TONGA COUNTRY REPORT

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This country report is based on previous work done by Zann et al (1984), Ellison, J. C. (1988 and 1989), Prescott, N (1992a and 1992b), Ellison J.C. in the Tonga Environment Planning and Management Strengthening Project (TEMPP) Working Paper (WP) No. 5 (1998), Working Paper No. 17 (1999) and Prescott N.et.al. (2001), Environmental Management Plan for the Lagoon System. There are also other studies and reports on Tonga that are also relevant for research, monitoring and management of wetlands and specifically mangrove (refer references).

INTRODUCTION

Background

Mangroves are a taxonomically diverse assemblage of tropical tree species that inhabit the intertidal range of sheltered shores. In the SPREP Region of the Pacific Islands the total mangrove area is about 343,335 ha. Tonga had an area of 1,000 ha of mangroves 20 years ago (Saenger et al., 1983), but this has since been reduced by clearance and conversion to other uses. From the 1990 aerial photo of Tonga, it is estimated that that only around 500 ha or less of mangroves left, a 50 - 60 % area lost. (Per obs). The mangrove cover has since reduced, with losses from coastal reclamation, particularly on shores ad adjacent to Nuku'alofa.

The mangrove area of Tonga is small in global terms, but the community structure of mangroves in Tonga makes them unique among the world's mangroves. The largest mangroves areas in Tonga occur on Tongatapu, a low limestone island of rolling hill topography. Prevailing winds and associated wave action are the S.E. Trades, hence mangroves occur on the leeward north shore, and in the extremely sheltered semi - enclosed Fanga 'Uta lagoon (Figure 1). Degree of exposure to ocean exchange affects sediment budgets in the mangrove system, manifested by sediment quality and influencing mangrove community structure. The tidal range is 1.07 m, semi-diurnal with a slight inequality.

In 1983 it was found that of the 58 kin of Fanga 'Uta shoreline (Figure 1), 44.5 km are covered by mangrove tidal forest (Zann 1984). The coverage is greater on the western sector, being about 30 to 35 km, as compared with about 14 km on the eastern sector's 24 km circumference. The southern coast of the Mu'a sector is comprised of raised limestone and hence, is less suitable for mangrove growth; and the mangrove zone is very narrow.

Mangroves of Tonga

Eight mangrove species are found in Tonga, all are indigenous. These are listed in Table 1.

Table 1: Mangrove species present in Tonga

Scientific name and nomenclature	Tongan name
Common	
Rhizophora mangle L. (Rhizophoraceae). (Pseudonym = *Rhizo*	Tongolei or Tongo
Rhizophora stylosa Griff. (Rhizophoraceae).	Tongolei or Tongo
Brugidera gymmorrhiza (L.) Lamk. (Rhizophoraceae)	Tongo ta'ane
Excoecaria agallocha L. (Euphorbiaceae)	Feta 'anu
Rare	
Luninitzera littorea (Jack) Voigt. (Combretaceac).	Hangale
Heritiera littoralis Dryand. (Sterculiaceae)	Mamea
Xylocarpus granatum Konig (Meliaccae).	Lekileki
Xylocarpus moluccensis (Lamarck) Roemer	Lekileki

Mangrove functions and values

Mangrove ecosystem provides important ecological functions (services) and also provides goods for the local population. The mangrove areas have significant uses for the people of Tonga. Mangroves are being traditionally exploited for construction wood, and the gathering of crabs, fish and fuel wood, for traditional medicines, and dyes for tapa making.

Tannins from the Rhizophoraceae used for protection of nets and fish traps owing to their fungicidal properties. The prop roots of *Rhizophora* are frequently used for the construction of fish traps, fuelwood, or light construction. The timber of *Lumnitzera littorea is* a good building material, being hard and durable, and resistant to marine borers. Bark of *Bruguiera gymnorrhiza* is used in Tonga to make a decorative dye for tapa (Prescott, 1992). There is a range of traditional medicines derived from mangroves. Bark from *Xylocarpus* species are used by Tongans for treatment of internal bleeding and injuries (Whistler, 1992).

