STATUS OF THE CORAL REEFS IN THE PACIFIC FREELY ASSOCIATED STATES

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From east to west, the Freely Associated States include the Republic of the Marshall Islands (the Marshalls or the RMI), the Federated States of Micronesia (FSM), and the Republic of Palau. The Federated States of Micronesia – Kosrae, Pohnpei, Chuuk, and Yap – along with Palau, are known as the Caroline Islands, which are among the longest island chains in the world at 2,500 km.

All of these Micronesian islands were formerly a part of the Trust Territory of the Pacific Islands administered by the United States after World War II. All three countries achieved independence within the past 25 years but retain close economic and strategic ties to the United States (Hezel 1995). Although the process was initiated as early as 1979, the Compacts of Free Association for the RMI and FSM did not go into effect until 1986[176]. The Palau Compact was approved later[177] but was not effected until a few years after that.

Mostly unmapped, estimates of coral reef habitat for the Freely Associated States range from 11,600 km^2 (Spalding *et al.* 2001) to 81,500 km^2 (Holthus *et al.* 1993, Maragos and Holthus 1999). Throughout the region, there is high diversity of corals and associated organisms.

The human population is heavily dependent on coral reefs and related resources both economically and culturally.

The Republic of the Marshall Islands[178]

Introduction

The Republic of the Marshall Islands encompasses approximately 1,225 individual islands and islets with 29 atolls and 5 solitary low coral islands (Fig. 292). Situated from 160°-173° E, and between 4°-14° N, the Marshalls have a total dry land area of only about 181.3 km^2. However, when the Exclusive Economic Zone (by statute, from the shoreline to 200 miles offshore) is figured in, the Republic covers 1,942,000 km^2 of ocean within the larger Micronesia region. There are 11,670 km^2 of sea within the lagoons of the atolls.

Land only makes up less than 0.01% of the area of the Marshall Islands. Most of the country is the broad open ocean with a seafloor that reaches 4.6 km (15,000 ft). Scattered throughout are nearly a hundred isolated submerged volcanic seamounts; those with flattened tops are called **guyots**[179].

The average elevation of the Marshall Islands is about 2 m (7 ft) above sea level. The air is warm and moist; humidity is around 80% with considerable salt spray. The air temperature averages 27.8° C (82° F) with a range of 24-32° C (76-90° F). Rainfall tends to be seasonal, ranging from 4 m a year in the south to as little as 0.6 m a year in the

Figure 292. Satellite imagery of Aur and Maloelap Atolls (Photo: Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center).

[176] Pub. Law 99-239, the Compact of Free Association Act of 1985.

[177] Pub. Law 99-658.

[178] Much of this information was from a report by the National Biodiversity Team of the Republic of the Marshall Islands (2000).

[179] These were geological masses formed millions of years ago that were not quite able to keep pace with subsidence or reach sea level to become or remain as islands or atolls.

Figure 293. As demonstrated by the lush coral garden in this picture, there are still healthy coral reefs on Majuro (Photo: Marshall Islands Visitors Authority).

north. In extremely dry years, there may be no precipitation on some of the drier atolls. Tropical storms (typhoons) are relatively rare, but can be devastating.

The atolls vary in size from Kwajalein, the world's largest atoll with 16.4 km^2 of dry land and a lagoon of 2,174 km^2, to Bikar with only 0.5 km^2 of land, but with 37.4 km^2 of lagoon, and Namdrik with more land (2.7 km^2) but only 8.4 km^2 of lagoon. Individual islands range from tiny sand-spits and vegetated islets that are inundated during storms and extreme high tides, to much larger islands such as Kaben Island at Maloelap Atoll, and Wotho Island, the main island at Wotho Atoll; both are over 8 km^2. Lagoons within the atolls typically have at least one deep-pass access; however, some, such as Namdrik, have no natural passes.

The atolls and islands of the Marshalls formed when fringing reefs began to establish and grow around ancient emergent volcanoes. After that, the volcanic peaks gradually sank and shrank, leaving lagoons in the vacated spaces and eventually became coral atolls after the volcanoes disappeared entirely beneath the reefs and sediments of coral atolls. The five solitary islands were formed in much the same way, but the peaks were small enough that no interior lagoon developed. With seamounts and guyots, the subsidence took those volcanoes and reefs far below the surface of the sea.

Mostly, the atolls of the Marshalls are not circular, nor do they have uniform islets. They are much larger than those in the Indian Ocean and are surrounded by numerous islets. The islets are more dominant on the windward side and seemingly sprawl around a deep lagoon. They are also different from other atolls because they are deeper and have more circulation within their lagoons.

The islets are extremely young geologically and likely formed either when sea level dropped about 2 m to its present level around 4,000 years ago or in the aftermath of large waves that cast large reef blocks, coral rubble, and sand up on top of shallow reefs. Then vegetation, birds, crabs and other animals colonized the emergent islands, and eventually the Micronesian ancestors of the present day Marshall Islanders arrived. In contrast, the atoll reefs are 50 million years old or more, and up to a mile thick atop their volcanic foundation.

Condition of Coral Reef Ecosystem

In general, the reefs of the Marshall Islands are in good condition. Even those in the former nuclear test sites show remarkable recovery, although many of the larger bomb craters may not fill in for years, if at all. The reefs near the urban areas of Majuro are stressed, but still have an abundance of fish and invertebrates (Fig. 293). Recent information on the status of coral reefs of the Marshalls can be found in Maragos and Holthus (1999), Price and Maragos (2000), and the National Biodiversity Team of the Republic of the Marshall Islands (NBTRMI, 2000).

Marine Algae and Higher Plants – There have been 222 species of macroalgae, 3 species of seagrass, and at least 5 species of mangroves identified from the RMI. A salt-tolerant shrub or tree (*Pemphis acidula*) often forms monospecific stands in the intertidal region[180]. Other members of the mangrove community are found in inland depressions rather than along the coast. The principal mangrove species (*Bruguiera gymnorrhiza*) is

Figure 294. Three-banded anemonefish (Photo: Marshall Islands Visitors Authority).

[180] The area between low and high tide.
[181] Jellyfishes, hydroids, anemones.

found throughout the country. *Sonneratia alba*, *Lumnitzera littorea* and *Rhizophora* species, are only found on a few of the atolls (NBTRMI 2000).

Corals and Other Macroinvertebrates – There are at least 362 species of corals and other cnidarians[181] 40 species of sponges, 1,655 species of mollusks, 728 species of crustaceans, and 126 species of echinoderms on the coral reefs of the RMI.

Fish – There are at least 860 species of reef fishes recorded throughout the country. Seven species of fishes are endemic to the Marshalls and another 17 to the nearby area. One of these endemics, the three-banded anemonefish (*Amphiprion tricinctus*) is exported for aquariums (NBTRMI 2000, Fig. 294).

The after-effects of some of the 67 nuclear tests in the northern Marshalls between 1946-1958 on fish have also been studied, but most studies were years after the tests ended. Noshkin *et al.* (1997) summarized the results from all available data on the radionuclide[182] concentrations in flesh samples of reef and pelagic fish collected from Bikini and Enewetak Atolls between 1964 and 1995. Although $^{239+240}$Pu and ^{241}Am have not significantly accumulated in the muscle tissue of any species of fish, a variety of other radionuclides had accumulated in all species of fish from Bikini and Enewetak lagoons (Noshkin *et al.* 1986). Over the years, many of those radionuclides have diminished by radioactive decay and natural processes (Noshkin *et al.* (1997). Those authors report that fish collected in the 1980s and 1990s show only low concentrations of a few remaining long-lived radionuclides. By the 1990s, ^{207}Bi remained below detection limits in muscle tissue from all reef fish except goatfish. Levels of ^{137}Cs diminished to detection limits in mullet and goatfish at many islands, and ^{60}Co was found everywhere low in concentration or below the limit of detection.

Figure 296. Tourism has not been heavily developed in the Marshall Islands (Photo: James McVey).

Figure 295. These trees were cleared for the construction of the Majuro airport (Photo: James McVey).

Marine Reptiles and Mammals – Five species of sea turtles and 27 species of marine mammals have been observed in the Marshall Islands (NBTRMI 2000).

