National coral reef status report Tonga

Edward R. Lovell

Asipeli Palaki

Prepared jointly by the International Ocean Institute (IOI) South Pacific and the Kiribati Fisheries Division for the International Coral Reef Initiative (ICRI) and the South Pacific Regional Environmental Programme (SPREP).

Introduction

The Kingdom of Tonga is located in the central South Pacific (Figure 1) and consists of 174 scattered islands of which 37 are inhabited (Figure 2). The present population is spread over the four main island groups of Tongatapu, Ha'apai, Vava'u and Niuas. Almost three quarters of the population live on Tongatapu (~66 979) with the total population 97 784 (Statistic Dept., 1996). Owing to limited natural resources, the population are largely subsistence farmers and fishermen. Overseas earnings come from agricultural products, tourism and remittances from Tongans working abroad (Zann, 1994).

The Kingdom's north/south axis spans 950 km including the Minerva Reefs. The Royal Proclamation of August 24 1887 established the Kingdom of Tonga as all islands, reefs, foreshores and waters lying between 15° and 23°30' South and 173° and 177° West (Campell and Lodge, 1993). This proclamation covers an area (land and sea) of about 395 000 km^2. The shallow water reef flat covers about 550 km^2 with an additional 3 045 km^2 of sea floor within the 200 m deep shelf. The Royal Proclamation of June 15 1972 confirmed the rights of the Kingdom of Tonga to the islands of Teleki Tokelau and Teleki Tonga (the Minerva Reefs) and all islands, rocks, reefs, foreshores and water lying within a radius of 12 miles thereof, extending to 179° W, the westerly extent of the Kingdom. Considering this claim, the territorial waters of Tonga encompass an area of 700 000 km^2 (Zann, 1994). The ownership of the Minerva Reefs is currently in dispute with Fiji.

The Tongan archipelago is situated along the boundary of the Pacific and Australian tectonic plates. It comprises both volcanic and uplifted coral islands and reefs, which cap the peaks of two parallel submarine ridges stretching south of Fiji. Volcanic islands include 'Ata island (southwest of Tongatapu, Lat. 22° 30 S and Long. 176° W), Hunga Ha'apai, Hunga Tonga, Kao and Tofua islands at Ha'apai, Late and Fonualei in Vava'u, and the two Niuas. These volcanic islands were formed on the volcanic arc running from the south ('Ata) to southeast and to the north to northwest (the two Niuas). The two Niuas are near the arc and explanation is still vague with regards to their formation. A few new islands were formed (volcanic eruption) on this arc in the last few years and only one still exists, while the rest sank again. Niuafo'ou's last erupted in 1942. Kao and Tofua are still active.

The archipelago has fringing, barrier and submerged reef types. The Niua group are high volcanic islands surrounded by fringing and barrier reefs. The Vava'u group, to the south, is generally composed of high volcanic and elevated limestone islands with reef communities or fringing reefs. High volcanic and low limestone islands characterize the Ha'apai. The reef types comprise reef communities, fringing, barrier and lagoon reefs. Tongatapu, the largest island, and 'Eua are limestone-capped islands which with low islands form the Tongatapu Group (Maragos and Holthus, 1999). The reef

areas are fringing and lagoon reefs with coralline algal reefs. These form a unique fringing reef along the south coasts of Tongatapu and 'Eua Islands. (Nunn 1993).

The prevailing winds are southeasterly and occur generally from March to October. The cyclone season (November to March) is still predominated by the trade winds but is subject to higher rainfall and the occasional tropical cyclone. The average rainfall in the capital Nuku'alofa is 1733 mm. (UNEP/IUCN, 1988) with the temperature range from 110 C to 320 C. The Niuas have a warmer climate as the result of the lower latitude.

Although the coral reefs extend along the fringes of all the islands, a comprehensive overview has only been conducted for selected areas (Zann, 1982; MPCJ 1997; Holthus, 1996). There is a lack of scientific observation and analysis for most reef areas (Table 1).

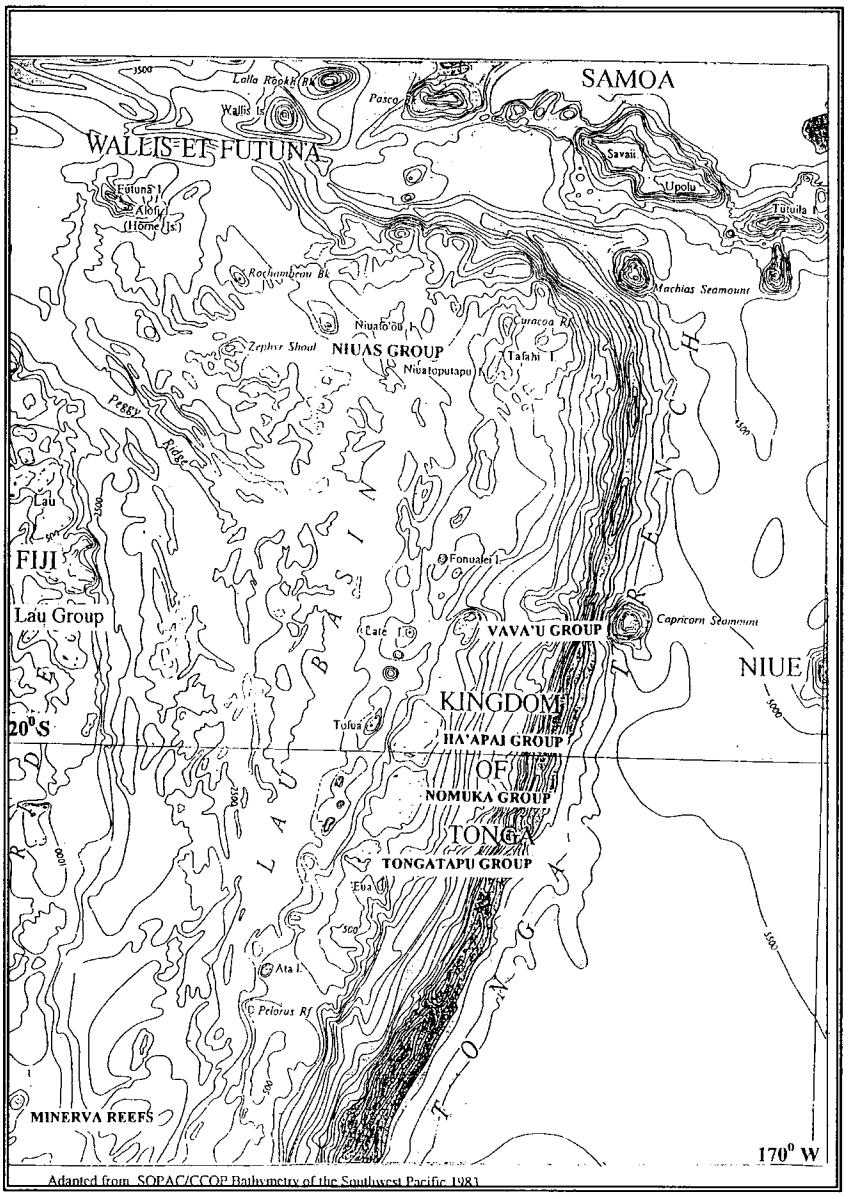

Figure 1
Bathymetric Map of Tonga.