Mangrove ecosystems also provide useful services for the interface area between land and sea. They provide habitats to support fisheries, protection of land from marine inundation, during storms and sea level rise, act as a sink for sediments, nutrients and other contaminants to maintain coastal water quality (self cleaning), and promote coral reef and seagrass growth offshore. The main cleaning systems are tidal exchange of water, biodegradation and settlement/capture of mud. This self cleaning is important for the semi enclosed Fanga'uta lagoon and is dependent on the health of the mangrove ecosystem.

Mangroves have been shown to be important fish habitats (Robertson and Duke, 1990), with high densities of juvenile fish, indicating their function as a fish nursery. Mangroves sustain a food-chain within the mangrove habitat, and associated research has demonstrated the levels of tidal export of mangrove material (Robertson et al., 1988); and the significance of this in offshore food-chains (Alongi and Christoffersen, 1992). In

Tonga, the lagoon and its wetland area is an important habitat for at least part of the life cycles of the two species of mullet *(Mugil cephalus and Valamugil seheli)* fished in Tongatapu, for snappers *(Lutjanus.kasmira),* trevallies *(Caranx spp.),* groupers *(Epigephelis spp.),* breeding grounds for three types of emperors *(Lethrinusspp.),* and several species of penaeid prawn. The banded sea snake *Laticauda colubrina* has been recorded in the lagoon. Crabs *(Sesarnia* sp.) and molluscs *(Littorina s*p.) are common in the mangroves.

Mangroves are also habitat for birds, which can include rare or endangered species. In Tonga, birds that utilise the mangroves include the Wattled Honeyeater *(Foulehaio carunculata),* Pacific Reef Heron *(Egretta sacra),* Pacific Black Duck *(Anas superciliosa)* and the Great Crested Tern *(Stema bergii).* Migrants include the Pacific Golden Plover *(Pluvialisfulva),* Wandering Tattler *(Heterosceles incanus)* and Bar-tailed Godwit *(Limosa lapponica)* (Scott, 1993).

Community Awareness

Prescott (1989) carried out a study of mangrove area conservation values, by interviewing villagers in Tonga. She showed that 83% of people interviewed used the mangroves in some way, primarily for tapa dye, fishing gear or medicines. There was concern with the over-exploitation of mangroves, and suggestion that there should be public awareness education and increased protection. There was also high awareness of the ecological function of mangroves, 64% knowing that mangroves sustained a food chain that benefit fish, prawns and crabs, and 90% recognised that mangroves had a protective function as a buffer zone.

Matoto in (TEMPP WP 28, 37 & 5 1) surveyed community awareness and opinion of the mangrove wetland, reported that the vast majority of respondents to the household surveys considered clearing of mangroves bad, with people seeing them as important because they provide coastal protection (against winds, coastal flooding and soil erosion, traditional dyes and because their loss was connected with a decline in fishery in general. However, some people said that clearing of mangroves was good because it assisted development, increased the amount of available land, decreased mosquitoes and increase the supply of dyes (VVTP 28, 1999 and WP 51, 2000b). There is clearly an opportunity here for improving understanding of the role of mangroves and how they could be used sustainably. Loss of mangrove habitat is considered by fishermen to be a major factor in the reduction of the mullet catch (Spiller 2001).

Interestingly, the household surveys also revealed that most people (67%) recognized the importance of reserves to allow species to grow or to provide a sustainable harvest, and to set aside breeding areas. Despite this, 27% of people thought that reserves were not important because they limited access to marine resources, which were their main source of income or food (WP 37, 2000a).

Mangrove protection legislation

There are several species of legislation in Tonga, which have provisions for coastal/wetlands development or for protection/conservation. Tonga could have the oldest piece of legislation for mangrove protection in the Pacific as in the 1934 Birds and Fish Preservation Act, amended in 1974, prohibits the cutting or removal of mangroves in any area (Prescott, 1992a).

Birds and Fish Preservation Act, amended in 1974

(Laws of Tonga, 1988 Revised Edition, Volume, Chapter 125)

2. In this Act-
"protected area" means any area comprising land, or water, or land and water, as is specified in the Third Schedule hereto;

Part ll- Protected Areas.

6. The area specified in the third schedule to this Act is hereby declared as a protected area; and the Prime Minister may by Order with the consent of Privy Council amend the Third Schedule.

