show increasing coral cover. Trends across the Kingdom are unclear. Early GCRMN reef monitoring and continued PROCFish monitoring will provide better information in future, but monitoring on other islands is required.

Coral reef health and resilience – NOT CONSIDERED

The available data are insufficient to describe the health and resilience of these reefs. Regular monitoring at existing sites and expansion to additional sites is required.

Use of reef resources

Coral reef resources are very important to the people of Tonga for income and food security. The main wild-capture fisheries in Tonga are offshore tuna and pelagic fish, deep sea fisheries for snappers and groupers and inshore artisanal and subsistence fisheries for reef species [(4)]. The PROCFish surveys found high rates of seafood consumption in coastal communities of up to 92 kg/person/year for finfish and 21 kg/person/year for invertebrates [(7)]. Shallow-water fisheries are a vital component of the subsistence fishery and are an important source of income with changes to a cash based economy [(7)]. Fish are mainly caught using handlines and spearfishing, although gill netting, cast netting and trolling are also used in some areas such as Ha'atafu. Invertebrates such as sea cucumbers, strombus shells, clams, octopus and lobsters are collected by free diving using low-cost equipment. Giant clam meat is a delicacy taken mainly for domestic consumption [(7)]. Unlike other Pacific islands, reef resources are 'open access' allowing multiple user groups to fish across Tonga. Destructive fishing practices still appear to be practiced, for example, bomb fishing is reported to be commonly used in Fanga'uta lagoon to target mullet [(4)].

Reef fishes constitute most of the inshore catch, supplying more than 70% of the total annual catch in Ha'apai [(7)]. Landings of reef fish in Nuku'alofa in 1993 made up 70% (200 mt) of the total artisanal finfish landings, with parrotfishes (Scaridae) being the main target. The PROCFish surveys showed that catch varied from place to place, but that the main finfish species landed included emperors, snappers (Lutjanidae), surgeonfish, parrotfish, rabbitfish (Siganidae), and groupers [(7)]. Humphead (Maori) wrasse (*Cheilinus undulatus*) has recently been targeted for live fish exports to Hong Kong after an exploratory commercial license was issued in 2009 [(4)]. Approximately 300 specimens were reported as being exported but the illegal landings from night divers is unknown, prompting calls for more protection for this species in Tonga [(4)].

Reef fish and other marine resources appear to have been moderately to seriously overexploited in Tonga [(3, 4, 7, 8)]. Black corals and molluscs were reported to be depleted in some areas, and the horse clam is probably locally extinct [(3, 7)]. As described above, clams and some sea cucumbers have significantly declined and are now in very low numbers [(7)]. Reef fishes have decreased in size, and large predatory fishes appear to be uncommon or rare. One species of mullet, *Mugil* *cephalus*, used to comprise up to 70% of the commercial mullet landings but is now believed to be 'on the verge of becoming locally extinct' [(7)]. Catches of deep water fish have also dramatically declined, prompting calls for increased controls to manage these stocks [(4)]. The giant clam (*Tridacna derasa*) is severely overfished and *Tridacna tevoroa* (endemic to Tongan waters) has been overfished in the Ha'apai group [(3)]. The cockle (*Gafrarium tumidum*) is extinct in certain parts of Tonga and is very rare in markets [(4)]. Aquaculture ventures and protected areas have been set up for species such as clams (e.g. community-based giant clam sanctuaries – 'clam circles) to help reverse declines in wild-capture fisheries [(3, 4)].

Sea cucumber exports were developed during the mid 1980s and peaked in 1992. Declines in harvests from 1992 led to harvesting being banned in 1997 [(7)]. Political pressure has led to the overturning of long-time bans on harvesting sea cucumbers. The 2009 harvest targeted species such as *Holothuria nobilis, H. fuscogilva* and *H. scabra* for the Asian market. These species are known to be vulnerable to fishing pressure and stricter management of these species is needed [(4)]. During the 1990s, trochus shells *Trochus niloticus* were introduced from Fiji and the green snail *Turbo marmoratus* were introduced from Vanuatu and Japan. Both species have become established and baseline assessments have been conducted to investigate stock status [(3, 7)]. Two species of giant clams have also been introduced to Tonga [(7)].

There is an active marine aquarium trade in Tonga. Fish used to be the main targets, but harvests of live rock and invertebrates have increased significantly since the late 1990s [(7)]. Invertebrates and live rock together accounted for 89% of marine aquarium exports in 2004. Other species taken include giant clams (supplied by the Tonga Fisheries mariculture centre) and hard and soft corals [(7)]. There have been numerous complaints to the Department of Fisheries from the public about the fishery, and in 2008, the Department banned the export of live rock from Tonga [(4)]. There are allocated harvesting areas for the industry, and a management plan and regulations are now in place. However, fisheries monitoring and enforcement have suffered due to lack of funding [(4)].

The demand for marine resources is predicted to increase due to Tonga's growing population, a change in diet towards animal protein and products, and continued demand for marine products overseas, particularly from Asian countries [(4)]. The 2011 *Reefs at Risk Revisited* analysis suggests that over a third of Tonga's coral reefs are threatened by overfishing (moderate risk or higher), and the 2005 UNEP/SPOAC Environmental Vulnerability Index [(9)] and 2009 Pacific Ocean Synthesis report [(10)] also suggest that fishing poses a threat.

Tourism is a relatively small industry compared to other countries such as Fiji, with 25 139 tourists visiting Tonga in 2003. Nevertheless, tourism makes a significant contribution to Tonga's economy, accounting for $17 million in 1997, and generating $12 million in local income and 2 200 jobs [(8)]; although dated, these statistics provide an indication of the actual and potential economic impacts [(8)]. The launch of services between Tonga and Australia and New Zealand via Pacific Blue has increased tourist access. Tonga also has one of the world's few swim with whale tourism operations, with tourists swimming and snorkelling with seasonally migrating humpback whales. Tourism can increase fishing pressure to supply reef fish or delicacies like lobster, and increase physical damage to coral reefs from indiscriminate anchoring [(3)]. Tourism can also drive coastal development, leading to degradation of coastal habitats. The 2005 UNEP/SOPAC assessment [(9)] indicates that tourism poses a significant environmental risk to Tonga [(9)].

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

There are some data on trends in resource status, use and sustainability, and numerous reports and accounts consistently suggest that reef resources have noticeably declined. The reports include localised extinctions, declines in abundance and size of targeted species, and collapses of stocks such as sea cucumbers. Predators are uncommon and small. There is also active investment in projects and activities to restore depleted stocks. While there are reports suggest significant changes, the extent of declines are not well understood.

Factors affecting reef health and condition

The most disturbed areas in Tonga in 2002 and 2004, were: Faga'uta Lagoon in Tongatapu (eutrophication, coral mortality, fisheries collapse); Nuku'alofa and adjacent northern Tongatapu (physical disturbances, habitat loss, overfishing, eutrophication and coral mortality); inner Neiafu harbour in Vava'u (sedimentation, COTS outbreaks and coral mortality); and Pangue harbour on Lifuka Island in Ha'apai (eutrophication, high coral mortality) [3, 5]. These issues have persisted and remain potential stressors for coral reefs in Tonga.

The marine environment is periodically affected by cyclones, tsunamis, and volcanic activity. Cyclones have caused significant damage to the coral reefs in Tonga in the past, and a tsunami in October 2009 affected several Tongan communities, especially on Niuatoputau Island. The tsunami generated 15 m high waves that washed fish onto beaches and 'smothered' the coral reefs around the island with sediment [4]. In February 2009, a volcanic eruption destroyed marine ecosystems around Hunga Tonga [4]. The 2005 UNEP/SOPAC Environmental Vulnerability Index [9] lists natural hazards as significant risks to Tonga's environment.

Pollution and eutrophication also affect Tonga's coastal waters and reefs [4]. Tonga does not have adequate sewerage systems and eutrophication has been reported, particularly around Nuku'alofa. In Fanga'uta Lagoon, Tongatapu, urban runoff and eutrophication are the suspected causes of loss of hard corals, with septic systems the probably source of increased nutrients [3]. However, farming may also cause eutrophication, and runoff of fertilizers from squash farming in the 2000s has been linked to algal blooms [4]. There are also concerns over waste from boats and ships, with regular arrivals and departures of containerships and inter-island ferries. About 500 yachts arrive in the Port of Refuge harbour in Vava'u every year, but there has been no effective regulation of waste dumped off these vessels [8]. Eutrophication and algal blooms have also been suggested as factors contributing to COTS outbreaks. The increasing use of pesticides and fertilizers in agriculture, and chemicals used in power supply and construction may also enter the marine environment and groundwater, affecting marine organisms and compromising human health [4, 8]. Pollution from solid waste is also an issue, especially in urban areas. There are only two municipal waste dumps (one on Tongatapu and one on Vava'u), so waste, including old vehicles, diapers, industrial and domestic waste, is often dumped on beaches and vacant land [8].

Poor land-use practices may also lead to increased sediment runoff. Commercial farming with machinery can over-work soils, and land tillage on slopes increases the risks of soil erosion [4]. Deforestation is also a significant issue with an estimated decrease in forest area of 26% between 2006 and 2010 [4], such that slopes have become unstable with increased sediment runoff. Coastal development also has the potential to affect the coral reefs. Urbanisation near Nuku'alofa and Neiafu has increased demand for land, resources and infrastructure [4]. Construction and quarrying activities, and mining sand and gravel, have increased sedimentation and damaged coastal habitats. Siltation from construction sites and quarries and causeways has damaged reefs in Nuku'alofa, Neiafu in Vava'u. Causeway construction in the Ha'apai and Vava'u groups have also caused siltation and damage to reefs [3], and over time, disrupted natural water flows and caused a build up of mud [3]. The construction of Vuna Wharf in Nuku'alofa is considered to have damaged adjacent coral reefs through dredging and sedimentation [4]. In Tongatapu lagoon, illegal land reclamation is a significant threat to mangroves [4], and extraction from sand dunes and beaches is also ‘a major problem’ [3]. Population growth and coastal development are assessed as posing significant risks to Tonga’s environment [9, 10].

Climate change is also a threat and Tonga experienced coral bleaching in 2000, and several recent cyclones have damaged Tonga’s reefs [3]. Climate change may alter the frequency and severity of these events, causing increased coastal erosion [3], and rising sea levels will increase inundation and are considered a significant risk [4, 10]. The western district of Tongatapu is already vulnerable to sea water intrusion and the coast is receding [4]. Damage to crops and livestock from droughts or floods could increase pressure on marine resources for food. The *Reefs at Risk* assessment indicates that by 2030, all of Tonga’s reefs will be threatened by the potential effects of increasing sea temperatures and ocean acidification.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

Reports and risk assessments have identified threats to Tonga’s coral reefs, , and suggest these factors and their effects have increased, or are likely to increase. However, information is insufficient to quantify trends and links to coral reef health and resilience.

Governance and management

Tonga has legislation, policies and planning instruments to support the management and sustainable use of marine resources including: the *Fisheries Management Act* (2002); the *Fisheries Management and Conservation Regulation* (2008); the *Environment Act* (2003); the *Parks and Reserves Act* (1976); and planning instruments such as the National Biodiversity Strategy and Action Plan (2006) [1, 4]. Environmental sustainability also features in Tonga’s national Strategic Development Plans [8], and Tonga is also a signatory to the Convention on Biological Diversity [4].

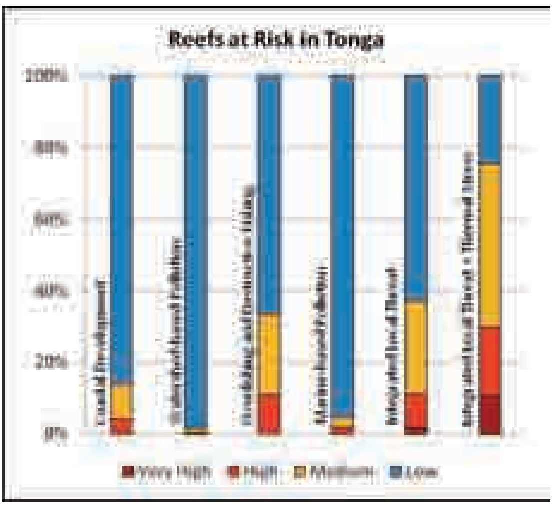
The *Fisheries Management Act* provides protection for whales, green and hawksbill turtles, and places restrictions on the take of other turtle species [4]. The Act also regulates the catch of some species (mostly invertebrates) with size limits and seasonal closures. Fishing on SCUBA is banned without written permission. The Act and regulations provides the legal basis to establish *Special Management* Areas which are community-based fisheries management areas [1]. Pilot projects have been implemented to develop community based fisheries management plans for inshore fisheries [8]. Clam circles are community-based sanctuaries to protect clam stocks, and numerous clam circles have been established recently using government supplied juveniles [3]. Projects to improve waste management and disposal have been implemented, and there are several programs to increase environmental awareness and stewardship by local communities [4, 8]. These include localised community-based efforts to replant forests and conserve wetlands and coastal habitats, and public awareness campaigns. Environmental education has been integrated into the school curriculum [4].

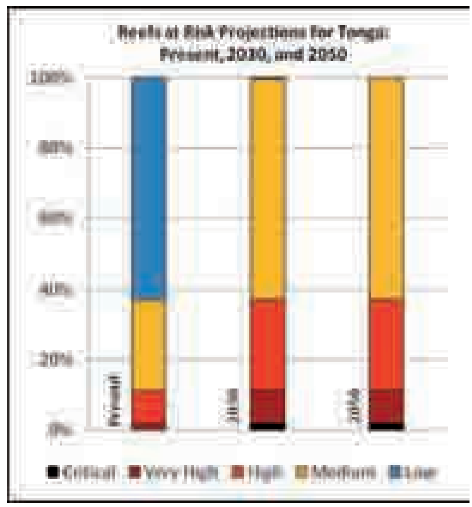
Unlike most Pacific island nations, there is no recent history of customary marine tenure in Tonga, and marine areas have been ‘open access’ since 1887 [1, 3, 4]. However, there are a number of designated reserves with 18 official marine protected areas (MPAs) reported for Tonga [4]. However, most of these appear to be inactive [1], and monitoring and enforcement has been lacking [4], but 6 new special management areas have recently been established around Tonga: Tongatapu [2], Ha’apai [3] and Vava’u [1]. A 7th special management area is being developed at Nomuka [4]. These co-management arrangements are reported to be ‘working well’ with improved knowledge amongst stakeholders of conservation and sustainability, and a 33% increase in the area being managed and conserved [4]. While the program was originally funded through AusAID

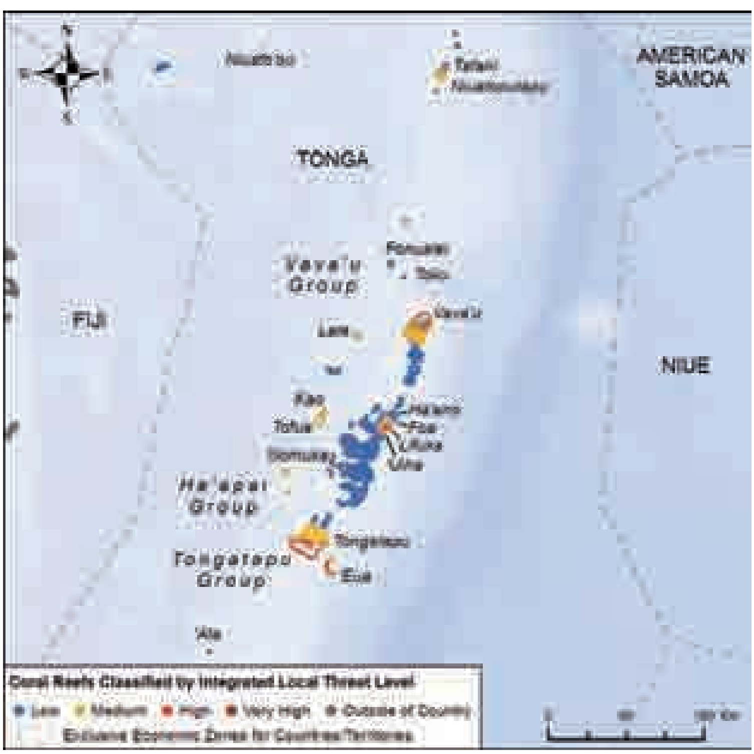
Reefs at Risk Revisited: Tonga

WORLD RESOURCES INSTITUTE

The *Reefs at Risk Revisited* analysis estimates that nearly 40% of Tonga's coral reefs are currently threatened (medium risk or higher), mainly from the effects of overfishing and pollution. When combined with observations of thermal stress over the past 10 years, the number of threatened reefs increases to 75%. The reefs around Tongatapu and Vava'u, the main populated islands in Tonga, are the most at risk. By 2030, projections for thermal stress and ocean acidification suggest that the number of reefs assessed as being at the highest risk will increase from 10% to nearly 40%. The full report, methods and full size maps are on: http://www.wri.org/reefs.







(Australian aid agency), the process is now funded through the Tongan Department of Fisheries [8].

While the existence of legislation, planning and marine reserves is a promising sign, there are concerns that management approaches and sustainability issues are not coordinated across government departments, plans and legislation [4]. There are also problems reported about funding and capacity, long-term financing of conservation and management initiatives, a lack of political will, lack of adequate legislation and a lack of capacity and skills [4]. There are also reported compliance issues; for example, destructive fishing is banned, but still appears to be practiced [4]. Previous efforts to replenish stocks through re-introductions of species, mariculture and re-seeding during the 1980s have been unsuccessful due to lack of enforcement and poaching [3, 7]. The 2002 National Coral Reef Status Report for Tonga cites serious problems with a lack of enforcement, non-compliance, a lack of fisheries management plans for reef fisheries, and a lack of political will to act of recommendations [3]. There is also no overall land use policy for Tonga [4]. Lastly, the lack of monitoring data and information on the status and trends of coral reefs and marine resources, are frequently mentioned as challenges to management [3, 4, 8].

Governance and management – NOT CONSIDERED

There are planning instruments and management tools in place in Tonga, and more recent projects to establish community based management initiatives are promising signs. However, there are also numerous problems in coordinating and implementing marine and environmental management. The lack of data and monitoring make it difficult to describe trends in management activities and resource use and status.

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Wallis and Futuna

- Marine Area: 300 000 km²
- Coastline: 129 km
- Land Area: 274 km²
- Reef Area: 940 km² [(1)]
- Total MPAs: 0 [(1)]
- Area of MPAs: 0 km² [(1)]
- Total LMMAs: 0 [(1)]
- Mangrove Area: ND
- Percentage of reefs threatened (local threats and thermal stress): 66%
- Population (2011 est): 15 398 [(2)]
- Population (2050 proj): ND
- Population growth (2011 est): 0.35%
- Urban population (2008): 0% [(2)]
- GDP: USD $60 million (2004 est) [(2)]
- GDP/Cap: USD $3 800 (2004 est) [(2)]

Data from *ReefBase Pacific,* the *SPC Statistics and Demography* database, *Reefs at Risk Revisited* and Govan (2009). Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated, proj = projected, ND = data unavailable).

Overview

The territory of Wallis and Futuna consists of 3 high volcanic islands: Wallis (Uvea), Futuna and Alofi, and are an overseas territory of France and operate under French law [(2)]. Subsistence agriculture is the main economic activity in the territory, with about 80% of labour force earnings coming from primary industries such as coconut plantations, vegetable gardens, livestock raising and fishing [(2)]. Revenue also comes through French Government subsidies and from tuna licensing fees from Japan and South Korea [(2)]. The main city of Matā-Utu on Wallis Island is approximately 780 km north east of Fiji. The islands of Alofi and Futuna (sometimes referred to as the Horn Archipelago) are approximately 230 km southwest of Wallis; whereas Alofi is not inhabited permanently and is only 1.8 km away from Futuna [(3)].

Wallis Island has fringing reefs around most of the coastline, and an encircling barrier reef several kilometers off the coast [(3, 4)]. In contrast, the reefs around Futuna and Alofi are narrow fringing reefs [(4)], with no offshore barrier reef [(3)]. Although monitoring activity has increased in the last 10 years, relatively few scientific studies have been conducted on Wallis and Futuna. Spalding (2001) reported 'moderate' reef diversity with 30 coral genera and 330 species of benthic fishes.

Status, health and resilience of coral reefs

Monitoring began in 1999 with coral cover recorded at 3 sites: Wallis West; Futuna West; and Alofi West. In 2002, monitoring was expanded to an additional 3 sites: Wallis East; Futuna East; and Alofi South-West, with more surveys in 2005 and 2010/11 at all 6 monitoring sites. Monitoring is conducted by the CRIOBE (Centre for Research and Environment Observatory) based in French Polynesia. Since 2010, fish communities have been monitored at these sites by the territorial service of the environment of Wallis and Futuna in collaboration with CRIOBE. These programs provide data to the Polynesia Mana Node of the Global Coral Reef Monitoring Network (GCRMN), and contribute to programs run through the IFRECOR (French Initiative for Coral Reefs) and the ICRI (International Coral Reef Initiative).