Water Quality – Coastal construction for ports, docks, airfields, causeways, and roads has affected water quality in the RMI (Fig. 295). Development projects often require sources of fill material expand land areas. That lead to dredging and filling adjacent reef areas (Maragos 1993). While underway, construction along the shoreline mobilizes suspended sediments and turbidity and can change the circulation patterns in lagoons.

Coastal Populations and Reef Economics

In 1999, the Marshall Islands supported a population of 50,840 people (J. Butuna pers. comm.). This represents a dramatic 9.9% increase in population size over the last ten years.

Tourism is low (Fig. 296). Only 5,246 visitors traveled to the Marshall Islands in 2000 (B. Graham pers. comm.). However, even though there are few visitors, the contribution to the economy is important – an estimated $3 million in 1998 (U.N. Economic and Social Commission for Asia and the Pacific 2002).

The gross value of fisheries output for the Marshall Islands was $19.2 million in 1995 (FAO 2002). Subsistence and artisanal fishing play an important

[182] Radionuclides and isotopic forms (chemical abbreviations and superscript numbers are in parentheses) mentioned in this paragraph are plutonium ($^{239+240}$Pu), americium (^{241}Am), bismuth (^{207}Bi), cesium (^{137}Cs), and cobalt (^{60}Co).

Figure 297. Satellite imagery of Bikini Atoll (Photo: Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center).

role in the Marshall Islands, especially in the outer atolls, where they provide the local population with a major source of animal protein.

Environmental Pressures on Coral Reefs

Human Stresses – In general, the more apparent impact to the reefs of the Marshall Islands is lifestyle change, loss of traditional conservation knowledge, and urbanization. Lack of proper trash disposal results in occasional dumping in the lagoon or ocean, which, at the very least, causes aesthetic damage. Periodically, fishing vessels have broken loose from their anchor and hit the reef, damaging the coral structure as well as spewing fuel over a large area.

Figure 298. Residents now eat coconut crabs from islands affected by nuclear testing (Photo: James McVey).

Poaching reef species happens and surveillance is limited.

Invasive and non-native species are a subtle, but potentially more permanent threat, especially on land. Many terrestrial invasive species have been documented, and some of these, such as ironwood (*Casuarina equisetifolia*), can impact coastal areas by out-competing the native vegetation protecting the shoreline.

Fouling marine invertebrates have been introduced, especially in ports where they probably arrived on ship hulls. Non-native algae and fishes have been documented**,** but the full impact of their presence has not been studied. Indications are that invasive species have the highest potential to damage coral reefs. (NBTRMI 2000, N. Vander Velde pers. comm.).

Harvesting 'live rock' and other coral reef products also has serious implications. Many species are exported for the aquarium trade. Seashells are heavily used in handicrafts.

The most destructive series of human impacts involving RMI islands, atolls, and lagoons occurred nearly 50 years ago. On March 1, 1954, a thermonuclear test bomb, code-named "Bravo," was detonated on Bikini Atoll (Fig. 297). Within seconds, it was a mile-wide 15-megaton blast – a fireball vaporizing entire islands and reefs – creating a huge crater in the reef. Fish, corals, and other marine and terrestrial animals were destroyed when millions of tons of water and debris were thrown high into the air and then fell back to the lagoon (Simon 1997, Walker *et al*. 1997, Robison and Noshkin 1999, Niedenthal 2000). Winds spread the radiation to nearby atolls, including inhabited Rongelap and Utrik and uninhabited Rongerik and Ailinginae.

Unfortunately, the complete picture of nuclear testing on the Marshalls' biodiversity is neither simple, nor necessarily what it seems to casual observers. For example, J. Delgado (1996) observed in his book, *Ghost Fleet*, that there was "no tangible evidence of the testing" on Bikini. J. Maragos (pers. comm.) counters, however, "the 2 km wide and 50 m deep crater in the reef at the Bravo test site is certainly evidence of lasting impacts, along with the islands that were evaporated by the Bravo blast."

Although a half-century has passed, the full extent of the impact on the biota – radioactive materials that came through the nuclear testing program – are uncertain (NBTRMI 2000). As R. A. Kenchington and B. Salvat (1988) stated, "Radioactive wastes may have long-term and largely unpredictable effects upon the genetic nature of the biological community." Risks from the consumption of large amounts of locally grown food are still acknowl-

edged, even though returning residents are again eating the crabs (Fig. 298).

Natural Stresses – Although major typhoons are rare, they are devastating when they hit, not only to the land but also near-shore coral reefs. In 1991, Typhoon Zelda hit the southern atolls, quickly followed in early 1992 by Typhoon Axel, which scoured the south-facing reefs of Majuro, covering the land, including the airport with coral debris and rubble. Shortly thereafter, Typhoon Gaye ravaged much of the northern atolls, including Wotho. In late 1997, Paka changed from a tropical storm to a typhoon while over the Marshalls and caused considerable damage to Ailinglaplap (N. Vander Velde pers. comm.)

Climate Change and Coral Bleaching – Of all ecosystems, coral reefs are considered the most sensitive to global warming. Coral reef countries, such as the Marshalls, are thus at risk, of not only the destruction of their critical services – fishing, shore protection, tourism and biodiversity – but also of the possible disappearance of the lowest-lying countries, should the ocean level rise even moderately (NBTRMI 2000, Fig. 299). It was suggested during an inter-governmental meeting that such countries could be considered for United Nations Environmental Programme protection as 'endangered species' (South Pacific Regional Environmental Programme 1989).

Because they are low, any increases in sea level will severely impact the atolls. Moreover, it takes time for coral larvae (recruits) to successfully colonize new surfaces, and the erosive forces of waves, currents, herbivorous fish, boring urchins, sponges, and algae all counteract constructive forces. Under normal conditions, coral skeletons and the other components of a coral reef can provide sand and rock to replenish what is lost to islands from natural erosion. For instance, in the Marshalls, the growth rate for healthy reef is estimated to be much lower than that of individual live corals, and it is not clear whether upward reef growth could keep pace with erosion of the islands.

If the growth rates of corals are reduced, then atoll islets become more vulnerable to erosion. If sea level temperature rises, bleaching events and coral death could follow and effectively reduce overall reef growth. In 2002, the average sea temperature around the Marshall Islands is about 29° C, near the upper limit for coral survival. According to T. Goreau (pers. comm.) of the Global Coral Reef Alliance, the increase of 1°C (1.8°F) could trigger massive coral bleaching and die-off.

Climate change can impact ocean currents and weather patterns. A recent report on climate change in the Marshall Islands projected that air temperatures will continue to rise on all atolls with the highest increases in the northern areas (Crisostoma 2000). Total rainfall will decrease and there will be an increase in severe droughts especially in the northern atolls. And the intensity and frequency of extreme events (storms and storm surge) will increase.

These conditions also can negatively impact freshwater supplies. A decrease in rainfall can result in people using groundwater to the point it becomes salty. An increase in sea level also allows more salt to seep into the groundwater.

Current Conservation Management

Mapping – Benthic habitats need mapping. Although coastal resource atlases have been prepared, mapping of coral reef habitats and uses for Arno, Majuro, and Kwajelein Atolls. A South Pacific Applied Geoscience Commission (SOPAC) sponsored project was recently started to map the coastal areas of Majuro.

Research, Assessment, and Monitoring – Pioneering studies on coral reefs in the Marshall Islands encompassed several atolls before 1955 (Tracey *et al.* 1948, Hiatt 1950, Ladd *et al.* 1950, Wells 1951 and 1954, Emory *et al.* 1954). In 1987, a two-volume report on the natural and biological resources of Enewetak Atoll is perhaps the most comprehensive treatment of any of the Marshall Islands (Devaney *et al.* 1987). In

Figure 299. Low islands' existence is threatened by sea level rise (Photo: James McVey).

1988, J. Maragos coordinated coastal resource inventories and atlases of Arno, Kwajalein, and Majuro Atolls. There were additional marine biodiversity surveys of the northern RMI islands and atolls involving marine biologists and cultural specialists[183]. In 2001, S. Pinca led a systematic survey of coral reef resources with community support through the College of the Marshall Islands and the Marshall Islands Marine Resources Authority. It was the first of such studies; similar studies are planned for some of the northern atolls (including Ailinginae and Rongelap) and the southern atoll of Jaluit in 2002.