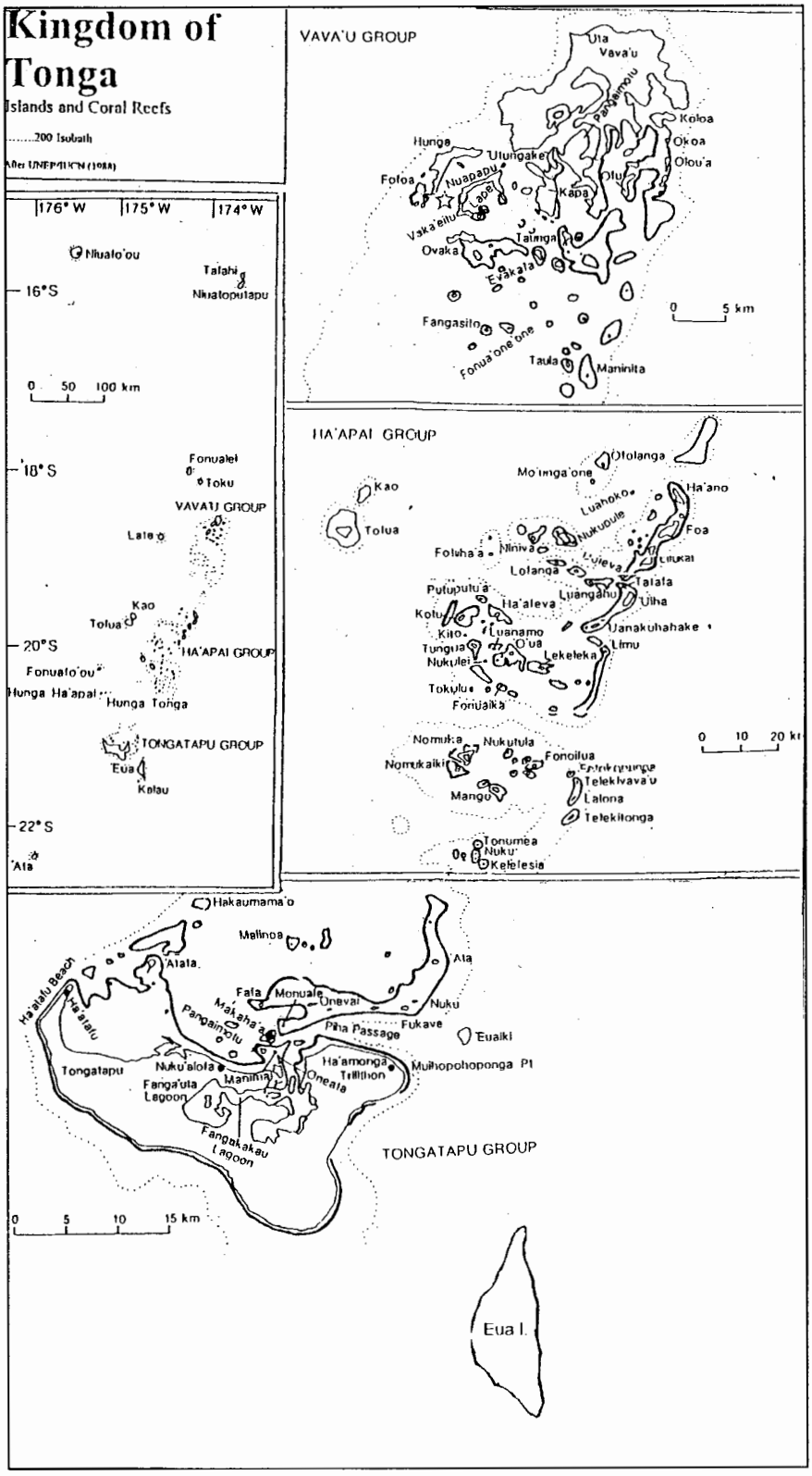

Figure 2
Kingdom of Tonga: Islands and Coral Reefs.

Status of coral reefs

Few assessments of Tongan coral reefs have been conducted. Description has been made by Dawson (1971) of Tofua, Kao, Late and Vava'u. Chesher (1984a,b; 1985) described areas around Tongatapu, Nomuka, Ha'apai and Vava'u groups. Zann *et al.* (1984) studied Fanga'uta Lagoon and adjacent coral reefs. Nunn (1993) described the unique algal-ridge forming a fringing reef along the southern coasts of Tongatapu. The Marine Parks Center of Japan (1997) conducted an inventory of the corals, molluscs and fish of Tonga's marine reserves around Tongatapu. Holthus (1996) described the coral reefs of Vava'u.

Marine Area (km2)	Total No Island Systems	Total Land Area	Total Population (1987)	No. of Recognizable Reef Systems				Tot.Lagoon And Reef Area (Km2)	Tot. Reef Perim (km)
				Reef Communities or submerged Reefs	Fringing	Barrier Or Lagoon	Atoll		
700,000	174	699	98,689	7	37	6	0	?	?

Adapted from Maragos and Holthus (1999)

Table 1
Geographic Statistics

Island and Reef Types

Details of the islands shows the types of landforms and reef types that exist (Table 2). Much information is lacking, representing gaps in our understanding of the coral reefs of Tonga. Some island types are basically volcanic some of which are active but most are composed of non-calcareous rock. The high limestone islands represent old coral reef accretion, which has been uplifted and aerially eroded. These are Pleistocene or Holocene in origin. Low coral islands are composed of deposits of coral rubble or sand.

From the larger islands of Tongatapu and 'Eua in the south, a series of reefs extend northward to Ha'apai and Vava'u. The reef types are fringing, which are represented as narrow reefs on the more recent volcanic islands to wide margins around the low islands and may contain lagoons. Platform reefs exist as detached shelf reefs. Other types are wave-cut raised reefs, lagoon and barrier reefs. Lagoon reefs are the patch reefs within the lagoon or the reef that surrounds it. The barrier reefs are those detached from the island. Reef communities are those reefs composed of coral assemblages but not being incorporated into a consolidated reef substrate. They may be referred to as submerged reefs or exist on soft bottom sediments. The long Ha'apai reef is unique as it lies on the upthrust edge of the Indian-Australian plate. The Ha'apai Group contains the largest area of coral reefs in Tonga, and amongst the largest in the South Pacific (Zann, 1994).

Name	Island Type & Number	Island Area	Reef Type	Reef Perimeter	Lagoon Area (km2)	Number of Passes and Channels	Number Lagoon Reefs
Niua Group							
Fonualei	1 high volcanic	3.12	Fringing	?	0	0	0
Niua Fo'ou	1 high volcanic	52.3	?	26.8	0	?	0
Niuatoputapu	1 high volcanic	15.6	Barrier	18.8	?	?	?
Tafahi	1 high volcanic	3.4	?	7.3	?	?	?
Toku	1 high volcanic	0.4	Fringing	2.6	?	?	?
Vava'u Group							
Euakafa	?	0.52	?	?	0	?	0
Fangsito	?	0.067	Reef community & fringing	?	0	?	0
Fofoa	?	0.83	Fringing	?	?	?	?
Fonua'one'one	?	0.049	Fringing	?	0	?	0
Hunga	1 high limestone	5.6	Fringing	18.6	?	?	?
Kapa	1 high limestone	6.4	?	15.0	?	?	?
Koloa	?	1.8	?	?	?	?	?
Lape & Langitau	2 islands	0.04	?	?	?	?	?
Late	1 high volcanic	17.4	?	28.8	?	?	?
Maninita	?	0.028	Fringing	?	?	?	?
Nuapapu	?	3.2	Fringing	15.7	?	?	?
Ofu	?	1.25	Fringing	?	?	?	?
Okoa	?	0.44	?	?	?	?	?
Olou'a	?	0.49	?	?	?	?	?
Ovaka	?	1.3	Fringing	?	?	?	?
Pangimotu	1 high limestone	9.2	?	?	?	?	?
Taula	?	0.041	Fringing	?	?	?	?
Taunga	?	0.36	Fringing	?	?	?	?
'Uta Vaba'u	Many high limestone	86	Fringing	?	?	?	?
'Utungake	1 high limestone	0.93	?	?	?	?	?
Vaka'eitu	1 high limestone	6.90	Fringing	99.0	?	?	?
Vava'u	1 high limestone	103.6	?	?	?	?	?
55 Other Islands in the Vava'u Group Totaling 4,456km2							
Ha'apai Group							
Fetoa	?	0.16	?	?	?	?	?
Fetokopunga	?	0.008	?	?	?	?	?
Foa	1 high coral	13.4	?	18.1	?	?	?
Fonoifua	1 low coral	0.16	?	?	?	?	?
Fonuaika	1 low coral	0.02	Fringing	?	?	?	?
Fonuafo'ou	Submarine volcanic & intermittent island	0	Reef community	0	0	0	?
Fonualei	1 high volcanic	4.3	?	?	?	?	?
Fotuha'a	1 high	1.13	Reef community	11.0	0	0	?
Ha'afeva	1 high limestone	2.02	Barrier	14.8	?	?	?
Ha'ano	?	6.58	?	?	?	?	?
Hakauata	?	0.02	?	?	?	?	?
Home	1 submarine volcano	0.0	Reef community	?	0	?	?
Hunga Ha'apai	1 high volcanic	0.4	?	?	0	?	?
Kao	1 high volcanic	11.6	Reef community	14.2	?	?	?
Kelefesia	1 high volcanic	0.12	?	?	?	?	?
Kito	1 high	0.012	Fringing	?	?	?	?
*Kotu	1 high	0.16	?	?	?	?	?
Lalona	1 low	0.28	?	?	?	?	?
Lekeleka	1 low	0.12	?	?	?	?	?
Lifuka	1 high limestone	11.0	?	21.8	?	?	?