Monitoring at the 6 sites involves 1 m^2 permanent photoquadrats along a 20 m^2 belt-transect (20 m x 1 m). Photographs are analysed to determine live coral cover, with corals identified to genus, and sometimes to species level. A 'manta tow' survey provides coral cover and community composition data at a larger scale. Reef fish are monitored on 3 belt-transects of 200 m^2 (50 m x 4 m) per site. These surveys are carried out in the vicinity of the coral monitoring sites and at the same time. All fish species observed in transects are identified, the abundance of fish is recorded, and sizes of individuals are estimated.

Wallis

The coral reefs around Wallis are in good condition. The 2 monitoring sites on the barrier reef have little exposure to land-based human disturbance, such that coral cover at Wallis West has increased since 1999, with the 2010 survey reporting 52% live coral cover [(5)]. Fishing and recreational sports are the main sources of disturbances on these reefs. At Wallis East, coral cover has remained stable since 2002, with 26% live coral cover reported in 2011 [(5)].

In 2010, the average abundance of reef fishes at Wallis West was 447 individuals per transect (average density of 2.2 individuals per m^2). Reef fish communities at Wallis were dominated by

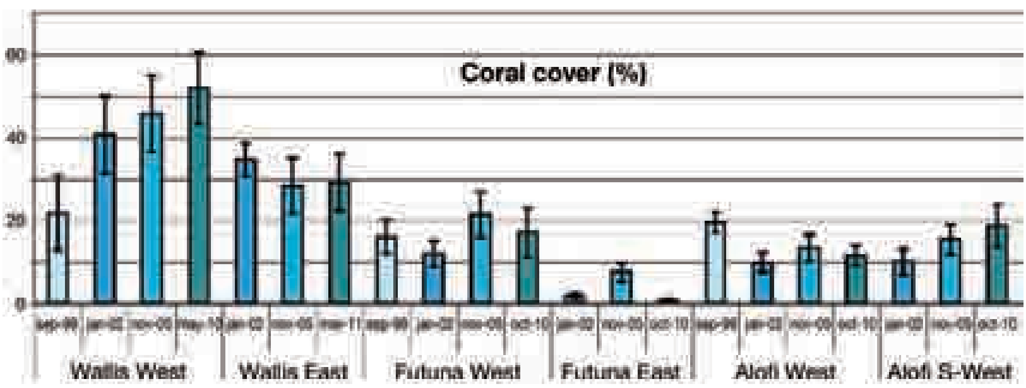

Fig . 1. Average coral cover across survey sites at Wallis, Futuna and Alofi. There is a clear trend of an increase in coral cover at Wallis West and Alofi South-West, while some decreases are evident at Futuna East and Alofi West. Other sites show variable cover percentages (Figure modified from Chancerelle 2010 [(5)]).

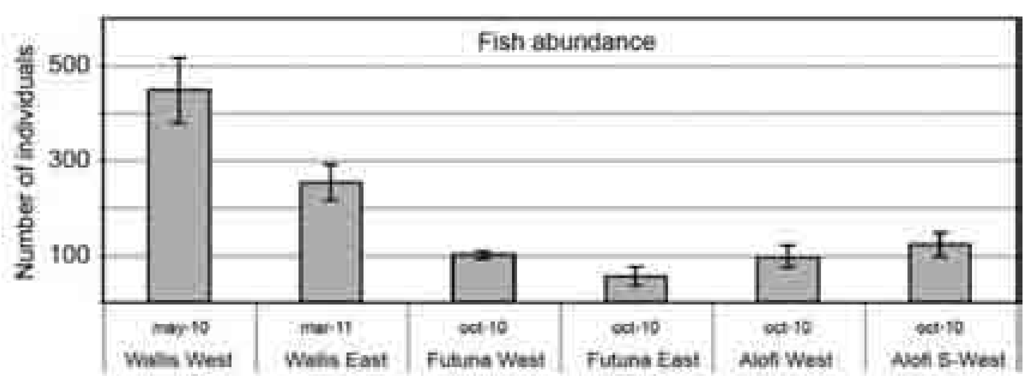

Fig. 2. Mean abundance of fish communities (per 200 m^2 transect) at Wallis, Futuna and Alofi in 2010-2011 (Figure modified from Chancerelle 2010 [(5)]).

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plankton feeders such as damselfishes (Pomacentridae), followed by carnivorous fishes such as emperors (Lethrinidae), snappers (Lutjanidae), squirrelfishes and soldierfishes (Holocentridae). The number of carnivorous fishes recorded suggests that fish communities in Wallis are relatively healthy, however, the absence of large fish suggests some impacts of fishing.

Futuna

The fringing reefs around Futuna show varying levels of coral cover and diversity between sites. These changes appear to be driven by the condition of fringing reefs which are subject to many pressures from human activities. At Futuna West, live coral cover has remained relatively stable since 1999, ranging from 12% to 22%, with 17% live coral cover recorded in 2010 (Fig. 1) [(5)]. In contrast, coral cover at Futuna East is relatively low and while coral cover reached 17% in 2005, it declined to 1% in 2010 (Fig. 1) [(5)].

In 2010, the average abundance of fish communities at Futuna West was 99 individuals per transect, yielding a density approximately 0.5 individuals per m^2 (Fig 2). The abundance of fish communities at Futuna East was lower, with an average abundance of 54 individuals per transect. Fish communities at Futuna differed from those at Wallis. Surgeonfishes (Acanthuridae) were the most numerous, with few snappers and emperors reported, and squirrelfish and soldierfish virtually absent. Butterflyfishes (Chaetodontidae) (which are associated with high coral cover) were seldom seen. The low abundance of carnivores and butterfly fish suggest poorer health of coral reefs around Futuna, with high cover of algae on dead corals at the monitoring sites.

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Alofi

The fringing reefs around Alofi have had 10% to 20% live coral cover since 2002, with highest live coral cover on the southwest coast (Fig. 1) [5]. Coral cover at Alofi West has declined from about 20% in 1999, to about 10% in 2010 (Fig. 1), a similar trend to that at nearby Futuna West [5]. At Alofi Southwest, coral cover has been constantly increasing, and reached 19% in 2010. The abundance of fish is 96 individuals per transect for Alofi West and 121 individuals per transect for Alofi Southwest. These values are similar to Futuna West.

Cyclone Tomas

In March 2010, cyclone Tomas struck the north-east coast of Futuna causing extensive damage to a coastal road, and water, electricity and communication infrastructure. The cyclone also partially destroyed villages and deposited large amounts of coral debris in some areas. Cyclone Tomas also damaged some reefs on nearby Alofi but to a lesser extent than reefs around Futuna; there were limited impacts on Wallis.

The ability of coral reefs in Wallis, Futuna and Alofi to recover from disturbance events, such as cyclones, suggests good resilience. Surveys of reefs around Futuna and Alofi in 2010 revealed active coral recovery, with many small colonies developing on the bare substrate created by cyclone Tomas. Moreover, at Wallis West and Alofi Southwest, coral cover has been increasing over the last 10 years. This increase may be due to the cessation of destructive fishing techniques (fish poisoning) as well as recovery from major disturbance events prior to 1999. Indeed, the reefs of Wallis and Futuna have experienced numerous disturbance events with 6 cyclones and significant impacts since 1958 [6]. Nevertheless, understanding reef health and resilience will require further information about disturbance and recovery cycles over longer time frames, as well as information about reef processes such as coral recruitment and recovery, disease and community structure.

Status of coral reefs – STABLE (low confidence)

There is limited long-term information about reefs in Wallis and Futuna; most reefs are relatively healthy, with high coral cover and diversity. There is little evidence of widespread and prolonged stress, damage, or loss of coral cover, although there are signs that some fringing reefs around Futuna and Alofi may be affected by human activities, and the absence of large fish from Wallis is notable. Nevertheless, more information is needed to confidently describe reef status.

Coral reef health and resilience – STABLE (low confidence)

There is little information on the health and resilience of coral reefs in Wallis and Futuna; most surveyed reefs appear to be able to recover from disturbance events, and disturbed reefs show active recruitment of new corals. Similarly more information is needed.

Use of reef resources

Coastal fishing is an important subsistence activity in Wallis and Futuna, and reef resources constitute an important part of the diet [3]. However, demand for fisheries products may outstrip supply, and the small weekly market on Wallis (revived in 2010) often cannot source enough product to supply demand. It is unclear whether the lack of supply is caused by over-exploitation of existing stock, or limited fishing effort.

Only 15 fishermen say their main activity is fishing, but their employment status as professional fishers allows them to benefit from subsidies for fishing equipment. Fishing techniques include nets, lines, traditional fishing by women (now rare) and hand-spears. A wide range of fish are taken by artisanal subsistence fishers including surgeonfishes (Acanthuridae), triggerfishes (Balistidae), butterflyfishes (Chaetodontidae), hawkfishes (Cirrhitidae), stingrays (Dasyatidae), wrasses (Labridae), emperors (Lethrinidae), snappers (Lutjanidae), tilefishes (Malachanthidae), mullets (Mugilidae), goatfishes (Mullidae), moray eels (Muraenidae), boxfishes (Ostraciidae), angelfishes (Pomacanthidae), damselfishes (Pomacentridae), parrotfishes (Scaridae), groupers (Serranidae) and pufferfishes (Tetraodontidae) [(3)]. On Futuna, fishing pressure is high on reef flats as these flats are easily accessible and many people fish these areas, especially when rough weather restricts access to offshore fishing grounds. The offshore fishery is not developed, and the long-term viability of recent attempts (2010) to develop tuna fishing operations is unknown.

Small shells are harvested to supply a trade in jewellery and handicrafts, and shellfish (clams, 'grisettes', oysters) are also consumed by local families. The quantities taken are unknown for these small fisheries; monitoring is needed to ensure sustainable resource use.

Trochus and sea cucumber (bêche-de-mer) are also harvested. The amount of exported trochus shells has remained fairly constant at 37 tonnes per year. The sea cucumber fishery was closed in 2005 following scientific recommendations [(7)], but the fishery re-opened in 2010 with a quota of 10 tonnes of dried sea cucumber product per year.

Fishing regulations in Wallis and Futuna prohibit certain practices. Destructive fishing practices were causing significant reef degradation in areas around Futuna and Alofi during the 1980s [(3)]. Destructive fishing methods such as using steel bars to break open the reef, natural or synthetic poisons and explosives have now been banned. Additionally, other techniques that can lead to over-fishing such as spear fishing using SCUBA and using spearguns at night have also been banned.

There is little information available on trends and patterns in reef resource use in Wallis and Futuna. The **UNEP/SOPAC Environmental Vulnerability Index** [(8)] indicates that fishing poses little risk, but *Reefs at Risk Revisited* assessed that up to one-third of reefs in Wallis and Futuna are threatened by over-fishing or destructive fishing. The lack of data about fishing activities increases uncertainty in describing these trends.

Use of reef resources – EVIDENCE OF CHANGE (low confidence)

There is very little information on trends and patterns of reef resource use. The only scientific assessment suggested that sea cucumber stocks had declined and the fishery needed to be closed. More information is needed to describe trends and sustainability of current fishing practices.

Factors affecting reef health and condition

The coral reefs of Wallis and Futuna are affected by a number of indirect pressures including anthropogenic factors such as pollution and sedimentation, and major disturbance events such as cyclones. The 2005 **UNEP/SOPAC Environmental Vulnerability Index** [(8)] identified coastal development and population density as potential environmental risks for Wallis and Futuna. On Wallis, coastal development and erosion are the main factors affecting inshore reefs in the lagoon, and cause increased turbidity and sedimentation. During the rainy season, the Wallis lagoon and coastal waters around Futuna become turbid, and muddy sediments have accumulated near poorly built roads [3]. Recent uncontrolled sand mining, cyclones and rising sea levels have caused extensive coastal erosion on both Wallis and Futuna. Unfortunately, the construction of inappropriate coastal protection measures such as seawalls have exacerbated coastal erosion, to the extent that some beaches have been lost from around Wallis [3]. Further offshore, the barrier reefs around Wallis lagoon may suffer from localized impacts from anchor damage.

Futuna's coastal fringing reefs are affected by numerous pressures. Inappropriate farming practices and development have cleared vegetation on steep slopes that are prone to erosion, leading to increased sediment runoff over nearby reefs [3]. Pollution from solid waste is also a particular issue on Futuna. The near-shore landfill is inadequate and was supposed to be closed and the site rehabilitated, however, this has not happened due to lack of funds.

Coral reefs in some areas of Wallis and Futuna are also threatened by sewage pollution and effluent from pig farms. Many households use inadequate septic tanks and tank discharges do not meet environmental standards [3]. There are about 30 000 pigs on Wallis and Futuna. Most are housed in small piggeries along the coast, but effluent treatment is inadequate. These pressures are greatest around densely populated areas of both islands.

Wallis and Futuna's coral reefs are also affected by disturbances such as cyclones, however, coral bleaching has not been recorded [3], and no crown-of-thorns seastar outbreaks have been reported. Climate change projections, however, suggest that rising sea temperatures and ocean acidity may threaten coral reefs throughout Wallis and Futuna, with all reefs assessed as being at medium, high, very high or critical threat levels by 2030.

Factors affecting coral reefs – EVIDENCE OF CHANGE (low confidence)

The main factors affecting Wallis and Futuna's coral reefs are land-based pollution, coastal development, erosion and sedimentation. Climate change will also affect these reefs. However, there is insufficient information available to quantify trends and pressures.

Governance and Management

The Environmental Code, adopted in 2007, has only been partially implemented and improvements need to be made to deliver effective management. The roles and responsibilities of the state (French administration), Territory and traditional chiefs need to be clarified to ensure compliance and the enforcement of environmental regulations in coastal, reef and lagoon areas. Land ownership issues also complicate the coordination and delivery of environmental management.

Specific resource protection measures have been implemented through legislation introduced in 1994. Destructive fishing techniques (e.g. explosives, iron bars, poison fishing) are banned (Arrêté n° 94-200) and fishing around fish aggregation devices is prohibited (Arrêté n° 94-201), as is spearfishing using SCUBA or spearfishing at night (Arrêté n° 94-202). Fishing for coconut crabs or crayfish is regulated (Arrêté n° 94-203). There are also restrictions on the size and numbers of trochus collected (Arrêté n° 94-204). Minimum and maximum mesh sizes for nets are defined by regulations, as well as minimum and maximum catch sizes for some species (mud crabs, coconut crabs, lobsters, trochus). However, some of these restrictions only apply to exported products (e.g. trochus), and there are no controls over the domestic use of most of these products. Illegal fishing practices (e.g. poison fishing or 'futu') have declined over the

Reefs at Risk Revisited [9]*: Wallis and Futuna*

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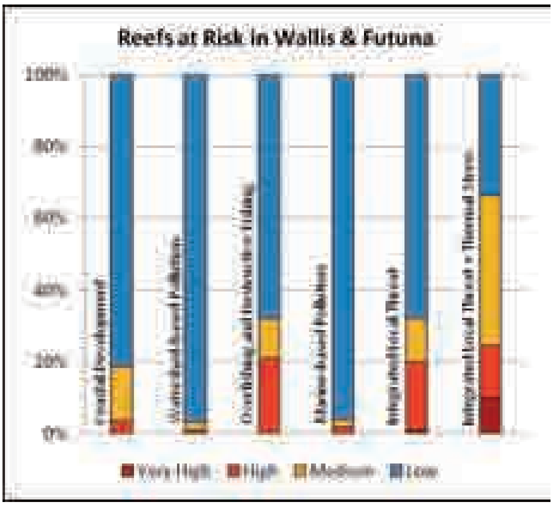
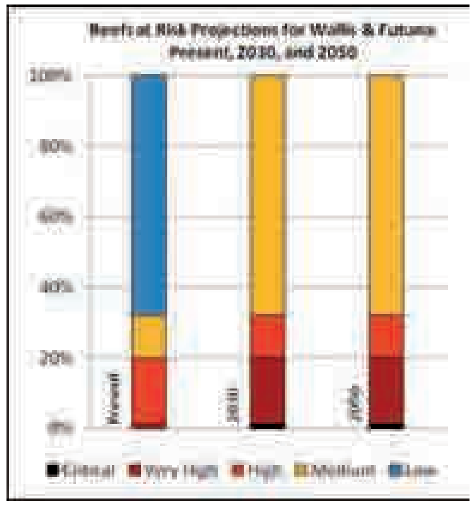
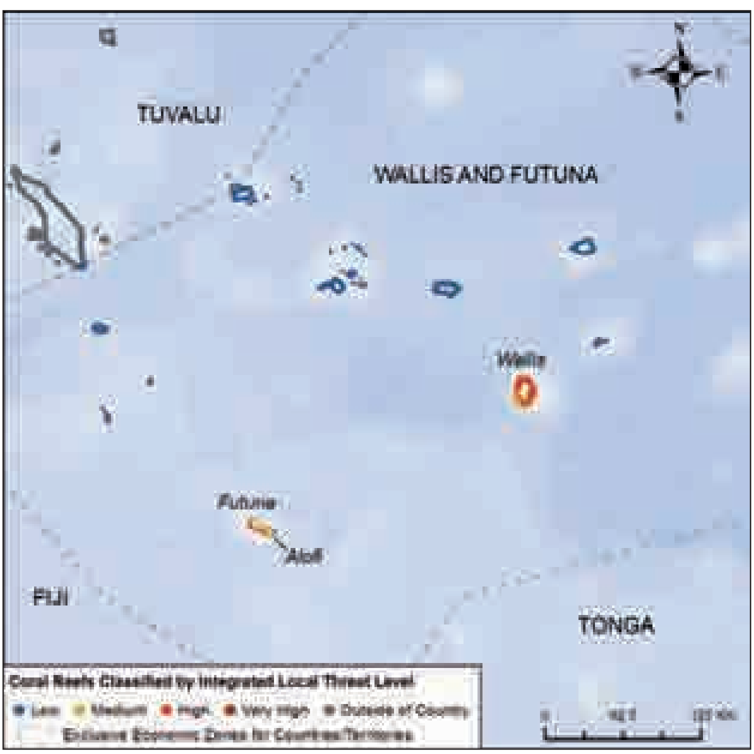
The *Reefs at Risk Revisited* assessment reports that the coral reefs of Wallis and Futuna are currently most threatened by overfishing and coastal development. When the impact of thermal stress is integrated with local threats, 66% of coral reefs in Wallis and Futuna are assessed as being at risk. Future projections of ocean warming and acidification (based on sea surface temperatures over the past 10 years) suggest that by 2030 all reefs in Wallis and Futuna will be threatened with a third of reefs at high, very high or critical threat levels. The full report, methods and full size maps are on: http://www.wri.org/reefs.







last 4 years. However, active management and enforcement is still required as there are still incidences of non-compliance.

The protection of reefs in Wallis and Futuna is supported by national French legislation (décret du 7 juillet 2000) which has given power to the French Initiative for Coral Reefs (IFRECOR) to develop a national strategy for coral reefs, formulate recommendations to ensure the protection and sustainable development of coral reefs, and to raise public awareness of coral reef issues. Wallis and Futuna has a local IFRECOR committee but the committee has no enforcement powers. The committee has launched and implemented some programs such as initiating public consultation in 2009 for the creation of a Management Plan for Maritime Areas (PGEM) for each island. While this plan may provide an adaptive framework for managing marine areas (including coral reefs) around Wallis and Futuna, implementation will be very difficult. Scientific studies are underway to identify potential marine managed areas (MMAs) and marine protected areas (MPAs), and will provide information to help develop the PGEM. However, there are no MMAs, MPAs or reserves in Wallis and Futuna. Customary marine areas previously existed on Wallis but they are no longer active.

Governance and management – NOT CONSIDERED

Wallis and Futuna has several legislative acts and regulations that provide for management of coral reefs, but many of these have not been fully implemented. There is insufficient information to describe their effectiveness in ensuring conservation of coral reefs and marine resources.

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Hawaiian Islands

- Marine Area: 1 823 000 km^2
- Coastline: 1 482 km
- Land Area: 464 km^2
- Reef Area: 3 834 km^2
- Total MPAs: 19
- Area of MPAs: 362 600 km^2
- Mangrove Area: 7 km^2
- Percentage of reefs threatened (local threats and thermal stress 2011): 28%
- Population (2011 est): 1.36 million
- Population (2035 proj): 1.6 million
- Population growth (2010 est): 1.2%
- Urban population (2000): 92%
- GDP: USD $900 million(2000 est)
- GDP/Cap: USD $12 500 (2000 est)

Data from *ReefBase* and *Reefs at Risk Revisited* and Hawaii Census Data (http://hawaii.gov/dbedt/info/census) unless denoted by a reference number. Data are estimates only and may vary between sources depending on terminology and data sets used (est = estimated; proj = projected).

