The status of the coral reefs of Tuvalu

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Introduction

Tuvalu, formerly known as the Ellice Islands under the British Protectorate consists of nine coral islands and atolls (see Figure 1). It lies in the south central Pacific, north of Fiji, and geographically located between 5°31' and 10°45' South, 176° and 180° East. With a population of approximately 10 114 (Tesfagiorhis, 1991), Tuvalu's small land area of only 26 km^2 has 40% of the population residing In the capital, Funafuti. The overall population density was 395 persons km^2 with Funafuti scoring the highest (1372 persons km^2) (Tesfagiorhis, 1991). Tuvalu's population is 96% Polynesian and the local tongue is akin to Samoan, although English is widely spoken. The country places much hope for future economic growth on the fishery resources contained within its large EEZ area, which covers 900 000 km^2 (SPC est.) of the South Pacific Ocean. Tuvalu's EEZ has a higher ratio of sea to land area than any other nation. Open waters range to approximately 5000 m at their greatest depth. Scattered throughout the EEZ are many submarine seamounts whose summits may rise to within 30 m of the water's surface (Sauni, 1997).

Tuvalu's shallow marine environments are dominantly fringing and patch reefs. Five of the islands are true coral atolls, with a continuous eroded reef platform surrounding a central lagoon, three islands are comprised of a single islet made up of sand and coral materials (McLean & Hosking, 1991). One island though, has the character of both an atoll and reef island. These atolls and low coral islands are generally subject to constant change through continuing growth of living corals, erosion and accretion of wave action. All the atolls and islands are low-lying, with an average elevation of about 3 m above sea level. Patch reefs and relatively barren coralline sand flats within shallow ($\leq$ 50 m) lagoon waters are surrounded by deep open ocean. There is no continental shelf to seaward of any of the islands, the only substantial areas of shoal water being found in the internal lagoons. Water depths increase very rapidly from the coast to over 1000 m within a few kilometers from the shore or outer reefs.

Status of coral reef benthos

Reefs prior to 1998

Unlike other islands in Tuvalu, Funafuti alone had had extensive research on its marine habitats and geomorphology (McLean & Hosking, 1991; Robert *et al.*, 1989; ADAB (Australian Development Assistance Bureau), 1985; Johnson, 1961). Nonetheless, the information gathered is relatively the same in all the atolls and islands. The coral atolls are characterised by a perimeter of coral islands and coral reefs and relatively extensive lagoons formed by the submergence of the volcanic origin centre. The first attempts at proving Darwin's theory of atoll formation were undertaken through core sampling on Funafuti and its adjoining reefs. The lagoons reach depths of 60 m and are comprised of

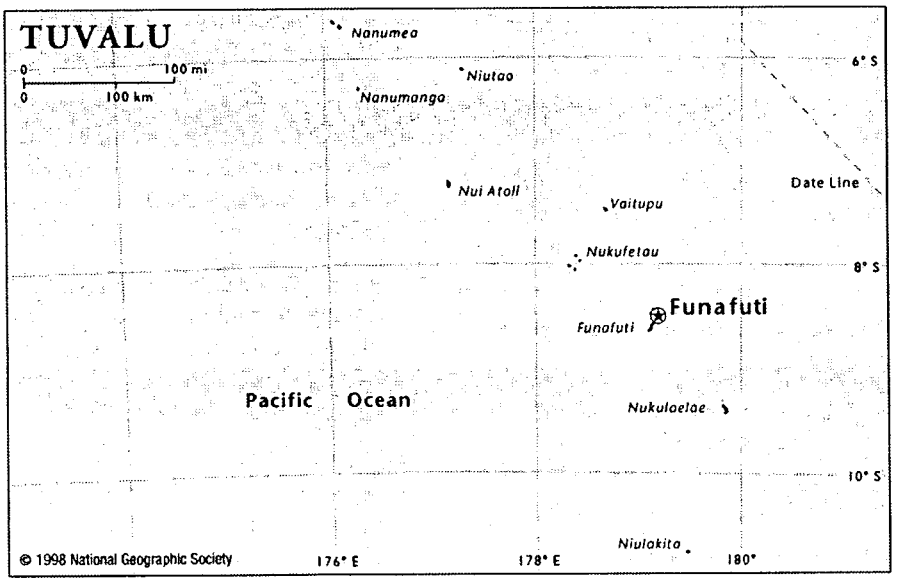


Figure 1
Map of Tuvalu.

coralline sand flats that are of low productivity due to the lack of any land based nutrient runoff and higher productivity reef flats.

Intermittent coral heads, protruding from the sand mantle cover large areas of the lagoon floor. At least, for the deep central part of Funafuti lagoon and many sloping margins, few coral heads ranged from 30–50 m (ADAB, 1985). Coral fauna on atolls and islands includes representatives of most major coral families; the majority of which consist almost entirely of acroporine skeletons (ADAB, 1985). On Funafuti, the deep lagoon bed is inferred to be underlain by algal sand for up to 20-25 m; this is then followed by an irregular coral surface whose base is an inferred unconformity at depths up to 70m below datum (McLean & Hosking, 1991).

In Tuvalu, the atoll islands are characterised by relatively narrow reef platforms and limited lagoonal area. Table 1 provides a summary of the geography of Tuvalu.

Atoll beaches are mainly formed and consist of foraminifera sand, with deposits of moderately well graded medium and coarse sand with fine content (< 75mm) of 0-5 % and gravel content 0–20 %. Gravel content is usually *Lithothamnion* or shell fragments (ADAB, 1985). Also, *Halimeda* sand

Reef Top	Nanumea	Nanumaga	Niutao	Nui	Vaitupu	Nukufetau	Funafuti	Nukuelaelae	Niulakita
Reef Type	atoll	patch	patch	atoll	Atoll/patch	atoll	atoll	atoll	patch
Reef Platform	1710	413	306	1601	906	2559	3696	1404	74
Islets	366	301	235	352	529	331	275	183	42
Beaches	21	71	2	22	17	65	27	33	8
Reef Flat	1323	98	69	1228	361	2163	3398	1188	24
Lagoon	325	-	-	337	109	9093	20521	2377	-

Table 1
Reef and Island Areas (ha) of Tuvalu (Source: McLean & Hosking, 1991).

occurs in all deep-water areas while foraminifera sand is only found in shallow areas. *Halimeda* sand, which is derived from the calcareous plant *Halimeda*, was found accumulated on the lagoon floor; the thickness of the deposits increases from the shallow water towards the lagoon centre but most large deposits are in excess of 20 m depth. The most extensive deposit of this material is less than 27 m of water and is estimated to contain up to 7 000 000 m^3 of *Halimeda* sand. An enormous quantity of this sand is available from the lagoon floor in water depths of 30–50 m (ADAB, 1985).

Lime sand, formed largely from the skeletal remains of calcareous algae, exists around the lagoon margin in water depths generally 15 - 25 m towards the shore of Funafuti island (ADAB, 1985), often mixed with foraminifera sand. The deposits are more extensive than those of the foraminifera sand but are fine and variable; deposits often form only a small film over the reef. The total available quantity of mixed foraminifera and lime sands is of the order of 320 000 m^3.

1998 coral bleaching

There are no current documented records or surveys on the 1998 coral bleaching, and no research on the impact of the bleaching phenomenon has been carried out. Nonetheless, there is anecdotal evidence on past coral bleaching observations among the islands of Tuvalu; mainly on Funafuti.