Limu	?	0.04	?	?	?	?	?
Lofanga	1 high	1.46	Fringing and lagoon	?	?	2	?
Luahoko	1 low	0.001	Fringing	?	?	?	?
Luanamo	?	0.024	Fringing	?	?	?	?
Luangahu	?	0.61	Fringing	?	?	?	?
Mango	1 high volcanic and limestone	0.64	Fringing and lagoon	?	?	?	?
Manoiki	?	0.16	?	?	?	?	?
Matuku	?	0.34	?	?	?	?	?
Meama	?	0.002	?	?	?	?	?
Mo'unga'one	1 high limestone	1.15	?	?	?	?	?
Niniva	?	0.49	Reef community	?	?	?	?
Nomuka	1 high limestone	5.34	?	?	?	?	?
Nomukaikai	1 high volcanic and limestone	0.66	Fringing	?	?	?	?
Nuku	2	0.016	Fringing	?	?	?	?
Nuku Falau	?	0.012	Fringing	?	?	?	?
Nukulei	?	0.012	Fringing	?	?	?	?
Nukupule	?	0.032	Fringing	?	?	?	?
Nukutula	?	0.08	Fringing	?	?	?	?
Ofolanga	?	0.89	Barrier	?	?	?	?
O'ua	?	0.97	?	?	?	?	?
Putuputu'u	?	0.001	?	?	?	?	?
Tatafa	?	0.23	?	?	?	?	?
Teaupa	?	0.02	?	?	?	?	?
Tanoa	?	0.012	Fringing	?	?	?	?
Telekitonga	1 low	0.45	?	?	?	?	?
Telekivava'u	1 low	0.02	?	?	?	?	?
Tofua	1 high volcanic	49.9	Reef community	26.7	?	?	?
Tolulu	1 low	0.012	?	?	?	?	?
Tonumea	1 high limestone	0.12	?	?	?	?	?
Tungua	?	1.52	?	?	?	?	?
Uanakuhihifo	?	0.1	Fringing	?	?	?	?
Uanakuhahake	?	0.49	Fringing	?	?	?	?
'Uiha	1 high	5.37	?	?	?	?	?
Uoleva	1 limestone	3.0	?	?	?	?	?
10 Other island in the Ha'apai Group Totaling 0.594 km2							
Tongatapu Group							
'Ata	1 high volcanic	2.27	?	?	?	?	?
'Eua	1 high volcanic	87.43	Fringing	45.2	?	?	?
Kalau	1 island	0.2	?	?	?	?	?
Minerva	1 low coral	?	?	?	?	?	?
Tongatapu	1 high limestone & 7 low coral islets	259.3	Fringing and lagoon	135.0	?	?	?
'Euaike	1 high limestone	1.05	?	?	?	?	?
Mahaha'a	1 low coral	0.039	Fringing	?	?	?	?
Malinoa	1 low coral	0.73	Fringing	?	?	?	?
Manima	1 low coral	0.03	?	?	?	?	?
Monuafe	1 low coral	0.02	Lagoon	?	?	?	?
Nuku	?	0.04	?	?	?	?	?
'Oneata	1 low coral	0.078	?	?	?	?	?
Pangaimotu	1 low coral	0.223	Fringing and lagoon	?	?	?	?
14 Other Islands in the Tongatapu Group Totaling 1.427 km2							

Adapted from Maragos and Holthus (1999): after Dahl (1991); ENEP/IUCN (1988)

Table 2
Islands and Coral Reefs of Tonga.

It is evident from the Table 2 that much needs to be documented with respect to the details of the coral reefs of Tonga. This lack of assembling knowledge prevents an accurate assessment of the country's natural wealth. Its value to tourism or fisheries relies on an understanding of the nature of the reef resource. One of the goals of the management of this resource is to quantify the nature of the reefs (i.e. replace the question marks). This is fundamental to development of coral reef management plan.

Biodiversity

There were 192 species of scleractinian corals described from the reefs around Tongatapu (11 reefs were sampled including the marine reserves). The coral coverage range from 2% Mounuafe reef to 50% at Hakaumama'o reef reserve (MPCJ, 1997). Holthus (1996) found that there was a mix of healthy, degraded and recovering coral communities (36 reef sites sampled in Vava'u). The reefs are described with respect to corals (73), echinoderms (6), some shellfish, algae and seagrass, and an overview of the reef types. The presence of the crown-of-thorns starfish was recorded through noting feeding scars.

Threatened and depleted species

Black coral (*Antipathes*) and some molluscs were considered depleted in some areas of Tonga (ESCAP, 1990). There are six species of giant clam known to Tonga. *Hippopus hippopus*, the horse foot *Tridacna* clam has become extinct in Tonga in recent times (McKoy, 1980). This is also the case in Fiji and human collection is implicated but the fate of the species remains a mystery. The giant clam Tridacna derasa is considered severely over fished and has given rise to a mariculture program to re-establish the populations (Chesher 1986, 1987, 1991, 1993; Chesher and U. Fa'anunu, 1991). The species *Tridacna tevoroa*, endemic to the Lau and Tongan waters, has been overfished in the Ha'apai Group (Zann, 1994).

The survival of the green and hawksbill turtles may be threatened (Braley 1973 a,b; 1974). They are protected by law during the nesting season, though this is largely ineffectual (ESCAP, 1990).

Status of fishes

Biodiversity

General surveys have concentrated on the marine park areas. 229 species of fish were found in 39 families in the reefs around Tongatapu. Hakaumama'o Reef Reserve showed the greatest diversity with 127 species in 28 families. The most common families are the Labridae and Pomacentridae. Reef Fish of Tonga (Smithsonian Institute, 1993) provide information on the fishes of the Kingdom. 55 species of bivalves and 83 species of gastropods from 3 different habitats: seagrass bed, coral reef, sand were described (MPCJ, 1997). There are 13 species of holothurians, three, of which, are important commercial species.

The Coral Reef Environment: Kingdom of Tonga

a) The islands (left to right) of Pangimotu, Makaha'a, Manima and 'Oneata north of Tongatapu. The coral reefs radiate around Pangaimotu and Makaha'a with seagrass beds appearing as darker, blotchy areas inshore and, extensively, between the islands of Makaha'a, Manima and 'Oneata.

b) The coralline (*Porolithon*) algal ridge/fringing reef growth off the southwest coast of Tongatapu.

c) Narrow fringing reefs line the deep channel (~20m) between Vava'u and Pangai Motu with Neiafu middle right.

d) Wave cut notch on Koloa, a raised limestone island in the Vava'u Group.

e) A fringing reef Uonukuhahaki I. and Uonukuhihifo I. (left) and their fringing reefs in the southern portion of the Ha'apai Group.

f) Seagrass meadows north of Tongatapu with the green algae, *Cladosiphon sp.*, fouling the beds.

g) The seaward slope (5-6m depth) adjacent to Ha'atafu Beach Reserve, Tongatapu. Evidence of the coral bleaching event can be seen.

h) Close up of the coral assemblage (from g) shows coral bleaching resulting from the recent South Pacific warm water event. Bleaching in this *Acropora* dominated assemblage was largely confined to the corymbose colonies.

Fisheries

The average reef fish production is indicated in Table 3. The catch for the various localities are given in Table 4.

Subsistence fisheries production (mt)	Nominal Value (US$)	Commercial fisheries production (mt)	Value (US$)	Total fisheries production (mt)	Nominal Value (US$)
933	1,901,208	1,429	2,806,641	2,362	4,707,849

After Adams and Dalzell (1999) in Eldridge *et al.* (1999)

Table 3
Subsistence and Commercial Fisheries: Annual mean production - 1989 to 1992.

	Commercial	Subsistence	Total
Nuku'alofa	1,000	375	1,375
Vava'u	250	280	530
Ha'apai	100	180	280
Other	79	98	177
TOTAL	1,429	933	2,362

FAO Digital Atlas, 1998

Table 4
Catch landings (tonnes).

The finfish resource from the shallow-water reefs has been a major source of protein both in the subsistence and the artisanal fisheries in Tonga. 1993 estimates of fish landings at two landing sites, Vuna and Faua in Nuku'alofa, indicate that fish species classified as shallow-water reef fishes make up almost 70 per cent (200 mt) of the total artisanal finfish landings there. The main fish family recorded was parrotfishes. In 1987, the shallow-water reef fish landing in the Tongatapu artisanal fishery was estimated to be 333 mt of which emperors were the main family. 140 tonnes of mullet were landed. Apart from the reef and lagoon fish, other coral reef fisheries are beche-de-mer, the molluscs (trochus, triton, shell collecting, *Tridacna spp.*), aquarium coral and fish, and precious coral.

Though many of the mollusc resources are not harvested on a sustainable level, these resources have been an important seafood component in both the subsistence and artisanal levels of utilization. Giant clams have been subjected to heavy exploitation leading to very low populations in certain areas. The estimated shellfish (including giant clams) landing at Vuna and Faua in 1993 is 118 mt with *Anadara* making up 34 per cent and giant clams 33 per cent.

The development of the aquarium fish trade in Tonga has led to the utilization, not only of the small colourful reef fishes, but also juvenile giant clams, other shellfish species, corals and sea anemones (Matoto, 1997; Oliver and Smith 1994; Matoto et al. 1996). Export data submitted by the main aquarium fish exporter indicate that, in terms of the number of pieces exported during 1993, corals made up about 60 per cent of the total exports during the year. Between 1995 and 1996, aquarium exports by composition were fish 27 %, live coral and rock 29 %, soft coral 27 %, invertebrates 15 %, giant clams 2 %. Of the fish, 54 % were damselfish, 17 % angelfish, 11 % wrasses, 8 % clownfish, 6 % hawkfish, 2 %, butterfly fish and 2 % tangs (Matoto, 1997).