Overview

The Hawaiian archipelago includes both the 'main' Hawaiian Islands (MHI) and the remote Northwestern Hawaiian Islands (NWHI), which are separated by approximately 250 km of open ocean; these are all within the State of Hawaiʻi of the USA [(1)]. These islands and atolls stretch in a 2 900 km chain in the north central Pacific, and comprise nearly 25% of the coral reefs in US waters (including states and territories) [(1)]. The MHI are recent, high volcanic islands and include 8 populated large islands, including Hawaii (also called the Big Island), Oʻahu and Maui. The coral reefs around these islands are mainly fringing reefs, but there are also two barrier reefs and reef slopes and patch reefs [(2)]. In contrast, the 124 islands of the NHWI are mostly small islands and low-lying atolls, reefs and submerged banks [(1)]. Most of the islands in the NWHI are uninhabited. In June 2006, the NWHI were declared as a National Monument, the Papahānaumokuākea Marine National Monument, covering 362 600 km^2. The coral reefs of the NWHI are probably the most undisturbed and pristine coral reefs in US waters.

The Hawaiian archipelago contains more than 7000 marine species, with about one quarter to one half of these species found exclusively in the NWHI. The remote location of these reefs has stimulated a diversity of flora and fauna including many endemic, rare, threatened or endangered species such as the green, leatherback, and hawksbill sea turtles and the Hawaiian monk seal [(1)]. The flora and fauna contain some of the highest levels of endemic species for tropical ecosystems worldwide, thus this archipelago is an important biodiversity hotspot [(3)]. There are 366 described algal species, including several endemic species not found in the MHI [(1)]. There are 57 hard coral species, including 11 new species and 29 range extensions in the NWHI [(4)]. The high rate of coral endemism (30%) is predominately attributed to the NWHI, with just 3 genera accounting for 88 percent of the endemic coral species [(1, 4)].

Status, health and resilience of coral reefs

Hawai'i's coral reefs have been extensively studied since the 1970s, although most of the large-scale monitoring programs started in the late 1990s. Research and monitoring are conducted through state and federal agencies including the US Fish and Wildlife Service, National Oceanic and Atmospheric Administration (NOAA), the Hawai'i Division of Aquatic Resources (DAR), US Geological Survey, US Environmental Protection Agency, Hawai'i Coastal Zone Management, National Fish and Wildlife Foundation, National Marine Sanctuary Program, National Park Service, and other organizations including the Nature Conservancy, the University of Hawai'i and the Hawai'i Institute of Marine Biology [(3)].

NOAA's Pacific Islands Fisheries Science Center- Coral Reef Ecosystem Division's ongoing Pacific Reef Assessment and Monitoring Program (RAMP) conducts regular water quality and coral reef monitoring in the Main Hawaiian Islands. NOAA's Northwestern Hawaiian Islands Coral Reef Assessment and Monitoring Program (NOWRAMP) conducted research cruises in 2000, 2002, 2004 and 2005 [(5)]. These programs monitor, assess and map reef habitats within the Hawaiian Islands using Rapid Ecological Assessments (REA), towed diver surveys, and survey large areas of habitat and collect environmental information (e.g. temperature, nutrients, salinity) using data loggers and TOAD (Towed Optical Assessment Device) [(3)].

The average live coral cover in the MHI was reported to be ~19% in 2008 [(6)]. A meta-analysis by the DAR Coral Reef Assessment and Monitoring Program (CRAMP), the PIFSC-CRED, the Fish Habitat Utilizations Study (FHUS) and the West Hawai'i Aquarium Project (WHAP) identified broad-scale patterns of coral reefs within the MHI [(3)]. The CRAMP used fixed transects and photoquadrats at 30 sites in shallow (1-3 m) and deep (7-10 m) water, while the PIFSC-CRED surveyed 108 sites using 2 or 3 x 25-m transect lines at each site [(3)]. The FHUS examined fish assemblages and benthic characteristics in marine protected areas and the WHAP project focused on reefs managed for the aquarium trade in West Hawai'i [(3)]. Analysis of 1682 independent sites across the MHI, revealed average live coral cover of 19.9% with the dominant species being *Porites lobata* (8.5%), *Porites compressa* (3.8%), *Pocillopora meandrina* (2.5%), *Montipora capitata* (2.3%), *M. patula* (1.6%), *M. flabellata* (0.3%), and *Pavona varians* (0.3%) [(3)]. Coral cover was greater on islands towards the south (Molokini, 45% and Kahoolawe, 49%) and lower in the northern part (e.g. Ni'ihau, 4%) [(6)]. Storm waves are the predominant physical forces structuring exposed reefs in the MHI, with the exception of sheltered sites where anthropogenic activities and variable recruitment levels are the main structuring factors [(3)]. Reefs adjacent to populated coasts generally display lower live coral cover, with reefs near highly-populated Honolulu and Waikiki having considerably reduced coral cover [(3)].

Average coral cover in the NWHI in 2008 was 19% [(6)], with the highest being from Maro Reef in the East to the lowest at Necker Island in the West [(1)]. Trends in coral abundance and diversity are similar, being highest in the large coral atolls (French Frigate Shoals, Maro Reef, Lisianski/ Neva Shoals) and decreasing in reefs extending to the northwest [(1)]. A study found no significant differences in coral cover at 27 permanent sites between 2000-2002 and 2006 corroborating reports of healthy reefs within the NWHI [(3)].

The status of many marine resources in the MHI has declined in the last 20 years while those in the more isolated and protected NWHI remain in good condition [(2)]. Long-term monitoring (more than 30 years) of 10 sites in the MHI indicates that coral cover has declined by 12% on average, while another study reports 70% of sites monitored for more than 10 years have shown a total average decline of 8% [(6)]. Meanwhile, reports of very old, single coral colonies in the NWHI indicate long-term stability of these reefs [(1)]. In addition, a variety of coral growth forms found in the NWHI seem to be uncommon in the MHI, indicating possible recent changes between these two regions of the archipelago [(1)]. Ships traveling to the MHI have introduced

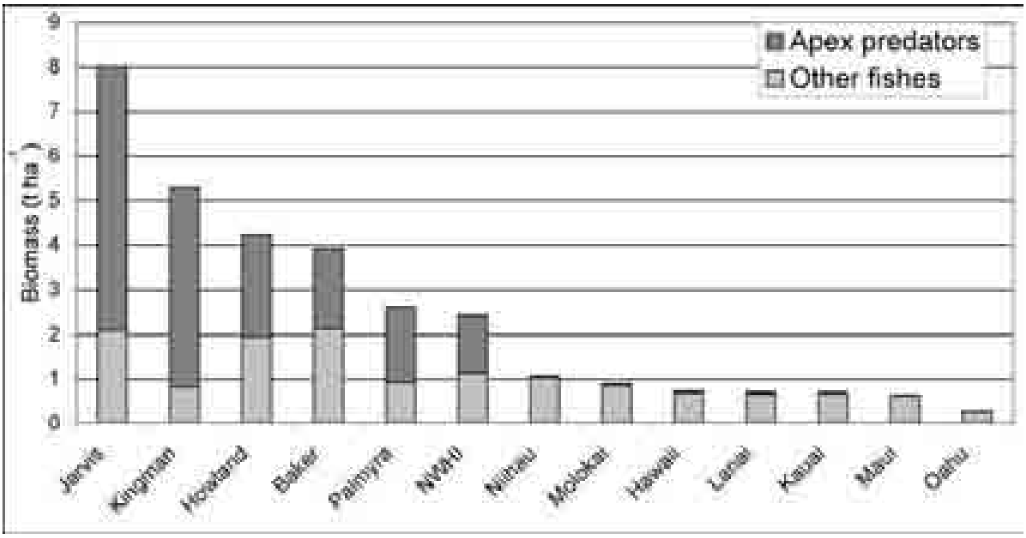

Fig. 1. Graph of fish biomass for apex predators and other fishes around the remote US Pacific Remote Island Areas, the NWHI and the MHI which has almost no apex predators (from Friedlander et al. *2008).*

several invasive invertebrate species [(1)]. In contrast, surveys in the NWHI have found no marine invasive invertebrates with the exception of inhabited Midway Atoll [(1)].

There are indications that reef fisheries in Hawai'i have been declining over the last century [(2, 3)]. While fish populations in the NWHI appear to be stable and with indications of a stable trophic structure and large populations of apex predators [(6)], fish populations near population centres in the southern Hawaiian Islands appear to have been altered due to fishing pressures. Trends in reef fish biomass of common reef fishes between the NWHI and MHI reveal stark differences, especially for commercially important species and high-level predators in the two areas [(1)]. The abundance, density, size, biomass and species composition of shallow-water reef fishes were dramatically lower in the MHI than in the NWHI [(2)], where there is a substantially higher fish standing stock (nearly 300% greater) than corresponding habitats in the MHI; these differences are attributed to overfishing [(1, 6)]. Trends in fish biomass on shallow reefs in the MHI appear to correspond to the size of nearby human populations; the densely populated island of O'ahu (with more than 70% of Hawai'i's 1.3 million residents) has very low numbers of high level predators and the lowest overall fish biomass [(2, 3)] (Fig. 1). Assessments of 55 fish species targeted in commercial, recreational and ornamental fisheries show that nearly three quarters of these have been depleted, with large mobile predators particularly affected [(3)]. About 75% of the MHI fish species are below over-fishing thresholds (25% of virgin stock biomass) [(6)]. Thus fishing activities have had noticeable impacts on shallow water reef communities in the Hawaiian islands [(3, 11)].

There are low, but widespread occurrences of 8 coral diseases within the MHI, with the highest prevalence of diseases being on O'ahu, Maui and Hawai'i [(3)]. There is enhanced prevalence of *Porites* growth anomalies in the MHI (59.7% of sites surveyed) compared with those of the NWHI (4.9% of sites surveyed), which appear related to larger human populations in the MHI [(3, 7)]. The *Montipora* white syndrome was first documented in 2004 on O'ahu and has since been reported throughout the MHI; this could be another indicator of declining health of MHI coral reefs [(3)]. Reef-fish diseases such as skin tumors have been attributed to contaminants in Maui, as well as disease transmission from introduced blue-lined snapper (*Lutjanus kasmira)* to native goatfish (*Mulloidicthys* spp.) [(3)].

Status of coral reefs –STABLE/EVIDENCE OF CHANGE (high confidence)

The reefs of Hawai'i are among the best studied reefs in the Pacific. Most reefs in the NWHI appear stable, while reefs in the MHI vary from good condition to reefs showing signs of deterioration from anthropogenic stress, seen as declining coral cover and reef-fish populations. The main threats in the MHI are land-based pollution, coastal development, invasive species and overfishing, with reefs around densely populated islands showing the most change.

Coral reef health and resilience – STABLE/EVIDENCE OF CHANGE (high confidence)

While the more remote NWHI coral reefs show good health and resilience, reefs near populated centres have been damaged by human activities, with decreased coral cover, reef fish and other reef resources. Local fishing pressures have reduced fish populations. Low levels of widespread coral disease are attributed to anthropogenic stresses. Most reefs in the MHI appear in reasonably good condition; however some appear to lack the ability to recover from frequent stress. These trends suggest the health and resilience of Hawai'i's reefs are relatively stable, with evidence of localised changes.

Use of reef resources

Coral reef fisheries are a culturally significant part of traditional Hawaiian life, contributing to recreation, commerce and culture [(2)]. A survey of 1600 households in 2004-05 reported that 31% and 10% of Hawaiian households participate in recreational and subsistence fishing, respectively [(3)]. There are also small-scale commercial fisheries and collection of species for the aquarium trade [(6)]. Risk assessments suggest varying levels of threat posed by different fisheries in Hawai'i. The **Pacific Ocean Synthesis** report suggests that the aquarium trade poses a moderate threat, while artisanal, recreation and subsistence fishing, by-catch and discharge, and commercial fishing pose severe threats [(8)]. *Reefs at Risk Revisited* also suggests that overfishing is a threat to coral reefs around the populated MHI. In contrast, there is very little fishing pressure on the more remote and protected NWHI. Fishing pressure has reduced since the declaration of the Papahānaumokuākea Marine National Monument (PMNM), with the bottom fish line fishery closing in mid-2011 and the lobster trap fishery closing prior to 2008 [(6)]. There is also no collection of live fish or corals for the aquarium trade in the NWHI [(6)].

In the MHI, annual fisheries landings data from DAR from 1966 for the 4 main coastal commercial fisheries (seine net, handline, spear/dive and gillnet) show that the reported catch in the handline fishery has declined since the early 1990s, while spearfishing catches have risen and gillnet fishing remained constant [(3)]; but catch-per-unit-effort (CPUE, as fish weight per trip) show relatively stable trends, suggesting that landings reflect changes in fishing patterns and use of more efficient gear. Seine nets are the most efficient with the highest recorded CPUE, followed by gillnet, spear and handlines [(3)]. However, the CPUE of the seine net fishery has decreased during 40 years, and fish composition has shifted from jacks, bonefish, and threadfin to species of lower commercial value such as surgeonfishes and goatfishes [(3, 6)].

Recreational and subsistence fishers do not require fishing licenses or to report their catch, yet these fishers take a higher catch in Hawai'i [(3, 6)]. A dramatic recent increase in the registration of recreational vessels coincides with a spike in recreational reef fishing [(3)]. In 2001 the Hawai'i Marine Recreational Fishing Survey revealed that goatfishes, surgeonfishes and jacks top the catch in terms of numbers caught, but the full extent cannot be determined due to variations in fishing methods, multiple landing sites and hundreds of targeted reef fish species [(3)]. Key measures to reduce intense fishing pressures have been identified: increased restrictions of efficient gear types such as gill nets and SCUBA particularly at night; increased use of area closures; and bag limits [3].

Commercial landings data from 1980 to 1990 show a decline in CPUE with a simultaneous increase in the number of fisherman [2]. Similar CPUE drops were seen for recreational and subsistence fishers despite innovations in fishing technology [2]. A 1997 DAR survey of 'kūpuna' (elders), and 'kama'aina' (local residents), revealed that Hawaiian residents also have perceived a trend of declining fisheries over the last few decades [2].

The commercial aquarium fishery is a significant economic activity in inshore waters with landings of 990 000 specimens valued at $1.93 million in 2006 [6]; the total value is 3-6 times greater when the collectors and wholesalers are included [3]. The fishery targets 203 fish species and 54 invertebrates, with the primary species targeted are juvenile yellow tang (*Zebrasoma flavescens)* [3]. Several years of high recruitment and increased numbers of collectors nearly doubled the catch and value of this industry from 2000 to 2006 [3]. The fishery on O'ahu, however, has declined while Hawai'i Island has become an increasingly important source of specimens contributing over 75% of the reported value of the fishery in 2006 [3]. Although the collection and trade of live coral and marine rock are strictly prohibited, some illegal activity reportedly occurs [3].

Tourism is Hawai'i's main industry, with continued growth since the 1970s; there was a 59% increase from 1990 to 2007 [2, 3]. Visitor numbers are projected to continue increasing as more services become available and the outer islands become more accessible [3]. With the decline of agriculture and development of several world-class resorts, islands which previously received fewer visitors such as Lana'i are gaining more from tourism [3]. More than 82% of tourists to the Hawaiian Islands participate in some form of ocean activity, also there is increasing pressure from coastal development, pollution and recreational use. High tourist numbers and levels of use have reduced the amenity of some areas to locals [3].

Use of reef resources – STABLE/EVIDENCE OF CHANGE (medium confidence)

Long-term data on commercial fisheries combined with anecdotal information from the larger recreational fishery sector, suggest that fish resources have declined in the MHI with declining CPUE and fishers targeting less valuable species. Fishers also perceive that fish stocks have declined. Tourism is also a major activity and continued expansion may damage some reefs. However, the reef resources of the NWHI appear to be relatively pristine and reduced fishing has been enforced with the establishment of the PMNM.

Factors affecting reef health and condition

Hawai'i's coral reefs experience other pressures and environmental stressors such as coastal development, pollution, sedimentation, marine debris, invasive species, as well as storms and cyclones, outbreaks of crown-of-thorns seastars (COTS), and the potential effects of climate change [3, 6, 9]. These pressures were identified in the Pacific Ocean Synthesis report which highlighted pollution, anchor damage, invasive species, land-based sedimentation, coastal development, marine debris and the effects of climate change [8]. The *Reefs at Risk Revisited* analysis also suggests that watershed pollution, coastal development and potential climate change effects pose significant threats to some reefs in the MHI. In contrast, there are virtually no local pressures (e.g. coastal development) that threaten the coral reefs of the largely uninhabited NWHI [2].

Coastal development in Hawai'i continues, although at a slower pace due to recent economic declines. Sugarcane and pineapple farms are being converted into residential and commercial use [(3)], which is increasing the sediment flows into coastal habitats, especially because wetlands and flood plains have been filled and developed with storm drains and concrete channelized streams [(2, 3)]. Some inappropriate coastal construction sites on Kauai and Hawai'i have resulted in costly lawsuits after causing damage to nearby coral reefs [(3)]. Shipping channels have been dredged and widened to accommodate large container ships, cruise ships, inter-island ferries and expand commercial and recreational facilities. In Maui, two expanded harbor sites are proposed, possibly replacing 6 ha of coral reef to provide easy access for commercial and recreational boats [(3)]. It is estimated that cruise ship port calls will increase by 3 times in the next few years, thereby adding to the potential for increased pollution, accidental anchor damage and ship groundings [(3)].

While coastal water quality in the MHI is generally 'very good' [(3)], land-based pollutants such as sediments and nutrients represent a high threat to some reefs. Sediment-loading from near-shore developments remains one of the top threats to the reefs and probably the leading cause of reef alteration in the MHI, despite several measures taken to reduce erosion and sedimentation including culling of feral animals, closure of military live firing ranges and reducing large agricultural plantations on some islands [(2, 3)]. There are 7 wastewater treatment centers in Hawai'i with 5 discharging via deep-water outfalls below 40 m [(3)]. However, as many as 200-300 spills per year were reported during 2000-2004 and these represent a problem by introducing pollutants to near-shore coral reef habitats [(3)]. A study on Maui found that sewage discharge may be washed back into near-shore habitats due to water circulation patterns and groundwater, thereby aiding in overgrowth by marine algae [(6)]. An estimated 100 000 cesspools in the MHI contribute to nutrient and pathogen seepage onto coral reefs [(2, 3)]. Outdated or inadequate sewage treatment systems on densely populated coasts of O'ahu and Maui continually raise 'concern' from the public [(3)].

Marine debris continues to be a problem as both community and government groups engage in clean-up efforts with some communities engaging in monthly cleanup activities [(3)]. From 2005-2006, 5 formal and community clean-up efforts were initiated for at least 7 islands, including O'ahu, Maui, Lana'i, 'Big Island', Molokai, Kauai and Kaho'olawe with as much as 88% of recovered debris being derelict fishing gear [(3)]. Pacific Ocean currents deposit an estimated 52 tons of marine debris and fishing gear onto the reefs and atolls of the NWHI every year [(6, 9)]. This debris causes physical damage to reefs, spreads invasive species to new areas, and traps and entangles marine animals, especially endangered turtles and seals [(3, 9)].

There has been a long history of ships visiting Hawai'i, such that many species were introduced via fouling on vessels. In addition, there have been many deliberate introductions [(3)]. It has been estimated that 287 species have been introduced into the MHI while only 5 are known in the NWHI [(6)]. Of particular concern and high public awareness are invasive algae, and several community-based groups are attempting to eradicate these species [(3)]. Fishes such as the peacock grouper (*Cephalopholis argus*) and blue-lined snapper (*Lutjanus kasmira*) were intentionally introduced in the 1950s and 60s to augment declining food and game fishes, and have since become established in about half of the Hawaiian Archipelago reefs. However, the Peacock grouper have not become targets for fishers due to concerns over ciguatera poisoning [(3)], and they may be contributing to declines in aquarium fishes, invertebrates and some food fishes [(3)]. The spread of invasive species is one of the major risks identified for continued conservation of the NWHI [(6)].