Figure 300. According to the RMI National Biodiversity Strategy and Action Plan, developing sustainable fisheries is a priority (Photo: Marshall Islands Visitors Authority).

Several beaches on Majuro were surveyed as part of a training and monitoring program for the RMI Environmental Protection Agency in 1993-1994 (J. Maragos, pers. comm.). The status of subsequent beach and reef monitoring is not known. A coastal management program was conducted for Majuro in the late 1990s. It produced several small publications which have had a limited effect on conservation of the RMI coral reef ecosystem (UNDP/Majuro Atoll Local Government/RMI EPA/MIMRA 1998).

The U.S. Army regularly monitors Kwajalein Atoll environments, marine life, and other wildlife of islands and reefs that it leases and uses for its ballistic missile testing program (M. Molina pers. comm.).

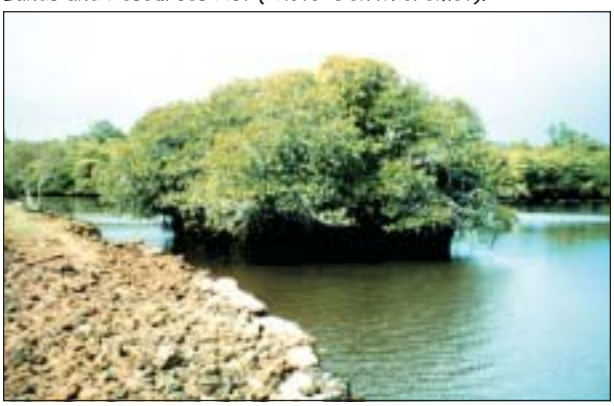
Several RMI agencies are actively involved in protecting coral reef ecosystems. Primarily, these are the Marshall Islands Marine Resources Agency and the Environmental Protection Authority. In 2000, the National Biodiversity Strategy and Action Plan (NBSAP), as well as the National Biodiversity Report (NBTRMI 2000) were approved by Cabinet. These documents are now available to the general public. Both address to at least some extent the need for conservation and management of the natural resources. The National Report contains extensive lists of marine organisms. The NBSAP recommends strengthening the concept of 'mo,' a traditional system of taboo that identified certain areas as 'pantries' that could be harvested only periodically. This was done in both terrestrial areas and coral reef ecosystems. The NBSAP also addressed the need for sustainable fishing practices (Fig. 300) and a retention of local knowledge. Implementation of these recommendations is pending (NBTRMI 2000).

Government Policies, Laws, and Legislation

Harding (1992) summarized the relevant International Laws. The Compact of Free Association between the United States of America and the Republic of the Marshall Islands (1986, Title One, Article VI) has a pledge between the two countries 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." In Section 161 (b), the Marshall Islands has an obligation to develop and enforce comparable environmental standards and procedures to those of the United States.

The Convention for the Protection of the Natural Resources and Environment of the South Pacific Region and related protocols was ratified in 1987 "to prevent, reduce and control pollution resulting from vessels, land-based sources, seabed activities, discharges into the air, disposal of toxic and non-toxic wastes, testing of nuclear devises, and mining."

Figure 301. Mangroves are protected by the RMI Public Lands and Resources Act (Photo: Ben Mieremet).



[183] Titgen *et al*, 1988, Thomas *et al*. 1988, AAA Drafting and Engineering *et al*. 1989a and b, Manoa Mapworks 1989, Maragos *et al*. (eds) 1993a and b, Maragos 1994.

As a Compact Nation, a number of U.S. laws are legal authorities for conservation of RMI reef resources (relevent U.S. laws are in Appendix IV).

The **Marine Mammal Protection Act** provides protection for dolphins and other marine mammals captured during commercial fishing operations in the eastern Pacific Ocean.

The **National Environmental Protection Act** provides for studies of the impact of human activities on natural resources to prevent degradation or impairment of the environment; and may involve the enforcement of regulations of human activities to ensure safe, healthful, protective, and aesthetically and culturally pleasing surroundings.

The **Coast Conservation Act** protects and preserves the coast from sea erosion or encroachment of sea-related to development activities. These laws apply to coastal activities such as building, depositing wastes or other material from outfalls, vessels, the removal of sand and living materials[184], dredging and land reclamation, mining or drilling for minerals. But it does not include fishing within 7.6 m (25 ft) landward of mean high water line and 61 m (200 ft) seaward of the mean low water line.

The **Planning and Zoning Act** requires local governments to establish a Planning Commission and Planning Office to oversee coastal zoning activities and assure compliance.

The United States Army Kwajalein Atoll is under U.S. laws and regulations, including CITES, NEPA, and the Migratory Bird Act.

Relevant RMI laws protecting coral reef resources include the **Republic of the Marshall Island Constitution** (1979, Article X), which preserves traditional land tenure and titles system. It holds that no person with customary land rights may alienate or dispose of land without approval of traditional landowners, but the government retains the authority to acquire land or aquatic habitats and establish conservation and research programs for resident endangered or threatened species.

Under the **Public Lands and Resources Act** (1988 Title 9, Chapter 1, Section 3), all lands below mean high water mark belong to the government, with exceptions, but no one has the right to abuse, destroy, or damage mangroves or land (Fig. 301).

The **Marshall Islands Marine Authority Act** of 1988, revised in 1997, provides authority for the

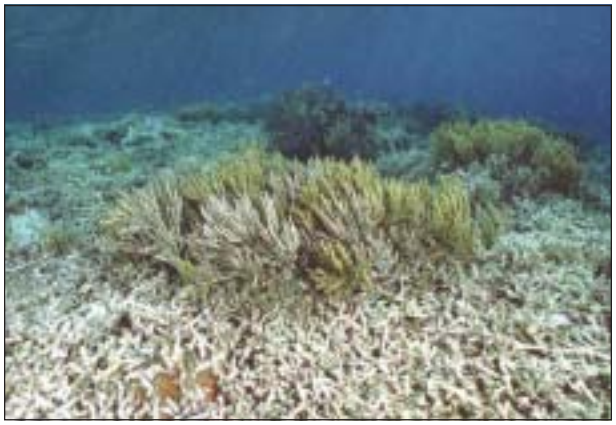


Figure 302. Dynamite fishing is prohibited in the Marshall Islands (Photo: Wolcott Henry).

licensing of foreign fishing vessels and activities other than foreign fishing. This includes the development of local fisheries, licensing local fishing vessels, non-commercial fishing, and fish processing. Section 3(1) of this act forbids the taking of hawksbill turtles, sea turtles and their eggs on shore and selling turtle products. Section 12 provides 15 areas for which the Authority may make regulations, including the conservation of fishery waters, protection of fish, the operation of domestic and foreign fishing vessels, licensing, pollution, and the export of fish. Part VI prohibits the use of explosives (Fig. 302), poisons, or other noxious substances to catch fish, the possession of fishing nets or gear not conforming to prescribed standards, foreign fishing vessels from fishing without a license, and the taking of artificially planted or cultivated sponges. It also sets size and seasonal limitations on the taking of black-lipped pearl oysters.

The **Marshall Islands Marine Resources Authority Act** (MIMRA) of 1989 prohibits the use and possession of drift nets within the exclusive economic zone of the RMI. This act also regulates the harvesting of the imported topshell gastropod and establishes an open season of no more than 3 months in any 12-month period. Topshells may be taken only by citizens of the Marshall Islands who either live where they have the right to fish under local law or have a MIMRA fishing license. To be harvested, the gastropod must have a shell of at least 3 inches in diameter at the base.

The **Republic of the Marshall Islands Environmental Protection Authority** (RMIEPA) has regulations controlling all earthmoving activities, or any construction or other activity that disturbs or

[184] This covers coral, shells, vegetation, and sea grass.

alters the surface of the land, coral reef ecosystems, or the bottom of a lagoon. This includes all excavations, dredging, embankments, land reclamation, land development, mineral extraction, ocean disposal, and the depositing or storing of soil, rock, coral or earth. Under these regulations, those engaged in earthmoving must design, implement, and maintain effective erosion control plans, sedimentation control plans, and cultural preservation measures to prevent accelerated erosion, accelerated sedimentation, and disturbing potential cultural resources. RMIEPA regulates the uses for which marine waters shall be maintained and protected, specifies water quality standards, prescribes standards necessary for implementing, achieving, maintaining specified marine water quality, and assures that no pollutants are discharged into RMI waters without treatment or control to prevent pollution, except for permitted activities. Additionally, the Marshall Islands have strict marine pollution control requirements, oil pollution prevention measures, and prohibitions concerning the discharge of sewage from vessels.