Harvesting of sea-cucumber for consumption on the subsistence level has never been high. This resource forms only a small portion of the local fishery. However, the commercial production of

bêche-de-mer for export has been a major development within the last few years. Some limited processing was reported in the 1980's but the industry boomed starting in 1990 when markets were established for a species currently known in Tonga as the sandfish, *Holothuria scabra*. This sea-cucumber species is abundant in shallow lagoons and fetches higher prices than the teatfish.

Two giant clam species, *Tridacna* gigas and *Hippopus hippopus*, were re-introduced into Tonga in 1990 and 1991. Both species are believed to have become locally extinct. The giant clam project started in Tonga with the creation of clam circles in 1986. Clam circles were created by the Ministry of Lands, Survey and Natural Resources in an attempt to revitalize the stocks of these animals. Several community giant clam sanctuaries were initiated. The first community-based clam circle was set up in Vava'u (Falevai community circle) and the Fisheries Division has continued with the program. Due to faster growth rates, the current giant clam project is concentrating on the production of *T. derasa* and *T. tevoroa* and the establishment of community-owned ocean nurseries. Recent inspection has revealed the clam circles at Falevai to be depleted of clams due to stealing and lack of attention. Signs have been erected to warn yachts from anchoring there (World Bank Report, 1999c).

Four hundred live *Trochus niloticus* were introduced from Fiji in 1992 and released on a reef west of Tapana Island, Vava'u (donor FAO). In 1994, 1100 were released in Tongatapu (donor JICA). In 1995, 500 were released in Ha'apai (FAO/JICA donors). In 1994, there was the first spawning induction and 2000 were released in Vava'u, Ha'apai, Tongatapu, and Niue. The second spawning in 1997 produced 10 000. About 2000 were released in Ha'apai and Vava'u. Evidence of new recruitment were reported from Vava'u, Ha'apai and Tongatapu.

Fifty mature green snails, *Turbo marmoratus*, were introduced from the Republic of Vanuatu in 1995. Twenty of these green snails were released in the wild at Hufangalupe but 23 were kept in baskets at the Ministry of Fisheries' giant clam ocean nursery in Sopu (FAA 1994). In 1996, 320 were introduced from Okinawa, Japan and 30 introduced from Vanuatu. 2719 were released in Tongatapu, 2500 in Vava'u, 500 in Ha'apai. In a seed production and release program in 1997, 40 were released. The program continues with 1900 (1997), 3800 (1998) and 10 000 (1999) released in cages and raceways. JICA researched an environmental impact assessment, though there has been no attempt to conduct an EIA for other species.

Four *Panulirus* species of spiny lobsters are found in Tonga. The main species harvested are the double-spine lobster (*P. penicillatus*) and the slipper lobster (*Parribacus caledonicas*). Information on the stock size, ecology and biology of this animal is incomplete. The stock is declining from overfishing.

There are seven species of mullet in Tonga. Four, of which, are currently fished and declining due to being overfished. In 1992, MOF/JICA set up a project to culture mullet in Tonga. Fish fry of the species *L. macrolepis, V. seheli, M. cephalus* from the wild and were reared for re-stocking in pens constructed near Tofoa in Fanga'uta lagoon but was later destroyed by hurricane.

Fisheries policies

Tonga's overall fishery policy is to increase fish production for export and as a source of high-quality protein for Tongans. Along with long lining and mariculture, future management objectives are to improve the subsistence and small-scale commercial fisheries. This involves development of fishery co-management arrangements to promote greater involvement by fishers and communities in inshore resource management.

Tonga has a limited natural resource base except for the potential of the EEZ. Fish is one of Tonga's highest export commodities, and marine fish offer considerable potential for sustainable resource

development. Although increasing amounts of imported fish and meat are consumed, especially in the urban centers, fish remains important particularly in the outer islands. Lack of land means an increasing reliance on the subsistence marine products. Subsistence activity from shallow-water reef and lagoons surrounding the islands provides a vital source of protein. The Government of Tonga is concerned with developing methods of increasing commercial production of fisheries without overexploiting. Fisheries are important but Tonga is a net importer of fish products. Much of the fishing is semi-commercial. 70% of the total annual catch are reef-lagoon fish. Octopus is popular and often abundant. Clam fishing used for local consumption, decoration and a small amount of export. Black coral is collected and fashioned into jewelry. Turtles are eaten for eggs and meat with the carapace used for decoration and jewelry.

Natural and anthropogenic threats to biodiversity

Anthropogenic Threats

75 % of the islands are uninhabited. The population is principally located on Tongatapu and around the provincial centers on 'Eua, Lifuka in the Ha'apai and Neiafu in Vava'u. The population is growing at 0.5 % annually and there is an urban growth of 2.5 %. As a result, fishing has reduced stocks around Tongatapu and other populated areas.

Anthropogenic threats may involve construction, quarrying, pollution, overfishing, recreational activities or tourism. Fishing activities such as gleaning, dynamite or poisoning can have persistent impacts. Siltation from construction and quarrying sites have degraded the reefs adjacent to Nuku'alofa and Neiafu, Vava'u, though this is a localised problem in all of the groups. Causeway construction in the Ha'apai and Vava'u has caused degradation. Mangrove cutting has been banned but still occurs. Sand mining from beaches and dunes is a major problem.

The World Bank Report (1999b) identified threats at the community level as waste or rubbish pollution, pressure on resources from outside users, the cutting of mangroves and damaging of corals. Pollution and damage may result from discarded fish-fence wire and batteries. Removal of shell, gravel and muddy sands has destroyed mussel habitat. Causeway construction has blocked the water interchange and caused a build up of mud, which affected *Gafrarium* stocks. Anchoring in the clam circles was perceived as a problem. Net fishing and sophisticated gear use contributed to overfishing.

Eutrophication

Tonga does not have a sewerage system. Eutrophication by sewage (septic systems) occurs particularly at Nuku'alofa. An estimated 250 t of fertilizer is used on Tongatapu and Vava'u each year as of 1990 (ESCAP, 1990; Zann, 1994).

In Fanga'uta Lagoon, Tongatapu, an increase in seagrasses and mangroves and a decline in stony corals were to some extent attributed to eutrophication from urban nutrient run-off (Zann *et al.,* 1984; Zann and Muldoon, 1993). Landfill and the cutting of mangroves were considered problems.

The monitoring program currently running as part of TEMPP project (Tonga Environmental Management and Planning Project) is assessing the physical and environmental parameters such as nutrients, trace metals, pesticides, and general biology of the lagoon (Morrison J. 1999). The monito-

ring is budgeted to the Environmental Planning and Conservation Section, Ministry of Lands, Survey and Natural Resources to continue to the project.

Initial assessment of the physical and environment parameters, seem normal (e.g. pH, salinity, temperature, dissolved oxygen, and turbidity. The results were similar to other non-polluted lagoons being relatively free of contamination.

Summary research results found that nitrate and phosphate are limiting with respect to seasonal patterns. Four general surveys per year and a monthly program for nutrients are underway. Nitrates and phosphates are below the EPA guidelines. Ammonia was slightly elevated in some areas but below the EPA guidelines. The possible sources are septic system contamination.

Tests for E. coli in water, sediment and shellfish found levels below the EPA and WHO guidelines. The lagoon is considered safe for recreation and gleaning. Pesticides residues were sampled in sediment and soil. Two pesticides were present but in very low (ppb) concentrations (Chen, 1999).

Trace metals, though present in shellfish and sediments were unlikely to cause any major health problems. For many elements, the concentrations were below the detection levels, confirming no major problems with metal contamination (Brown and Morrison, 1999).

Tourism

Tourism is increasing with fishing pressure on delicacy items like lobster. SCUBA diving is available in Nuku'alofa and Vava'u increasing tourist appeal and making more of the coral reef available. Tongan tourism increased from 17 000 annually in 1982 to 25 500 in 1992. In some areas, the continuous fossicking by tourists is responsible for the breakage of corals though that caused through gleaning by Tongans is widespread and far exceeds this. Habitat loss has impacted other marine life. Anchorage of boats whether due to local fishing or tourism (diving boats etc) can be a problem.

Overfishing

For inshore fisheries, increased fishing pressure driven by improved access to markets, rising prices, and population growth is resulting in remarkable declines of important inshore marine resources (World Bank, 1999 a,b,c). There are numerous indications that both the condition of the resource is deteriorating and conflicts between user groups are increasing. Unlike the situation in other Pacific Island countries, coastal communities in Tonga have no preferential access to adjacent resources. This open-access situation may have worked reasonably well in the era of subsistence fisheries, but it has fairly recently collided with commercial realities and the carrying capacity of inshore resources. There is heightened concern by residents of outer islands that Tongans from anywhere, especially commercial operators from Tongatapu, could harvest the food resources adjacent to their villages in outer islands thereby affecting the food security situation. The Ministry's management interventions in inshore fisheries appear to fall into two categories: (1) implementation of the provisions of the Fisheries (Conservation and Management) Regulations 1993, and (2) bold action in support of fisheries which have collapsed (e.g. banning the export of giant clams in 1994 & beche-de-mer in 1997).