Outbreaks of COTS have caused severe declines in live coral cover with surveys revealing low abundances (3.4 COTS per hectare) of COTS throughout Hawai'i. Several localized outbreaks have been reported including the July 2005 outbreak on the north shore of O'ahu with hundreds of individuals per km^2 area of reef [(3)]. Storms, cyclones and tidal surges also cause periodic disturbances to the coral reefs [(3, 9)]. Yet only two major cyclones have struck the islands in recent

Reefs at Risk Revisited [10]: *Hawaiian Islands*

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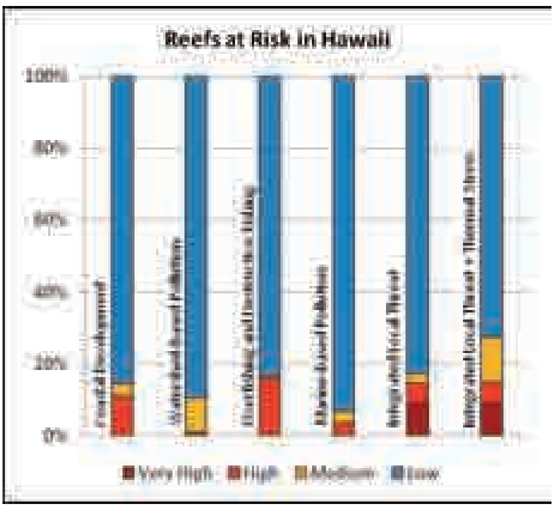
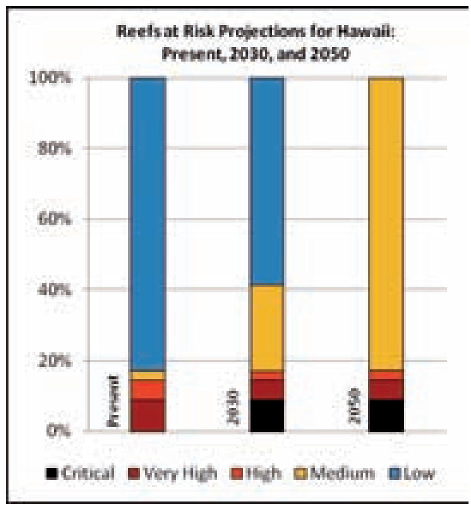
Reefs at Risk Revisited found that most (83%) the coral reefs in the Hawaiian Islands are at low levels of risk from local stressors. Overfishing and coastal development are the primary local threats. Thermal stress from above-average sea temperatures over the past 10 years adds to these local stressors, bringing the percentage of threatened reefs in the Hawaiian Islands from 17% to about 28%. The reefs around the main islands such as O'ahu, Kauai, Maui and Molokai are most at risk. Projections for thermal stress and ocean acidification from climate change suggest that by 2030, over 40% of coral reefs in the Hawaiian Islands will be threatened, with around 9% being in critical condition. The full report, methods and full size maps are on: http://www.wri.org/reefs.





decades (1982, 1992) along with approximately 5 tropical storms within the same time-frame, and these events have not caused widespread or significant damage [3].

Hawaiian waters have become warmer with an increase in sea surface temperature (SST) of 0.8°C since 1956; this is consistent with predictions associated with climate change [3]. Coral bleaching does not appear to have caused long-term damage to Hawai'i's coral reefs, and only 3 bleaching events have been recorded (O'ahu in 1996; and the NWHI in 2002 and 2004) [2, 3]. Recovery from bleaching events appears to be driven by patterns of recruitment pulses of 10 to 15 years for some coral species [3]. Nevertheless, projections of SST and ocean acidification suggest that climate change poses a significant threat to Hawai'i's marine environment [8], with all the reefs potentially at risk by 2050.

Factors affecting coral reefs –STABLE/EVIDENCE OF CHANGE (medium confidence)

The data available indicate that the Main Hawaiian Islands coral reefs are coming under increasing pressure from overfishing, pollution and sedimentation, coastal development and invasive species, with damage to some reefs clearly evident near highly populated coastlines. There are many fewer threats to the more remote Northwestern Hawaiian Islands. Marine debris is affecting all reefs and the potential impacts of climate change could be severe.

Governance and management

The State of Hawai'i Department of Land and Natural Resources, Division of Aquatic Resources (DAR) is the main agency responsible for the coordination of reef management efforts within 0-3 nautical miles of the Main Hawaiian Islands (MHI) [2]. However, ineffective coordination of state, federal, academic, NGOs, and other groups has been an ongoing problem. The DAR's Hawai'i Coral Reef Strategy: Priorities for Management in the Main Hawaiian Islands 2010–2020 attempts to coordinate management efforts, and key state and federal partners comprise the Coral Reef Working Group which advises the development of the strategy [2]. The DAR also compiled the marine component of the Comprehensive Wildlife Conservation Strategy as well as a draft Marine Protected Areas (MPA) framework [2]. The Coral Reef Working Group has also developed 6 Local Action Strategies (LAS) within the last decade to address the key pressures affecting coral reefs: land-based pollution; aquatic invasive species; recreational impacts on reefs; coral reef fisheries; climate change and coral disease; and lack of public awareness [2, 3]. Projects implemented through the LAS strategies include: improving land-use management through traditional practices at the 'ahupua'a' (watershed) level; increasing public awareness about appropriate land-use practices; developing cost-effective methods to remove invasive species; agency and community-based projects to remove invasive algae; hull inspection programs to prevent the spread of invasive species (especially to the NWHI); installing moorings to reduce anchor damage; training tourism operators in environmental stewardship; supporting community-based management of fisheries; and developing rapid response protocols to monitor coral bleaching and disease [2, 3].

Within the MHI, the state government manages 34 near-shore areas that restrict fishing activities, including 11 Marine Life Conservation Districts (MLCD), 20 Fisheries Management Areas (FMAs), and 3 other managed areas. There are also areas on O'ahu and Kauai with restricted access due to military and security reasons [3]. However, the combined area of all no take and negligible-take areas and restricted access reserves comprises only 4.8% of nearshore waters in the MHI, and these areas are mostly around O'ahu and Kauai or within the Kahoolawe Island Reserve [3]. As a result, most other islands have few controls on fishing and the remaining 95.2% of nearshore waters are open to fishing [3]. Amendments to state legislation in 2006 introduced requirements for lay-net registration, attendance and inspection, placed limits on dimensions and soak times, and prohibitions on the use in streams and stream mouths as well as around the entirety of Maui and several sections of water off O‘ahu [3]. However, there has been inadequate compliance and enforcement of fishing restrictions, and current regulations fail to protect many species from harvest before they reach reproductive age [3]. Furthermore, there is inadequate recreational fishing information and management, which is probably the major fisheries in the MHI [3]. Additional restrictions on overly efficient gear types such as gillnets and SCUBA fishing (particularly at night) may need to be considered, as well as revised, bag limits, and larger area closures [3].

The 11 MLCDs in the MHI were initially designated for local conservation of marine species and to aid in replenishment of the surrounding areas. Extensive biological surveys and digital benthic habitat maps by NOAA assessed the efficacy of these MPAs and found that indicators such as species diversity, species richness and biomass were significantly higher in MLCDs than in unprotected adjacent waters, regardless of habitat type [3]. Overall fish biomass and the number of large fishes (>20 cm) was 200% and 150% greater, respectively, in protected areas than adjacent waters open to fishing. Apex predators and other resource species were noted to be larger and more abundant within the MLCDs [3]. However, these positive changes appear to be confined within the boundaries of the MLCDs, as all 11 MLCDs appear to be of inadequate scope and size to positively benefit adjacent fishing areas through the export of fishes [3].

To address declining stocks of species targeted for the aquarium trade, a network of 9 Fish Replenishment Areas (FRA) which prohibit aquarium fish collection were established around West Hawai‘i in 2000 [3]. Over the following 7 years, the density of aquarium fish increased within reserves for 8 of the 10 most heavily collected species [3]. The number of aquarium fish collectors has also increased, as has the total number of fish collected and the associated total value of the fishery [3]. Compliance with the FRAs is reported to be generally good and the levels of conflict between collectors and other ocean users has decreased [3]. Moreover, evidence indicates that adult stocks of the top target, the yellow tang, are higher not only in the reserves, but also in adjacent areas [3].

Native Hawaiians have developed an intimate knowledge of local ocean resources and have a history of managing these resources to ensure long-term sustainable use. Through the ‘kapu’ system, chiefs would restrict fishing at particular sites during certain periods, such as in the spawning season [2]. Community-based stewardship has become increasingly prevalent in recent years. The Community Conservation Network joins over 32 communities to coordinate active participation in local management of coral reefs [2, 3]. These groups have been effective in removing more than 100 tonnes of marine debris from MHI beaches from 2005 to 2007 [2]. Locally-managed marine areas incorporating traditional marine stewardship practices aid in the effectiveness of reef management and compliance with regulations [6].

Coral reef management in the NWHI is predominantly administered through the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve created in December 2000, which lead to the creation of the Papahānaumokuākea Marine National Monument (PMNM) in 2006 as the largest nature reserve in the United States (3910 square nautical miles) [9]. The PMNM is co-managed by 3 agencies (NOAA, the U.S. Fish and Wildlife Service, and the State of Hawai‘i’s Department of Land and Natural Resources) which developed a comprehensive Monument Management Plan that included more than 65 000 public comments over 9 years [2]. Biologically significant areas have been set aside as 5136 square nautical miles of Special Preservation Areas with additional conditions, restrictions and prohibitions [9]. For example, the commercial bottomfish fishery and associated pelagic fishery has been prohibited and any vessels fishing legally within the areas are prohibited from anchoring on corals [9]. Traditional Hawaiian practices are allowed provided they comply with the conditions stipulated in the Proclamation [9] and recreational activities, including diving are restricted to the Midway Atoll Special Management Area [9].

Governance and management – EVIDENCE OF CHANGE (medium confidence)

Many management plans, strategies and regulations are in place to protect Hawai'i's coral reefs, with large variations between the NWHI, where comprehensive management is aimed at protecting these reef resources, and the MHI where a mix of management arrangements are implemented through many agencies and programs. There has been improved coordination, planning, community engagement, and stronger fish management in some reserves in the MHI. The declaration of the PMNM and improved management in the MHI are strong positive trends. Nevertheless, further management action is required to ensure the sustainable use of Hawai'i's coral reefs, such as improving coordination of research and management; improving fisheries regulations, compliance and enforcement; ensuring that a sufficient area of MHI waters is successfully managed to conserve coral reefs; and effective 'on ground' implementation of management arrangements.

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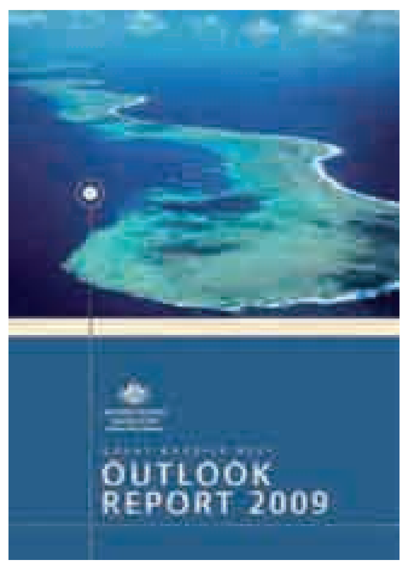
Section II: Information Management in the Pacific

Outlook Reports for a Pacific coral reef system: Australia - Great Barrier Reef

- Marine Area: 344 400 km^{2*}
- Coastline: 2 300 km
- Land Area: 21 km^2
- Reef Area: 24 838 km^2
- Total MPAs: 1 (whole GBR is an MPA)
- GBR Population: 1.11 million
- GBR popln annual growth: 2%
- GBR popln (2026 proj): 1.57 million
- GBR economic value (2005/06): AUD $5.4 billion

Data from the Great Barrier Reef Outlook Report 2009 (proj = projected)
* Area of the Great Barrier Reef Marine Park



Australia has extensive coral reef systems; however, the Great Barrier Reef (GBR) is Australia's main coral reef ecosystem in the Pacific. The Great Barrier Reef Marine Park Authority recently completed a major program to assess the current status and future outlook for the GBR. The *Great Barrier Reef Outlook Report 2009,* published in July 2009, describes the values of the GBR, the status and trends of individual components of the ecosystem, pressures and threats, current management and management effectiveness, and projections for the future. The project took more than 3 years to complete and involved extensive consultation with local communities, government agencies, scientists and risk assessment professionals to develop the mechanisms and processes used in the report. The Outlook Report assessed 90 individual components of the biological, physical, chemical, ecological, social, cultural and economic aspects of the GBR in the assessment process. These principles and approaches, although very greatly simplified, were used to develop the descriptive criteria used in this report on the Pacific coral reefs. Below are the main findings of the *Great Barrier Reef Outlook Report 2009*.

The future outlook for the Great Barrier Reef

The Outlook for the GBR is 'at a crossroad'. Climate change is one of the main issues facing the future of reefs, and its effects on the GBR will be determined by the nature and extent of future global climatic changes as well as the resilience of the GBR ecosystem itself. Nevertheless, the GBR also faces pressures from declining water quality, pollution from land-based sources (catchment runoff), loss of coastal habitats and coastal development, as well as remaining pressures from fishing (e.g. such as targeting of predators, bycatch, and illegal fishing). Some areas of the GBR continue to be exposed to increased levels of sediments, nutrients and pesticides which have caused mangrove die back and affected some inshore reefs. Some of these pressures are predicted to increase in the future, especially with ongoing population growth in the catchments adjacent to the GBR.

There is reliable information available for many components of the GBR, and the most of these appear to be relatively good condition. However, the GBR has experienced some declines since European settlement of Australia some 200 years ago. There are concerns over declines of some species such as dugongs, marine turtles, seabirds, some species of sea cucumber (bêche-de-mer) and sharks. While the coral reefs appear to be in generally good health, some inshore reefs have deteriorated. In contrast, some species and habitats appear to be recovering. For example, humpback whales are increasing due to the cessation of commercial whaling, and parts of the GBR Lagoon which were damaged by bottom trawling are recovering. More remote areas are recognised as being in very good condition. While there is a strong research capacity and expertise focused on the GBR, there are also many knowledge and information gaps, particularly about the resilience of the GBR ecosystem, and best practice management of cumulative impacts.

The management of the GBR has significantly improved in recent years, and the GBR Marine Park is often cited as being one of the best managed marine areas in the world. Recent achievements include introduction of by-catch reduction devices and new controls on fishing effort and closures. Management of non-extractive uses such as tourism, shipping and defence were assessed as being 'more effectively managed' and a lower risk to the GBR environment. The rezoning of the GBR Marine Park in 2003-2004 increased the area of no-take marine reserves to 33% of the total area of the Park. The rezoning provides greatly improved protection for the

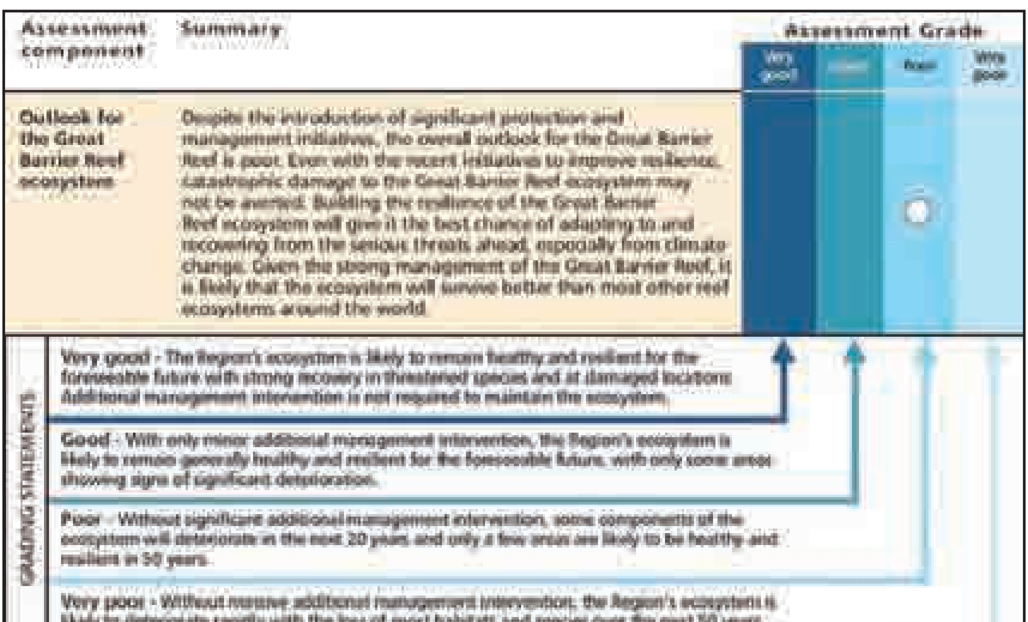


Fig. 9.4.1. Outlook for the Great Barrier Reef Ecosystem, from page 180 of the Great Barrier Reef Outlook Report 2009. In spite of management efforts, the future outlook for the GBR is ***Poor****. However, the report urges action to build the resilience of the GBR to allow it to adapt to and recover from increasing pressures and future impacts.*

range of habitats and biodiversity of the GBR. Recovery of targeted fish populations in some areas has been recorded due to these management actions.

Given the strength of current management of the GBR, it appears likely that the GBR ecosystem is better situated to survive future threats than most other reefs around the world. Nevertheless, management of the GBR faces numerous challenges. The main issues facing the GBR (climate change, catchment runoff and coastal development) originate from outside the GBR, and these cross-boundary issues complicate management efforts. In spite of management successes, the future outlook for the GBR is assessed as **Poor**, and catastrophic damage to the GBR may not be averted, especially from climate change. The Executive Summary of the report states:

Ultimately, if changes in the world's climate become too severe, no management actions will be able to climate-proof the GBR ecosystem.

However, this is not a mandate to cease efforts to manage the GBR. The concluding paragraph of the Executive Summary states:

Further building the resilience of the GBR by improving water quality, reducing the loss of coastal habitats and increasing knowledge about fishing and its effects, will give it the best chance of adapting to and recovering from the serious threats ahead, especially from climate change.

The Outlook Report summaries, fact sheets, data, and the complete *Great Barrier Reef Outlook Report 2009* are available online at:

http://www.gbrmpa.gov.au/corp_site/about_us/great_barrier_reef_outlook_report

There are particular problems within the Pacific to gain access to, and share information. This problem is exacerbated because most of the Pacific Countries and Territories are small and lack the necessary resources to generate, access and store environmental information on their own marine resources as well as learn from adjacent countries. Below are two Case Studies developed to resolve these access problems and assist Pacific peoples gain access to environmental information:

- The Pacific Environmental Information Network;
- ReefBase Pacific

The SPREP Pacific Environmental Information Network (PEIN) and Information Resource Centre (IRC)

The management and transfer of knowledge amongst the nations and territories, organisations and communities across the Pacific is a challenging task. In many cases, knowledge gained from research, data collection, status reports and information about projects are not effectively shared, making this information difficult to locate, and may not be stored effectively. As far back as 1992, SPREP (Secretariat of the Pacific Regional Environment Programme) recommended enhancing its role as an information hub and 'clearing house' for environmental information about the Pacific.

The SPREP Library Information Resource Centre (IRC) and Pacific Environmental Information Network (PEIN) programs were designed to increase and improve the flow of high quality environmental information between SPREP headquarters (in Samoa) and environment departments and organisations throughout the Pacific. The PEIN program was established in 2001 with funding from SPREP and the European Commission to address the lack of environmental information about Pacific island countries and territories. PEIN is part of the Information Resource Centre (IRC) and linked to an extensive network of international and regional information networks. Countries can also request IRC and PEIN to assist in gathering difficult to find environmental information.

The objectives of IRC/PEIN are to:

- collect, store and disseminate scientific and technical information on environmental and development concerns in Pacific island countries and territories;
- liaise and co-ordinate with other national, regional and international organisations to circulate information and publications in the region;
- assist other SPREP projects and programs by disseminating appropriate information to specific groups in the region;
- disseminate SPREP publications upon requests from outside the region on a fee-recovery basis; and
- provide technical assistance and advice on the establishment of National Environmental Information Centres (NEICs) through the EU/SPREP PEIN Project

The IRC webpage provides access to over 34,000 environmental records of 20 Pacific island states and territories, available in National Environmental Information Centres (NEICs) established by the PEIN in American Samoa, Cook Islands, Federated States of Micronesia, Fiji, Kiribati, the Marshall islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu.

Visit the IRC and PEIN at: www.sprep.org/publication/pub_top.asp

The PEIN contains country profiles (see example below) with links to economic, demographic and environmental information and reports, and links to databases and videos; users can subscribe to in-line digests and RSS feeds. The IRC/PEIN won the Stockholm Challenge Environment Category in 2004. The IRC and PEIN have proved to be an invaluable resource in the preparation of this report.