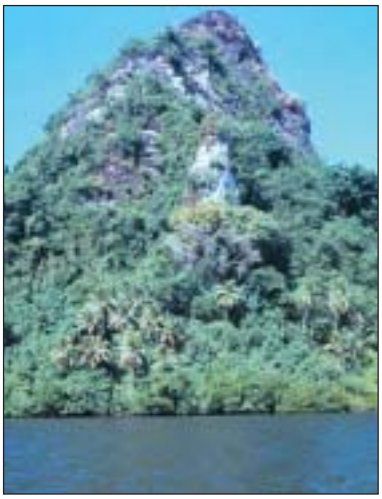


Figure 303. Pohnpei is a volcanic island (Photo: James McVey).

A variety of local regulations on Bikini, Ujae, Lae, Jabot, Jaluit, Utdrik, Mejit, and Wotje protect nesting turtles and their eggs and prohibit a variety of activities (e.g., walking on reefs between islands) and regulate the taking of marine resources.

Figure 304. Ship wreck in Chuuk Lagoon, FSM (Photo: FSM Visitors Board/Tim Rock).

Conclusions and Recommendations

At present, the coral reefs of the Marshall Islands are in good condition. While the two atolls used for the nuclear testing program experienced unique stresses, the reefs of the RMI as a whole have escaped the extensive damage seen in other parts of the world. The remoteness of many of the atolls and the fact that the country as a whole is relatively isolated has helped to minimize many potential impacts. However, this isolation also leaves the coral reefs vulnerable to illegal or semi-legal exploitation. Moreover, increased globalization and the pressures to change from the traditional subsistence economy could easily alter the present situation and allow at least some of the stresses discussed before to become more serious threats.

The Federated States of Micronesia

Introduction

The Federated States of Micronesia (FSM) is comprised of four states – from east to west, Kosrae, Pohnpei, Chuuk, and Yap. Along with Palau, these comprise the Caroline Islands. Each island or group has its own language, customs, local government, and reef tenure system. Traditional leaders (Chiefs or their equivalent) and community groups are active in traditional governance as well as western-style, democratically elected officials. This dual system provides opportunities and challenges to reef and marine resource protection.

FSM has high islands and low atolls, and a strong dependence on coral reefs and marine resources, both economically and culturally. Each state supports population centers on high volcanic islands surrounded by barrier reefs (Pohnpei, Chuuk) or very broad fringing reefs that are nearly barrier reefs (Kosrae, Yap). All states except Kosrae also include remote clusters of atolls and low coral islands (Maragos and Holthus 1999). Spalding *et al.* (2001) estimated total shallow-water coral reef area off the FSM to be 5,440 km^2.

Figure 305. Aerial view of two of the islands that make up Yap State (Photo: Ben Mieremet).

Kosrae is a single volcanic island with a landmass of 109 km^2 and an elevation of 629 m. It is surrounded by a fringing reef and has a single harbor.

The volcanic island of Pohnpei is the largest island in the FSM and is the FSM capitol (Fig. 303). It has an area of 345 km^2 with a well-developed barrier reef surrounding a narrow lagoon. It and the eight nearby coral islands and atolls make up the state of Pohnpei.

Chuuk State (formerly known as Truk) has 15 inhabited volcanic and coral islands and atolls. Chuuk Lagoon is the largest atoll in the FSM and serves as the population and political center of Chuuk State. It is famous for the Japanese wrecks that were sunk in the lagoon during World War II (Fig. 304).

Yap State has a main volcanic island approximately 100 km^2, along with 15 coral islands and atolls (Fig. 305). The peoples inhabiting the offshore atolls and coral islands in Chuuk, Yap, and Pohnpei states are among the most traditional, with a highly sophisticated marine tenure and associated marine resource management system.

Condition of Coral Reef Ecosystem

The condition of FSM coral reef ecosystems is generally good to excellent (Fig. 306). Most of the reefs in the low islands are in excellent condition. The primary human impacts come from fishing pressure and ship groundings.

Reefs in Kosrae have been impacted by coastal development, specifically the construction of an airport built on top of a broad reef at Okat. Some dredging and road construction projects have resulted in the destruction of specific reef areas including much of Okat.

Marine Algae and Higher Plants – Crustose coralline algae are abundant on the reefs. FSM has 14 species of mangroves.

Corals and Benthic Cover – The reefs around the island of Pohnpei vary in condition. Surveys done after a ship grounding found the average coral cover above 20% adjacent to Sokehs channel, and limited survey information from the barrier reef shows 50-70% at selected sites. Due to high annual rainfall and steep volcanic topography, erosion and sedimentation can be heavy. Upland clearing of forested areas to grow sakau (kava) has resulted in landslides and other impacts to coastal villages and resources.

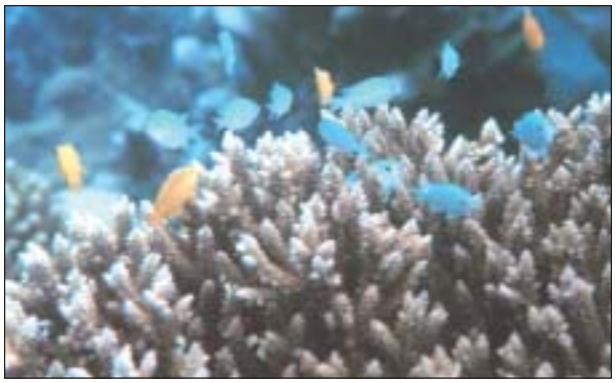


Figure 306. Most reefs in FSM are quite healthy (Photo: James McVey).

Surveys of 18 sites around Yap island made in 1995 and repeated 16 months later found mean coral cover at 28.8% and 28.7% respectively (Richmond and Birkeland 1997a), even though a typhoon hit the island between those surveys.

Fish and Fisheries – According to FishBase (2002), reef-associated fish comprise 873 of the 1,125 marine fish species recorded for the FSM. Overall catch and export data are limited. Overfishing by foreign commercial fishers has been documented.

Quantitative assessments of fisheries resources within the FSM are needed.

The greatest impact on fish within the FSM has been commercial export. To reduce this, Yap and Kosrae have limited export largely for personal/family use, allowing only coolers of fish to be sent

to relatives on Guam and in the CNMI. Chuuk had the largest commercial export, and some commercial export of fish and crab had been occurring from Pohnpei. A recent outbreak of cholera in Pohnpei shut down the export of fish and also affected exports from the other islands in the FSM (A. Tafileichig pers. comm).

Destructive fishing practices, including explosives taken from World War II wrecks, have caused localized reef damage, especially in Chuuk lagoon.

A small sea cucumber fishery operating in Yap was closed down in the mid-1990s.

Figure 307. Spearfisher with a barracuda in Yap State (Photo: FSM Visitors Board and Tim Rock).

Water Quality – There are no problems with sedimentation and erosion or coastal pollution in the uninhabited atolls. The coral cover in Chuuk Lagoon indicates generally acceptable water quality. Dredging and filling for road expansion, causeways, ports, and airfields built on reefs have degraded water quality on Kosrae, and to a lesser extent at the other high islands.

Coastal Populations and Reef Economics

The population for all FSM inhabited islands has grown by 22.6% over the past ten years to 133,100 in 2000 (U.S. Census Bureau 2002). The most populated centers occur at Kolonia, the national capitol on the north side of Pohnpei Island, and within Chuuk lagoon on several volcanic islands. Population growth has been rapid, with Chuuk already considered overcrowded. In contrast, the neighboring coral islands and atolls retain stable populations. These islands also have more traditional control over coral reefs.

Tourism has been growing in the FSM. In 1998, 30,000 tourists visited and spent $3 million (B. Graham pers. comm.). Each of the states have modern jet airfields and deep draft harbors.