In many areas, overfishing of inshore resources is now severe and the deficiencies of a centrally implemented, regulation-based management system are becoming apparent. Fishery regulations are generally poorly understood or observed, and enforcement through Tonga's many scattered islands and reefs are difficult or impossible. The government is thus now investigating the possibility of co-management arrangements, under which responsibilities would be shared between government and fishing communities. Many local fishers and communities are in favour of such arrangements, and a pilot project is likely to be soon underway in Ha'apai (Petelo *et al.*, 1995; Gillett, 1997).

A ban on beche-de-mer exporting has been imposed in response to serious overfishing during the past five years. The ban is for ten years, although there is provision for a review after five years. Overfishing is a problem with other species, particularly clams. Black coral has also been over-exploited. The method of dragging an anchor line along the seabed to collect black coral is damaging to general benthos.

Destructive fishing techniques can be a major contributor to reef degradation. These involve smashing reefs to chase fish into nets, and the turning and breaking of rocks and coral to take invertebrates. Trampling of coral during food gathering on reef flats is a problem. Poisons such as bleach and pesticides are used.

Impacts on Vava'u Reefs

Holthus (1996) found human destruction and degradation of the coral reefs of Vava'u resulted directly form the breakage of coral during fishing activities, and indirectly from the input of increased silt and possibly chemicals (e.g. pesticides) and nutrients. Indicators of disturbance, *Acanthaster, Diadema spp.* and dead standing coral, were concentrated near land and in the eastern reef areas where coral diversity and live coral cover were found to be lower. Chesher (1985) found that 65% of the 100 reefs surveyed showed evidence of coral destruction from both natural and anthropogenic sources. Coral breakage through destructive fishing techniques during gleaning activities has heavily damaged some areas. The use of poisons may be widely destructive to fish and invertebrates and have long term impact. He detailed pollution sources (Chesher, 1984a).

Areas of Impact

Areas of disturbance are Fanga'uta lagoon in Tongatapu (eutrophic, major coral mortality and collapse of fisheries); Nuku'alofa and adjacent northern Tongatapu (physical disturbance, loss of habitat, eutrophic, overfishing, coral mortality). The inner reef areas along Ha'atafu Beach have experienced a proliferation of algal growth (*Turbinaria and Sargassum spp.*) in recent years due to eutrophication of lagoon waters. Inner Neiafu Harbour in Vava'u has been affected by sedimentation, crown of thorns, overfishing, and coral mortality (Zann, 1994).

Natural Impacts

Natural threats are volcanic activity, tropical cyclones, *Acanthaster* outbreaks, coral bleaching, coincidence of low spring tide, high temperature and rainfall. Coral mortality and the colonization by blue green algae may result from a variety of natural circumstances but may be attributed to stresses caused by storm damage, pollution, causeway construction and destructive fishing techniques (Chesher 1985). As most islands are low and lack rivers, soil loss and flooding is minimal. Flooding can be a major problem with cyclonic rain on Tongatapu.

Destructive cyclones occurred in the years of 1982, 1995, 1997, 1999 and 2000. In 1998, an El Niño year, high temperature during a daytime (noon) spring low tide affected benthic marine organisms. La Nina periods following El Niño are characterized by a period of heavy rain, decreased salinity and may affect marine organisms, especially during spring low tide.

The crown- of- thorns starfish, *Acanthaster planci*, have been reported throughout the archipelago. Outbreaks of the starfish have not been noted but chronic elevation of numbers has been recorded in Vava'u harbour in the early 1970 and 1980's. Moderate numbers were recorded at Ha'atafu and Pangaimotu Island off Tongatapu in 1992 (Zann and Muldoon, 1992).

Current and potential climate change impacts

Global warming

In recent years, concern has grown that the Earth's atmosphere is changing due to human causes burning of fossil fuels and deforestation among them. It is feared that this effect may cause global warming with an increase in sea temperatures. Studies suggest that global change of this magnitude could cause significant problems, including melting of the icecaps resulting in a sea level rise.

Global warming and sea-level rise are of concern in the low islands in terms of an alteration of coastal processes, submergence, pollution of groundwater and coral bleaching. Climate change may mean increased cyclonic activity, alteration in the rainfall pattern and periodic elevation in sea temperature.

Coral bleaching

Coral reef bleaching is a response to stress. The bleaching refers to the colouration of the organism resulting from the breakdown in the mutualistic dependency between the coral and the zooxanthellae. The corals lose some or all of the symbiotic microalgae (zooxanthellae), living in its endodermal cells. The effect occurs in diverse invertebrate taxa. It frequently results in a white colouration due to the whiteness of the coral skeleton or the soft coral tissue. A bleached organism may be particularly brightly coloured due to the appearance of its natural animal coloration in the absence of the darker, green/brown, zooxanthellae. Though bleaching may be caused by a variety of stresses (freshwater, ultra-violet light). The recent widespread bleaching observed globally is the result of prolonged periods (few weeks or more) of elevated temperature 1-20C above average sea temperatures.

Historically, published records of coral reef bleaching incidents from 1870 to present suggest that the frequency, scale and severity of recent bleaching events are unprecedented. There have been 60 major events from 1979 to 1990 globally (Glynn, 1993) with four of the most severe occurring in French Polynesia in 1994; Maldives and Indian Ocean in 1997/98; the Great Barrier Reef in 1998; Palau in 1998 and Fiji, Tonga and Cook Islands in 2000. There has been a co-occurrence in many coral reef regions and often over the bathymetric depth range of corals with > 95% mortality in some areas.

Causes of small scale bleaching events can often be attributed to particular stresses but the widespread effect is certainly from elevated temperatures caused by maximum seasonal solar heating and calm clear weather allowing the sea surface to heat up. Global temperature satellite surveillance by the National Oceanic and Atmospheric Agency (NOAA) has revealed areas of elevated sea surface temperatures, which exceed the average sea temperatures for periods of time and are characterized by a bleaching event. A constant referred to as Degree Heat Weeks (DHW) is now being tested to determine the extent of bleaching as the result of both degree of elevation over the average, and length of warming period. In the Maldive Islands situation (Wilkinson *et al.,* 1999) and currently in Fiji, the satellite assessment of hotspots was very accurate in determining the areas and degree of bleaching that occurred.

Given the projected elevation of temperatures (1-20C) over the next 30 years (Manabe *et al.,* 1991), there is concern that the upper thermal tolerance limits of many reef-building corals could be exceeded. Many corals may be unable to adapt physiologically or genetically to such marked and rapid temperature increases. Coral bleaching around the world would increase in frequency and severity until it occurred annually by 2030, unless global warming is reversed. Depending on its severity or frequency of occurrence, a single bleaching event will take reefs from 30 to 100 years to recover. If there

is unrestrained warming, then the coral fauna will be progressively reduced and require a much longer recovery time. Genetic accommodation, replacement by heat resistant species and/or global cooling would ameliorate the effects of bleaching (Hoegh-Guldberg, 1999).

The South Pacific bleaching event currently underway was the result of the warming of a band of oceanic water extending from Fiji to Easter Island and included the Cook Islands and Tonga. Bleaching has occurred in all of those places.

In Fiji, bleaching is 90% in some areas. Only a few species remain unaffected. The effect is not uniform with less bleaching in the far northern part of the group. Other areas of the country for some unknown reason appear less affected. The bleaching is mainly confined to shallower than 30m and is not widespread at 40m.

Tongan Bleaching Event

Tonga has reported coral bleaching (February, 2000) around Tongatapu and the Ha'apai Group. Observations from the Ha'atafu Reserve on Tongatapu (May 5-10) revealed the phenomena to be widely evident on the reef slope and in the lagoon. The event was similar to Fiji with the corals exhibiting varying degrees of bleaching. The nearshore lagoon is dominated by Montipora hispida with M. incrassata subdominant. Though representing areas of substantial coral cover, these species showed only minor bleaching. By contrast, *Goniastrea retiformis, Platygyra sinensis* and *P. daedalea* were invariably 80-100 % bleached.

On the outer reef slope, the corymbose *Acroporas* were most notably affected with the tabulate colonies showing only minor bleaching and, in many cases, unaffected. Coral death was minimal with a visual estimate of 2-5 %. Those that had died and were covered in part or wholly by algal growth were the hydrozoan corals *Millepora exaesa* and *M. dichotoma*. Among the Acroporas, *A. humilis, A. monticulosa* and *A. robusta* were characterized by varying degrees of death. The first two showed a range of minor bleaching to total colony death. Some colonies of *A. robusta* were apparently entirely unaffected though other colonies were part or totally dead. Many colonies of this species were totally bleached though still living.

Future Bleaching Events

In 1997-98 the hottest average sea temperatures on record occurred in the Indian Ocean and this effect migrated throughout the Indian Ocean to varying degrees. The southeast Asian and western Pacific area was affected with particularly devastating effects on the coral reefs of Palau. In some places, the coral mortality was >95 %. Coral reefs became algal reefs.