ReefBase Pacific: a new information system for the Pacific's coral reefs

The global distribution, breadth and diversity of coral reefs means that coral reef research, management and conservation is conducted by a large and diverse group of organisations and agencies around the world. Together, these organisations produce an immense amount of information on the world's coral reefs. Some of this information is published as scientific papers which are stored and maintained in scientific journals and publications databases. However, there is a substantial amount of *grey literature* about coral reefs; reports, data, information and assessments that are not produced for scientific journals, but are intended for specific purposes such as project progress reports, stock assessments or policy documents. This information is spread across the dozens of institutions and agencies working on coral reefs, making it difficult to locate and access this information.

ReefBase Pacific and ReefBase are information systems that are designed to help organise and make available information on coral reefs. ReefBase is a global system, while ReefBase Pacific is the first regionally-focused product from the global ReefBase system. Launched in 2008, ReefBase Pacific is part of the Coral Reef InitiativeS for the Pacific (CRISP) programme, and is managed through the WorldFish Center and funded through the Agence Française de Développement (AFD) and the United Nations Foundation. The core objectives of ReefBase Pacific are:

- To develop a collaborative and region-wide network of professionals involved in reef fisheries and coral reef research, conservation, and management in the Pacific that will effectively share data, information, and experience
- To assemble an unprecedented knowledge-base on reef fisheries and coral reef resources monitoring, conservation and management in the Pacific
- To utilize the network and knowledge-base to establish an easily accessible information system which provides researchers, managers and local stakeholders with instant access to relevant information for the sustainable use of coral reef resources in the Pacific; and
- To widen the scope, impact, and effectiveness of current reef fisheries and coral reef management, conservation and information sharing activities.

ReefBase Pacific is intended to improve the quality and accessibility of data and information on coral reefs, reef associated livelihoods and resource use. It contains a unique collection of information for those interested in the coral reefs of the Pacific. The system also contains GIS data: spatial data that allows users to view and build customised maps that show monitoring sites, grey literature (many reports downloadable as PDF documents), and images, project details and project contacts. The website is available in either English or French, and contains information in a variety of languages spoken by the peoples of the Pacific.

ReefBase Pacific currently holds in excess of:

- 2 507 publications (*2 163 English, 308 French, 1331 in full text PDFs*)
- 1232 photos
- 694 monitoring sites
- 77 project details
- 176 contacts
- 85 organizations
- 2021 species profiles
- 22 country profiles

ReefBase Pacific users can search for information on particular Pacific coral reefs species by searching through the species guides, or search for reef monitoring programs. ReefBase Pacific also includes a ToolBox for reef managers that contains species profiles, manuals, guidelines and advice for managing coral reefs. Users can also view country profiles that present summary information for Pacific countries, or search the database for publications, reports, images, etc. (Fig. 1).

In addition, ReefBase Pacific has produced a stand-alone version of the system on DVD to make it accessible to users without reliable high speed internet connections. ReefBase Pacific has proved to be an invaluable resource in the preparation of this report.

View data and information available from ReefBase Pacific at:
www.sprep.org/publication/pub_top.asp

Contact ReefBase Pacific at: reefbase@cgiar.org

Case studies: Sustainable development of reef resources

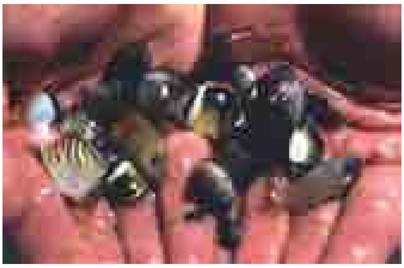
There is a recognised need for information, tools, ideas and options to help Pacific communities ensure that reef resources are used sustainably. Many organisations and projects are working towards these goals with projects that focus on management of resource use and monitoring of industries to ensure current practices are sustainable (e.g. fisheries management and monitoring programs), education and outreach programs, and projects that develop opportunities for alternative, environmentally and economically sustainable livelihoods (e.g. eco-tourism, aquaculture). These Case Studies illustrate is recent work to develop alternative livelihoods for Pacific communities:

- Post Larval Capture and Culture (PCC)
- Reef Restoration
- Reef sharks and tourism
- Bio-prospecting

Post-larval capture and culture (PCC)

Post-larval capture and culture (PCC) projects are being explored and trialled in several locations throughout the Pacific by several organisations and programs. These PCC projects capitalise on the opportunity to capture larval reef fishes, molluscs and crustaceans as they enter reef lagoons, and then 'grow out' these larvae to sell as higher-value aquaculture products such as high value food fishes, fish for the aquarium trade, or to provide stock for re-seeding degraded reefs. The aquarium trade in particular, has been a major industry in the Pacific for more than 30 years, exporting product to the United States and Europe, and increasingly, to Asia.

In natural coral reefs, larval fishes, corals, molluscs, crustaceans, and many other reef organisms, spend variable amounts of their larval life developing in the open ocean before settling onto coral reefs. While reef organisms may produce hundreds of thousands of larvae, most of these larvae and post-larvae are consumed by predators, and very few survive to adulthood. Consequently, harvesting larvae at early life stages before these extremely high mortality rates will have minimal effect on natural levels of recruitment and settlement, and an insignificant impact on the reefs. Consequently, PCC projects can mitigate pressures on exploited coral reef resources and may be able to provide alternative livelihoods for Pacific communities.



Post-larvae need to be captured using specific techniques such as crest nets or light traps, and once captured, the larval species need to be identified to select the targets for culturing. The selected larvae are reared in conditions selected to ensure their health and survival during 'grow out'. Transport and marketing systems need to be developed if the goal is an export industry. Successful PCC requires research and field trials to develop the methods before being introduced into communities. CRISP has undertaken research projects to address these knowledge gaps. PCC projects have been implemented in several Pacific countries to support this potential industry. These include:

- Researching the factors affecting the culture of coral reef fishes;
- Investigating the factors influencing recruitment of reef fishes, pearl oysters and crustaceans;
- Developing guides to identify larval fish and crustaceans;
- Exploring methods to capture, identify and culture coral reef fish larvae in French Polynesia and Fiji;
- Exploring the effects of culture conditions on survival of released fish (Fiji);
- Exploring economically viable PCC techniques in French Polynesia (Bora Bora);
- Feasibility studies of PCC for the aquarium trade in the Federated States of Micronesia; and
- Exploring the effects of reef degradation on the recruitment success of crustaceans and molluscs.

Post-larval capture and Culture (French Polynesia)

Bora Bora Eco-fish is a small company operating in French Polynesia that is trialling PCC techniques in Bora Bora and the Marquesas islands. The company is collaborating with a major international marine ornamental wholesaler based in Hawaii, but also supplies PCC mantis shrimps (a gourmet delicacy) to local restaurants and hotels. The companies will trial export of PCC product to Hawaii and from there, to the wider international market. This industrial trial could demonstrate the feasibility of PCC to replace wild captured aquarium species that are currently shipped to Asian and American markets.

Joint ventures have been established to trial PCC techniques in Bora-Bora, in Kiribati and in the Federated States of Micronesia to market and export PCC products. A preliminary evaluation found that the Federated States of Micronesia could be suitable for a PCC industry.

Importantly, the economic viability and the management and legal issues involved in PCC are being explored. These include discussions on the potential for eco-certification of suppliers, resorts and developments using PCC to re-seed coral reefs, and the implications of international agreements such as CITES and import conditions applied by importers such as the European Union. Meetings and conferences have been held to discuss the potential development and issues involved in the trade of marine ornamental fishes.

Currently, only Vanuatu and Tonga have legal arrangements to manage the aquarium fish trade. Papua New Guinea has a draft management plan and management options have been identified for Fiji. Thus, PCC has potential and further work is required to develop the technology for success

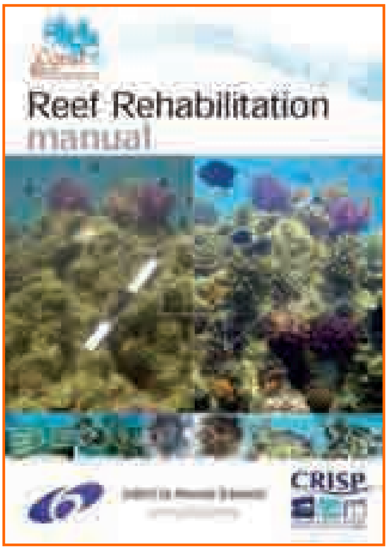
Exploring legal issues involved with the aquarium trade in Fiji

The marine aquarium trade is a significant industry in Fiji, providing 16% of all fisheries revenue; second only to tuna. The legal framework for managing trade of aquarium fish in Fiji has been explored, revealing a number of challenges and issues with the existing legislation. A range of legal options have been identified that could help address these issues including: 1. introducing a new legislative act to cover all aspects of the marine aquarium fishery; 2. introducing amendments to Fiji's *Fisheries Act* to regulate the trade; and 3. to introduce new *regulations* under the Fisheries Act. This last option was the preferred option and draft *Regulations* have been prepared for consideration by stakeholders and the Department of Fisheries.

in the industry; it is important to ensure that PCC projects and the wider aquaculture and marine ornamental trade are appropriately managed for economic viability, as well as social and environmental sustainability.

More information of PCC activities: http://www.crisponline.net/CRISPPRODUCTS/Postlarval-CaptureandCulturePCC/tabid/308/Default.aspx

Reef rehabilitation



Reef rehabilitation aims to enhance or restore reefs, and is one tool used to manage human impacts in Pacific reef areas. Despite considerable advances in reef rehabilitation over the last 35 years, it must be noted that coral reef rehabilitation is still in its infancy as a discipline. Active reef rehabilitation includes direct interventions, for example, activities to re-seed, re-introduce or enhance species, populations or ecological processes by using methods such as aquaculture, coral transplantation, species introductions or removing macroalgae (seaweeds) and/or consolidating the substrate to enhance successful coral settlement and recruitment. Passive rehabilitation includes indirect measures that protect reef functions and biodiversity and thus, enhance coral reefs. Passive rehabilitation could include management activities to reduce overfishing or pollution, and support the reefs' capacity to recover naturally.

The aims of reef rehabilitation may vary considerably between communities and projects. Reef rehabilitation projects may be focused on rebuilding or enhancing fisheries, or may be focused on restoring benthic biodiversity, or increasing shoreline protection. These different aims require different approaches to administering the programs. Additionally, active reef rehabilitation should be viewed as just one option within a broader integrated coastal management plan, and should not be considered as an alternative to management.

Putting resources into implementing effective management is generally considerably cheaper than diverting them into active rehabilitation measures such as coral transplantation, and usually more efficient. Furthermore, at sites where there are already significant local human impacts affecting coral reefs, some form of management needs to be implemented to reduce these impacts, before any attempt at active rehabilitation is made. If this is not done, active reef rehabilitation projects and interventions have a high risk of failure and may waste valuable resources.

The *Reef Rehabilitation manual* (2010) provides a overview of reef rehabilitation work that is occurring around the world, and provides detailed, 'hands on' advice, based on lessons learnt from previous projects on how to carry out coral rehabilitation in a responsible and cost effective manner. The reef rehabilitation manual and more case studies and reports are available on-line at:

www.crisponline.net/CRISPPRODUCTS/Reefrestoration/tabid/310/Default.aspx

Reef Restoration Case Study 1

Transplantation of coral colonies to create new patch reefs on Funafuti Atoll, Tuvalu

This collaborative project was conducted by the Foundation of the peoples of the South Pacific International (FSPI) and Tuvalu Association of NGOs (TANGO), and was initiated as part of the Coral Reef InitiativeS for the Pacific Programme (CRISP). The project was driven by local concerns about declining fish catches in the lagoon, believed to be caused by the loss of extensive branching coral thickets due to macro-algal overgrowth and predation by the corallivorous snail *Drupella* sp.

In addition to ecological outcomes, the project also assessed the cost-benefits of engaging a local NGO, fishers, school children and others in the local community to carry out low-tech reef restoration efforts. The social implications of the project were also considered and formed an integral part of the overall project methodology.

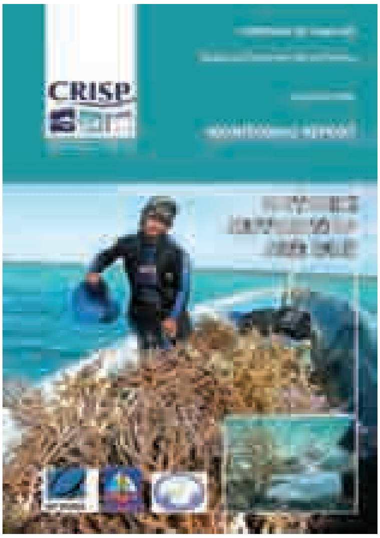
The aims of the Tuvalu reef rehabilitation project were:

- To create suitable habitats for juvenile fish in areas with currently low fish abundance;
- To recreate branching coral thickets on sandy substrate where there was no harmful macro-algae and *Drupella* sp.;
- To increase community awareness of the importance of healthy reef habitats for sustainable fisheries;
- To assess the cost-benefits of engaging local communities to carry out low-tech reef restoration efforts; and
- To demonstrate that current disturbance factors (presence of high abundances of *Stegastes* spp. territorial fish possibly due to overfishing of predators, macro algae overgrowth, corallivorous gastropod infestations) are major contributors to the reduction in fringing reef fisheries biomass.

At the end of the project, awareness raising was conducted with the community about the causes of reef degradation and the importance of coral reefs. The community's knowledge of coral reefs and of the sources of local impacts were considered to have increased. There was a gradual increase in both the number and diversity of fish species at the restored reef patches. Many of these fish were juveniles of species targeted by local fisheries.

Reef Restoration Case Study 2

Transplantation of corals to a traditional no-fishing area affected by coral bleaching in Fiji



In 2000 and 2002, Fijian reefs within a traditional (or tabu) area were damaged by a coral bleaching event. Restoration was undertaken at Ucuiledi Reef, Moturiki Island Fiji, at the request of the local communities in order to help restore fish populations. The aim of the project was to improve food security and consequently, community livelihoods. The project was also intended to test low-cost restoration methods which emphasised local community involvement, for use in shallow, low-energy reef areas.

The project consisted of collecting coral colonies and fragments in areas adjacent or close to the tabu area, transporting them by boat to the tabu area and transplanting them at a density of one colony or fragment per square meter. Although monitoring was planned for an 18 month period, it was only undertaken for 9 months as most of the corals died. The rehabilitation covered approximately 2000 m^2 within a 1 hectare patch reef and about 2000 coral colonies and fragments were transplanted in total. Although 12-16% of colonies showed 50% partial mortality at 1, 3 and 6 months, by 9 months, 75% of the transplants were completely dead and about 20% were severely damaged due to a coral bleaching event in May. Coral bleaching was observed in naturally occurring colonies of *Acropora* and other genera in the reef restoration site, at the control reef and the donor reef, indicating that the bleaching was unrelated to the transplantation.

So what could have been done differently? Donor and transplant sites should be as similar as possible with respect to environmental conditions (wave, current, depth, temperature light and disturbance). Although corals sourced from the outer lagoon reef survived well initially, in the longer term they seemed poorly adapted to the more extreme conditions experienced the restoration site. The branching *Acropora* sp. used as transplants were not common on patch reef tops such as the rehabilitation site. It has been suggested that it may have been better to choose growth forms and genera more suited to the mid-lagoon habitat or the restoration site.

Reef sharks in Palau: business partners or dinner guests?

Contributed by Gabriel Vianna (University of Western Australia) and Mark Meekan (Australian Institute of Marine Science); photos by Peter Verhoog, Save Our Seas Foundation

Reef sharks are one of the principal attractions that draw dive tourists to Micronesian reefs. Palau has taken the lead in shark conservation in the Western Pacific by declaring a total ban on shark fishing in their waters, creating a nation-wide shark sanctuary. However, illegal fishing for the shark fin trade still threatens the future of these animals, and we lack data on the status and movement patterns to develop the best strategies for enforcement and management. Collaboration between the Australian Institute of Marine Science, Micronesian Shark Foundation, University of Western Australia and the Save Our Seas Foundation seeks to provide these vital data, create links among community and ecotourism groups, and raise awareness of the value and threats to these animals. To achieve effective conservation, programs combining tagging, community monitoring, socio-economic studies and education programs have been implemented.

Photo-identification, acoustic telemetry and community monitoring by dive operators is used to track sharks around the popular dive sites on Palau. Over 3 years these methods have produced an extensive library of shark photos, records of shark-sightings by dive masters during 1600 dives and more than 1.5 million acoustic detections of tagged sharks at the main dive sites. The highest abundances of sharks occur at the popular dive sites of Blue Corner, Siaes Corner and Ulong Channel. Sharks in Palau have strong patterns of site fidelity and residency, with most remaining at the same sites over many months or years and tagged sharks producing an average of 243 detections per day.

Reef sharks are iconic marine species that are tourist attractions, especially to the SCUBA diving industry. Research in Palau has shown that sharks are resident to certain locations and may remain there for years. Reef shark tourism generates approximately US $18 million in tourism related revenue every year.

Our work not only focuses on biology, but also on the socio-economic value of reef sharks. In partnership with the Pew Charitable Trust, we examined the value of shark-diving tourism to the economy of Palau and it accounts for up to 8% of the gross domestic product, generating approximately US$18 million per year. This income has important social implications, not only by providing money for the dive industry, but also by contributing a significant amount of employment, taxes and income to other sectors of the community and the Palauan Government.

To raise awareness of the importance of sharks to the ecology of reefs and their plight worldwide, the Micronesian Shark Foundation, in collaboration with the Palau Conservation Society, has led a shark education and awareness program in all schools in Palau.

Reef sharks are in decline throughout much of their range in the tropics. Our study takes a multi-faceted approach to address this problem to ensure that sharks retain their role as keystone predators within the reefs of Palau. Beyond Micronesia, we believe that Palau offers a powerful example of the potential value of reef sharks, not only as an intrinsic part of the ecology of reefs, but also as a renewable source of income, rather than a targeted fishery from which local people receive little value.

Bio-prospecting

Bio-prospecting refers to research that seeks to identify active ingredients in marine organisms. These active marine substances (AMS) are chemical compounds isolated from various marine organisms that may have therapeutic or agricultural potential. Isolating AMS can be a complex process involving basic stages of harvesting organisms (e.g. algae and sponges), sorting and identifying them. The AMS are extracted and analysed to identify and isolate active substances, and further activity tests need to be carried out to identify potential uses such as anti-inflammatory or anti-malarial properties. If successful, these steps may culminate in industrial-scale manufacture and application 12-15 years after the organisms have been harvested.

There is growing interest in commercially useful genetic resources and biochemical processes in the Pacific region, reflected in the development of a rising number of industrial applications being developed and patents being filed. Given the potential commercial benefits and length of the process, it is important to support the development of legal frameworks in countries that own the natural resources to ensure that financial benefits are equitably shared, particularly where long lead-in times may apply. In many cases, bio-prospecting activities are not governed under the same legal rules and management restrictions that apply to accessing fisheries resources, even though both involve exploitation of natural resources.

Various bio-prospecting projects have been carried out in the Pacific, including:

- The results of the first bio-prospecting mission conducted by IRD Noumea in Vanuatu, Fiji and the Solomon Islands, focused on algal taxonomy and the isolation of AMS are being released. Similar efforts have been carried out in French Polynesia in the past couple of years by IRD Papeete and CRIOBE (Moorea);
- Knowledge of algae taxonomy was presented in an article describing the genus *Turbinaria*, and two articles on Rhodophyta have been published;
- Legal protection measures for marine biodiversity were published by Professor Jean-Pierre Beurier. This work links with efforts to improve the legal

framework in Fiji, Vanuatu and the Solomon Islands which are all involved in developing AMS through the Coral Reef Initiatives of the Pacific programme.

Bio-prospecting in the Pacific is still in its early stages, and no chemicals derived from Pacific marine organisms have been developed into marketable drugs or substances. But several compounds are showing promise. A district in Fiji has licensed plants and marine organisms for testing in Japan and set up a conservation trust fund of US$30 000 with the proceeds. An orange sponge (*Jaspis coriacea*) from Fiji has produced chemicals for medical research and the US company involved is giving 2-5% of the proceeds from sales to support further research in Fiji. Chemicals from the sea hare (*Dolabella auriculata*) and another orange sponge (*Jaspis johnstoni*) are in advanced human trials for anti-cancer activity. A red alga from Fiji has recently yielded a new class of chemicals that is active in killing cancer cells and in treating HIV.

The Universities of the South Pacific (USP) and Papua New Guinea (UPNG) are playing leading roles in the sustainable development of bio-prospecting, having set up local enterprises to increase local ability to perform the work.

For more information about bio-prospecting research and activities in the Pacific, visit:

- www.crisponline.net/CRISPPRODUCTS/BioprospectionandABS/tabid/314/Default.aspx
- www.islandsbusiness.com/islands_business/index_dynamic/containerNameToReplace=MiddleMiddle/focusModuleID=5504/overideSkinName=issueArticle-full.tpl

Case studies:
Management of Coral Reefs

Locally Managed Marine Areas (LMMAs) in the Pacific

What is an LMMA?