THIRD SCHEDULE- PROTECTED AREA
(Inserted by Act 24 of 1974)

The following area is hereby declared to be a protected area: -
The whole the lagoon in Tongatapu known as Fanga'uta and Fangakakau, being the area lying to the South of a straight line drawn from Niutao on the northernmost point of Nukunuku Motu and including the straights known as Holeva and all mangrove foreshore.

7. (1) No person may, within a protected area, and without the prior consent in writing of the Prime Minister
(i) discharge or cause to be discharged into the protected area any effluent or noxious or toxic liquid of substance;
(11) erect and harbour, wharf, pier, jetty or other building works, temporary or permanent;
(iii) cut, damage, remove or destroy any mangrove;
(iv) erect any fish-fence, or set any fish trap; or trawl or fish (including shellfish) or engage in fishing for commercial purposes;
(v) carry out any boring, drilling or dredging operations.

1976 Parks and Reserves Act

This legislation provide for the establishment of a Parks and Reserves Authority by Cabinet. The Parks and Reserves Authority was recently established in 1998 with the following membership:

- Minister for Lands, Survey and Natural Resources (as chair), and with the power to co-opt members
- Director of Agriculture and Forestry
- Director of Fisheries
- Director of Tourism
- Secretary for Lands, Survey and Natural Resources
- Environmental Planning and Conservation Section (secretariat).

The functions of the Authority is to designate reserves, develop regulations and provide policy and management direction for reserves/protected areas. Up to day the Authority has officially met only once (Per obs.).

The Land Act

(Laws of Tonga, 1988 Revised Edition, Volume 4, Chapter 132).

2. "foreshore" means the land adjacent to the sea alternately covered and left dry by the ordinary ebb and flow of the tides and all land adjoining thereunto lying within 15.24 meters of the high water mark of ordinary tides.

113. The foreshore is the property of the Crown and the Minister may with the consent of Cabinet grant permits to erect stores or wharfs or jetties thereon or to reside on any portion thereof or he may the like grant a lease for any of the purposes aforesaid.

Interpretation: foreshore land may be used for stores or wharfs or jetties with an appropriate pen-nit. It has been commented that the residential use by its mention after stores or wharfs or jetties implies a limited use, perhaps for convalescence from illness. Allocation for town allotments or tax allotments is not specifically referred to here.

However, this protection legislation is largely disregarded, with numerous examples of mangrove areas being allocated for agricultural clearance or settlement. Large mangrove areas at Poptia and Sopu have already been lost, while the largest forest at Folaha/ Nukuhetulu (see Figure 1), and the eastern bay of Vava'u are fully allocated (despite a recommendation not to do so) (Prescott 1992a, 1992b).

1985 EIA Policy Decision

The Cabinet in 1985 passed this policy decision that development projects with likely environment effects must have as EIA carried out by the Ministry of Lands, Survey and Natural Resources' Environment Section. This policy decision is usually ignored (Per. obser).

1996 Fisheries Act

This legislation provides for the Minister of Fisheries to designate areas, for fisheries reserve. No fisheries reserves have been established under this Act.

MANGROVES DESTRUCTION IN TONGA

Major threats for the mangrove ecosystem in Tonga are clearance and reclamation for other uses and apparent mangrove dieback at Muifonua and at Mu'a/Lapaha and Ha'ateilio area. Ellison in (TENTP VY`P 5, 1998) established the cause of the dieback, and to identify corrective action. The Muifonua mangrove dieback is caused by restriction of tidal exchange. Where as in the latter areas, several human induced threats are the main causes of the dieback. Both of these areas are large urban areas located adjacent to the mangroves, probably resulting in particularly heavy pressure on mangrove resources, for construction wood, firewood, medicines and manufacture of dyes.

Pigs commonly walk and dig in the mangrove mud looking for shellfish to cat. This disturbs the mangrove mud with several consequences. The mangrove seedling is

disturbed and knocked over and natural regeneration is prevented. As mangrove mud is naturally low in oxygen, oxygenation naturally occurs at through structures such as crab holes and root fibres. Disturbed mangrove mud has poor structure, and tends to therefore be very low in oxygen. This will cause reduced rates of tree growth and seedling success, and reduced numbers of fauna such as crabs and fish. To the north of the lagoon, from Popua all the coast to Tofoa is the growing city of Nuku'alofa mangrove conversion for commercial and residential purposes are the main threats as shown by decreasing areas of mangrove from air photos of 1968, 1981 and 1990.