Quantitative assessments of fish resources within the FSM are limited, but some market information suggests the scale of the fisheries operation may be substantial (Fig. 307). In 1998, the gross value output of FSM fisheries was estimated at $86.4 million (FAO 2002). The greatest impact on the fish in the FSM has been from commercial export. FSM earns about $18-24 million annually from licensing fees for foreign vessels fishing for tuna in its waters (U.S. Office of Insular Affairs 1999).

Environmental Pressures on Coral Reefs

Human Stresses – As with the other high islands, road construction and development projects without adequate erosion control have been responsible for reef damage from sedimentation. Dredging projects associated with airport and harbor construction have destroyed specific reefs (Fig. 306), and subsequent increases in freshwater runoff have limited recovery.

Increased population is a concern for the future of some islands as they come to terms with the need for associated infrastructure, including sewage processing plants and outfalls. And if not carefully guided, planned tourism development has the potential to impact reefs.

Export fisheries have been a problem for Chuuk and there have been numerous reports of destructive fishing practices in the past.

Ship groundings have been a problem for both the high and low islands. Foreign long-liners have been abandoned on numerous FSM reefs, with no funds

Figure 308. Causeway on Chuuk with remnants of a coral dredging operation from construction (Photo: James McVey).

available to clean up oil spills or remove the ships. Larger shipping vessels have also run aground, most recently in Satawal and on Pohnpei.

Maragos and Fagolimul (1996) reported extensive direct (13,000 m^2) and indirect (300,000 m^2) impacts of the 1994 grounding and subsequent removal of a large freighter at Satawal Island, Yap State. Sediments generated by the erosion of reef at the site migrated to other reef areas more than a kilometer away, smothering corals, burying reef flats, creating new beaches on the island, and damaging reef life in the largest fishery reserve. Later, the people of Satawal reached an out-of-court settlement of more than $2 million from the ship owners (J. Maragos pers. comm.).

Global Warming and Coral Bleaching – There is concern about potential sea level rise from global warming inundating the low islands and atolls. Tropical storms and related weather patterns are also an issue. Marine scientists documented the impact of a destructive 1990 typhoon passing over remote reefs in Pohnpei State (Holthus *et al.* 1993, Fig. 309), including large waves passing over Minto Reef. These picked up massive coral heads from the lagoon, depositing them on the reef flat and killing a variety of associated wildlife.

FSM reefs have experienced bleaching, but information is limited.

Current Conservation Management

Mapping – Some FSM shallow-water coral reef and associated benthic habitats have been mapped but only off the four high island population centers. Coastal resource inventories and atlases have been prepared for the islands of Pohnpei, Yap, Kosrae, and Moen Island in Chuuk Lagoon[185] and initiated for the rest of Chuuk Lagoon. Consistent with similar initiatives in the Marshalls, the FSM inventories summarized the species, habitats, uses, and conditions of reefs, and the atlas maps portray the location of study sites, coastal uses, protected areas, cultural sites, bathymetry and distribution of reef habitats surrounding these islands.

Assessments and Monitoring – The College of Micronesia-FSM has faculty and staff trained in marine resource assessment and monitoring.

The FSM has regulatory agencies (Environmental and Marine Resource) with trained personnel. Each state has a Marine Resources Management office and an Environmental Protection Agency office. Cooperation among regional institutions formalized under the Marine Resources Pacific Consortium and funded by the DoI is intended to increase local and regional capacity for assessment and monitoring.

Figure 309. Damage done to a coconut and breadfruit plantation in FSM by a typhoon (Photo: James McVey).

Non-governmental organizations are active in the FSM, primarily The Nature Conservancy, and offer technical and financial assistance for related programs. The Peace Corps also has a presence in the FSM, and some of its volunteers have been involved in monitoring programs.

Coral reefs are protected by MPAs in the Trochus Sanctuaries Heritage Reserve and Kosrae Island Heritage Reserve. Other conservation areas are presently being negotiated in partnership with the FSM National Government.

Chiefs and other traditional leaders usually control protection of specific areas. In Yap, the villages own the reefs, and have authority over resource use. A number of the islands have areas set aside for reef protection and limit resource extraction, but currently the FSM lacks the enforcement capacity to protect these MPAs (A. Edward pers. comm.).

Gaps in Current Monitoring and Conservation Capacity

Technical expertise in the FSM has been increasing, with a number of highly trained individuals dispersed among the College of Micronesia-FSM, the regulatory agencies, and local institutions like the Pohnpei Environmental Research Institute. Funds are a limiting factor, especially as financial support from the Compacts of Free Association is

[185] Cheney *et al*. 1982, Elliott and Maragos (1985), Holthus 1985, Manoa Mapworks 1985 and 1987, U.S. Army Engineer Division 1986, Manoa Mapworks and Sea Grant 1988, Orcutt *et al*. 1989, Environmental Resources Section 1989.

decreasing. Development of local talent and less dependence on expatriate technical staff must become a priority.

Both development projects and agricultural practices have already been responsible for reef damage (Fig. 310), and are expected to get worse. Integrated watershed management programs need to be developed.

Reef fisheries on Chuuk have been over-exploited. Improved coordination of management activities among the states is recommended. Programs for educating and involving the community need to be expanded.

Conclusions and Recommendations

The reefs within the FSM are in relatively good condition. However, land use practices on the high islands are a concern. Reef fisheries on some islands have been over-exploited. Damaging blast fishery practices have been documented in Chuuk Lagoon as late as 1994 (J. Maragos pers. comm.).

Integrated watershed management programs need to be developed. Improved coordination of management activities among the states is recommended. Education and programs involving the community need to be expanded. Ship groundings need to be addressed at the State and National level possibly requiring vessels to post bonds to cover any damage to the reefs. Additional support for the resource agencies is necessary if they are to meet their mandates.

The Republic of Palau

Introduction

The Republic of Palau is a separate sub-archipelago at the western end of the Caroline Islands. It is the westernmost archipelago in Oceania, located 741 km east of Mindanao in the southern Philippines and about 1,300 km southwest of Guam.

The islands and reefs of Palau stretch 700 km from Ngaruangel Atoll and Velasco Reef in the north to Helen Atoll in the south. There are about 20 large and intermediate islands and over 500 small islands (Fig. 311). The biggest island, Babeldaob, is volcanic. Koror (the capital) lies on the south of Babeldaob with the other islands in the chain south of it. Koror and the southern islands are separated from Babeldaob by a deep pass (30-40 m), Toachel El Mid, which cuts in from east to west, separating the reefs of Babeldaob from all the southern reefs. The southwestern islands of Palau lie about 339-599 km southwest of the main Palau archipelago.

Figure 310. Betel nut agriculture on Yap (Photo: FSM Visitors Board and Tim Rock).

Most of the population resides in Koror and Babeldaob. Beyond the main islands to the north are two atolls and one submerged atoll reef. One large atoll (Helen) and five smaller low coral islands are up to 600 km to the south (Maragos and Cook 1995). The islands exhibit numerous island and reef types.

On the western coast of Palau there is a 144-km, well-developed barrier reef protecting the main cluster of islands from north of Babeldaob to the southern lagoon, then merging into the fringing reef. Peleliu is at the southern end of the fringing reef. Off the east coast of Babeldaob, the barrier reef is not well developed. Only Ngchesar and Airai have a barrier reef. Ngerchelong, Ngarard, and Melekeok do not. Ngiwal has a submerged barrier reef about 5-10 meters below sea level.

Figure 311. Palau contains over 500 small islands (Photo: Kevin Davidson/PICRC).

The southern lagoon has much more extensive barrier reefs, lacking passage on the west side while the southeast side has numerous gaps and passes extending into the lagoon. Hundreds of rock islands or emergent coral reefs are concentrated in the southern lagoon.

Maragos and Meier (1993) estimated the total area covered by shallow-water coral reefs to be 1,661 km^2.

Condition of the Coral Reefs

Marine Higher Plants – Nine species of seagrass have been reported from Palau (Tsuda *et al*. 1977). Seagrass is found throughout Palau, from Kayangel Atoll through Babeldaob to Peleliu. The whole shoreline of Babeldaob, Koror, and Peleliu is covered with seagrass; even the lagoon side of the barrier reef has seagrass. Also, nine species of mangroves have been confirmed along with several more subspecies on Palauan islands and islets.