In the worst case scenario, events as severe as 1998 are now projected to become commonplace by 2020. Globally, coral reefs are expected to face bleaching every year by 2030. During the past 100 years the gradually increasing sea temperatures have been pushing the reefs closer to their tolerance levels, so now even the slightest increase in temperature can cause coral bleaching, This was witnessed in the Solomon Islands this year.

The question remains as to how well the corals will adapt to the hotter conditions. Corals are not showing any sign they can adapt fast enough to keep pace with changes in ocean temperature. Most of the evidence indicates bleaching events are signs that the genetic ability of corals to acclimatize is currently being exceeded (Hoegh-Guldberg, 1999). Natural selection may prevail with the alteration in the species composition of the affected reefs.

Rising Sea-level

Sea levels have fluctuated widely in the geologic past. Since the last ice age, sea level has been relatively stable. However, during the past 20 years, concern has been expressed in the scientific community that the atmosphere may be warming, and causing sea levels to rise catastrophically, with the melting of polar ice.

If sea level change is a reality, it will have dramatic effects on coastal communities throughout the world. Although, coral reefs may be able to continue their upward growth with little real change in reef communities. However, there are limits to the rate of effective upward growth. Coral reefs represent a variety of locations and their growth rates also vary. Reefs which occur at depth grow more slowly and may be approaching the Darwin Point (Grigg, 1982) where they may 'drown' due to tectonic submergence. Some coral reefs that cannot continue their upward growth may have growth retarded due to factors such as chronic turbidity.

El Niño conditions are accompanied by lower than normal sea level in the Western Pacific, which may lead to widespread death of corals due to exposure to air. Corals and coralline algae, and certain other reef organisms are distributed in well-defined zones. Organisms are distributed as they are in relation to tidal levels in the intertidal zone partly in response the rates of exposure. If for any reason such organisms are subject to different levels of exposure, they may die. Some are found only in wave washed areas or very shallow water, and very far from the intertidal zones.

Increase in cyclonic storm intensity, rainfall extremes, frequency of El Niño events

Anecdotal observations include:

- a greater frequency of cyclones in the last few years;
- increased rainfall;
- higher average water temperature;
- sea level trend positive (19mm/yr.) during the last few years;
- seasonal variation shift by few weeks;
- coral bleaching event in Tonga;
- potential changes of the marine ecosystem and habitat due to changes in salinity etc.

Potential climate change impacts:

- erosion of coastal environment;
- low lying areas in Tonga will be affected by the ingress of sea water;
- changes in marine habitats.

Marine protected ateas

The concept of parks and reserves is not new to Tonga. In 1946, 'Ata, the then Minister of Lands, gazetted a park reserve at Haveluloto along the shore of Fanga'uta Lagoon. This set the legal prece-

dent of parks and reserves coming under the Ministry of Lands and demonstrate the foresight on the part of the Tongan government. Then in 1972, King Taufa'ahau Tupou 1V declared 2 reserves at Muihopohoponga and at Ha'amonga Trilithon. Muihopohoponga is a 2 km stretch of beach on the extreme eastern end of Tongatapu. The Ha'amonga Trilithon, the Stone Henge of the South Pacific, is a 23 hectare reserve. Under the Parks and Reserves Act of 1976, Tonga has gazetted two national parks, which comprise the entire islands of Mounuafe and Malinoa and five marine reserves. In 1979, two reserves were established around the island of Malinoa and Mounuafe and three reefs at Pangaimotu, Hakaumama'o and Ha'atafu. The Ministry of Lands, Survey and Natural Resources administers parks and reserves.

The Minister for Lands is the chairman of the Parks and Reserve Authority with the members including the Secretary for Lands, Survey and Natural Resources, Secretary for Fisheries, Director of Agriculture and Forestry, Director of Tourism, Head of Environmental Planning and Conservation Section of the Ministry of Lands, Survey and Natural Resources.

The whole Ha'apai group was declared as the Ha'apai Conservation Area by Cabinet following the recommendations by SPREP, Ministry of Lands, Survey and Natural Resources and the Ha'apai Committee. Proposed reserves for Vava'u are the Coral Garden at Nuapapu, Maninita and Mounu Island. Biological surveys or inventories of the reserves were carried out by Marine Parks Center of Japan (MPCJ) and the Ministry of Lands, Survey and Natural Resources in 1997.

The Ministry of Lands, Survey and Natural Resources coordinates policymaking, natural resources and enforcement, as well as parks and reserves. Under the Parks and Reserves Act (1972), there were five marine reserves on Tongatapu (see below). Some areas have been protected through Royal Proclamation. Fanga'uta and Fangakakau Lagoons are protected under the Birds and Fish Preservation Act of 1915 against commercial fishing, traditional fish traps, effluent discharge, dredging, the construction of any building works, harbours, wharves, piers or jetties, or the cutting of mangrove trees.

The Parks and Reserves Act 1988 protects, manages and develops natural areas. The following five parks and reserves have been established under this Act (WCMC 1991):

- Fanga'uta and Fangakakau Lagoons Marine Reserve - Tongatapu
- Hakaumama'o Reef Reserve
- Pangaimotu Reef Reserve
- Monuafe Island Park and Reef Reserve
- Ha'atafu Beach Reserve
- Malinoa Island Park and Reef Reserve.
- 'Eua Island National Park*

(* not marine)

Areas of black coral have been set aside by Government and a program of fragmenting and planting are management measures. Protected clams, arranged in circles, were also established to promote re-establishment of clam stocks. Turtles are theoretically protected through the Bird and Fish Preservation Act.

Enforcement of park boundaries and regulations is poor. From the Fisheries Sector Study (Gillett 1997), Adams and Ledua (1997) reviewed the regional experience with reserves and stated some of the problems:

- Marine protected areas do not have a good record in the Pacific. It is usually difficult to get community agreement to set them up, and in areas where they do exist they are rarely respected or effec-

tively enforced. The lack of respect for the legislation sometimes results from its new and novel nature. Community-based management or involvement in decision making is a new concept to Tonga as well as the other Pacific countries. Generally legislation in Tonga uses a top down approach. Progress is being made with the community and NGO involvement is now in place.

- A particular community could be required to give up effective ownership of an area (even if legal ownership is vested in the State) for the long-term benefit of other communities.

- The efficacy of reserves for rehabilitating or sustaining surrounding fisheries has not yet been unequivocally proven whilst their capacity to divert resources from other, perhaps more effective management and conservation methods, is well known. Despite this there is widely held belief and evidence that reserves are effective for rehabilitating and sustaining marine resources. Reserves are established for different purposes (IUCN categories) and each reserve serves its duty well enough even though there may be abuse through fishing.

- With marine reserves in place, fisheries managers may be lulled into tranquillity and feel that nothing further need be done. Generally, however, diverse activities have been carried out in the reserves. A management plan is in place with a program of development. Funding and manpower can be a problem for some aspects of development and monitoring.

In view of the above concerns, Gillett (1997) recommended only carefully considered and judicious use should be made of marine protected areas for inshore fisheries management in Tonga. Attention should be given to:

- Establishing reserves only where there is full consultation and agreement from adjacent communities;

- Realistically appraising the amount of surveillance/enforcement required for each reserve;

- Assessing the total amount of Ministry surveillance/enforcement resources available for all inshore resource management and assuring that those resources channeled to reserves are in proportion to the benefits from reserves (i.e. not a dominant portion of all surveillance/enforcement resources)

Clam Circles and other protection

The first clam circle was at Mounu Reef and was established by the Ministry of Lands, Survey and Natural Resources with Dr. Richard Chesher and in the Pangaimotu Island Reserve. The first community-based sanctuary was established at Falevai by the Ministry of Lands and the Falevai community. Through awareness of the project's objectives, respect was gained for the clam sanctuary concept. The success was the result of developing local understanding, providing legal protection and local involvement. A video was made and proved effective. In 1990, the King gave a prize for the best Giant Clam Sanctuary, which exists today. Sadly poaching occurred by a Fisheries officer in Vava'u. The Ministry of Fishery later established many clam circles in Vava'u.

Policing of reserves, generally, is not difficult but funding is the main problem. There are two boats for patrol and scientific survey. Equipment was provided by JICA. Policing in Tongatapu of several marine reserves has been a problem. Unlike the clam projects, the locals were not involved in the creation of and the gaining of respect for the reserves. Protection has proved to be extremely difficult.

Game fishermen tag and release billfish and international billfish tournaments encourages tag and release. Sailing charter companies encourage protection of the marine environment by providing details of suitable anchorages. 1997 Guidelines were created and piloted by collaborative efforts between government officials and operators in an attempt to further protect the maritime environment (Ruffle-Klugkist, 1998).