Extend of Mangrove Destruction

Air photographs from 1968, 1981 and 1990 were examined to indicate the scale of mangroves loss, and the sequence of loss over the last 30 years (TENTP VY`P 5). Field surveys were also carried out in 1998 and 1999 to determine the species of mangroves affected in the dieback, identify extent of species zones, and to assess mangrove conditions.

Mu'a / Lapaha

Changes detected from the air photographs are described from south to north along the Alaki/ Tatakornotonga/ Mu'a/ Lapaha/ Hoi shoreline.

At Captain Cooks Landing to the east of Alaki, in 1968 wide and dense mangroves occurred to the west and east of the landing opening with the lagoon. This was unchanged in 1981, except for some widening of access channels cut through the mangroves towards Tatakornotonga. A dramatic change is apparent between 1981 and 1990. In the dense section of mangroves immediately west of Captain Cooks Landing, a strip of mangroves 20 m wide was removed parallel to the seaward edge of the mangroves along the coastal length of 20Gm., leaving a strip of mangroves 10 m wide at the seaward edge. To the east of Captain C06ks Landing, all mangroves were removed between 1981 and 19,90 except for a narrow Strip less than .10m wide along the seaward edge. Along this 500 m of shore between Captain Cook's Landing and Tatakomot6nga, a width of up to 70 m mangroves were removed in this period, except for remnant patches towards the landward margin.

At Tatakornotonga, in the southern section of the bay dense mangroves occurred in 1968, of 60-90 m width, with occasional access channels cut through. By 1981 most of these had been removed, except for a narrow seaward margin of 10 m width along a 700 m length of shoreline. In the northern section towards the peninsular, mangroves had already been removed before the 1968 photograph, leaving a remnant narrow seaward margin similar to that described for Alaki. By 1991, there were virtually no mangroves left in this section, except for right on the peninsular.

North of the peninsular, on the Mu’a section of coast, no large areas of mangroves occur on the 1968 photograph. There are no seaward remnants indicative of a former distribution.

North of the Mu’a section, at Lapaha, no large areas of mangroves occur on the 1968 photograph. There are no seaward remnants indicative of a former distribution.

North of Lapaha, at Hoi, on the 1968 and 1981 photographs mangroves are more extensive and occur in a dense margin of up to 150 m. The 1991 photograph shows these mangroves are partially cleared especially in the southern section of the bay, close to

Lapaha. Remnants are left along the narrow seaward margin, similar to the earlier pattern of clearance in Alaki and Tatakornotonga.

Pea / Ha'ateiho

Similar patterns of dieback were found at Pea/ Ha'ateiho, on the western Branch of the FangaUta lagoon.

The 1968 air photograph of Pea/ Ha'ateilio shows a continuous and dense mangrove margin on the lagoon shore. There were up to three paths cut through the mangroves for access, adjacent to central Pea, Ha'ateiho and Veltongo. There was a continuous seaward margin of *Rhizophora,* and behind this a mixed mangrove zone of *Rhizophoral BruguieralExcoecaria.* The latter two are distinguishable by larger, paler tree crowns on all air photographs.

The 1981 air photograph of Pea/ Ha'ateiho shows great expansion of settlement in the southern section of Ha'ateilio, south of the main road. Smaller increase occurred in Pea and Veitongo. Gaps appeared in the mangroves, with clearance of landward zones of mangroves, particularly offshore of Ha'ateiho, and adjacent to the access tracks.

The 1990 air photograph shows continued settlement expansion in southern Ha'ateilic, and southern Pea. The mangroves offshore of Ha'ateiho are greatly reduced, with large areas of the foimer landward zone of mixed *Rhizophor'al BruguieralExcoecaria* cleared to bare Rad. Some sections have been filled and houses built. Clearance of the landward zone of mangroves continues east to the eastern edge of Ha'ateiho with the golf course beyond which mangroves remain intact.