Coral and Benthic Cover – Within the whole Indo-Pacific region, Palau's coral diversity approaches the highest coral diversity of the Philippines, Indonesia, and Australia (Fig. 312). When assessments and biotic characterizations are complete, scientists expect diversity to be about 25% higher than that for Guam (R. Richmond pers. comm.).

Maragos (1994b) estimates Palau has 425 named species of stony corals belonging to 78 genera, although some of the species names may be synonyms (J. Maragos pers. comm.). There are an additional 120 species of octocorals in 57 genera (J. Starmer unpubl. data). For reefs in good condition, coral cover generally ranges from 50-70%. Coral diversity is moderate to high, ranging from 45-95 species at different sites. Coral cover at lagoon slopes of the barrier reef is 60% with a diversity of 45 species.

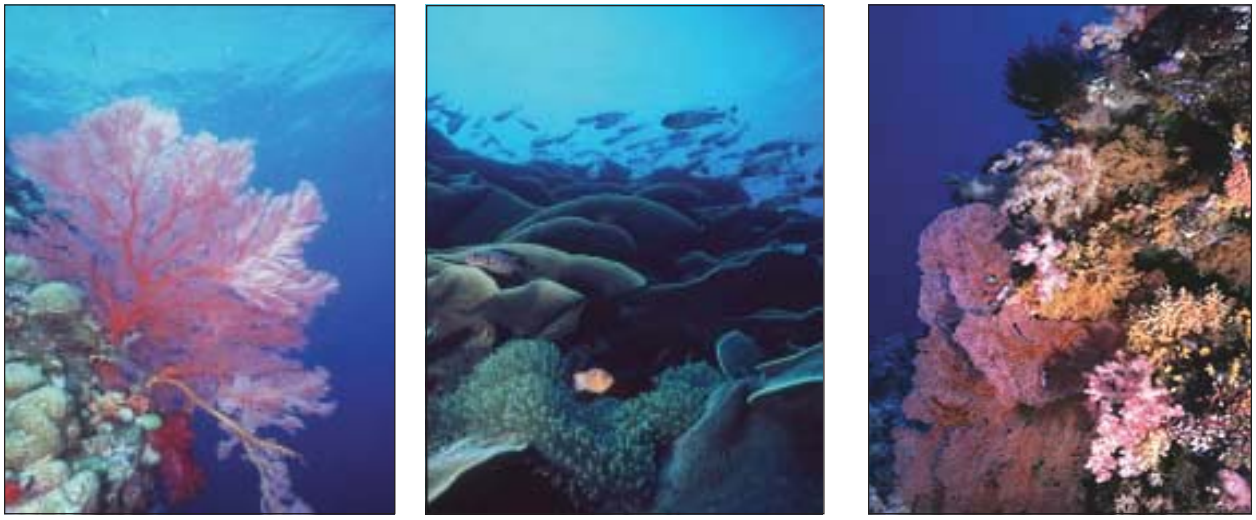
The ocean reef slopes reach a total length of 62.7 km. Coral cover at the northeast slopes average 10% with an average of 35 species. The protected bight at the southern end of Ngkesol has higher coral cover and diversity (45 coral species accounting for about 25% of total cover). Along western ocean-facing reef slopes, coral cover ranged from 60 to 70% and diversity averaged 35 species. Northwestern ocean-facing reefs have lower coral cover (10-20%), but had higher diversity, with 50 species encountered during the REA. The northern reef slopes protected by Ngerael, Ngkesol and Kayangel reef have higher coral abundance and diversity.

The lagoon of Kayangel Atoll generally has low coral cover and diversity, but the Atoll had a total of 126 species of corals belonging to 47 genera. The Ulach channel along the western rim supports healthy marine communities including corals. During the REA surveys in 1992, the average coral cover for the outer walls was 70%, 50% inside. Coral cover at the ocean slopes averaged 20-25% along its 62.7 km length, with 40-50 coral species at different sites along the ocean slopes.

The western Babeldaob lagoon has over 500 patch reefs. Coral cover on the slope of the patch reefs is around 50%. Diversity ranges from 45 to 70 species in different sites. Several rare coral genera are found in these patch reefs including *Cynarina*, *Zoopilus*, and *Siderastrea*.

The 1992 Ngermeduu Bay Natural Resource Surveys, found 200 species of corals (Maragos, 1992). Areas away from freshwater and sedimentation stress average 50 species of corals per site, with several sites with as many as 60 species. The sites with higher diversity also have high coral cover averaging over 50%, sometimes as high as 70%.

Figure 312. Palau's coral reefs exhibit high biodiversity (Photo: Ethan Daniels, Kevin Davidson, and PICRC).



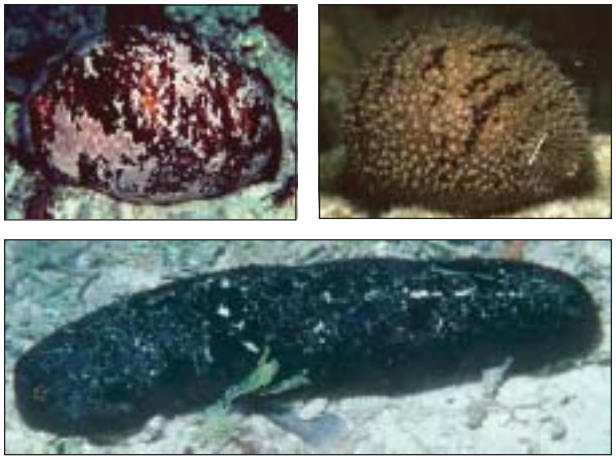


Figure 313. Sea cucumber species from Palau's coral reefs (Photos: Gustav Paulay).

In 1976 and 1991, there were quantitative surveys on the fringing reef at the southern tip of Malakal. These showed no significant differences in coral cover. In 1976, the coral cover at the reef margin was 60.3%, the slope was 73.6%. During the survey of the same sites in 1991, coral cover was 55.7% at the reef margin and 82.2% at the slope (Birkeland *et al*. 1976, Birkeland *et al*. 1993).

Before the 1998 bleaching event in Palau, the remote reefs were generally healthy and in good condition. The reefs closer to population centers or areas where there is development are showing signs of degradation and are not as healthy as the remote reefs. The bleaching event severely affected most reefs in Palau.

Other Macroinvertebrates – Over 300 species of sponges have been reported from the Palau Archipelago (Spalding *et al*. 2001). According to these authors, a total of 144 species of marine invertebrates other than coral were observed around Kayangel atoll alone.

The Ngermeduu Bay Natural Resource surveys identified 170 species of invertebrates other than corals (Richmond 1992). There, the seagrass beds support numerous species of echinoderms including edible sea cucumbers (Fig. 313), whereas suspension feeders dominate the mouth of the bay.

The crown-of-thorns starfish (*Acanthaster planci*) is a problem in areas of Palau. They target the few remaining *Acropora* corals that survived bleaching.

Fish and Fisheries – Palau has the largest number of reef fish species within Micronesia, a total of 1,278 known species. But based upon gaps of known distribution of fish, Myers (1999) projects this should be 1,449 (Fig. 233).

Fish populations in the main islands of Palau are showing signs of overfishing when compared to the Southwest islands where fishing is less intense (Donaldson 1993). Highly desired species of fish are either absent or present in low numbers around the main islands of Palau.

A 1991 REA recorded 467 species of fish from Kayangel, Ngeruangel/Velasco and 495 species from the Northern Lagoon and barrier reef complex (Amesbury 1992). These were the most diverse regions of Palau.

Ngermeduu Bay had 277 species of fish (Amesbury 1992). This area is unique in that it has two overlapping types of fish communities. One is the rich coral reef assemblage typical of other areas in Palau and Micronesia. The second community is dominated by planktivores, more commonly found in Indonesia.

There were 347 fish species recorded from West Babeldaob during an REA (Maragos *et al*. 1994). Adding the 277 species from Ngermeduu Bay Natural Resource Surveys (Amesbury 1992) brings the total for West Babledaob to 400 fish species. Three hundred thirty-seven species of fish were recorded for East Babeldaob during the 1991 REA.