An LMMA is an area of near-shore waters and coastal resources that is largely or wholly managed at a local level by the coastal communities, land owning groups, partner organisations, and/or collaborative government representatives who reside or are based in the immediate area [1].

Expanding LMMAs in Fiji

Fiji has shown an impressive rate of expansion of locally managed marine areas known as the FLMMA, supported by a national network of NGOs and government organisations [2]. More than 200 villages across the 14 provinces have established some form of community-based management and the numbers have increased steadily every year over the last decade. Part of this increase can be attributed to the community-to-community exchange of knowledge and skills [1].

Navakavu LMMA in Vitu Levu Island, Fiji

The Navakavu LMMA is the fishing ground for four villages (Nabaka, Namakala, Muaivuso and Waiqanake) which are on the Muaivuso Peninsula, 13 km southwest of Suva. The local communities have exclusive rights to extract fish and other resources from their fishing grounds. In 2002, the communities responded to concerns about declining fish catches and set up a no-take zone with a number of resource use regulations. They were supported by the Fiji LMMA network and University of the South Pacific [3]. A study of finfish catches between 2002-2006, suggests that there has been an average increase of 3% in finfish catch, most likely due to the establishment of the LMMA [5].

Many Pacific Island communities have long practiced traditional mechanisms to manage their natural resources such as seasonal bans and temporary no-take areas (tabu) [1]. Communities often have a concept of community marine tenure that is recognised at the community level and in some cases, by national laws. These traditional systems can be adapted for modern use to help ensure that marine conservation efforts will benefit local communities [4].

Community-based or locally managed marine areas (LMMAs) are increasingly being implemented by many Pacific Island communities. The main driver in most cases is a desire in the community to maintain or improve livelihoods, often in connection with perceived threats to food security or income. In the Pacific, conservation and sustainable use are often seen as inseparable parts of traditional environmental stewardship [1].

Today, many communities and local leaders are working with governments and NGOs to develop management plans based on traditional practices to address major problems facing their marine areas [4]. A regional gathering of Pacific Island community members and practitioners in 2000 coined the phrase Locally Managed Marine Area as most applicable to the types of marine resource management being undertaken or envisaged in the region [1].

There has been a remarkable increase of Marine Managed Areas (MMAs) in the Pacific in the last 10 years; with more than 500 communities from more than 15 independent countries and territories being involved in establishing MMAs including many LMMAs. This is a unique global achievement [1].

LMMAs in Samoa

Samoa has benefited greatly from government investment in community-based fisheries management. In the late 1990s, it resulted in a national network of many village fisheries management areas, of which at least 50 appear to be active today (with numbers still increasing) (1).

LMMAs are generally considered to be a complementary and sometimes more culturally appropriate approach to marine protection and management in the Pacific Islands than centrally-managed MPAs; that is, areas that are largely or wholly controlled by a central government body or an outside organisation, sometimes from afar. The area of each LMMA can vary widely. Large LMMAs (around 50 km^2) include Kia in the Solomon Islands, Aleipata and Sfata MPA in Samoa and Pere in PNG. The largest LMMAs are Macuata and Yadua Taba in Fiji being more than 1 000 km^2 (1).

Conservation tools employed within an LMMA may involve a combination of management approaches that include species-specific reserves, temporary or shifting reserves, and/or harvest effort limitations (such as gear or seasonal restrictions) (4). A fully protected no-take area may be one such tool; however, a LMMA differs from a typical MPA in that LMMAs are characterised by local ownership and/or control, whereas MPAs are frequently designated by levels of management via a top down approach (4).

The community can decide upon many different management actions that for their LMMA; part of the process is for the community to identify what threats they face before suggesting management actions that are suitable and locally applicable. Actions can range from limiting commercial fishing licenses and/or use of gillnets or poisons used to kill fish, to identifying no-take areas or species. Other actions may include banning mangrove and coral extraction, replanting and rehabilitating mangrove areas, establishing village health committees to organise beach and water clean-ups, and overseeing toilet construction and rubbish dumps (2).

There are many benefits of LMMAs and community-based resource management. Not least, some communities report rapid increases of marine resources within closed areas. Other benefits include improved food security, increased economic opportunities, improved governance, better access to information and services, improved security of tenure, cultural recovery and strengthening community organisations. The spread and endurance of LMMAs is attributable in great part to the perception by communities that benefits are, or are very likely to be, achieved (1).

The LMMA Network of conservation practitioners with similar conservation aims was launched in 2000 and has operated since in Fiji, Palau, PNG, the Federated States of Micronesia, Indonesia, Philippines and the Solomon Islands. More recently, Vanuatu has joined and other countries are becoming involved, including Samoa, Cook Islands, Tuvalu, French Polynesia, Hawai'i and New Zealand. The main activities of the Network include formal learning through monitoring based on a structured guide, informal learning through exchanges and meetings, training and support of national networks (1).

There has been a large increase in Melanesia and Polynesia in the number of conservation and managed areas over the last decade. The application of community-based coastal resource

LMMAs in Vanuatu and the Cook Islands

Many communities in Vanuatu have preserved traditional management in the form of 'tabu' areas and in others this tradition has been revived with the support of fisheries officers, other government organisations and NGOs. About 80 villages are estimated to actively manage their marine resources in this manner in Vanuatu. The Cook Islands also have a number of traditional taboos known as 'ra'ui' that have been maintained, and ra'ui were reintroduced on the main island of Rarotonga in 1998, 6 of which remain at present (1). These areas usually consist in temporary fisheries closures.

management is the common theme. Traditional knowledge and resource ownership combined with a local awareness of the need for immediate action are frequently the starting points for these initiatives [1].

Community initiatives such as those found in Fiji, Samoa, Cook Islands and Vanuatu are not based solely on traditional mechanisms, as communities find ways of adapting traditional practices to modern times and integrating community governance into wider national contexts. In some instances communities undertaking local management arrangements may approach governments and NGOs for scientific knowledge to complement their traditional knowledge base [1].

Integrating LMMAs into policy and legislation

The different ways that communities approach the establishment of LMMAs results in the development of different roles for national or local legal frameworks. Fundamentally there are two extreme positions that communities may take; some communities may not be interested in, or may actively oppose developing formal legal mechanisms to support management of the LMMA. This could be due to:

- belief that legislation will not result in any actual enforcement benefits;
- complex, slow, bureaucratic or even costly processes;
- poor matching of the existing legal structures to the actual needs of the community;
- fear that such formal state or provincial involvement will reduce local resource rights or even ownership; and/or
- fear that the results will be less flexible than the entirely community driven approach, for instance for rotating or opening a closed area, or changing management objectives [1].

In contrast, other communities may activity seek to have their LMMAs integrated with formal legislation in local bylaws, or state and national legislation. These communities may pursue this because the community feels that this will provide:

- formal support for their traditional management systems, especially enforcement and legal support for the most serious infringements;
- more authoritarian or rigid support for the enforcement of rules within the community;
- a tool to enforce community rules on outsiders not necessarily subject to local traditional authority; and
- an obligation by governments to provide more enforcement [1].

Traditional use of marine resources agreements in the Great Barrier Reef, Australia

While not formally recognised as LMMAs, there are many marine areas in the Great Barrier Reef that have some form of traditional tenure. Traditional Owners of the Great Barrier Reef have been working with the government to formalise a different sort of traditional marine management arrangement in the Great Barrier Reef Marine Park. *Traditional Use of Marine Resources Agreements* (TUMRAs) are developed with Traditional Owners and accredited under State and National legislation. For Traditional Owners, the legislative basis of the TUMRA is an important aspect. Having an accredited and legally recognized agreement in place lets everybody know what 'sea country' means to the relevant Traditional Owners, clearly records their sea country boundaries, and provides information on how they are looking after their sea country both in keeping with traditions and through contemporary co-management with government agencies. A TUMRA implementation plan may describe ways to educate the public about traditional connections to sea country areas, and to inform other members of a Traditional Owner group about the conditions of the TUMRA. From a management perspective, TUMRAs provide an agreed basis for Traditional Owners and marine park managers to work together to protect cultural values and to manage culturally important species in accordance with traditional lore and to ensure sustainability.

Tetepare Conservation Area: Solomon Islands

Contributed by Gillian Goby

Tetepare Island, in the Western Province of the Solomon Islands, is one of the conservation jewels of the South Pacific. This is the largest uninhabited (for 150 years) tropical island in the Southern Hemisphere, and is home to one of the Solomon Islands' leading conservation projects and a unique, locally-owned and managed eco-lodge that attracts visitors from around the world. What makes Tetepare extraordinary is that the forests remain totally intact in a country, which has lost a very large area of forests to commercial logging. Some 73 bird species, 24 reptile, 4 frog and 13 mammal species have been recorded on Tetepare, including several rare and endemic species. However, this represents only a small portion of the island's biodiversity. In recent years, researchers have discovered 3 new species of fish, one new fish genus and one potential new fish family in Tetepare's freshwater rivers. The coral reefs of the region support some of the highest diversity of fishes and corals in the world, second only to Raja Ampat in Indonesia. Green snail populations still occur on Tetepare although they have disappeared from most of the Solomon Islands.

Tetepare Island is protected and managed by the Tetepare Descendants Association (TDA). The entire island has been set aside for conservation, and the TDA has also established a 13 km long no-take MPA. This permanent closure also includes the land area from the low water mark to 500 m inland. The MPA protects Tetepare's reefs, lagoons and coastal waters from all harvesting and is the largest MPA in the Solomon Islands.

TDA employs rangers to patrol the island and the MPA. Signs have been installed and are maintained at each end of the MPA; TDA rangers have enforced this closed area since 2003. The aim of this MPA is to provide habitats to protect the reproduction of marine species and gives TDA the opportunity to preserve a portion of Tetepare's pristine ecosystem in its natural state.

In June 2010, Descendant members of the TDA and their communities also decided to create and patrol two more temporary MPAs around Tetepare, to help stocks recover from a recent increase in harvesting. The temporary MPAs will operate on a one-year-on, one-year-off rolling basis. The TDA runs numerous monitoring programs to supports conservation work, including:

The TDA runs a community based turtle tagging and nest monitoring program on Tetepare Island

- Marine and resource harvest monitoring (fish, green snail, sea cucumbers, clams);
- Fish biomass surveys;
- Seagrass surveys;
- Basic water quality monitoring;
- Forest surveys; and
- Turtle tagging and nest monitoring.

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Section III: Summary and Conclusions

Confidence and information gaps

This report has summarised the current status and future outlook for the coral reefs of 22 Pacific Island Countries and Territories (PICTs). Our findings are that the coral reefs of the Pacific are predominantly in good health with relatively low levels of direct damaging stresses. Global climate change is the most serious threat to their future outlook, as underlined previously in the 2009 Pacific Ocean Synthesis report (1), the 2011 Reefs at Risk Revisited (2), the 2005 UNEP/SOPAC Environmental Vulnerability Index (3) and the 2008 GCRMN global status report (4). There are, however, many caveats.

In this report, we have used available information to describe trends and patterns for each of the 5 themes, acknowledging gaps and uncertainties in the information. A level of 'confidence' is used to describe each theme (see *Introduction* and *Appendix A* for information sources and confidence levels). Unfortunately, there is insufficient information for many PICTs to make definite statements; this was also a conclusion of the Pacific Ocean Synthesis Report (1) and GCRMN reports (4). The low level of information reflects the social, cultural, economic and political circumstances of these PICTs, which may have limited resources and capacity for effective monitoring. In contrast, other Pacific countries have more resources and capacity and have a long history of monitoring, which improves confidence in describing reef trends. Elsewhere, long-term monitoring programs have only recently been established and thus cannot provide information about trends and patterns. However, these recent surveys provide critical baseline data which will enable the description of coral reef trends and patterns in the face of climate change. Because many of the island groups are scattered across vast stretches of ocean, it is particularly difficult to monitor remote reefs on a regular basis, and assess fisheries catches and effort data. These issues have been recognised in assessing status and confidence levels.

Knowledge gaps

For some themes, there was insufficient information to adequately describe trends and patterns with a high level of confidence:

- **Describing reef health and resilience**: assessing reef health and resilience requires long-term data from several locations over decadal time spans with emphasis on disturbance and recovery cycles. This also requires information on processes such as coral recruitment, changes in species composition, grazing by herbivores, calcification rates, etc. These variables can be difficult to measure and require considerable technical expertise. Thus reef health and resilience could not be described for many countries. Nevertheless, this information is essential to understand how reefs respond to pressures and provide early warning before catastrophic changes occur. This information is also essential to assess management effectiveness and for adaptive management;
- **Use of reef resources**: most descriptions of patterns in reef resource use were assessed as low confidence. This is because there are few detailed long-term catch and fishing effort

data at the species level across all fishery types, and lack of species level stock assessments or risk assessments. This information can be difficult to collect over long periods, especially for subsistence and artisanal fisheries, and in remote areas. These uncertainties result in discrepancies over trends and risks between some sources, but these data are crucial to detecting trends in reef resource use and status of fisheries and exploited species;

- **Factors affecting coral reefs**: the description of these trends was assessed with low confidence for most countries. While risk assessments identify many risk factors, and anecdotal reports describe impacts on coral reefs, in most cases there was insufficient quantitative information to measure the trends (e.g. amount of erosion over time) and confidently link trends to impacts on coral reefs. Collecting these data may require integrated monitoring programs which are resource intensive and require high level technical expertise. However, this information assists managers understand how coral reefs respond to management initiatives.
- **Governance and management**: this theme was assessed with the least amount of information and the lowest confidence level. There was often information on existing management arrangements, plans, policies, laws and regulations, but there was little information on implementation and management effectiveness. For example, there was little information on whether reef users were aware of the regulations, the level of compliance and acceptance of these rules, the level of enforcement, the effectiveness of administrative planning and review procedures, and the actual 'on-ground' effects of these on coral reefs. Governance and management are very challenging to monitor, and would require government and community support, integrated monitoring programs, and multidisciplinary approaches with biologists, fisheries managers, business process analysts, social scientists, economists and other technical specialists involved. The need for better integration was identified in the Pacific Ocean Synthesis Report [(1)].

Throughout this report we have concentrated on using information sources that are freely available and accessible to readers throughout the Pacific. This includes a large amount of grey literature accessed mainly through ReefBase Pacific and the SPREP Pacific Environmental Information Network (see *Case studies: knowledge management*). These information depositories have been invaluable. We encourage those interested in the Pacific to become familiar with these resources, and we **strongly urge those working in the Pacific to lodge their material within these knowledge management systems** to ensure that those working in the Pacific have access to this information.

The status and health of coral reefs in the Pacific

- Trends in coral cover vary from country to country. While trends in reefs can be detected for individual countries, a strong regional trend is not evident;
- Many reefs appear to be generally healthy, but there are also many signs of decline, especially around population centres;
- The main drivers of coral cover at larger scales include storms and cyclones, outbreaks of crown-of-thorns seastars and coral bleaching;
- At more localised scales, coral reefs are driven by the interactions between many natural, environmental and human factors. The main human factors affecting reefs are overfishing, coastal development, urban and agricultural pollution and especially increased sedimentation from deforestation and unsustainable agriculture; and

- Fishing and harvesting constitute a special category as these are critical nutritional and cultural activities, but increases in these activities have affected coral reef communities across the Pacific. The magnitude of these effects varies between countries and islands

The trends and patterns in reef condition and health vary between countries. This is not surprising given the dynamic nature and complexity of coral reef ecosystems, and how rapidly they can change between years and locations. Every region (Southwest Pacific -Melanesia, Micronesia and Polynesia Mana) showed evidence of increases and decreases in coral cover; thus regional comparisons should be avoided because of inadequate comparative and quantitative data. Of the island and archipelago states where trends could be described: 3 showed increasing trends in coral cover; 7 had both increases and decreases; and 8 showed evidence of declining coral cover.

At larger scales (i.e. island chains in an archipelago), the main drivers of patterns in reef communities are cyclones, outbreaks of COTS and coral bleaching. These disturbances have affected all the countries considered in this report at some time, but fortunately, most reefs appear to have strong capacity to recover. This recovery suggests that Pacific reefs are faring better than reefs elsewhere in the world, a conclusion supported by the 2011 *Reefs at Risk Revisited* report which assessed about 50% of Pacific reefs at 'Low risk' (2). Nevertheless, this also means that half of the Pacific's reefs are threatened (medium risk or higher) which clearly indicates that there is no room for complacency. Additionally, the number of threatened reefs has increased by 60% since the first *Reefs at Risk* assessment in 1998 (2). Although coral cover may have increased after disturbances in many locations, the condition and integrity of the ecological processes that sustain coral reefs and would allow them to recover from future disturbances is not known for most reefs.

At the local scale, the condition of coral reefs is driven by complex interactions between many natural variables and human influences. There were many reports of adverse changes in reef fish populations, such as declining fish biomass, smaller fish and altered fish communities, especially near populated areas. The magnitude of reported declines varied between countries, but more data are needed to describe such patterns with confidence.

Threats and challenges facing coral reefs in the Pacific

- The Pacific Island countries and territories face increasing pressures and challenges;
- The main threats include overfishing, coastal development, land-based and marine-based pollution, and sedimentation;
- Population growth and globalization are underlying issues that contribute to these pressures; and
- Global climate change is already affecting some Pacific societies and their coral reefs. The predictions pose serious threats to Pacific coral reefs and island communities

In spite of the ecological and societal differences between the islands, nations and territories of the Pacific, most communities face similar challenges.

Overfishing

Fishing and harvesting of marine species have affected coral reefs across the Pacific. While there are few detailed stock assessments or long-term coastal fisheries datasets, a wealth of anecdotal reports and proxy datasets suggest that fishing activities have damaged reef fish and invertebrate communities, with declines in abundance, diversity and biomass reported from many locations. For the 19 countries that had sufficient information to describe trends in reef resource use, all showed evidence of negative changes in patterns of reef resource use and status of target species. The threats to Pacific coral reefs posed by fishing are highlighted in *Reefs at Risk Revisited* which lists overfishing, including destructive fishing, as the greatest local threat facing the Pacific's coral reefs (2). Likewise, the *Pacific Ocean Synthesis Report* lists overfishing as having severe impacts in 40 of the assessed countries, including many countries included in this report. A literature review for the 2010 *Outlook Report on the State of Marine Biodiversity in the Pacific Island Region* reported that coastal fisheries resources are over-exploited in 55% of the Pacific islands (5), although there was high uncertainty due to limited data (3).

Pollution and coastal development

Development, modification and intensive use of coastal areas is leading to increased pollution, habitat loss and degradation from coastal development, and sedimentation of inshore waters; all have affected coral reefs on the populated islands of the Pacific and also affect mangroves and seagrasses (4, 6). All of the PICTs considered in this report showed some impacts from increased runoff of nutrient and sediment rich water resulting from deforestation, overgrazing, poor farming and land-use practices, or development. These polluted waters result in eutrophication and sedimentation of lagoon waters, smothering reefs and promoting algal growth. These threats are higher around volcanic 'high islands' with intensive agriculture and heavy seasonal rainfall. Pesticides and other toxins leach into ground water and accumulate in lagoonal sediments such that fish in some locations are contaminated at levels above health standards. Unusual fish kills have also been linked to pollution, and some communities perceive that increasing incidences of ciguatera poisoning are linked to pollution.

A 2011 synthesis of catchment management issues and case studies of coral reefs (6) is available online at: www.crisponline.net/CRISPPRODUCTS/Integratedcoastalmanagement/tabid/312/Default.aspx

The coral reefs in many countries in the Pacific show damage from coastal development such as the construction of ports, roads, seawalls, tourist resorts, commercial and residential properties. On some islands, corals, coral rock and coral sediments have been dredged for building material, resulting in smothering of nearby reefs and direct physical damage. Poorly constructed roads lead to erosion and sedimentation; for example, road development in Palau has resulted in considerable reef damage. Modification of coastlines by building seawalls, reclaiming land and dredging ports has altered water circulation patterns around reefs and lagoons, causing erosion in some areas and accumulation of sediments in others.

Coastal and urban development result in intensive human activities in restricted areas which can result in increased pollution. There is inadequate treatment of sewage and municipal and industrial waste on many islands. Waste management is especially challenging on smaller islands and atolls due to the limited space to develop adequate landfill areas. Many reports indicate that inadequate waste management and sewage treatment has led to degradation of water quality and the accumulation of waste and debris on shorelines and reefs. Pollution has become a serious community health issue on some islands. Moreover, accumulated plastic rubbish and marine debris is a significant problem on some islands, with large amounts of plastic debris washing up on beaches. Increased development of tourism resorts and military bases has resulted in more demand for fish and invertebrate resources, and have caused physical damage through recreational overuse of reefs. For example, the increases in military personnel and tourists on Guam are increasing pressures on waste management infrastructure and reef health.