Coral reef biodiversity

Mangroves and seagrasses

Small stands of mangroves occur on three of the limestone islands and two of the atolls include two species (Woodroffe, 1987; Scott, 1993). The dominant species in the mangrove swamp and ponds is *Rhizophora mucronata*. Associated species on raised areas within the main swamp complex include trees and shrubs such as *Scaevola taccada*, *Calophyllum inophyllum*, *Guettarda speciosa*, *Cordia subcordata*, *Pemphis acidula*, etc. Of these only *Rhizophora* extends into the main tidally inundated areas, rooted in soft organic "mangrove mud". The swamps and ponds are fringed by much richer terrestrial vegetation, which extends down to high water mark. The aquatic flora of these enclosed tidal areas consists only of sparse filamentous algae such as *Chlorodesmis* and *Microcoleus*. The marginal mangrove areas are characterised by large populations of a small gastropod, a *Terebra* species.

Flora

The flora of the lagoon sands is relatively depauperate (ADAB, 1985). The main primary producers, and the dominant components of plant cover in most lagoon areas, are calcareous algae of the genus *Halimeda*. *Halimeda* species range from the intertidal zone to depths of 40 m and more. The main species identified in the ADAB (1985) report are *Halimeda macroloba*, *H. opuntia* & *H. cylindrica*. Additional species collected and identified by the 1896 – 1898 Expedition include: *H. tuna*, *H. laxa* (now *H. gracilis*), and *H. cuneata* var *elongata* (now *H. copiosa* f. *elongata*). *Halimeda gracilis* was also recorded by Chapman (1955) in dredging from 50 m depth, 2.4 km south of Fualifeke on Funafuti. Other relatively common genera include the brown algae *Padina* and *Dictyota*, notably *D. dichotoma*; the green *Caulerpa*; and the heavily branched red *Liagora* (ADAB, 1985). The main common species of *Caulerpa* is *C. racemosa*, while the "turtle-grass", *Syringodium isoetifolium* is also found in Funafuti lagoon.

The most significant plant components of the patch reefs and coral heads are crustose coralline algae of the family Corallinaceae, commonly known as *Lithothamnia* (ADAB, 1985). The dominant Corallinaceae recorded in recent and Pleistocene materials from the Funafuti borings are *Porolithon onkodes, P. craspedium, P. gardineri, Goniolithon frutescens, Lithothamnion philippii* and *Lithophyllum subtilis* (Johnson, 1961). The coral head epiflora is somewhat identical to that of the sand. The main differences are that the smaller *Halimeda* species, *H. opuntia* and *H. cylindrica*, are more common on coral, and the larger *H. macroloba* less so; *Dictyota, Padina* and *Liagora* are much more abundant; and *Caulerpa* species, notably *C. racemosa*, are common on the coral heads but not on sand. *Halimeda* species bear a foraminiferal epifauna, primarily *Sagenina* (ADAB, 1985). The flora of the reef flats is similar in species composition to that of the submerged coral heads, but differs in the relative abundance of the species concerned.

Three main growth forms of flora are branching, nodular and crustose. These were referred to by the Royal Society Expeditions of 1896-1897 as *Lithothamnion ramosus, L. nodosus*, and *L. philippi*, respectively. The crustose and nodular forms also colonise living corals, particularly on the shallow fringing reefs near the main entrance channels to the Funafuti lagoon (ADAB, 1985).

Fauna

Like other atolls in Tuvalu, the infauna of Funafuti lagoon bed sands consists largely of worms, molluscs and formaninifera. According to ADAB (1985), mature *Lambis truncata* can be found on the sediment surface. In a statement recorded by Chapman (1900-1903; cited in ADAB, 1985), the spurred forms of *Calcarina* and *Tinosporus...* are both common near the rim of Funafuti lagoon. Further, ADAB (1985) states that the number of genera of the foraminifera range from 21 to 28; this fluctuation of which could have been caused by the greater influence of marine conditions and food-supply from the seaward face. Nonetheless, in the middle of the lagoon only 3 genera are present, namely, *Sagaenina, Amphistegina*, and *Heterostegina*. Whilst, the greater number of generic forms gradually die out towards the centre of the lagoon, a few, with some special varieties, make their appearance and in tolerable abundance, in consequence of the more tranquil conditions prevailing there.

Worm tubes are primarily terebellid, cirratulid and phyllodicid polychaetes, including *Phyllodoce*; specimens of which are held at the Australian Museum. The infauna of coral heads is very diverse, and is comparable to that of the reef flats. It includes boring annelids, sipunculids such as *Aspidosiphon, Cloeosiphon, Lithacrosiphon, Parasiidosiphon, Phasocolosoma* and *Themiske*, boring sponges such as *Clione* species, molluscs such as *Arca, Lithophaga, Tridacna* and *Vermetus*; encrusting foraminifera such as *Polytrema* and various echinoderms and crustacea. Besides the corals themselves, the epifauna of the submerged coral heads includes encrusting foraminifera and sponges such as *Polytrema planum* and *Hippospongia dura*, sparse hydrocorallines and ascidians, various small echinoderms and crustacea and a wide range of molluscs (ADAB, 1985).

The epifauna of the lagoon floor sands of Funafuti which include hermit crabs, holothurians and sponges is relatively sparse but in abundance (ADAB, 1985). Two sponges are common in potential source areas and referred tentatively to as *Euspongia irregularis* and *Spinosella glomerata*. Below 25 m depth the sponges are replaced by species of *Clathria, Echinodictym* and *Acanthella* (Whitelege, 1897). Holothuria recorded in 1983 include *Microthele nobilis, M. axiologa, Thelenota ananas, T. anax* and *Halodeima atra* (ADAB, 1985). Of these, however, only *H. atra* is abundant, and this species is largely confined to the intertidal zone to about 4 m depth. According to Zann (1983), *Bohadschia marmorata* is reported from the *Bohadschia* (then "*Holothuria*") *argus*.

Echinoderms were also very sparse, with a single large *Culcita acutispina* species and several small *Linckia* spp. being the only representatives (ADAB, 1985; Whitelegge, 1897). Whitelegge (1897)

recorded the common blue, *Linckia laevigata* but this species was not found in recent surveys. Occasional large molluscs such as *Lambis truncata* were also recorded. Two species of pearl oysters, *Pinctada maxima* and *P. margaritifera* have been recorded (Belhadjali, 1998).

Corals

The lagoon has low benthic cover with staghorn and other corals dominating reef tops; however, it has a high cover by *Dictyota* and other macroalgae. The reef slope is dominated by *Acropora* including *A. nobilis* and *A. florida*, with lower cover of plating *A. hyacinthus* and several corymbose forms. The dominant algae in this habitat include *Halimeda* species and several types of corallines. The coral cover and species diversity on the reef slope is about the same as channels.

On the ocean side terrace habitats are rich in coral cover and diversity. The channels have good cover by staghorn and plating *Acroporas* in addition to species of *Montipora, Favia, Fungia, Hydnophora, Montastrea, Pocillopora verrucosa* and *P. edyouxi*. The dominant macroalga present is *Halimeda*, though corallines and turf algae are also common. On the ocean side however, terrace habitat is dominated by the presence of low ridges running perpendicular to the shoreline out to the break of slope at approximately 20 m depth. The area is dominated by a wide variety of corals, including large plates of *Acropora hyacinthus*, faviids, pocilloporids (*P. verrucosa, P. edyouxi*) and the macroalga *Halimeda*. The coral cover was approximately 40 % at the two southern passage controls, being lower (~12 %) at Papaelise. Species richness was, however, approximately the same on the ocean side of Funafuti lagoon.

Crown-of-thorns

Signs of crown-of-thorns outbreaks are frequently found on the lagoon and ocean terrace of Funafuti, ranging from 0 to 119 cotsha^{-1} (Anon., 1995; Funafuti Marine Conservation Area, 1997). Crown-of-thorns starfish were also observed at 37% of the sites surveyed on Funafuti (Belhadjali, 1998). Anecdotal evidence also suggests that *A. planci* densities are also high (>100 cotsha^{-1}) on some of the bommies on Funafuti lagoon.