Figure 314. Newly discovered fish species and new range extensions found in Palau during exploration of deep reefs (Photos: Richard Pyle, Bishop Museum).

Channels serve as important pathways for migrating fish. For example, the Toachel Mlengui channel, located slightly north of the Ngermeduu Bay entrance and 15 km southwest of Daimechesengel pass in Ngardmau, is important to the coral reef ecosystem because it serves as a pathway for fish traveling between the lagoon and ocean reefs. Located 85 km south, the Sengelokl pass, however, only offers a subtidal connection between the western ocean and the southern lagoon, so does not play a prominent role.

Figure 315. Sea snake (Photo: National Undersea Research Program).

Marine Reptiles and Mammals – There are four species of sea turtles known to use Palauan reefs. Historically, the Rock Islands supported large numbers of endangered hawksbill turtle nesting sites. But in recent years the poaching of eggs and the take of turtle shell for bekko jewelry have drastically reduced nesting activity. This species and part of its critical habitat is now protected within the Rock Island Reserve. Elsewhere, on unprotected reefs, hawksbill turtle nesting is diminished or has been eliminated altogether from excessive harvesting (NMFS and USFWS 1998).

According to G. Paulay (pers. comm.), two species of sea snakes are known from the reefs of Palau – the egg-laying banded sea snake (*Laticauda colubrina*), and the viviparous yellowbellied sea snake (*Pelamis platurus*, Fig. 315). The latter species is pelagic, ranging from East Africa to the Pacific coast of the Americas (Allen and Steene 1996).

There are reports of two species of marine mammals, including the endangered dugong or sea cow (*Dugong dugon*).

Table 25. Sale of fishery products from areas throughout Palau (Source: Palau Marine Resource Division).

Location	Time Period	Fish Sold (kg)
Koror	1992-1998	513,030.0
Kayangel	1992-1998	91,862.4
Ngerchelong	1992-1998	230,578.7
Ameliik	1992-1998	40,773.9
Ngatpang	1992-1998	102,435.1
Ngeremlengui	1992-1998	319,771.9
Ngardmau	1992-1998	33,919.9
Airai, Mekekeok, Ngiwal, and Ngchesar	1992-1998	8,970.6
Ngarard	1992-1998	124,230.0

Eutrophication in Malakal Harbor has been directly linked to fishing vessels anchored there, as fishers remain onboard with inadequate sanitation or waste disposal facilities.

Coastal Populations and Reef Economics

Over the past ten years, the Palauan population increased 23.4% to about 18,800 in 2000 (U.S. Bureau of Census 2002).

Tourism is now a major component of the economy. In 1999, over 78,000 tourists a year visited the islands, contributing around $78.8 million annually to the local economy (B. Graham pers. comm.). The number of foreign visitors and workers has increased dramatically over the past decade, and the population center is shifting to Babeldaob, by far the largest (volcanic) island in Palau.

As with the FSM, the more remote islands, atolls, and villages retain more traditional population levels and controls over coral reefs.

Commercial fisheries generate a reported $6.4 million in gross value output (FAO 1998). Table 25 shows the fish products sold to markets in Koror from different areas throughout Palau (Marine Resource Division unpub. data).

Environmental Pressures on Coral Reefs

Human Pressures – Palau has already done a great deal toward limiting the impacts of tourists on reef resources. Mooring buoys, laws preventing the collection of corals, and diving tour operator education help conserve the culturally and economically important reef resources. Now the largest direct impact on some reef sites is the volume of divers with varying levels of training.

At the moment, the single greatest concern is the Compact road project for Babeldaob. It has a number of potential impacts on reefs. First, acute and dramatic erosion and sedimentation are likely to occur during and after construction. There are likely to be chronic, long-term impacts from damaged upland habitats.

Second, the road will open large areas to development, increasing both land and reef use with the

resulting impacts on water quality and reef health. Finally, plans to dredge for fill material needed to build the road base have the potential for reef damage. Once built, the increased population (both local and visitors) will require additional sewage treatment and other support facilities.

Foreign-based fishing activities are already a problem (Fig. 316). Poachers from Indonesia and the Philippines are frequently encountered on Helen's Reef.

Ship groundings have also been occurring off the main islands as well as those in the south (Fig. 317).

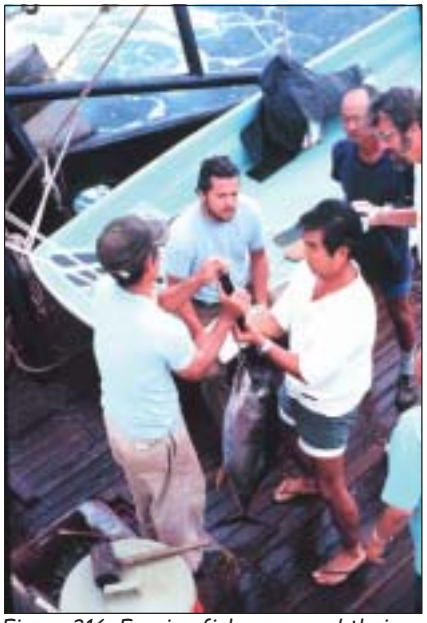


Figure 316. Foreign fishermen and their catch on Sonsorol Island in Southwest Palau (Photo: James McVey).

Natural Stresses – Natural stress includes outbreaks of crown-of-thorn starfish, typhoons **(**even though rare**),** and big waves from storms. Although the Palau islands generally lie south of the main pathway for typhoons in the northwestern tropical Pacific, infrequent tropical cyclones do pass over the islands.

Climate Change and Coral Bleaching – Palau experienced substantial coral bleaching in 1997, when an estimated 30% of its reefs were heavily impacted. *Acropora* corals were especially susceptible, and in many places mortality was high (Figs. 318 and 319). In 1998 surveys of Ngaruangel, live coral coverage ranged from 10-30% with an average cover of 5-10%. An estimated 30-50% of these were bleached. All adult *Acropora* table-type corals were dead, yet juvenile colonies less that 10 cm in diameter had almost full survival (C. Birkeland pers. comm.). An estimated 75-85% of soft corals in the west and south side of Ngeruangel were also bleached.

On the eastern side of the atoll, coral cover on the slopes ranged from 1-10%, averaging 4%; about 20% of the live coral was bleached and all staghorn coral had died. Live corals consisted mainly of massive corals. Dead coral cover averaged 10-25%.

The lagoon patch reefs showed very low live coral coverage. Only a few blue-colored coral **(***Heliopora*) and brain corals (*Porites***)** remained on the patch reefs. All the *Acropora* corals were dead.

The southern side of the main channel was similar to the patch reefs, with most corals dead (PCS unpub. data).

Moderate coral bleaching was observed at Helen and Tobi Reefs in early December 1996 (P. Colin pers. comm.).

During the summer of 1999, most corals at Helen reef died from a bleaching event (P. Colin pers. comm.). Other islands in the Southwest must have also been affected, since offshore reefs in the Palau main islands were impacted the most (C. Birkeland pers. comm.).

During a late 1998 survey of Oruaol Libuchel patch reef, a state conservation area for Ngatpang, live coral cover at the western side of the reef was 17% and dead coral covered 21% of the area (Golbuu, 2001). The eastern side had a higher coral cover (26%) and lower dead coral covered (11%). A nearby patch reef was also surveyed as a control for the conservation area monitoring. It had 31% live coral cover and 14% dead coral cover.

Ngchesar in east Babeldoab was seriously hit by bleaching in 1998. Most of the corals at the barrier reef died. The fringing reefs at Ngchesar were not as badly affected as the barrier reef. Some corals survived, mainly *Porite*s, but most of the *Acroporas* in the fringing and patch reefs are dead.

Surveys at Ngerumekaol (Ulong Channel) in Koror revealed a high percentage of dead coral. In the

Figure 317. Ship hard aground on Helen's Reef (Photo: James McVey).

northern channel, 35% of the coral cover was dead, while live coral was only 23%. Similar patterns were seen at the southern side, with 41% dead coral and only 24% live coral. The reef slope at Ngerumekaol had 23% coral cover, 33% of which was dead (Golbuu *et al*. 1999).