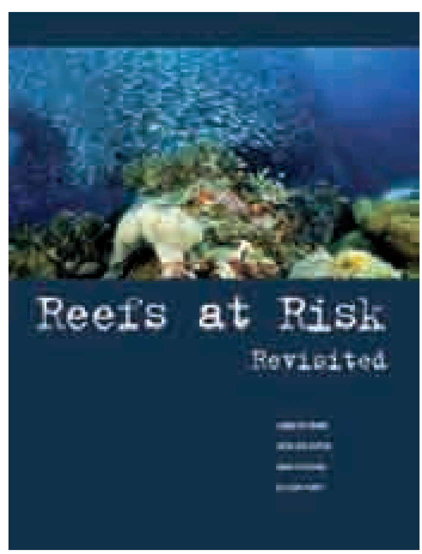
Marine-based pollution, including wastes from ships, spills of oils and other chemicals, can result in major pollution events, or more chronic pollution from daily operations of ships and ports (e.g. refueling, transferring cargo). The 2005 UNEP/SOPAC Environmental Vulnerability Index [3] identified spills as being significant risks for some of the countries. Cruise ships often carry thousands of passengers and can release large volumes of sewage and grey water [2]. Ship anchoring, groundings and accidents have caused physical damage to some reefs; if the wrecks are not removed, they continue to cause damage over many years and continually leach pollutants, including iron into iron-depleted waters, that is thought to generate "black reefs" at some atolls of the Pacific.

Increasing populations and globalization

The Pacific population is rapidly growing, with an estimated population of 10 million people in 2011, and growing to 15 million by 2035 [7]. These extra numbers and increasing urban migration from rural areas and remote islands add pressures on reef resources and threaten food security near the larger towns [1]. This increasing population also places further pressure on essential services and increases the volume of sewage and waste generated. There are reports from some islands of changes from subsistence and artisanal fishing towards fishing within the cash economy, leading to adoption of more efficient technology that increases fishing pressures. Globalisation, changes to cash-based economies and consumer culture have increased pressures on resources in some countries, and placed additional strain on waste management facilities due to the additional volume of wastes such as plastic packaging.

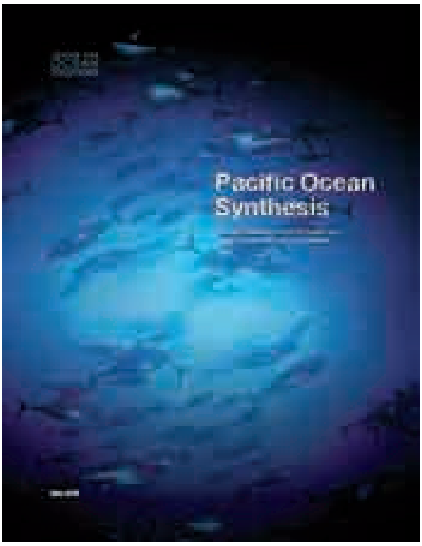
Global climate change

Climate change poses serious immediate and future threats to PICTs. This report relied heavily on the projections of climate-related threats to 2030 and 2050 from *Reefs at Risk Revisited*, and other reports. Rising sea temperatures that result in more coral bleaching are arguably the most highly visible impact of climate change on Pacific reefs. Major bleaching episodes throughout the region were recorded in 1998 and 2002, with more localised bleaching events over subsequent years. Some bleaching events caused significant coral mortality; while many reefs have shown good recovery, an increase in the frequency or severity of bleaching events could lead to long-term reef degradation [2].



Reefs at Risk Revisited assessed the risks climate change posed to coral reefs through thermal stress and ocean acidification up to 2050. This report and more information is at: www.wri.org/reefs

Ocean acidification arising from increased dissolution of carbon dioxide in seawater probably poses a more serious long-term threat to coral reefs [2]. Rising acidity will at first reduce coral growth rates, and weaken existing coral skeletons, but as acidity increases, the stony corals may be incapable of forming calcareous skeletons and maintaining reef structure and growth. Recent research investigating coral calcification in higher acidity waters near volcanic carbon dioxide 'seeps' showed reductions in coral diversity, recruitment and the abundance of hard corals [8]. Reduced calcification will also occur in other marine organisms such as crustaceans, molluscs and even some forms of plankton.



The Pacific Ocean Synthesis Report lists sea level rise as one of the main issues facing island communities in the Pacific. http://www.centerforoceansolutions.org/Pacific-Synthesis.pdf

Sea level rise is a real concern for many Pacific island nations. The *Pacific Ocean Synthesis Report* identifies rising sea level as a serious threat to many islands, especially low-lying atoll nations in Micronesia and Polynesia. The effects of sea level rise are already being felt in some areas with salt water intrusion into groundwater and taro pits, and erosion of low lying areas, especially during storm surges. Sea level rise will ultimately reduce agricultural production and force the movement of people off low-lying Pacific islands.

Changes in ocean current patterns and increases in sea temperatures may result in major changes to commercial tuna and other pelagic fisheries. These fisheries are highly valuable to the Pacific island economies and changes could threaten food security (see Box: *The vulnerability of fisheries in the Pacific to Climate Change*).

Lastly, climate change is predicted to increases the strength of cyclones and typhoons in the Pacific. These storms already cause major damage to Pacific communities and their coral reefs; increased in cyclone strength will add to the long-term degradation of coral reefs, especially when combined with other local and global factors.

Vulnerability of Tropical Pacific Fisheries and Aquaculture to Climate

The people of the tropical Pacific depend heavily on fish and shellfish for economic development, government revenue, food security and livelihoods. Climate change could affect the region's plans to maximise sustainable economic and social benefits from fisheries and aquaculture. Scientists and managers from more than 40 institutions collaborated on a Secretariat of the Pacific Community project funded by AusAID (Australian government aid) to assess the vulnerability of Pacific fisheries and aquaculture to climate change. The resultant book provides analyses of the projected effects of global warming on surface climate, the Pacific Ocean, fish habitats and stocks, and aquaculture production, across the vast domain of the 22 Pacific Island countries and territories. The effects of ocean acidification have also been evaluated.

The results are mixed, with both 'winners' and 'losers'. Tuna catches are eventually expected to be higher around islands in the eastern tropical Pacific Ocean, but lower in the west. Harvests from coastal fisheries and aquaculture are projected to decrease across the region. Yields from freshwater fisheries and pond aquaculture are likely to increase.

The book describes adaptations, policies and investments to reduce the threats of climate change to fisheries and aquaculture, and capitalise on the opportunities, and will be of interest to a broad range of stakeholders in the region, and their development partners

Text contributed by Johann Bell, Johanna Johnson and Alistair Hobday

This report was released in November 2011 and is available at: http://www.spc.int/en/component/content/article/216-about-spc-news/810-spc-book-highlights-climate-change-impact-on-pacific-fisheries.html

The e-book is now available at the link:
http://www.spc.int/climate-change/fisheries/assessment/e-book/

Additional information on the impacts of global climate change on Pacific marine ecosystems is available in *Reefs at Risk Revisited,* the *Pacific Ocean Synthesis Report* and *The Vulnerability of Fisheries in the Pacific to Climate Change* report, which are available on-line.

Management of coral reefs in the Pacific

While many nations have a legislative basis for coastal management, evidence suggests that in many countries, enforcement of laws and implementation of management is either weak or mostly lacking. However, there have been many positive developments. The expansion and success of community based management in the form of Locally Managed Marine Areas (LMMAs) is an encouraging sign that communities recognize the need to protect and manage reef resources. The initiative of the governments of Micronesia to form the Micronesia Challenge (www.micronesiachallenge.org/) with the aim of applying effective management to at least 30% of near-shore resources and 20% of terrestrial resources by 2020 represents a significant commitment to improved management. The declaration of the Pacific's largest MPA as the Phoenix Islands Protected Area (PIPA) in Kiribati (www.phoenixislands.org) is another significant achievement in managing coral reefs in the Pacific. PIPA was added to the UNESCO World Heritage list in 2010. Projects that explore alternative livelihoods and sustainable uses of reef resources are being implemented in many countries; several examples are described in case studies in the final section of this report.

The future outlook for Pacific coral reefs

This report synthesises information about the Pacific's coral reefs in a structured manner to provide a preliminary outlook for these coral reefs, using the 2009 *Outlook Report* of the Great Barrier Reef Marine Park Authority (GBRMPA) as a model. Four descriptive scenarios of the future are used to identify the future outlook options for the coral reefs of the Pacific, based on the 5 themes used throughout this report.

Scenario 1 **Outlook – Very Good**	The coral reefs of the Pacific are highly likely to remain healthy and resilient over the foreseeable future. Most reefs will remain in good condition and damaged reefs are highly likely to recover in almost all instances, and reef resources are highly likely to be sustained, rebuilt (if depleted) and managed sustainably. Additional stresses on reefs will be reduced to the extent that they have negligible effects on coral reefs. Additional management action is not required.
Scenario 2 **Outlook – Good**	With some management intervention, most of coral reefs in the Pacific are likely to remain healthy and resilient for the foreseeable future. Most damaged reefs are likely recover, and reef resources are likely to be sustained, rebuilt (if depleted) and managed sustainably. Signs of degradation will be localised to a few areas in the Pacific. Additional stresses on reefs (e.g. pollution, climate change) will be addressed with regular successes in reducing impacts on coral reefs. Pressures on reefs will be manageable.

Scenario 3 **Outlook – Poor**	Significant management interventions are required to keep pace with the pressures affecting reefs, or to attempt to halt and reverse declines. Pressures on reefs and resulting impacts will be common in most countries, and likely to increase in the next 20 years, presenting significant management challenges. Some damaged reefs are likely recover but other reefs show signs of long-term decline. Reef resources will continue to decline with collapses of some stocks. Additional stresses on reefs (e.g. pollution, climate change) will have significant impacts on coral reefs.
Scenario 4 **Outlook – Very Poor**	Without massive management intervention, the coral reefs of the Pacific will likely experience widespread degradation and loss over the next 50 years. Damaged reefs will experience phase shifts into persistent alternative states, and many fisheries stocks will be exhausted. Impacts from factors such as pollution push reefs into these persistent alternative states, and result in widespread losses of coral reef biodiversity and ecosystem function.

Future Outlook: Based on these scenarios, the **outlook for the coral reefs of the Pacific is considered to be Poor**. While many reefs are still in relatively good condition, some reefs show evidence of declines including chronic declines and changes. Increasing local pressures on reefs pose serious risks. While remote reefs are generally not exposed to the same level of pressure, global climate change presents a serious region-wide pressure that will affect both accessible and remote coral reefs. Significant management intervention will be required to overcome the many challenges to maintain the resilience of coral reefs to adequately resist pressures and threats; special efforts are required to manage the use of reef resources.

Concluding remarks and recommendations

The '**Outlook – Poor'** assessment for Pacific coral reefs is neither a criticism, nor a justification for inaction, but a '**Call for Action'**. The cultures, identities and livelihoods of people in the Pacific are intricately linked to the health of coastal and ocean ecosystems and resources; this is a key point. There are promising signs of action and improvements throughout the Pacific, and Pacific reefs are in better condition and at lower risk than many other coral reefs around the world. Pacific reefs are under lower population pressure than areas such as Asia, are generally remote from the large land masses, and most are surrounded by very deep water. This situation provides greater impetus to implement urgent management action to tackle the threats facing reefs of the Pacific. In particular, *Reefs at Risk Revisited* and the *Pacific Ocean Synthesis Report* contain a detailed list of recommendations for further action. Below is a shortened list of recommendations for further action that reflect calls from the Chapters above. If these actions are implemented effectively, the future outlook for the Pacific's valuable and unique coral reefs could be considerably improved:

1. **Climate Change:** Address climate change at its source by reducing emissions of carbon dioxide and other greenhouse gases. This will require actions at the global scale initiated through global forums, and includes actions implemented at national and local levels;
2. **Reef Resilience:** Maximise coral reef resilience to the effects of climate change by reducing local pressures such as overfishing, pollution and habitat degradation;
3. **Socioeconomics:** Address social and economic issues such as population growth and unsustainable commercial use of resources;
4. **Adaptation:** Identify and plan for the potential impacts of climate change on the social, cultural and economic circumstances of Pacific communities;

5. **Coastal Fisheries:** Improve management of coastal fisheries to ensure sustainable use of reef resources, and to halt destructive fishing practices;
6. **Catchment Management:** Improve management of the coastal zone to conserve coastal habitats, reduce erosion, plan for and manage coastal development;
7. **Reduce Pollution:** Reduce sediment and nutrient pollution through improved land-use practices in adjacent catchments;
8. **Waste Management:** Address pollution issues by improving and ensuring long-term maintenance of sewerage systems and waste management infrastructure;
9. **Alternative Livelihoods:** Explore alternative solutions to issues of overfishing, land-use and management (see *Case Studies*);
10. **Develop and maintain MPAs:** Maintain support for management initiatives such as establishing, maintaining, monitoring and enforcing networks of MPAs;
11. **Management Support and Resources**: Build capacity in reef monitoring and management within local government agencies and communities, secure long-term funding and support for these efforts and mainstream environmental considerations into decision making;
12. **Reef Co-Management:** Foster community-based management efforts ranging from education and outreach programs to the expansion of Locally Managed Marine Areas, and integrate these with formal management arrangements; and
13. **Raise Awareness:** Make a conscious effort to raise awareness of the problems facing coral reefs and the need for effective management with decision makers and all community members, demonstrating that all have a role in conserving coral reefs.

References: Summary and Conclusions

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Appendix 1: Details of descriptive themes

Status of coral reefs

This theme describes the current condition of coral reef ecosystems, but also the associated habitats such as mangroves which may be closely linked with coral reefs in some locations. Coral reef condition is usually expressed as a percentage of living coral cover of communities at monitored sites. Coral reefs are dynamic systems that experience periodic disturbances and declines that are usually followed by recovery in following years. This theme provides an indication of the current status of coral reefs compared to long-term trends.
This theme was described using status and trend information on coral reefs sourced from ReefBase Pacific, the GCRMN Status of Coral Reefs of the World 2004 and 2008, the Status of Coral Reefs in the South West Pacific 2004, and specific scientific publications and reports.

Stable: Coral cover is generally high and has been stable or increasing at most sites. No evidence of widespread and prolonged degradation of coral cover, or signs of stress or damage.

Evidence of change: Coral cover is high and stable at some sites, is increasing at other sites, but some sites are showing continued long-term declines. Signs of damage or stress evident at some sites.

Altered: Coral reef resources are at an altered state compared to previous conditions, including long-term declines in coral cover at many sites. Widespread signs of coral stress or damage.

Coral reef health and resilience

In this report, the health and resilience of coral reefs has been described by the level to which their ecological processes and community structure remain undisturbed, and by examining evidence of their ability to recover from disturbances. This relies on data such as trends in coral recruitment, and surveys of reef associated animals and plants such as macroalgae and fishes (predators, herbivores, fished species) to determine the level of disruption to reef communities. Further, long-term monitoring data provide information about cycles of disturbance and recovery. Collectively, these data provide important information about the state of the reef's *ecological infrastructure*, that is, the underlying ecological processes (e.g. recruitment, reproduction, nutrient cycling, predation, competition etc.) and community structures (e.g. abundance of predators, herbivorous fishes, macroalgae, invasive species) that are necessary to maintain coral reef ecosystems. These indices are available for a few countries in the Pacific, and cover some of the main variables recommended by the IUCN resilience assessment protocol for assessing coral reef resilience [(1)].
This theme was described using information on reef health and processes, and from trend data for patterns of disturbance and recovery of coral reefs. These data were sourced from ReefBase Pacific; the GCRMN Status of Coral Reefs of the World 2004, 2008 reports; the Status of Coral Reefs in the South West Pacific 2004, 2009; and scientific publications and reports specific to each country.

Stable: coral reef community structures appear to be stable and relatively intact compared to available baseline data or pristine reference sites, with good representation of key reef organisms such as predators and herbivores. Little evidence of altered or degraded reef ecosystem processes (e.g. recruitment failures, phase shifts in coral communities, losses of biodiversity), or major disruptions to reef communities (e.g. outbreaks of invasive species, mass mortality events, altered community structure). After disturbance events (e.g. coral bleaching, cyclones, crown-of-thorns starfish outbreaks), reefs recover to pre-disturbance state within expected time-frames.

Evidence of change: emerging evidence of changes in coral reef community structures at some sites, e.g. changes in the density or abundance of organisms such as large reef fishes between fished and unfished areas, changes in density of herbivores (e.g. parrotfish or urchins). Emerging evidence of changes in reef ecosystem processes (e.g. recruitment failures, phase shifts in coral communities, losses of biodiversity, increased recruitment following protection of spawning sites), evidence of disruptions to reef communities (e.g. spread of invasive species, population explosions of certain species, mass mortality events, altered community structure). Reefs show some recovery after disturbances, but recovery may be slower than expected or incomplete.

Altered: evidence of widespread changes in, and disruptions to, reef community structures. For example, altered community composition, reduced abundance, density or diversity of key species groups, clear evidence of widespread changes in reef ecosystem processes (e.g. recruitment failures, phase shifts in coral communities, losses of biodiversity), major disruptions to reef communities (e.g. outbreaks of invasive species or population explosions, mass mortality events, altered community structure). Reefs do not show signs of expected recovery after disturbances.

Use of reef resources

The theme describes trends in the use of coral reefs and other coastal resources such as mangroves that may help to sustain healthy reef ecosystems. This includes commercial uses such as fishing, aquaculture, tourism and aquarium collecting, as well as traditional and artisanal uses of coastal resources. This theme also includes information on emerging threats. Patterns of use may affect the health and resilience of coral reefs [(1)].

This theme was described using information available on the use of reef resources. Data were sourced from ReefBase Pacific; the GCRMN Status of Coral Reefs of the World 2004, 2008 reports; the Status of Coral Reefs in the South West Pacific 2004, 2009; the UNEP/SOPAC Environmental Vulnerability Index 2005; the Pacific Ocean Synthesis Report 2009; Reefs at Risk Revisited 2011, the FAO Fisheries Database; and publications and reports specific to each country.

Stable: Resource use appears to be stable with no evidence of significant damage or long-term impacts to reef condition, health or resilience. Trends in resource use do not appear to threaten long-term sustainability of exploited resources. If such changes are evident, they occur on a very small scale, and are localised to a handful of reefs or locations. Destructive use of reefs and resources (e.g. cyanide or bomb fishing, coral mining, mangrove destruction) is extremely rare or non-existent.

Evidence of change: resource use patterns are changing that may be increasing or decreasing pressure on coral reefs. Evidence that resource use is causing changes in the condition and health of some exploited resources and habitats. Trends in resource use may threaten the long-term sustainability of exploited resources or the health of habitats. These changes and effects are evident in several reefs and locations. Destructive use of reefs and resources (e.g. cyanide or bomb fishing, coral mining, mangrove destruction) known to occur in a few locations.

Altered: resource use patterns have changed, and current resource uses have increased pressure on reef resources and threaten the long term sustainability. Evidence of negative changes in the condition and health of resources and habitats. These changes and effects may operate across numerous reefs and locations. Destructive use of reefs and resources (e.g.

cyanide or dynamite fishing, coral mining, mangrove destruction) occurs in a number of locations.

Factors affecting reef health and condition

This theme describes large-scale factors and processes that affect coral reef condition and health, and may present risks to coral reef ecosystems. These 'risk factors' may operate at local, regional and global scales. Localised factors are specific to individual locations or countries, and tend to be related to human use and ecological impacts such as the effects of land use, population growth, coastal development, pollution and mining, and losses of biodiversity. Regional and global factors operate over larger areas and include factors such as geophysical forces and events (earthquakes, tsunamis), oceanography, climate and climate change, and severe weather events. Many of these factors are specifically considered in the Reefs at Risk Revisited assessment process, and are recommended for assessment by the IUCN coral reef resilience assessment protocol (Obura and Grimsditch, 2009)
This theme was described using information available on the environmental risks, patterns and trends, and existing risk assessments. Data was sourced from ReefBase Pacific; the GCRMN Status of Coral Reefs of the World 2004, 2008; the Status of Coral Reefs in the South West Pacific 2004, 2009; and the United Nations Population Division, and publications and reports specific to each country. Particular use was made of the UNEP/SOPAC Environmental Vulnerability Index 2005, the Pacific Ocean Synthesis Report 2009, and the Reefs at Risk 2011.

Stable: There are few risk factors identified that are likely to cause significant changes in reef condition and health. Little evidence of change in the frequency, intensity, or number of risk factors. Little evidence that these factors have caused long-term changes in reef condition or health. Population growth is not predicted to change coral reef condition or health.