To a lesser extent, the animals can also be found on Nukufetau (Belhadjali, 1997), and Nanumea (Belhadjali, 1998). According to Belhajdali (1998), one specimen of *Acanthaster planci* was found on Nanumea lagoon, feeding on table coral at 15 m water depth. The Tuvalu Fisheries Department has been monitoring the occurrences of *A. planci* in Tuvalu, to provide a database of crown-of-thorns occurrences.

Holothurians

Bêche-de-mer are not part of the traditional diet of Tuvaluans, thus, are of little interest. Seven species were recorded during fisheries surveys over the years with the white teatfish (*Holothuria fuscogilva*) and black teatfish (*H. nobilis*) being the more prominent ones (Belhadjali, 1998). The low commercial value species are also common, including the *H. fuscopuntata, Actinopyga mauritiana, Bohadschia argus, B. marmorata/vitiensis*, and *H. atra*.

The available stocks of bêche-de-mer appear to have declined dramatically having negative implications for the export market. For instance, the density of *Holothurus nobilis* was recorded on some lagoons to be 18.11 specimens ha^{-1}, and 7.57 specimens ha^{-1} in ocean sites. These densities are comparable to densities found in Tonga, 18.7 ha^{-1} (Preston & Lokani, 1990), or around Manus Island, PNG, 9.57 ha^{-1} (Lokani & Chapau, 1992, cited in Belhadjali, 1998). On Funafuti, the density of bêche-de-mer (*H. nobilis* and *Actinopyga miliaris*) ranged from 23.8-47.6 specimens ha^{-1}. These specimens were observed at 21% of the sites surveyed (Funafuti Marine Conservation Area, 1997).

Interest in exporting bêche-de-mer in Tuvalu dates back to the late 1970s and early 1980s. The Fisheries Department purchased bêche-de-mer from fishers and exported approximately 2.9 mt from 1979-1982 (Belhadjali, 1997). There has been no production and export in Tuvalu in subsequent years despite efforts to revive interest in the fishery. It is unlikely that with present low densities of bêche-de-mer, coupled with the small area of suitable habitat in the islands surveyed, any commercial venture would be viable.

Giant clams and other invertebrates

Two main species giant clams are found in Tuvalu: *Tridacna maxima* and *T. squamosa*; the former being heavily fished (Braley, 1988; Langi, 1990; Belhadjali, 1998). Poor stocks of giant clams are now available on islands with no lagoons and thus, rarely consumed. There is no commercial market for clams in Tuvalu except one atoll and the people rarely eat them now. Belhadjali (1998) found the abundance of giant clams in ocean sites to range from 14.02 clams ha^{-1} (*T. maxima* 6.9ha^{-1}, *T. squamosa* 7.12ha^{-1}) to 16.64ha^{-1} (*T. squamosa*) on some islands. There is a general trend in increasing abundance of giant clams from a South-North direction, however, *T. maxima* is not found in the northern islands. Giant clams in Tuvalu are especially susceptible to recruitment failure if the stock levels fall below sustainable limits (Belhadjali, 1998).

Only one specimen of *Trochus niloticus* was observed during the Funafuti Marine Conservation surveys. Belhadjali (1998) observed thorny oysters of the family Spondylidae in the atolls of Nukulaelae, Nui and Nanumea. The highest density of thorny oysters was in Nui lagoon, 555 ha^{-1} (Belhadjali, 1998).

Status of coral reef fishes

On Funafuti alone at least, 400 species of fishes have been documented (Jones *et al.*, 1991).

Trials to export valued demersal species predominantly of snappers to Hawaii were carried out in Tuvalu between 1992-1994. Artisanal fishermen on Funafuti sometimes sell their catch directly from handcarts. NAFICOT (The National Fishing Corporation of Tuvalu) operates a small fish retail outlet there, and during 1996 also made export shipments of deep bottom snapper, averaging 200-300 kg/fortnight. There were also attempts to export snappers to Marshall Islands and Fiji. Further, there have been numerous requests from overseas investors, particularly, from Asia, to establish an aquarium fisheries. Fishing trials and surveys conducted on Tuvalu's deep reef slopes between 1991 and 1994 indicated that stocks of deep-water snappers could sustain a catch of 100t yr^{-1}. Sauni (1997) reported a dominance of emperors, cods and groupers during his surveys, particularly, *Lethrinus gibbus*. Other species including spinefoot *Siganus vermiculatus, Lutjanus kasmira* and cardinal fish were also ranked high in numerical abundance (Sauni, 1997; see Table 5). Sauni (1997) highlighted that lagoon and reef species were prominent in terms of numbers and weight and, low catches by weight were, recorded for demersal and baitfish species.

In the past tilapia have been introduced into borrow pits in Funafuti and other locations, but this was not considered a success. The construction of Tuvalu's first purpose-built aquaculture pond, for milkfish, was completed on the island of Vaitupu in 1996. It is intended that operation of the Vaitupu pond will provide a model for subsistence aquaculture activity elsewhere in Tuvalu. Aquaculture research projects involving giant clams and introduced *Eucheuma* (*Kappaphycus*) seaweed have been carried

out, the former as a possible means of re-stocking wild populations, and the latter for commercial production. Neither has so far led to any kind of commercial development.

In attempts to create new resources and enhance available stocks, several undertakings were carried out, and are described below:-

- Tilapia and *Trochus* were introduced to Tuvalu in attempts to create new resources and small-scale fisheries based on them. The introduction of tilapia into borrow-pits on Funafuti resulted in long-term negative ecological impact and no local benefit, as tilapia is not favored as a food fish by Tuvaluans. *Trochus* were introduced to six islands (Funafuti, Nukufetau, Nukulaelae, Nanumea, Atafu and Nui) from Fiji and the Cook Islands in four separate introductions carried out between 1985 and 1989. Progress of the introductions is still being monitored. A survey of two of these islands in 1994 recorded few adult trochus.

- Fishing trials and surveys conducted on Tuvalu's deep reef slopes between 1991 and 1994 indicated that stocks of deep-water snappers could sustain a catch of 100t.yr^{-1}. Although government has promoted wider development of the export snapper fishery, there has been little private sector participation. This is due to a range of factors including the relatively high cost of entering the fishery, the local difficulty in raising capital, and the poor handling, distribution and export infrastructure that exists in Tuvalu.

- NAFICOT carries out commercial fishing using two of six fishing launches provided to Tuvalu in 1991 under Japanese grant-aid. The company sells its catch through a small fish retail outlet in Funafuti, and makes occasional exports of deep water bottom snappers.

NAFICOT also previously operated a pole-and-line vessel, Te Tautai, provided under Japanese aid. The vessel produced good catches during the 1980s, with a peak catch of 1091t in 1988. However, the operation suffered due to poor local supply of baitfish and Te Tautai was frequently obliged to fish in Fiji under a licensing agreement. The vessel was later chartered to the South Pacific Commission between 1991-1993 for regional tuna tagging work, subsequent to which it sank in Funafuti lagoon.

Tuvalu previously had no access agreements with foreign fishing interests, except via the US Multilateral Treaty, but since 1994 has made agreements with both Japan (10 vessels) and China (15 vessels). The conclusion of these agreements coincided with Tuvalu's deployment of a fishery patrol vessel provided by Australia under a defence cooperation agreement. Foreign fishing vessels took 3753 t of tuna and allied species in Tuvalu's EEZ in 1995. Of this 3267t (87%) was taken by US purse seiners.

Threats to coral reef biodiversity

Major issues affecting coral reefs and associated environments in Tuvalu are:

- Tropical cyclones, climate change and possible sea level rise;
- Reef channel blasting, channelling and dredging affecting corals, fish and water circulation;
- Over harvesting of marine resources;
- Pollution: sewage and waste disposal;
- Beach rock/ sand mining and sedimentation; and Ciguatera fish poisoning.
- Below are brief details of the above issues.