Flint (1999) notes seabird breeding sites of world importance. They are the islands of Fonualei, Hunga Tonga, Hunga Ha'apai, 'Ata, Late, and Tofua. There are 16 breeding species and only one sea bird reserve. The vulnerable species that nest here are Herald's Petrel, Audubon's Shearwater, and possibly Phoenix Petrel. The threats are mammalian predators and human use. Actions required are the survey of the nesting populations, protection, management, and predator control. There is moderate intern legislation for the protection of seabirds.

A detailed environmental management plan has been prepared but not implemented (ESCAP, 1990). Tonga is signatory to the Convention on Biological Diversity and the U.N. Convention on the Law of the Sea. It is not signatory to the Convention on International Trade in Endangered species.

Conservation needs to be preached from the pulpit. There must be a responsibility for the clergy to preach conservation. It could be used in Tonga with effective results.

Current monitoring and management capacity

Monitoring

There is currently a monitoring program on marine parks and reserves in Tonga, which includes six-monthly surveys of all the reserves, surveillance fortnightly, and an awareness program. A management plan for the Parks and Reserves is now in place. TEMPP (Tonga Environment Management and Planning Project) is a project of environmental capacity building by the Ministry of Lands. Its activities including a monitoring program for the Fanga'uta Lagoon which is conducted by EPACS.

Control, development and management of the fisheries resources are the responsibility of the Ministry of Fisheries. Problems exist with the regulation and management of coral reef fisheries. Active management intervention, as envisaged by the Fisheries Act, is largely absent (Gillett, 1997). In the eight years since the Fisheries Act became law, no fishery plans have been prepared. No licensing of fishing vessels presently occurs, and there appears to have been a lapse in the licensing system for fish fences. With a few notable exceptions, enforcement of the existing laws and regulations has been weak. The Sector Study's Legal Specialist noted that since the Fisheries Act came into operation, only a few fisheries cases have been prosecuted and there is currently no set enforcement or regular inspection programme.

Although the lack of information is sometimes cited as the reason for lack of management action, in many important and declining inshore fisheries there has been significant research. There seem to be numerous cases of substantial research leading to management suggestions upon which little action has been taken. For example, Preston and Lokani (1990) recommended several simple, easy-to-implement management measures for beche-de-mer, none of which were implemented until the fishery was doomed. Kailola (1995) gives detailed information and proposes management action for beche-de-mer, lobster, mullet, *Tridacna*, aquarium fish, coral, and octopus as well as seven other inshore resources, but there appears to have been no follow up action. Udagawa *et al.* (1996) give a history of advice on lobster management in Tonga and show "10 years of delay and negligence" in its implementation. This inactivity in fisheries management is thought to be related to the lack of accountability of the Ministry.

Management measures

Current programmes

Following are some recent or current programs:

- The JICA inventory surveys of the reserves, which includes corals, fishes and other coral reef organisms. There is a local training component in survey techniques.

- The Smithsonian Institute Washington D.C, conducted reef fish surveys

- The GEF/UNEP sponsored the development of the Biodiversity Strategy and Action Plan

- The National Tidal Facility (Aust.) program is monitoring sea level. This involves a tide gauge installation, data available for tide, sea level and temperature and other physical parameters.

- The International Maritime Organization (IMO) has a program concerned with marine pollution control.

- SPREP has a Biodiversity Conservation Area

Marine Tenure: a conservation strategy

Although practiced in the past, customary marine tenure has not been active in Tonga since 1887, and access to fishery resources is now open. Tongans may fish anywhere (apart from in marine reserves and other formally-declared closed spaces), and management is through legislation and regulation rather than a community-based system. Various fishery regulations have been promulgated, relating to size limits, licensing of fish fences, use of fish aggregation devices and the control of fish exports and processing facilities.

Surveys

The Australian Institute of Marine Science (AIMS) has conducted training in the Global Coral Reef Monitoring Network (GCRMN) techniques of coral reef survey using the AIMS Reef Monitoring and Data Entry System (ARMDES) method. Interest in the wild harvest of the edible seaweed *Cladosiphon sp.* for the Japanese market has led to the survey and assessment of resources throughout the Kingdom.

International and Regional Assistance

The South Pacific Regional Environmental Programme (SPREP) has actively supported studies in Tonga for reef description such as Holthus (1999) which involved fisheries recommendations for coral harvesting. Also SPREP supported an assessment made by Oliver and Smith (1994). SPC conducted an environmental impact assessment on the aquarium fish and coral trade (Moat et al. 1996). Matoto's (1997) description of the aquarium trade was supported by the University of Rhode Island. The Forum Fisheries Agency (FFA) compiled the Fisheries Resources Profiles: Kingdom of Tonga (Bell et al., 1994). The Food and Agriculture Organization (FAO) of the United Nations Development Programme (UNDP) produced the Fisheries Sector Study (1997). FFA and FAO provided a regional compendium of fisheries legislation (1993). Japan International Cooperation Agency (JICA) has developed an aquaculture project involving in research and facility.

Government policy laws and legislation

The overall theme during the Kingdom's Fifth Development Plan period (1985-1990) was geared towards identifying options to enhance the basic subsistence living. Thus emphasis was placed on the development of the commercial private sector which included fisheries. The Sixth Development Plan (1991-1995) aims at achieving sustainable economic growth conducive to a higher per capita income with special emphasis placed on export and tourism sectors. Fisheries have been identified as one of the sectors demonstrating the highest growth potential. It also encourages alternative fishing habits to prevent over-exploiting of tradition fishing grounds.

Below are acts that relate to coral reefs and several have been reviewed by Pulea (1992):

- Royal Proclamation 1887: The proclamation defines the extent and boundaries of the Kingdom of Tonga within the latitudes 15°S and 23.5°S and longitudes 173°W and 177°W from the Meridian of Greenwich.

- Royal Proclamation 1972: This proclamation defines the islands of Teleki Tokelau (North Minerva Reef) and Teleki Tonga (south Minerva Reef) and all islands, rocks, reefs, foreshores and waters lying within a radius of twelve miles thereof as part of the Kingdom of Tonga.

- The Continental Shelf Act of 1970 [CAP. 63]: The Act provides for the protection, exploration and exploitation of the continental shelf, the prevention of pollution in consequence of works in connection with the shelf, and for matters connected with those purposes. It empowers the King, by Order-in-Council, to delineate the boundaries of the continental shelf. No order has been made in exercise of this power (Campell and Lodge, 1993).

- The Fisheries Act 1989: The basic fisheries law in Tonga is the Fisheries Act 1989 (Campell and Lodge cited above). The Act provides for the management and development of fisheries in Tonga and other matters incidental thereto and repeals the Fisheries Regulation Act 1923, the Fisheries Protection Act 1973, and the Whaling Industry Act of 1935.

- Section 2 of the Act defines fisheries waters as the territorial waters of the Kingdom, internal waters, including lagoons, and such other waters over which the Kingdom of Tonga claims sovereign rights or jurisdiction with respect to the marine living resources by legislative enactment or by Royal Proclamation.

- Part II of the Act deals with Fisheries Conservation, Management and Development. Section 3 requires the Director (now Secretary) of Fisheries to progressively prepare and keep under review plans for the conservation, management and development of the fisheries in the fisheries waters of Tonga. The Director is required to consult with local government authority and local fishermen concerned in the preparation and review of each fishery plan. The Minister approves these plans. The general provisions of the act include prohibited fishing methods, reserved fishing areas, import and export of live fish, controls over the export of fish and fish products, statistics (Gillette, 1997).

- Bird and Fish Preservation Act provides protection for certain species of fish, birds and turtles, mangroves and the use of certain traps, drilling dredging or polluting of lagoons.

- Fisheries Regulation Act 1989 provides for the protection of whales, use of poisons and explosives and require licenses. Prohibit fishing for coral, marine mammals or leatherback turtles or not remove eggs. The remaining species of turtles are restricted to a season of 5 months. *Tridacna sp.* had size limits as have pearl oyster and triton shells. Collection of lobsters and slipper lobsters are restricted to size and banned if carrying eggs.

- Park and Reserve Act 1976 provides for the establishment of protected areas.

- Water Board Act, Acts 18 of 1966 and 19 of 1974. Enacted to minimize water pollution and water waste.

- Petroleum Mining Regulation. Ministry of Lands legislation to prevent pollution of high seas or coastal waters by oil, mud, or other fluids.

- Petroleum Exploration Act 1979, 1985. Ministry of Lands legislation to prevent to pollution of natural resources.

Several new items of legislation are:

- The Prevention of Marine Pollution Bill is drafted and waiting minor amendments before going to Parliament. This contains provisions for the prevention of the release or threat of hazardous substances such as oil and other pollutants to the marine environment

- Environmental Impact Assessment (EIA) Bill (Ministry of Lands, Survey and Natural Resources) contains provisions to formalize the requirement for environmental impact assessment before development approvals can be granted.