Analysis of the air photographs at both Mu'a and Ha'ateiho gives evidence of selective clearance of the landward *Britguiera / Excoecaria* zone of mangroves. These species are most-valued for construction wood and use for dyes (Ellison in TEMPP WP 5). Field survey showed many examples of mechanical damage to the man grove trees as a result of human cutting. Trees that had not been cut looked healthy, which indicates that there is not a broad scale ecological problem such as increase in salinity as speculated. It is apparent that the mangroves at Mu'a and Ha'ateiho have reduced in area in recent years not due to natural dieback, but due to human clearance.

Mangrove Species and Level of Human Impact

A baseline survey of mangrove species zones and to assess the level of human impacts was carried out between March and September 1998. This was a component of the AusAID - Tonga Environmental Management and Planning Project. There were 45 mangrove survey transects at 20 mangrove locations in the Fanga'uta/Fangakakau lagoon system (Ellison in TEMPP VY`P 17). Table 2 summarized the survey results, Table 3 gives the impacts code and Table 4 defines the impact type.

Table 2 Summary of Mangrove Baseline Survey Data

Transect Number	Village	Distance (m)	Species	Impact code	Impact type
0001	Tofoa (1)	0	Bare	5	CO, IC, OT
		15	Rm	3	CO, IC, OT
0002	Tofoa (2)	0	Mixed, Rm	2	CO, IC
		36	Rm	2	CO, IC
0003	Havelulotu (1)	0	Ea	5	BU, IC
		8	Rm	5	BU
0004	Havelulotu (2)	0	Grass	5	IC
		12.5-19	Rm, Ea	5	IC
		19-25	Rm	5	IC
0005	Havelulotu (3)	3-8	Ea	4	IC
		8-18	Rm	4	IC
0006	Hoi (1)	0-41	Rm, Rs	2	IC
		41-83	Rm, Rs	3	IC
		83-211	Rm	3	IC
0007	Hoi (2)	0-87	Rm, Rs	2	CO, ER, IC, MU, OT
0008	Hoi (3)	0-20	Rm	3	CO, ER, IC, MU, OT
0009	'Alakifonua (1)	0-150	Rm, Rs	4	ER, IC
0010	'Alakifonua (2)	0-32	Mixed	3-4	ER, IC
		32-45	Rs, Rm	3-4	ER, IC
0011	'Alakifonua (3)	0-10	Mixed	1	ER, IC
		10-45	Rm	1	ER, IC
0012	Malapo	0-18	Mixed	2	ER
		18-38	Rm	1	
		38-58	Rm	2	
		58-114	Rm	1	
		114-267	Rm	4	IC
0013	Vaini	0-10	Rm	5	IC, DU
		10-160	Rm	3	IC
		160-190	Rm	2	IC

Table 2. (continued)

Transect Number	Village	Distance (m)	Species	Impact code	Impact type
0014	E. Ha'ateiho(1)	0-28	Bare	5	IC
		28-34	L	4	IC
		34-64	Bg, L, Rm	4	IC
		64-94	Mixed	4	IC
		94-106	Mixed	3	IC
		106-140	Rm	3	
0015	E. Ha'ateiho (2)	0-21	Bare	5	IC, CO
		20-63	Rm	4	DU
		63-71	Bare	5	
		71-127	Mixed	4	IC, sewage
0016	Ha'ateiho (1)	0-60	Bare	5	IC, DU
		60-90	Rm	5	IC, MU
		90-112	Rm	5	IC, MU
0017	Ha'ateiho (2)	0-22	Bare	5	MU, IC
		22-52	Rm	4	MU, IC
		52-112	Rm	3	IC
		112-129	Rm, Rs	2	IC
0018	E. Halaleva (1)	0-30	Mixed	5	CO, oil, DU
0019	E. Halaleva (2)	0-11	Hibiscus	4	IC
		11-18	Ea	4	
		18-33	Rs, Rm	4	
0020	Veitongo (1)	0-22	Mixed	5	IC, BS, DU
		22-60	Mixed	5	
		60-78	Mixed	5	CO
		78-106	Rm	4	IC
0021	Veitongo (2)	0-15	Mixed	4	DU
		17-52	Rm	4	IC
0022	South Popua (1)	0-60	Mixed	5	DU, IC
		60-85	Rm	5	IC
0023	South Popua (2)	0-30	Mixed	5	DU, IC
		30-120	Rm	4	CO, IC, DU
0024	South Popua (3)	n.d	Ea	5	IC
		n.d-12	Bare	5	IC
		12-96	Rm	5	IC
0025	Kauvai (1)	0-9	Ea, mixed	3	IC
		9-75	Rm	4	IC
		75-64	Rs	4	IC
0026	Kauvai (2)	0-68	Rm	4	IC
0027	Fetoa (1)	0-78	Mixed	3	IC
		78-103	Rm	3	DU, IC
0028	Fetoa (2)	0-9	Bare	5	IC
		9-86	Rm	4	IC
0029	Folaha (1)	0-55	Rm	3	IC
0030	Folaha (2)	0-72	Rm	3	IC
0031	NW Nukuhetulu	0-540	Mixed	4	DU
		540-547	Rm	3	IC
0032	S. Nukuleka (1)	0-16	Rm	3	IC