Climate change impacts

Tuvalu faces serious coastal problems particularly with certain areas being inundated. Frequency of cyclones and storms further exacerbates this problem with increased erosion of beaches and changing patterns of coastline. For instance, the 1972 hurricane Bebe left irreparable damages on coastal areas. ADAB (1985) stated that this particular cyclone created what is now called the 'hurricane Bebe Bank' on Funafuti. The bank consists of an accumulation of gravel and cobble sized, partly rounded coral fragments which were deposited on the ocean reef fringing the south east part of the Fogafale atoll on Funafuti (ADAB, 1985).

Since the hurricane, the Bebe Bank's materials have been washed out on the reef, southwards along the beach and towards to the ocean channels where it dissipates. The material forming the bank is the hardest, most compact type of coral that formed dense, hard limestone. This is the only source of durable limestone on the atoll and the only viable source of rock that can be crushed for concrete aggregate. It is considered that the Bebe Bank affords protection to the islands in easterly winds and that removal of it from the eastern side of the islands would be detrimental. The total available volume of the material is 615 000 m^3 of which 575 000 m^3 is protecting the islands (ADAB, 1985). The Bebe Bank spits also enclose sheltered tidal pools (moats) containing small colonies of *Porites, Acropora, Lithothamnion, Caulerpa* and *Halimeda*, occasional holothurians and echinoderms, and a range of small fish, notably *Canthiogaster.*

Reef blasting, channelling and dredging

Dredging of lagoonal materials on Funafuti for engineering and construction purposes were seen as a threat to low coastlines (Berdach & Maynard, 1994). Lagoon or channel dredging, causeway and seawall construction, and similar earthwork projects are suspected of being linked with outbreaks of ciguatera poisoning. ADAB (1985) recommended that dredging could be sustainable over a period of up to six years. This is to ensure minimum disturbance to offshore and onshore biological and sociological environments. In regard to deposits at Bebe Bank east of Funafuti Island, it was recommended that the probable maximum rate of utilisation of this material should be low (2000 m^3yr^{-1}, or 40 m^3wk^{-1}); projection of the effects of removing other parts of the Bebe Bank would be up to 20 years premature. In fact, the Bebe Bank has changed dramatically in the last 12 years, during which time the recoverable deposits have accumulated, and further accumulation may occur. Similarly, the existing deposits may be dissipated under certain sea conditions (ADAB, 1985).

Over the years, channels have been constructed as part of aid-funded development programs. Existing channels vary in age, size and method of construction, with some extending for several hundreds of metres to sand or rubble beaches. Some channels are very wide and deep, and are known to have caused large changes in the physical and biological environments in the immediate surroundings. Below are summaries of reef status as reported in recent surveys on Funafuti lagoon.

Over-fishing

Berdach & Maynard (1994) stated that intensified exploitation of food fish could result in the direct depletion of near shore species which much of the population presently rely upon. Sauni (1997) gave an annual estimate of catch of 282.9 kg $person^{-1}yr^{-1}$ which is about 14 % lower than the annual mean fish consumption of 327.6 $kgcapita^{-1}$ estimated from the consumption household survey. It is speculated that

the high current consumption rate could be driven by high catch rates (Sauni, 1997). Sauni (1997) further discovered the increasing fishing assets per household compared to past records from the 1980s and 1990s. Based on data from the creel survey, the estimate per capita annual catch on Funafuti was 1.3 $kghead^{-1}hr^{-1}$, which is approximately 64 % greater than the SPC estimate of 1993 & 1994.

King (1995) estimated 26 t yr^{-1} of sustainable yield around 37nmi fishable habitat and 50 t yr^{-1} on seamounts for all islands. The annual sustainable yield for Funafuti alone is likely to be 8t yr^{-1} on this basis. Given this, it appears that the reef and lagoon areas primarily involved are being subject to unsustainable fishing pressure. According to Sauni (1997), catch and consumption rates for at least Funafuti and Nukufetau, indicate a high level of fishing pressure on existing standing stocks. Further, Sauni (1997) found a high level of fishing assets for each household in Tuvalu; this probably encourages fishers to prosecute modern forms of fishing and, hence further exacerbate pressures on stocks. For instance, the high investment of fishermen in modern boats is evidently aimed at achieving higher catches for sale (Sauni, 1997).

Coastal lagoon and fin-fish catches in Tuvalu will continue to be the main source of subsistence protein for the foreseeable future. Problems are likely to occur on Funafuti where yields from coral reef fisheries may not keep pace with population or tourism growth and, where there are no major efforts to target offshore fisheries, or the development of mariculture as alternatives (Sauni, 1997).

Pollution

With the exception of ubiquitous solid domestic litter in Funafuti lagoon (which, while unsightly, is biochemically benign), Tuvalu's coastal environment is relatively pollution-free (Berdach & Maynard, 1994). However, with continued population increases, it would be expected that increasing environmental pressures might result in pollution, landform alteration, and over-exploitation of resources. Increased human and animal waste entering the lagoon environment could lead to elevated bacterial levels, with resultant disease outbreaks and public health risks. Increased organic nutrient loading could also result in algal blooms that choke the corals upon which reef fish and other organisms depend for food and habitat. Other land-based pollution (from petroleum products, batteries, etc) could produce discharges of toxic substances into lagoons or coastal areas (Berdach & Maynard, 1994).

Coastal resources mining and sedimentation

Coral excavation from coastal areas for construction purposes is one major problem facing the atolls and islands of Tuvalu. Having minimal opportunities for exploring alternative coral rubble, the majority of Tuvaluans including the government have pressured coastal areas a great deal. As a consequence, the rate of erosion and sediment movements along coastal areas has increased drastically. Even so, with the construction of seawalls, whether cemented or manually stacking bulky stones as means of protecting erosion has indeed affected coastal and beach areas (Robert *et al.*, 1989).

ADAB (1985) referred to land reclamation material as medium to fine calcareous sand deposit varying in thickness to 25 mm. Virtually the whole lagoon beds in most atolls and islands have 2-4m thick, blankets of these sand deposits in water over 10 m deep. On Funafuti, cobbles from the hurricane Bebe Bank on the southern end of Funamanu and northern end of Falefatu Island are frequently used for engineering and building materials. The cobbles have a total quantity of up to 40 000 cubic metres (ADAB, 1985). It was cautiously advised not to over-exploit the deposits and so remove the erosion protection that they now provide to the island.

Whilst the coral fauna of the submerged heads is very depauperate, that of the lagoon rim and shallow shoals is relatively diverse, though not as diverse as that of the deep channels receiving ocean water. This suggests that whilst the turbidity, probably low nutrient status, and possibly the higher temperature of the lagoon waters all contribute to reducing coral diversity in the lagoon, the most significant factors are the low light penetration and high sedimentation rate (ADAB, 1985).

Ciguatera

Ciguatera fish poisoning is a serious problem in Tuvalu, particularly on Niutao, Funafuti and Nukufetau where outbreaks have been reported (Kaly & Jones, 1994a; Tebano, 1991). Fish species linked with ciguatera in Tuvalu vary from island to island. In Niutao alone, it was obvious that it has greatly suffered from the adverse impact of reef blasting which flared and spread ciguatera poisoning.

The trigger to the initial population explosion of the organism is not well understood. However, it is believed that disturbances such as storms, channel blasting and dredging or nutrient build up may be contributing factors. Kaly & Jones (1994a & 1994b) found no clear evidence for the view that physical disturbances, such as shipwrecks and boat passages, promote outbreaks of ciguatera fish poisoning. The boat channel on some of the islands and shipwrecks on others all exhibited *Gambierdiscus toxicus* densities and *Ctenochaetus strigosus* toxicity in the range observed at sites several distances from these disturbances (Kaly & Jones, 1994a & 1994b).