Evidence of change: Some risk factors identified have caused, or could cause, significant changes in reef condition and health. The frequency and/or intensity or number of existing risk factors is changing, new risk factors may be emerging. There is evidence that these factors have caused significant changes in reef condition or health in some locations. Population growth is likely to increase pressure on the natural environment.

Altered: Many risk factors are identified that have significantly changed reef condition and health. The frequency and/or intensity of these risk factors has changed or is projected to rise, increasing the degree of impact on coral reefs. There have been numerous impacts on coral health from these risk factors with little evidence of recovery. Population growth is placing significant pressures on the environment, projected population growth is likely to result in significant degradation of the environment.

Governance and management

The theme attempts to provide a brief overview and description of the governance and management of Pacific coral reefs. Management is a very complex issue; for example, the IUCN framework for assessing management effectiveness includes assessment of 3 areas of management: 1. design/planning; 2. adequacy/appropriateness of planning; and 3. delivery/implementation of management [2]. This theme provides only a brief synthesis and description of each these 3 areas, focusing specifically on the design and implementation of MPAs, and management of coral reef fisheries.
This theme was assessed using information available on the management of reef resources. Data were sourced from ReefBase Pacific; the GCRMN Status of Coral Reefs of the World 2004, 2008; the Status of Coral Reefs in the South West Pacific 2004, 2009; and any publications and reports specific to each country. Particular use was made of the UNEP/SOPAC Environmental

Vulnerability Index 2005, the Pacific Ocean Synthesis Report 2009, and the Reefs at Risk Revisited 2011.

Stable: Comprehensive and appropriate management has been developed for coral reefs, and can potentially ensure long-term protection and sustainable use of reef resources. There is sufficient funding, support, capacity and infrastructure to implement and maintain management efforts, and management plans and programs are effectively implemented. There is little evidence of non-compliance with management, and management effectiveness is being assessed and improved where necessary.

Evidence of change: Some management plans and programs have been developed for coral reefs. While management may be bringing about positive changes in patterns of use and resource condition, long-term protection and sustainable use of reef resources has not been achieved. There is insufficient funding, support, capacity and infrastructure to fully implement the management plan, which is only partly operational. There is evidence of non-compliance in some areas. Management effectiveness has only partly been assessed.

Altered: Management plans or programs have not been developed for coral reefs, or if developed, are limited in scale, or have not been effectively implemented. This has led to alteration and degradation of coral reefs in many locations. There is a lack of resources, support, capacity and infrastructure to develop or implement management. There is evidence of non-compliance in many areas, or the level of compliance is unknown, and is not measured. The effectiveness of management is not assessed.

References (Appendix 1)

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Appendix 2: Information, agencies and programs

This is a summary reports some of the agencies and organisations working towards coral reef monitoring and management in the Pacific, and which have assisted with this report (either directly or *via* obtaining data and information from their reports). This includes government agencies, inter-governmental agencies, NGOs and private organisations.

Centre de Recherches Insulaires et Observatoire de l'Environnement de Polynésie Française (CRIOBE)

The CRIOBE is a research centre located in Moorea, French Polynesia, and part of the Centre National de la Recherche Scientifique (CNRS) French marine stations national network. It is also connected with the Practical School of High Studies (EPHE). With a staff of more than 50 including technicians and researchers, CRIOBE provides a research base for visiting researchers, undertakes theoretical and applied research, and supports education and training for post-graduate students. The CRIOBE coordinates ReefBase Pacific and coral reef monitoring efforts throughout Polynesia including long-term monitoring of reefs in French Polynesia and neighbor Pacific Islands Countries and Territories (PICTS).
http://www.criobe.pf/

Conservation International (CI)

Conservation International was founded in 1987 as an NGO based in Virginia, USA, but with regional offices across the world including Fiji, Papua New Guinea, New Caledonia and Samoa in the Pacific. The CI mission is: Building upon a strong foundation of science, partnership and field demonstration, CI empowers societies to responsibly and sustainably care for nature, our global biodiversity, for the well-being of humanity. CI's Pacific projects include marine planning in New Caledonia, marine parks in Kiribati and Fiji, and sustainability projects.
http://www.conservation.org/explore/asia-pacific/pacific_islands/pages/overview.aspx

Coral Reef InitiativeS for the Pacific (CRISP)

CRISP is diverse program that aims to develop a vision for the future of coral reefs and the communities that depend on them. Through the CRISP, strategies and projects to conserve coral reef biodiversity, while developing the economic and environmental services that they provide are being explored and implemented. The CRSIP also helps to help foster collaboration and co-ordination between developed countries (Australia, New Zealand, Japan, USA), French overseas territories and Pacific Island developing countries. The CRISP funded through the French Development Agency (AFD) and comprises three major components: (1) Integrated Coastal Management and watershed management; (2) development of coral ecosystems; and (3) program co-ordination and development (including institutional support, technical support and extension). The CRISP is hosted by the SPC in Noumea, and has provided reports and information used in this report, including many of the case studies of projects and initiatives highlighted in Section 2 of this report.
http://www.crisponline.net/Home/tabid/36/Default.aspx

Global Coral Reef Monitoring Network

The Global Coral Reef Monitoring Network (GCRMN) is an operational network of the International Coral Reef Initiative. Its programs are supported by a range of organizations, working to improve management and conservation of coral reefs by providing manuals, equipment, databases, training, problem solving. A major function of the GCRMN is to help facilitate, co-ordinate and support coral reef monitoring efforts around the world. The GCRMN also helps secure funding for reef monitoring, and all these activities are coordinated in a global network. One of the most important features of the GCRMN is its publication series on the status of coral reefs around the world. These publications are one of the main information sources used in this report.

The core objectives of GCRMN are:

- To link existing organisations and people to monitor ecological and social, cultural and economic aspects of coral reefs within interacting regional networks.
- To strengthen the existing capacity to examine reefs by providing a consistent monitoring program, that will identify trends in coral reefs and discriminate between natural, anthropogenic, and climatic changes.
- To disseminate results at local, regional, and global scales on coral reef status and trends, to assist environmental management agencies implement sustainable use and conservation of reefs.

The GCRMN monitoring coordination is organised around GCRMN nodes which coordinate and facilitate monitoring efforts in participating countries. Experienced marine institutes assist in training, establishing of databases and problem resolution. The GCRMN Pacific nodes are currently located at the University of the South Pacific (Fiji), CRIOBE (Moorea, French Polynesia) and the Palau International Coral Reef Center (PICRC). The GCRMN encourages the use of ReefBase at WorldFish Center to store data, especially metadata.

http://www.gcrmn.org/

Global Environment Facility, Coral Reef Targeted Research and Capacity Building for Management (CRTR)

The Coral Reef Targeted Research & Capacity Building for Management (CRTR) Program is an international coral reef research initiative that provides a coordinated approach to credible, factual and scientifically-proven knowledge for improved coral reef management. CTFR partners include the Global Environment Facility, the World Bank and the University of Queensland, and 50 other organisations around the world. The CRTR goal is to address key gaps in the world's knowledge and understanding of coral reefs, and put new knowledge and technology into the hands of decision-makers and reef managers where it can make a difference. By addressing these knowledge gaps, the program can identify management options to address pressures on coral reefs.

The CRTR Program is coordinated through Centres of Excellence in the Philippines, Mexico, Zanzibar and Australia, which reflect the regional distribution of coral reefs and the management initiatives underway to conserve them. These centres are the focal points for research carried out by international scientists. Major areas of research include coral bleaching, ecological connectivity and processes, coral disease, modeling and decision support, remote sensing and reef restoration and remediation. CTFR projects provide some of the case studies used in section 2 of this report.

http://www.gefcoral.org/Home/tabid/2967/language/en-US/Default.aspx

Institute for the Coral Reefs of the Pacific (IRCP)

The IRCP, a scientific institute of the EPHE, works closely with CRIOBE on information and awareness raising activities, and actively participates in research and management of coral reefs in the South and Central Pacific.

The IRCP has 4 main objectives:

- To facilitate monitoring and observations of South and Central Pacific coral reefs;
- To provide a base that facilitates and promotes research on the environments, habitats and ecosystems of the Pacific, and establish a link between fundamental research, conservation and training on coral reef issues;
- To promote social and human sciences as complementary tools for coral reef sustainable management; and

To enhance communication, awareness raising about Pacific coral reefs, and provide high level advice and expertise on coral reef issues in multidisciplinary projects aimed at coral reefs con-

servation in the context of sustainable development, thus contributing to the future of coral reefs and the people that depend on them.
http://www.ircp.pf

Ministry of the Environment, Japan (MOEJ)

The Ministry of the Environment coordinates Japan's coral reef management, and it has supported coral reef monitoring and MPA networking in the East Asian Seas Region.
http://www.env.go.jp/en/ & http://www.coremoc.go.jp/english/top_e.html

National Oceanic and Atmospheric Administration (NOAA), USA

NOAA's Coral Reef Conservation Program (CRCP) supports effective management and sound science to preserve, sustain and restore valuable coral reef ecosystems for future generations. CRCP is a cross-cutting program that brings together expertise from a wide array of NOAA offices. CRCP works in strong partnership with coral reef managers to reduce harm to, and restore the health of, coral reefs (including deep-water corals) by addressing top national threats and local management priorities through conservation activities.
http://coralreef.noaa.gov

Secretariat of the Pacific Community (SPC)

The SPC has a long history of working with communities across the Pacific. It is an intergovernmental organisation that provides technical and policy advice and assistance to its Pacific Island members. SPC was established as an international organisation in 1947 and has 26 member countries and territories including American Samoa, Australia, Cook Islands, Federated States of Micronesia, Fiji Islands, France, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, United States of America, Vanuatu and Wallis and Futuna. The main SPC headquarters is in Nouméa, New Caledonia, but it has regional offices in Suva (Fiji), and Pohnpei (Federated States of Micronesia). The SPC also has country offices in Papua New Guinea, Solomon Islands and Vanuatu.

- The SPC's mission is to help Pacific Island people position themselves effectively to respond to the challenges they face and make informed decisions about their future and the future they wish to leave for the generations that follow.
- The SPC's vision is a secure and prosperous Pacific Community, whose people are educated and healthy and manage their resources in an economically, environmentally and socially sustainable way.

http://www.spc.int

Secretariat of the Pacific Regional Environment Programme (SPREP)

SPREP is a regional organisation established by the governments and administrations of the Pacific region. It is based in Apia, Samoa, with over 70 staff, and is the Pacific region's major intergovernmental organisation charged with protecting and managing the environment and natural resources. SPREP also manages the pacific Environmental Information Network which was a major source of the information used in this report.
SPREP's mandate is to promote cooperation in the Pacific islands region and to provide assistance in order to protect and improve the environment and to ensure sustainable development for present and future generations. SPREP has 21 Pacific island member countries and four countries with direct interests in the region
http://www.sprep.org

University of the South Pacific (USP) – Institute of Marine Resources

The University of the South Pacific (USP) Institute of Marine Resources (IMR) is based in Fiji. The Institute provides scientific and technical skills, and capacity-building, in aquaculture, marine resource assessments, marine surveying, coral reef monitoring/ database maintenance, and

socio-economic analysis for fisheries and aquaculture. Current activities centre on aquaculture, on coral reef monitoring, and on marine biodiversity assessment. The Institute also coordinates the South-West Pacific node of the Global Coral Reef Monitoring Network (GCRMN), providing much of the information on the SW Pacific coral reefs used in this report.
http://www.usp.ac.fj/index.php?id=imr

U.S. Department Of State

The Department of State is the foreign policy arm of the United States Government. The Department is dedicated to creating a more secure, democratic and prosperous world for the benefit of the American people and the international community. Within the Department, the Bureau of Oceans and International Environmental and Scientific Affairs is responsible for advancing sustainable development and natural resource conservation, including aspects related to coral reefs and coral reef ecosystems, through a wide variety of international treaties, organizations, initiatives and public-private partnerships.
http://www.sdp.gov/sdp/initiative/icri

WorldFish Center

The WorldFish Center is an international, nonprofit research organization dedicated to reducing poverty and hunger by improving fisheries and aquaculture. WorldFish is one of 15 members of the Consortium of International Agricultural Research Centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is a global partnership that unites organizations engaged in research for sustainable development with the funders of this work. The funders include developing and industrialized country governments, foundations, and international and regional organizations. The WorldFish Center is committed to meeting two key development challenges: 1) improving the livelihoods of those who are especially poor and vulnerable in places where fisheries and aquaculture can make a difference, and 2) achieving large scale, environmentally sustainable increases in supply and access to fish at affordable prices for poor consumers in developing countries. WorldFish maintains FishBase (www.fishbase.org), and ReefBase (www.reefbase.org) and was instrumental in developing ReefBase Pacific (www.pacific.reefbase.org) that was a major source of information for this report. WFC also maintains the GCRMN website (www.gcrmn.org).
http://www.worldfishcenter.org

The World Resources Institute (WRI)

The World Resources Institute is an environmental think tank that goes beyond research to create practical ways to protect the earth and improve people's lives. WRI's work in coastal ecosystems includes the Reefs at Risk series, which uses geographic spatial analysis to model threats to coral reefs, as well as the Coastal Capital project, which supports sustainable management of coral reefs and mangroves by quantifying their economic value.
Reefs at Risk Revisited (2011) is the latest publication in WRI's Reefs at Risk series, which began in 1998 with the release of the first global analysis, Reefs at Risk: A Map-Based Indicator of Threat to the World's Coral Reefs, and was followed by two regional reports for Southeast Asia (2002) and the Caribbean (2004). Reefs at Risk Revisited is a high-resolution update of the original global report that draws upon the improved methodology of the regional studies, more detailed global data sets, and new developments in mapping technology and coral reef science. It was a multi-year, collaborative effort that involved more than 25 partner institutions.
The Reefs at Risk Revisited project consolidates global data sets into a geographic information system (GIS) to model threats to coral reefs and map where reefs are at greatest risk of degradation or loss. The threats examined include local threats from human activities (coastal development, land-based and marine-based pollution, and overfishing) and global threats from a changing climate (ocean warming and acidification). In the absence of complete global information on reef condition, this analysis represents a pragmatic hybrid of monitoring observa-

tions and modeled predictions of reef condition. Data and maps from the Reefs at Risk Revisited project are presented in the country profiles in Section 1 of this report.
http://www.wri.org/reefs & http://www.wri.org/project/reefs-at-risk

WWF South Pacific

Since 1995, WWF South Pacific has been working with governments and communities to support Pacific Island people in conserving and sustainably managing their natural inheritance for present and future generations. The WWF South Pacific program promotes the development and implementation of sound policies and strategies that lead to sustainable marine resource management and biodiversity conservation, and also empower key stakeholders to implement them effectively. WWF South Pacific has a shared vision of Supporting Pacific Island people to conserve and sustainably manage our natural inheritance for present and future generations.
WWF South Pacific is managed from a regional base in Suva, Fiji, where conservation field projects, policy reviews, and campaigns are coordinated for many projects across the region. In 2004, WWF South Pacific had more than 100 staff.
http://www.wwfpacific.org.fj

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Authors

Andrew Chin has been working in marine research in the Great Barrier Reef since the 1990s. Andrew worked for the Great Barrier Reef Marine Park Authority (GBRMPA) in the research and monitoring section on reef monitoring and reporting, and impact assessment projects. He was also the editor of the *State of the Great Barrier Reef Report* and helped to develop the framework and structure of the GBRMPA's 2009 Outlook Report. He has also authored several chapters for GCRMN publications including the Australia and Papua New Guinea chapter of the 2008 GCRMN status report. Andrew is currently working at James Cook University in Queensland, Australia, focusing on the biology, ecology, conservation and management of sharks and rays. He is one of the founding members of the Oceania Chondrichthyan Society, a scientific society supporting research, management and conservation of sharks and rays in the Pacific.

Thierry Lison de Loma is the associate Director of the Institute for the Coral Reefs of the Pacific (IRCP). He holds a PhD in Marine Environmental Sciences from the University of Aix-Marseille (France), with a focus on biogeochemistry and ecology in coral reefs. He started to work on coral reefs by studying coral ecology in 1993, in the tropical island of La Réunion (Indian Ocean). He is now a specialist in coral reef fish ecology in French Polynesia, based at CRIOBE (CRNS-EPHE) in Moorea. He mainly focuses on the effects of specific disturbances/factors (global change, fishing pressure and MPAs) on long-term fish community dynamics. For the past 19 years, Thierry has been diving extensively in the islands of the South Pacific and Indian Oceans (from Pitcairn to Madagascar), for field work and for his own enjoyment. He is in charge of the GCRMN Pacific Node.

Katie Reytar is a Research Associate at the World Resources Institute. She is a co-author of WRI's *Reefs at Risk Revisited* report and specializes in GIS and data analysis. Katie has a M.E.S.M. in Coastal Marine Resources Management from the University of California, Santa Barbara and a B.S. in Environmental Engineering from the Johns Hopkins University.

Serge Planes has been involved in the study of population genetics of marine fish since the beginning of his career that started with his PhD in 1989. Over the past 20 years, he has published about 65 papers in international journals dealing with the population genetics of coral reef fishes and an additional 50 papers dealing with ecology, ecology of marine protected areas and recruitment of marine fishes. Such international recognition led to him being invited to participate as a member of the Australian Centre of Excellence on Coral Reefs and he has recently been incorporated into the scientific committee of the 12th International Coral Reef Symposium. Serge Planes is directing the LABEX "CORAIL" awarded in 2011 for 10 years, this being the major structural framework for research on coral reef ecology in France. He is also the Director of the Centre for Island Research and Observatory of the Environment (CRIOBE) and of the Institute for the Coral Reefs of the Pacific (IRCP), both based in Moorea, French Polynesia.

Karin Gerhardt has a decade of experience in marine park management, specializing in the Great Barrier Reef. Her work at the Great Barrier Reef Marine Park Authority has included marine park management, permit assessment, policy development and impact assessment. One of Karin's specialties is in Knowledge Management – specifically the acquisition, management and effective utilization of knowledge and information for managing marine areas. Her expertise in this area was instrumental in managing the information processes that were used to develop this report. Her current focus is on working with the Traditional Owners of the Great Barrier Reef in the management of Sea Country and capturing and evaluating the outcomes of the Reef Rescue Land and Sea Country Indigenous Partnership Program.

Eric Clua is a scientist based at the Secretariat of the Pacific Community (SPC Noumea, New Caledonia), where he is the coordinator of the Coral Reef InitiativeS for the Pacific (CRISP) programme. Eric holds a PhD in Marine Ecology from the Practical School of High Studies (Ecole Pratique des Hautes Etudes – EPHE), Perpignan, France. His interest in coral reef ecology, conservation and sharks has taken him to many islands across the South Pacific. He has developed, over the years, an intimate knowledge of the Pacific region, its coral reefs and its peoples. His role in promoting the sustainable development of coral reef related activities in the Pacific has been crucial.

Lauretta Burke is a Senior Associate at the World Resources Institute. Lauretta leads WRI's work on coastal ecosystems, including the *Reefs at Risk* project and *Coastal Capital* series on valuation of coral reefs. She has an M.A. in Environment and Resource Policy from the George Washington University and an M.A. in Geography from the University of California, Santa Barbara.

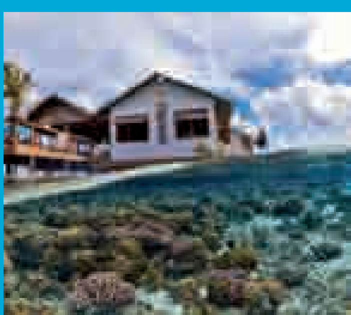
Clive Wilkinson has been the Coordinator of the Global Coral Reef Monitoring Network since 1996. He was formerly the Chief Technical Advisor for a coastal resource research program in 5 ASEAN countries and for an Australian project in Thailand after the massive tsunami of December 2004. He was an active field scientist on the ecology of the Great Barrier Reef at the Australian Institute of Marine Science with more than 100 papers published. He received BSc and PhD training in marine microbiology and ecology from the University of Queensland. He is based with the Reef and Rainforest Research Centre in Townsville Australia and now provides advice to governments on effects of global climate change on coastal ecosystems and potential adaptation policies.

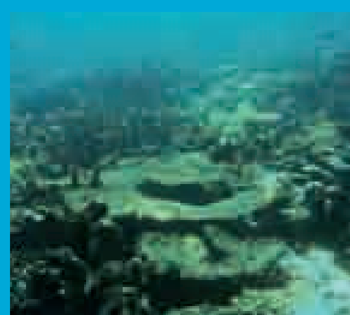
SPC Secretariat of the Pacific Community

SPREP/PROE

SOCMON

CRISP





The World Bank

CBD

WorldFish Center

Reef & Rainforest Research Centre

Australian Government

Great Barrier Reef Marine Park Authority