Marine conservation issues have been incorporated into the primary and secondary school curricula like geography and biology but hampered by shortages of funds. Main conservation topics for student research in the secondary school include marine parks, mangroves and coral reefs. Public awareness is through the environment section of the Ministry of Lands and Survey and Natural Resources and JICA at the Division of Fisheries. A National Environmental Awareness Week (Ministry of Lands) involves various activities including coral reef related topics and issues.

Gaps in capacity and requirements for legislation

There is a lack of governmental resources for the management of marine protected areas including monitoring, enforcement, and educational programs. Conservation and environmental regulations are inadequate, poorly implemented and enforced. Traditional forms of management and conservation are non-existent, being lost to an open access system. Open access fishing areas create a disincentive to conserve: "If I don't get it today, somebody may get it tomorrow". Fishermen equipped with modern fishing and boating gear and stimulated by commercial interests exacerbate the problem (Eldredge *et al.*, 1999).

Areas that require a pro-active approach are (after Maragos and Holthus, 1999):

- Education: There is a lack of educational materials, inadequate opportunities for formal education or public lectures. Conservation practices need to be promoted.

- Capacity-building: There are inadequate training programs that develop expertise in the management of coral reef areas. Information gained from fisheries data or otherwise needs to be better utilized in the decision making. There is often a lack of adequate capacity to survey and monitor coral reefs, particularly in a manner whereby the information can be effectively used.

- Village Orientation of Extension Services: The MoF extension services appear to be related to the more basic issue of enhancement of the stakeholder orientation of the Ministry. A review of another government department in Tonga similarly concluded that "responsiveness to clients and improved performance requires a fundamental shift in institutional culture to embrace a service and output achievement orientation". The challenge will be to devise strategies to re-orient the Ministry to the

stakeholders, rather than focussing on itself. Even with the best of intentions, the Ministry would not be able to fully cater to the needs of the fisheries stakeholders without input by those stakeholders. To develop a service and output achievement orientation which would encourage and enhance extension and other activities, there should be some form of permanent structured input by stakeholders into the Ministry's policies and workplans (Gillett, 1997).

- Accountability for the Ministries: Communication and feedback on projects are often lacking. There are no repercussions for inaction.

- Marine Protected Areas (MPA's): The success and desirability of the existing marine protected areas needs to be assessed. Other areas need to be designated throughout the Kingdom.

- Coastal Zone Management (CMZ): There is a lack of CMZ management and enforcement. Legislation needs to directly address the coastal zone. The laws need to be cohesive and may involve the development of a coral reef management plan. Ministries have a poor record of enforcing CZM regulations. With this realization, initiatives need to be pursued that promote community-based monitoring and enforcement.

Conclusion and recommendations for reef conservation

a) Develop a program of coral reef survey and long-term monitoring. This is particularly important around the urban centers as well as areas where little information exists.

b) Need to establish a database of coral reefs and marine organisms.

c) Establish a cogent policy for integrated coastal zone management and environmental impact assessment to control land-based influences such as construction, agriculture and pollution.

d) Conserve subsistence fisheries resources. Develop attitudes and measures to regulate fishing both in terms of overfishing and the use of destructive methods. Regulate commercial fishing on coral reefs.

e) Develop policy to establish coral reef-protected areas.

f) Education, particularly at the school level, of environmental and conservation issues. Traditional values should be incorporated into any program.

g) Encourage active public participation in coral reef issues. Education needs to be expanded into the community. Media should participate more. Village and church groups, and NGO's are important in education and management. Participation of fishermen is important.

h) Develop capacity building and training of government and non-government personnel in activities that lead to the protection of coral reefs (monitoring, EIA, education, enforcement).

i) Ministries working independently of each other need closer communication and cooperation.

j) Improve communication to facilitate regional cooperation and assistance.

k) Improve co-operation between government authorities concerned with coral reef stewardship.

l) Re-establish some marine tenure to reinforce the concept of community-based management of the coastal resources.

m) Provide support for the Ministry of Fisheries resource management based on effective extension work where the lack of funds and insufficient staff impeded success.

Table of Acronyms

AIMS	Australian Institute of Marine Science
ARMDES	AIMS Reef Monitoring and Data Entry System
DHW	Degree Heat Weeks
EPACS	Environmental Planning and Conservation Section
FAO	Food and Agriculture Organization of the United Nations
GCRMN	Global Coral Reef Monitoring Network
IMO	The International Maritime Organization
JICA	Japan International Cooperation Agency
MPCJ	Marine Parks Center of Japan
MoF	Ministry of Fisheries
NOAA	National Oceanic and Atmospheric Agency
SPREP	South Pacific Regional Environment Program
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
TEMPP	Tonga Environment Management and Planning Project

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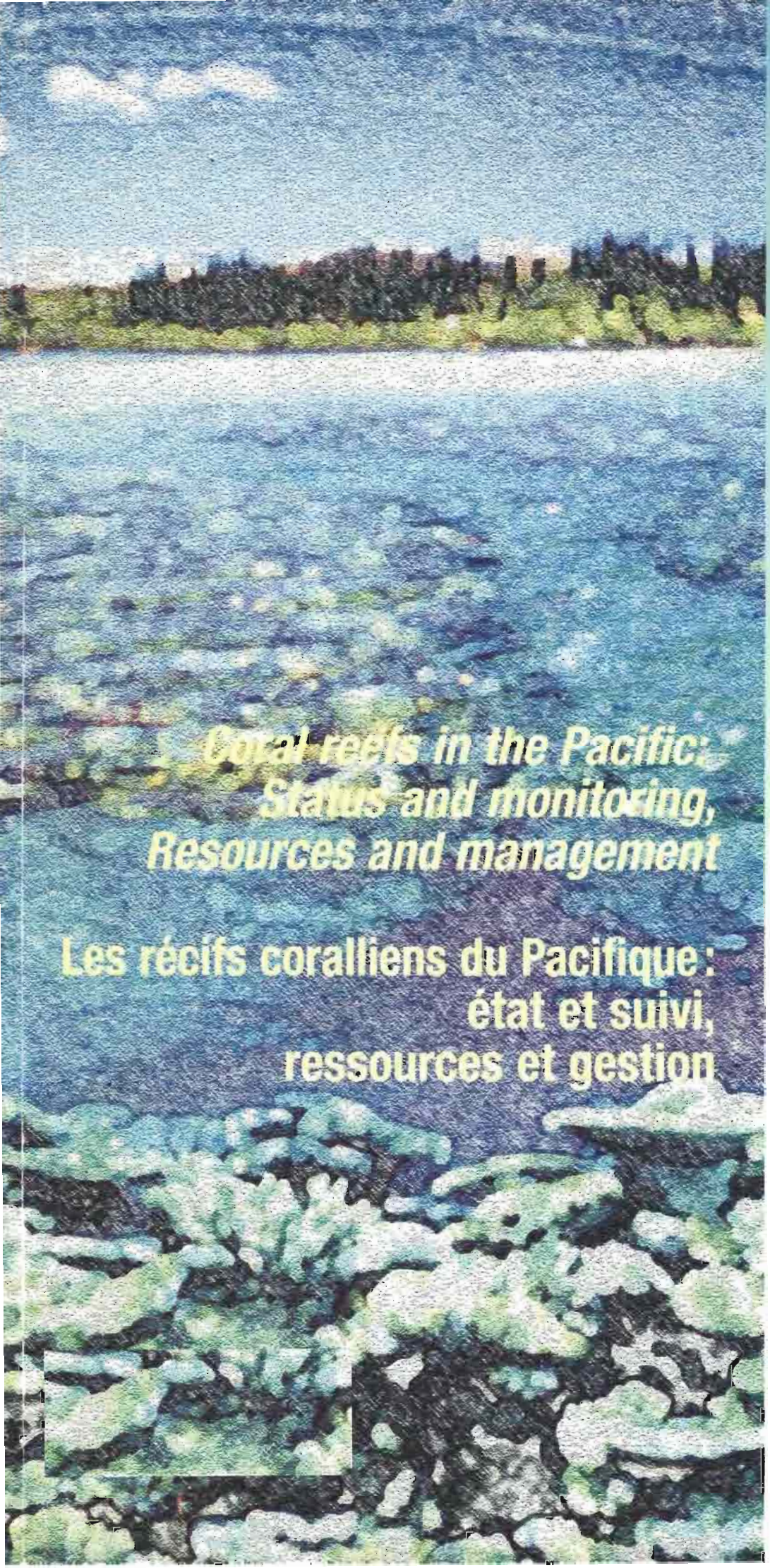

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Modèle de référence bibliographique à cette revue :
Adjeroud M. *et al.*, 2000. Premiers résultats concernant le benthos et les poissons au cours des missions TYPATOLL.
Nouméa : IRD. *Doc. Sci. Tech.* II 3, 125 p.

ISSN 1297-9635
Numéro **II** 5 - **Septembre 2002**

Distribué pour le Pacifique par le Centre de Nouméa

A regional symposium
International Coral Reef Initiative (ICRI)
Symposium régional

International Coral Reef Initiative (ICRI)
22-24 Mai 2000
Noumea IRD Centre - New Caledonia

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