Before the bleaching, Ngerumekaol had a healthy and diverse coral community with 52% live coral cover (Maragos 1991). During surveys of selected sites, a team from the University of Guam Marine Laboratory in July 1999 found bleaching was widespread and variable among the sites. *Acropora* corals have been devastated, experiencing the highest overall mortality.

Interestingly, corals found in estuaries close to shore survived better than corals farther away. This was very evident in Ngiwal where coral survival was highest closer to land. Offshore reefs, like Short Drop-Off, have been hit the hardest; mortality of Acroporas was nearly 100% (G. Paulay unpub. data). Even at 90 ft, there was around 90% coral mortality, including *Favia*, *Porites*, *Fungia*, and *Acropora*. Out of 3,630 colonies of corals from 52 genera surveyed in 1999 at several sites, 48% were living, 31% were dead, and 21% suffered varying mortality (G. Paulay unpub. data).

Fish populations were also affected by the recent bleaching event. Surveys at the Southwest Islands revealed the abundance of fish that prey on corals, use corals for shelter, or feed on fish that feed on corals decreased dramatically from 1992 levels (T. Donaldson pers. comm.).

Current Conservation Management

Mapping – Palau's shallow-water coral reef and associated benthic habitats have yet to be mapped.

Figure 319. A bleached Acropora *(Photo: Wolcott Henry).*

Figure 318. Acropora *corals on a Palauan reef prior to the 1998 bleaching event (Photo: Bruce Carlson).*

Assessment and Monitoring – The Palau International Coral Reef Center (PICRC) was created to enhance the knowledge about coral reefs and related marine environments so they can be effectively managed and conserved within the Republic and the Western Pacific. PICRC has established 14 permanent sites on shallow reefs to monitor corals, coral recruitment, and fish. In addition, PICRC has also surveyed close to 200 non-permanent sites around Palau.

The Palau Conservation Society is active in conservation activities in the archipelago, and collaborates on monitoring and assessment programs with the Coral Reef Research Foundation, Palau Community College, the Environmental Quality Protection Board (EQPB) and the Marine Resources Division. The Nature Conservancy has an office on Palau, and works with the other agencies and organizations on coral reef conservation. Palau has substantial expertise, but financial resources are somewhat limiting.

MPAs and No-take Zones – Currently, Palau has a total of 13 established MPAs. In 1956, the Rock Island Management and Preservation Act designated certain areas of the Rock Islands as reserves and others as tourist activity areas. This was Palau's first MPA.

The total area of Palau's coral reef ecosystems protected by no-take reserves is 65.3 km^2, which is equivalent to about 3.9% of the country's coral reef area.

Gaps in Current Monitoring and Conservation Capacity

Palau's PICRC needs funding to continue monitoring of its established long-term coral reef

sites and other surveys of Palau islands and atolls. Additionally, training in coral reef monitoring and assessment is required to monitor conservation areas for changes in structure.

Only with regular monitoring can resource managers effectively implement management plans. Currently, there are not enough technical personnel to do the required monitoring. Additional people need to be trained if consistent and robust monitoring is to be done.

Figure 320. Helen's Reef is a remote area that has been monitored mainly through REAs (Photos: James McVey).

So far, most of the training has been for short-term monitoring and is focused on collection techniques that are easy and not time-consuming. Coral identification is usually not covered. Without it, biological diversity surveys cannot be done, and the data that is collected may not truly reflect the actual condition of the coral reef ecosystem. For example, the Malakal sewer outfall study determined percent coral cover, and found no significant difference between 1976 and 1991. But species diversity decreased dramatically since 1973. So without taxonomic information, the conclusion would be that the reefs were doing well when they were not.

Periodically, funds are needed to bring people together for an REA of the entire reef environment from Ngeruangel to the Southwest Islands (Fig. 320). Reef studies tend to be limited to Koror and selected places in Babeldaob, neglecting unique areas far from Koror. The last comprehensive work on Palau reefs was in 1992 during the REA. Many of the places that were surveyed during that REA have not been studied since.

Figure 321. The Marine Protection Act regulates the collection of species targeted by the aquarium trade, such as the Moorish Idol (Photo: James McVey).

Government Policies, Laws, and Legislation

Palau National Government policies regarding environmental issues are given in the Palau National Master Development Plan (SAGRIC 1996). The Plan recommends actions necessary to protect the environment, including formalizing a policy process, instituting and strengthening education and research programs, protecting habitats and wildlife, managing waste, reducing pollution, and implementing new coral reef conservation legislation.

As a Compact Nation, U.S. laws apply to the conservation of Palau's coral reef resources. The **Marine Protection Act** regulates taking certain species of marine organisms, prohibits or limits certain fishing methods, and authorizes the Minister of Resources and Development to develop regulations regarding the collection of marine animals for aquaria or research (Fig. 321).

The **Environmental Quality Protection Act** was consolidated into Palau National Code as Title 24. Division 1 of this Act creates the EQPB and mandates it to protect the environment of Palau. Division 2 (Chapter 10) deals with wildlife protection. Protected sea life includes turtles (Fig. 322), sponges, mother-of-pearl, dugong, *topshell* gastropods and clams. Chapter 13 deals with illegal fishing methods including the use of explosives, poisons, or chemicals. Division 3 deals with the protected areas of Ngerukewid and Ngerumkaol.

The Natural Heritage Reserve System Act mandates a set of reserves, sanctuaries, and refuges to be identified, developed, and strengthened. The Palau Bureau of Natural Resources and Development is the body responsible for designating and nominating areas for inclusion in the reserve and developing regulations to implement the Act.

State Government legislation is also helping to preserve the reefs. The Rock Island Management

Figure 322. Green sea turtles and their eggs are protected by the Environmental Quality Protection Act (Photo: James McVey).

and Preservation Act designated certain areas of the rock islands as reserves and others as tourist activity areas (Fig. 323). Koror State Public Law K6-101-99 established the Ngerukewid Islands Wildlife Preserve and prohibited fishing in Ngerumkaol spawning area. Koror State Public Law (No. K6-119-2201, effective as of January 10, 2001) closed off Ngederrak reef (C. Emaurois pers. comm.).

The Fishing Conservation Act 1987 set aside two reef areas in Ngeremlengui State as a fish reserve and prohibited fishing in Toachel Mlengui channel during the summer months when fish are spawning. The Ngatpang Conservation Act of 1999 established the Ngatpang Reserve which includes three areas and Ngatpang's portion of Ngermeduu Bay. And the Ngiwal State Conservation Act of 1997 established Ngemai Conservation Area.

Conclusions and Recommendations

For effective coral reef management, regular assessment and monitoring of Palau coral reefs is required. Regular monitoring programs detect problems earlier, allowing more effective strategies to be developed. There should also be an emphasis on reports and publications from the monitoring program. There are many reports dealing with coral reefs buried in government offices and generally inaccessible to the public. Having this available to the community would increase awareness and support for conservation.

Palau Community College has a public library staffed by one librarian and five full-time staff. All the materials in the library are cataloged and available for online computer search. Since the library already has the facility, staff, and resources, it would be wise to designate it as a depository for all documents relating to coral reefs.

Effective management of marine resources requires an informed and supportive public, so education is another important aspect of reef conservation. School curricula from elementary to secondary and post secondary should incorporate environmental issues and concerns. Community outreach projects could extend this education and awareness to the communities. Efforts should focus on raising awareness among policy makers, traditional and political leaders, and villagers.

Catch levels and trends for reef fisheries should be monitored closely and accurately so effective management of coral reef fish resources can be implemented. Currently, only two fish markets in Koror are providing landings information to the Marine Resources Division. To have accurate market data, the Marine Resources staff need to have landings and catch data from all fish markets. Other information such as the type of fishing gear used and the number of hours spent fishing would help in determining the level of exploitation.

Finally, a collaborative program needs to be established between all the agencies and organizations involved with coral reef monitoring and management. This could be a strategic planning group, setting priorities and areas of focus for each group/area and focusing on problems that can only be solved with cooperation. With limited resources (time, money, and people) and a large coral reef area, everyone needs to work together to avoid duplication of effort and competition between the different groups. With a more coordinated effort, coral reef conservation will no doubt improve.

Figure 323. Palau's rock islands have been zoned to serve as marine reserves or tourism and recreation areas (Photo: William Perryclear/PICRC).