Moreover, in monitoring the Nanumea boat channels and trends at Niutao, it is suggested that disturbance may sometimes play a role. Kaly & Jones (1989) claim that the outbreak of ciguatera which occurred prior to the blasting of channels could not primarily be attributed to the cause; the blasting, however, initially exacerbated the problem by making already poisonous and highly prized reef fish available for consumption. Numerous studies show that the concentration of the presumed causative organism, *G. toxicus*, is not necessarily linked with an increase in toxin level or the outbreak of ciguatera (Tebano & McCarthy, 1984). The notable outbreak of ciguatera was in 1989 on the island of Niutao after a reef was blasted at the south-western part of the atoll (Tebano, 1991). Fish poisoning cases from other islands prior to 1982 could also be remembered by the old people of Tuvalu.

Current MPAS, monitoring and conservation management capacity

Fisheries management and conservation

In the pre-colonial times, there was a well-established system of traditional resource management, but this was broken down long ago. Traditional sea tenure in the past was important in limiting access to the fishery. Overfished species were protected and fishing activities were regulated by a strong mix of taboos, social restrictions and beliefs, to ensure a high yield from the waters adjacent to the atolls (Belhadjali, 1995b). Secrecy, clan specialization and other cultural features have aided management of fish resources (Zann, 1983). In Tuvalu, each clan has specific skills that are closely guarded. Kennedy (1931) described a lands court case in which a man in Tuvalu actually traded land for a fishing secret, because he did not convey this secret to his clan before his death, the clan requested, and was awarded, their traditional land back.

The invocation of a taboo (tapu), was an effective mechanism of enforcing a protective proclamation. Zann (1983) stated that the island king or community for breaches of fisheries legislation might impose a range of penalties from fines to removal of fishing rights. According to Sauni (1997), a person who continuously broke communal tapu was either beaten up or sent adrift (Lauti, T. & Vine, pers. comm., 1997). The tapus are rarely used today, but all tapu and various penalties were geared towards conserving fish stocks and settling disputes in the community. Sauni (1997) further stated that "sustainable development and conservation" are not new concepts. Rather, ancestors of Tuvalu have attempted to manage their marine resources, but, few of those practices involved have survived, although sea tenure was probably important in limiting access.

A conservation ethic remains very strong today and a wide range of conservation practices (e.g., prohibition of harvesting small clams on Nukufetau) are still in use (Sauni, 1997). Tuvalu has recently established its first marine park within the Funafuti lagoon, with the assistance of UNDP and the South Pacific Regional Environment Programme (SPREP). This marine reserve covers an area of 40 km^2 and includes six islets and adjoining reefs and waters. The goal of this initiative is the preservation of marine and terrestrial biodiversity. Responsibility of monitoring and policing of the reserve rests on the project personnel, Funafuti Town Council, the Environment Unit and the Fisheries Department. It provides a basis for fishery reserves being established elsewhere in Tuvalu. Furthermore, certain over-fished species such as giant clams and pearl oysters were protected and fishing effort regulated by various restrictions using social beliefs and tapu (Zann, 1983). The Fisheries Department has established a giant clam sanctuary on Funafuti in an attempt to restock giant clams. *Trochus* were also air dropped on a number of islands to restock the fishery.

Research and training

The Fisheries Department, often with the participation or support of external agencies, has undertaken fisheries research in Tuvalu. The research followed three main avenues:

- **Monitoring**, intended to allow ongoing assessment of the status of the main fisheries. A major activity has been the Ciguatera Monitoring Project, which was established in response to a severe outbreak on Nui island in 1988;

- **Surveys and resource assessments**, intended to provide snapshots or status reports on specific resources. Such surveys have been focussing on bottom fish, bait fish, pearl oysters, bêche-de-mer, trochus, tuna and giant clams; and

- **Development-oriented research**, aimed at identifying new grounds or techniques with commercial fishing or aquaculture potential. The major activity undertaken in this area has been research into deep-slope bottom fish resources that commenced in 1991, as well as the later development of a management plan for this fishery.

The Fisheries Department maintains an extension service that focuses on providing training for fishers in outboard motor maintenance, fishing techniques, fish processing and safety at sea. For instance, fish aggregation devices (FADs) were deployed around Funafuti during the early 1990s, and at all outer islands in 1993, to enhance subsistence and artisanal tuna fishing. Associated with the FAD programme was the development of mid-water fishing techniques suited to small fishing craft. Further, a marine training school on Funafuti provides courses for merchant seamen, most of whom subsequently serve on overseas cargo or fishing vessels. Higher-level training is usually sought overseas, often at the University of the South Pacific in Fiji.

A National Coordinating Center is under construction for the monitoring and management of foreign fishing vessel activities within Tuvalu's EEZ.

The Tuvalu Fisheries Department, through its extension section, began training fishers in Funafuti and Nukufetau, the only two islands identified as having any commercial beche-de-mer resources. The Fisheries Department also produced a leaflet in Tuvaluan.

Lagoon surveys

As part of a monitoring programme for coastal erosion of the inhabited islands within the atolls of Nukulaelae and Nukufetau, a series of beach profiles were established to help monitor the sediment movement and erosion rates of the more seriously affected parts of the coastlines. Robert *et al.* (1989) stated that problems of erosion and the construction of sea wall protection by using rocks obtained from the other uninhabited islands in the lagoon had caused erosion problems on Nukulaelae and Nukufetau islands.

Beach profiles were established around the main inhabited island of Nukulaelae and Nukufetau to monitor the erosion and sediment-transport trends of the coastline. Photographs of the beach profile locations were taken for re-surveying at periodic intervals; initially at six-monthly intervals for two years. Also, officials of the Lands Department continually monitor this work. Furthermore, a large black coral tree some 2 m high was seen in about 60m of water in Nukufetau lagoon; black corals were also sighted in Nukulaelae. It was reported that some additional black coral trees could be found at some deeper depths (Roberts *et al.,* 1989). There is some evidence of accumulation of phosphate at Nukufetau atoll.

Government policies, laws and legislation

The primary fisheries agencies are the Department of Fisheries (DOF) and NAFICOT. Both lie within the Ministry for Natural Resources. The DOF is responsible for the control, management and development of fisheries under the Fisheries Act, 1978. The NAFICOT is responsible for the commercial development of fisheries in Tuvalu through the National Fisheries Corporation of Tuvalu Act, 1980. The recent establishment of the Environment Unit within the same ministry shares some tasks with DOF in regard to related activities on conservation of marine resources.

The basic fisheries law in Tuvalu is the Fisheries Act of 1978, which was revised in 1990. The Act provides for the Minister responsible for fisheries to take such measures as he sees fit to promote the development of fisheries and to ensure that fishery resources are exploited to the full for the benefit of Tuvalu. Other relevant legislation includes the Marine Zones (Declaration) Act of 1993 and the National Fishing Corporation of Tuvalu Act of 1980, revised in 1982. The Marine Zones Act refers to sovereign rights to explore, exploit, conserve and manage living and non-living resources within the area of its jurisdiction. The Local Government Act gives local governments powers to improve and control fishing and related industries and prohibit, restrict or regulate the hunting, capture, killing or sale of fishes.