Table 2. (continued)

Transect Number	Village	Distance (m)	Species	Impact code	Impact type
0033	S. Nukuleka (2)	0-57	Rm	3	IC, ER
0034	S. Nukuleka (3)	0-37	Rm	4	IC, ER
0035	Nukuleka (1)	0-8 8-70	Mixed, bare Rm	5 2	IC, ER IC
0038	Nukuleka (2)	0-9	Rm	4	IC, ER
0039	NW Kanatea (1)	0-40	Rm	5	IC, pollution
0040	NW Kanatea (2)	0-15 15-28	Mixed Rm	4 3	DU, IC, pollution BS
0041	S. Nukuhetulu	0-30 30-188 188-203	Mixed, Bg Mixed Rm	2-3 5? 5?	IC, BS IC, BS
0042	S. Nukuhetulu	0-227 227-251	Mixed Rm	2 2	IC, BS
0043	S. Nukunukumotu (1)	0-360 360-600 600-840 840-1287	Rs Rs Rm Rs	2 3 2 2	IC IC IC
0044	S. Nukunukumotu (2)	0-120 120-330 330-401 401-581 581-640 640-880 880-1135	Mixed, Rs Mixed Rm Rs Mixed L Mixed	3 3 3 3 5 3	IC IC IC IC
0045	S. Nukunukumotu (3)	0-248 248-696	Mixed Rs	3 3	IC

Key to species
Rm = *Rhizophora mangle* (Tongolei)
Rs = *Rhizophora stylosa* (Tongolei)
Bg = *Bruguiera gymnorrhiza* (Tongo ta'ane)
L = *Lumnitzera littorea* (Hangale)
Ea = *Excoecaria agallocha* (Feta 'anu)

Table 3 Codes used to record the level of human impact on mangrove ecosystems in Table 2.

Code	Impact	% Cover Canopy	Example
0	No Impact	96-100	Even canopy of trees. No gaps. No evidence of human interference.
1	Slight Impact	76-95	Canopy of trees fairly continuous but some gaps. Some regrowth. Isolated cutting/ stripping of trees or some evidence of pigs digging up saplings.
2	Moderate Impact	51-75	Broken canopy of trees with lower regrowth and recruitment areas. Some trees cut and stripped.
3	Rather High Impact	31-50	Tree canopy is uneven, the majority of the area is not showing regrowth and there is bare mud.
4	High Impact	11-30	Only a few trees remain at canopy height. Extensive clearance and some recruitment, large areas of bare mud
5	Severe Impact	0-10	Extensive clearance to bare mud, little recruitment, few trees remain alive

Table 4 Codes used to record the type of human impact of on mangrove ecosystems in Table 3.

Code	Type of Impact
BS	*Bruguiera* (Tongo ta'ane) stripping for tapa dyes
CO	Infrastructure including houses, jetties, fish landing sites, construction sites or other coastal developments
ER	Erosion
IC	Cutting
MU	Multiple impact. Codes of multiple impacts noted.

The transects were located perpendicular to the shoreline through the mangrove ecosystem at all of the major mangrove areas on the Fanga'uta lagoon (Figure 1). The surveys indicate that zonation is simple and marked, with different species assemblages forming zones parallel to the shoreline from the lagoon fringe to the edge of dry land. The lowest zone (to seaward) consists of *Rhizophora mangle* and/ or *R. stylosa.* Landwards of the *Rhizophora* zone is,a *Bruguiera gymnorrhiza* zone, with occasional *Lumnitzera littorea.* The *Bruguiera* zone becomes interdispersed with *Excoecaria agallocha* towards land. These distribution patterns 'follow the zonation described by Ellison (1998) at Folaha/ Nukulietulu, Fatai and Sopu.