Several of the island councils have exercised the above powers and have enacted legislation to control fishing in their waters. Local government By-Laws in Tuvalu include several categories such as:

- Prohibition of certain fishing practices such as use of spears and nets with mesh size of < 1.5 inches; and the use of mechanically powered boats on one island;

- Prohibition of fishing practices in certain areas. For instance, the use of spears in waters enclosed by

the reef; fishing for rock cod using spear or net in specified areas of the lagoon; and, a ban on the use of fish traps and fish nets in a some designated areas;

- Prohibition of certain fishing practices in relation to certain species. For instance, prohibition on the use of nets < 1 inch mesh size to capture spinefoot;

- Prohibition of fishing practices in certain areas at certain times in relation to certain types of fish such as flowery cod between June and August using a spear or net in various areas;

- Licensing of commercial fishermen. Provision of licenses to allow commercial fishermen to sell their catch;

- Prohibition of the collection of shellfish for public health reasons. For instance, collection of shellfish, crabs, octopi, squids or crayfish within a hundred feet of a latrines.

In addition to the regulatory powers of the Minister for Natural Resources, the Councils of Chiefs (maneapa) exercises powers over fishing practices of the community. Enforcement of these maneapa laws is through the strong social conscience and responsibility that is characteristic of most Polynesian cultures (Belhadjali, 1995).

The Department of Fisheries maintains direct contact on technical issues with regional and international organizations dealing in fisheries. Policy and other matters are managed in the first instance through the Department of Foreign Affairs. Tuvalu is a member of the Secretariat of the Pacific Community, the South Pacific Forum Fisheries Agency (FFA) and the South Pacific Regional Environmental Programme (SPREP). Tuvalu is also party to a number of treaties and agreements relating to the management of regional fisheries, including:

- Treaty on Fisheries Between the Governments of Certain Pacific Island States and the Government of the United States of America;

- the Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific;

- the Niue Treaty on Cooperation in Fisheries Surveillance and Law Enforcement in the South Pacific Region;

- the Nauru Agreement Concerning Cooperation in the Management of Fisheries of Common Concern; and

- the Palau Arrangement for the Management of the Western Pacific Purse Seine Fishery.

Tuvalu is a signatory to the United Nations Convention on the Law of the Sea (UNCLOS) and the Agreement for the Implementation of the Provisions of the United Nations Convention of the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

Gaps in current monitoring and concervation capacity

Tuvalu faces great difficulties in establishing periodic monitoring and conservation of marine resources. Although a limited number of research projects have dealt with baseline information on coral reefs and pollution problems, very little appears to have been done on enforcement and monitoring programmes. There appears to be no existing standard concerning coral reefs against which performance and compliance can be evaluated. For example, it is very difficult to evaluate the

extent of damage in marine communities caused by shipwreck, spills, hurricanes or crown-of-thorn infestation.

Efforts in relieving fishing pressures on existing stocks have been the introduction of giant clams, *Trochus* and *Eucheuma* seaweed to better utilize appropriate habitat to produce exportable species (Wilson, 1995). These projects are important alternatives for home consumption and earnings and, would help relieve fishing pressures by actively engaging fishermen. They have not been well monitored and managed, and a need exists to review the future of these programmes. Furthermore, there are still important information gaps that need addressing. A great deal of important work remains to be accomplished on coral reefs of Tuvalu. Rapid environmental changes and rate of resource use are stimulating new avenues of research as are new research techniques and rapidly developing new fields of scientific endeavour. It is important to acquire sound knowledge base against which to measure and assess obvious and growing environmental stresses that threaten coral reefs.

The data needs concerning coral reefs of Tuvalu fall into two major categories: environmental baseline conditions and monitoring and, fundamental oceanographic and biological processes that control sensitivity to and recovery from environmental changes. Research work in the former has already been started but lacks manpower and funding for periodic monitoring. Little work has been done on the latter; for instance, no research on coral bleaching.

Attempts to provide access to wider markets for outer islands fishers have been constrained through inadequate shipping services, and lack of cold storage and other processing facilities at the landing sites. Trials have been made in the production and export sale of dried fish and of tuna jerky produced by solar-drying at outer island centres but so far these have not led to commercial development.

Furthermore, development of commercial fishing activities cannot progress until several critical constraints are removed, which include:

- lack of managerial knowledge and expertise to undertake planning and implementation of commercial fisheries ventures;

- lack of adequate and consistent data gathering required for accurate monitoring of the state of local fisheries resources and activities;

- lack of incentives to attract local fishermen to participate in commercial fishing activities; and

- potential threat of deteriorating coastal resources as a result of over exploitation by the large population on Funafuti atoll. This has hindered development of commercial fisheries activities in the past.

According to Belhadjali (1995), there is great potential for conflicts in the regulation of fishing and fisheries in Tuvalu, particularly due to the number of 'institutions' involved in the control of fishing. There are reportedly several 'hierarchy' conflicts between the council of chiefs and the local governments (Island/Town Councils). This lack of centralized regulations could potentially delay or hinder the development of commercial fishing enterprises.

One major potential source of dissension regards ownership of marine resources in the islands, especially Funafuti. There are several communities living on the capital Funafuti, many employed by the government. The question of ownership and access to the marine resources of Funafuti is one that needs to be settled quickly before further commercialisation of the fisheries occurs. Thus, Belhadjali (1995) states that the Tuvalu Fisheries Department has identified regulations of fishing and fisheries in Tuvalu as a major area that needs looking into before additional management strategies are implemented.

Conclusions and recommendations

Subsistence activities dominate Tuvalu's fisheries sector while the commercial fisheries sector is practically non-existent. Most of the fishing is at the subsistence level to provide food for immediate families and relatives. Fisheries centres have been established on several outer islands with the intention of providing fishers there with income earning opportunities.

There is sufficient evidence of declining population of harvestable reef fishes and invertebrates and thus, a genuine need for conservation and sustainable harvesting. Also, there are enough powers vested on the Minister of Natural Resources and local maneapa administrations to devise appropriate policies and tapus to control the concerns raised above. On one hand, some people generally thought that laws restricting fishing would be gradually accepted and on the other hand, people in the northern islands thought that the laws would be accepted in theory, but not in practice. As a result, a major gap or ongoing conflict exists between utilising and management of marine resources by the same users. The foremost strategy to solve such conflict would be simply raising the level of awareness among resource users based on hard scientific data. While research has been carried out in the past, consistent and regular surveys are needed to detect new trends and patterns on the status of marine resources.

In Tuvalu, there is only a handful of trained marine science graduates to carry out research and monitoring work on marine resources. The Fisheries Department is still very much relying on outside funding and expatriates to do the work instead. Even with new graduates, it often takes time to get them recruited by the Fisheries Department because of funding constraints. It is therefore recommended that the government secure funding and put in place positions to absorb new marine science graduates. It would be a major loss to the country if these graduates leave because of the reasons highlighted above.

All past research on marine resources wase properly documented and reports are stored in the Fisheries Department and Ministry of Natural of Resources head office. However, no proper database has been set up to store all these data. The Fisheries Department is working in collaboration with ICLARM to incorporate relevant data into FishBase. Regardless, it is recommended that a database should be set up within the Fisheries Department or the Ministry of Natural Resources head office to store information on coral reefs obtained from periodic surveys.

Research should be oriented to the establishment of environmental baseline conditions and the monitoring of changes against the baseline to provide a basis for management. Environmental baseline studies should include water quality, sediment and inventories of marine biological resources. Data collection on associated fishing effort to include economic and social factors is also recommended. The use of a Geographical Information System (GIS) would be most valuable to study the extent of coral reefs, mangroves and seagrass beds. A Marine Reference Collection should be encouraged and specimens should be deposited at the Marine Studies Collection of the University of the South Pacific. Basic data about the abundance, distribution and life history of the diverse fish species are also needed to establish a fish database for Tuvalu. The designing of a monitoring programme is recommended to identify trends and detect changes in coral reefs and related ecosystems. The programme should also differentiate changes attributable to natural processes from those due human activities, discriminate among the anthropogenic, climatic and other components and determine the potential of reefs and reef organisms as early warning indicators.

Based on the survey, Belhadjali (1998) recommended that there should fishing restrictions which include:

- Ban the use of underwater breathing apparatus (SCUBA and hookah gear) in harvesting of marine species;

- Ban the commercial export of giant clam meat to overseas markets;

- Maintain the current fishing ban on the introduced species *Trochus niloticus*;

- Licence commercial bêche-de-mer fishers that export to overseas markets; and

- Further research be carried to assess the reef fish resources and, monitor the population levels of crown-of-thorns starfish Acanthaster planci in Funafuti lagoon.

Similary, SPREP (1994) recommended:

- The establishment of permanent marine protected areas, representing different ecosystems, to give sanctuary for rare species, to provide protected areas for fish breeding and from which restocking can take place;

- Undertake a fish stock assessment survey (of key indicator species and the foods on which they rely) and an assessment of the threat from ciguatera;

- Institute a system of resting areas from fishing for various periods to encourage the recovery of marine species. This system has traditionally been used on some islands where island councils close certain waters for specific periods for cultural or management reasons;

- Stop fishing for species acknowledged as being rare such as giant clams and turtles; and

- Stop the practice of net fishing in those lagoon areas subject to heaviest fishing pressure (e.g., offshore from village areas);

ADAB (1985) recommended immediate and effective regulation of the utilisation of the existing available deposits of granular materials, in gravel to cobble sizes. This is to ensure effective protection of the island and thus, reduce erosion rate as a result of oceanic waves. Berdach & Maynard (1994) recommended that as far as environmental protection and resource management is concerned, an effective system of resource management be instituted which entails:

- Estimation of MSYs for those marine resources which are to be harvested;

- Establishment of policy guidelines and licensing of activities which affect the marine environment either directly or indirectly;

- Reliable monitoring of effort and yield;

- Evaluation of data; and

- Refinement and adjustment of licensing requirements and government of Tuvalu policy guidelines, as necessary.

On the whole, some excellent policies, legislation and plans have already been formulated. What is left now is the co-ordinated effort in the implementation. Among others, is the paramount importance of monitoring and research of coral reefs so as to compliment management and decision making that leads to conservation and sustainability of marine resources. A good data series on the status of coral reefs from years of research should play an important role in validating management and control measures over the long term. It is thus, strongly recommended that scientists should participate actively in coastal-marine conservation so as to appreciate the physical and biological complexity of marine resource systems. Moreover, such management should be extended to address additional economic, social and environmental objectives such as fisher's welfare, economic efficiency, the allocation of resources and environmental protection. Whichever options and management measures are selected, a permanent, even if low level system of data collection should be established to monitor the 'health' of marine resources and, to determine the effectiveness of management strategies.

Appendix: summaries of coral reef benthos and fishes in Tuvalu

Lyngbya majuscula	*Caulerpa racemosa*
Boodlea siamensis	*Pocockiella variegata*
Dictyosphaeria cavernosa	*Padina commersonii*
Valonia ventricosa	*Dictyota bartayresiana*
Halimeda opuntia	*Herposiphonia tenella*
Halimeda tuna	*Ceramium personatum*
Halimeda incrassata	

Table 2
Algae from Funafuti lagoon (Sources: ADAB, 1985).

Miliolina seminulum	*Orbitolites complanata*
Miliolina reticulata	*Orbitolites marginalis*
Valvulina davidiana	*Cymbalopora poeyi*
Calcarina hispida	*Tinoporus baculatus*
Amphistegina lessonii	*Polytrema miniaceum*

Table 3
Foraminifera from Lagoon beaches of Funafuti (Sources: ADAB, 1985).

Psammocora contigua	*Pocillopora damicornis*
P. haimeana	*P. eydouxi*
P. superficialis	*P. verrucosa*
Stylophora pistillata	*Favia pallida*
Platygyra daedalea	*Hydnophora microconos*
Plesiastere versipora	*Leptastrea cf. Bottae*
Pavona cf explanulata	*L. transversa*
P. varians	*Coscinaraea columna*
Fungia fungites	*Lobophyllia hemprichii*
F. scutaria	*Porites lutea*
Acropora aculeus	*P. lobata*
A. conigera	*P. lichen*
A. cytherea	*A. rosaria*
A. hyacinthus	*A. tenuis*

Table 4
Reef corals recorded from Funafuti (Source: ADAB, 1985).

Pelagics	
Elagatis bipunnulatus	*Acanthocynbium solandri*
Grammatorcynus bilineatus	
Demersal	
Epinephelus microdon	*Aphareius furca*
Pristipomomoides zonatus	*A. rutilans*
Aprion virescens	*Cephalopholis urodelus*
Scombroides lysan	*Lutjanus fulvus*
Lagoon and reef	
Lutjanus gibbus	*Lethrinus miniatus*
L. kasmira	*L. harak*
Sphyraena forsteri	*L. mahsena*
Siganus vermiculatus	*Monotaxis grandoculis*
Myripristis vilaceus	*Variola alboomarginata*
Carangoides fulvoguttus	*Kyphosus cinerascens*
Mulloidichthys dussumieri	*Naso unicornis*
Archamia lineolata	*Selar crumenopthalmus*
Pterocaesio diagramma	

Table 5
Common harvested reef fishes by local fishers (Source: Sauni, 1997).

Bibliography

ADAB, 1985 —
Tuvalu Lagoon Bed Resources Survey. Report prepared for the Tuvalu Government, Vol. 1.

ANON, 1995 —
Funafuti Marine Conservation Project preparation document, Environment Unit, Ministry of Natural Resources, Government of Tuvalu, 143 p.

BELHADJALI K., 1995 —
Tuvalu country statement: Joint FFA/SPC workshop on the management of South Pacific inshore fisheries, June 26-7, 1995, Integrated Coastal Fisheries Management Project, Technical Document No. 11, Noumea, New Caledonia.

BELHADJALI K., 1997 —
Beche-de-mer production in Tuvalu. Beche-de-mer Information Bulletin, No. 9, SPC, New Caledonia.

BELHADJALI K., 1998 —
A Survey of the Inshore Fisheries Resources of Tuvalu. Unpub. report prepared for the Fisheries Department, Ministry of Natural Resources & Environment, Tuvalu Government, 101 p.

BERDACH J. T., MAYNARD J.A., 1994 —
A study of the fisheries sector of Tuvalu: with recommendations for commercial and institutional development. Technical report prepared for Asian Development Bank and the Government of Tuvalu, 1-19.

BRALEY R. D., 1988 —
The status of giant clam stocks and potential for clam mariculture in Tuvalu. A report prepared for the Fisheries Division, Funafuti, Tuvalu, and the South Pacific Aquaculture Development Project, Suva, Fiji.

CHAPMAN F.,1903 —
J. Linn. Soc. (Zool.), 28: (1900-03): 381-2; 386-7.

CHAPMAN V. J., 1955 —
Pacific Science, 9: 354-356.

DAHL A. L., 1986 —
Review of the Protected Areas System in Oceania. UNEP & IUCN Commission on National Parks and Protected Areas, Gland, Switzerland.

FUNAFUTI MARINE CONSERVATION AREA, 1997 —
Preliminary survey of the Funafuti Marine Conservation Area. Unpub. report, Funafuti, Tuvalu.

JOHNSON J. H., 1961 —
Fossil algae from Eniwetok, Funafuti and Kita-Daito-Jima. In: U.S. Geol. Surv. Prof. Pap., 260-Z.

JONES G. P., KALY U. L., CLEMENTS K., 1991 — Preliminary records of the coral reef fishes of Tuvalu. *South Pacific Journal of Natural Sciences*, 11: 40-57.

KALY U. L., JONES G., 1991 — Preliminary assessment of a severe outbreak of ciguatera at Niutao, Tuvalu. *South Pacific Journal of Natural Science*, 11: 62-81.

KALY U. L., JONES G., 1993 — Pilot dredging project – Funafuti, Tuvalu: Assessment of ecological impacts on lagoon communities.

KALY U. L., JONES G., 1994a — Test of the effect of disturbance on ciguatera in Tuvalu. *Memoirs of the Queensland Museum*, 34(3): 523-532.

KALY U. L., JONES G., 1995 — Tuvalu Reef Channels Project – Project 1: Project plans and environment risks. Unpub. Report prepared for New Zealand Ministry of Foreign Afairs and Trade. Development Cooperation Division, 31 p.

KALY U. L., JONES G. P., 1994b — Long term effects of blasted boat passages on intertidal organisms in Tuvalu: A meso-scale human disturbance. *Bull. Mar. Sci.*, 54: 164-179.

KENNEDY D.G., 1931 — Field notes on the culture of Vaitupu, Ellice Islands. Polynesia Society, New Plymouth, England.

KING M., 1995 — Management plan for the deep-water bottom-fish fishery in Tuvalu. Unpub. discussion paper, Government of Tuvalu, 18 p.

LANGI V., 1990 — Marine resource survey of Nanumea and Nui Islands, Northern Tuvalu (giant clams, trochus, beche-de-mer, pearl oysters). Report for the Fisheries Division, Ministry of Natural Resources & Home Affairs.

MCLEAN R. F., HOSKING P. L., 1991 — Geomorphology reef islands and atoll motu in Tuvalu. *South Pacific Journal of Natural Science*, 11: 167-189.

PRESTON H. L., LOKANI P., 1990 — Report of a survey of the sea cucumber resources of Haápai, Tonga. Country Assignment Report, South Pacific Commission, Noumea, New Caledonia.

ROBERT B., SMITH D. M., REAGRIE E. S., SENEKA F., 1989 — Survey of Nukulaelae and Nukufetau Lagoons. Unpub. Report prepared for SOPAC Technical Secretariat & Lands Department, Tuvalu Government, 60 p.

SAUNI S., 1997 — An Assessment of Fisheries Statistics in Tuvalu: with specific reference to Funafuti and Nukufetau Islands. Unpub. MSc thesis, University of Newcastle upon Tyne, England, 94 p.

SCOTT, D. A. (ed.), 1993 — A Directory of Wetlands in Oceania. IWRB, Slimbridge, UK & AWB, Kuala Lumpur, Malaysia.

SPREP, 1994 — State of the Environment Report, Government of Tuvalu, 16-18.

TEBANO T., MCCARTHY D., 1984 — Ciguatera fish poisoning and the causative organism in the Gilberts, Kiribati. Institute of Marine Resources, University of the South Pacific, Publication, 46 p.

TEBANO T., 1991 — A preliminary survey on ciguatera fish poisoning in Tuvalu. Technical Report 11, Marine Studies Programme, University of the South Pacific.

TESFAGIORHIS H., 1991 — Tuvalu: 1991 Population and Housing Census. Analytical Report, Government of Tuvalu, 2: 1-5.

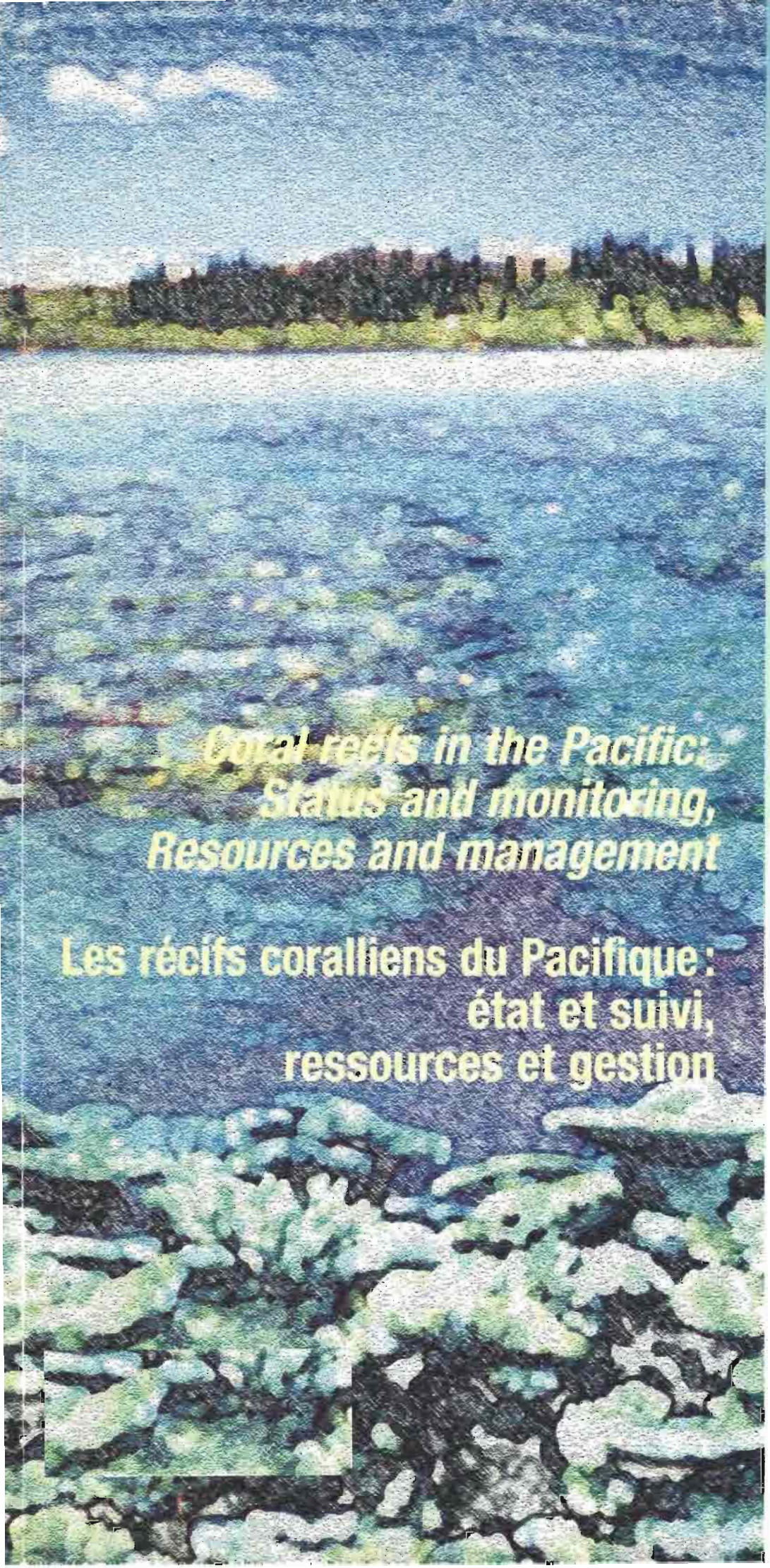
WHITELEGGE T., 1897 — The Crustacea. *Aust. Mus. Mem.*, 3: 127-154.

WILSON M. A., 1995 — Tuvalu: Fisheries Resources Profiles. Report prepared for the Forum Fisheries Agency, Solomon Islands, 98 p.

WOODROFFE C.D., 1985b. Vegetation and flora of Nui atoll, Tuvalu. *Atoll Res. Bull.*, 283: 1-18.

WOODROFFE C. D., 1987 — Pacific Island Mangroves: Distribution and Environmental Settings. *Pacific Science*, 41(1-4): 166-185.

ZANN L. P., 1983 — Traditional Management and Conservation of Fisheries in Kiribati and Tuvalu atolls. Institute of Marine Resources, The University of the South Pacific, Fiji, 1-23.



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