The transect data show that there is overall high human impact on the mangroves of the Fanga 'Uta lagoon. Locations with higher level of human impact, requiring rehabilitation, were shown to be Havelutotu, East Ha'ateiho, Ha'ateiho, East Halaleva Neitongo, Alakifonua and South Popua. Most common impacts are cutting of trees, dumping of garbage, reclamation for construction of houses. House construction usually introduces problems of sewage disposal. These problems are not new; they have been documented for over 10 years.

Mangrove Zoning Categories

Through various consultations with government agencies, communities and non-government organizations and based on previous and recent surveys, four mangrove zoning categories were considered suitable for Tongatapu. These are:

- Protection Zones
- Sustainable Usage Zones
- Rehabilitation Zones
- Alienable (Convertible) Mangrove Zones

The characteristics of each of these are outlines below.

Protection Zones

A Preservation Zone is a Conservation area where natural ecosystems, and constituent plant and animal species are permitted to live without interference. This allows retention of the natural ecosystem and ensures conservation of these species, and to allow people to experience the natural area, for education, ecotourism and recreation. Prescott (1989: 95) recommended that mangrove reserves be created in Tonga, to ensure that the diversity of plant and animal life is adequately protected.

Ellison in (TEMPP WP 17) explained the following criteria for selection of a Protection Zone may include:

1) Presence of threatened, rare, and endangered species, particularly rich biota, or undisturbed, old-growth communities. This was the primary criterion in designating Mangrove Forest Reserves in the Pohnpei Mangrove Management Plan (Federated States of Micronesia) (Devoe, 1992b, Metz, 1996).

2) The need to maintain intact mangrove to protect natural or human resources from excessive wave action, adverse weather and sedimentation.

4) The need to protect or maintain high fisheries or forest productivity.

5) Areas identified as of special value for scientific research, education and recreational amenities.

A Proposed Protection Zone – *Folaha/ Nukuhetulu Mangrove Forest*

The Folaha/ Nukuhetulu mangrove forest is the largest mangrove forest in Tonga (50 hectares), and owing to its sheltered position in the south west of the Fanga ‘Uta lagoon in Tongatapu has high diversity and is well established. Furthermore, palaeoecological studies have shown it to be the longest established mangrove area known in the Pacific islands, a refuge from which mangroves expanded as sea-level stabilized following the last de-glaciation (Ellison, 1989; Ellison and Stoddart, 1991). It is an excellent example of an area of high biodiversity, and it is strongly recommended that it should be set aside as a Protection Area, as defined by the Guidelines of AusAID & Government of Tonga (1996b).

Sustainable Usage Zones

A Sustainable Usage Zone is mangrove forest designated for sustained production of -,mangrove forest products. These may be used in domestic construction, dye for tapa making, firewood and medicinal and other cultural and traditional socioeconomic uses. In particular multiple use management of productive mangrove forest should aim to provide for:

-a sustainable supply of forest products
-a sustainable nursery and feeding ground for fisheries

The exercise of sustainable mangrove management has not yet been achieved in the Pacific Islands, and attempt to carry this out must be undertaken with sound theory (such as FAO, 1994), monitoring and review. The calculation of optimum sustainable yield from a mangrove resource can be achieved by exercises such as Bacon et al. (1988) Exercise 4.1 Calculating optimum sustainable yields for coastal resources.

Rehabilitation Zones

A Rehabilitation Zone is a mangrove area that has been so degraded that it can no longer offer mangrove resources for sustainable use, and has lost functional values such as protection of the shoreline from the impact of storms, and the stabilisation of coastal sediment to maintain the clarity of offshore waters. In order to re-establish these values, such areas need to be designated a rehabilitation zone, where active programs are undertaken to replant the mangroves.

Alienable (Convertible) Mangrove Zones

Alienable (Convertible) Mangrove Zones should comprise those areas where reclamation for urban and industrial development can be designated without unacceptably compromising the Permanent Mangrove Estate. Such areas might include, for example, less productive forest areas, areas already severely fragmented, or other areas deemed to be of little value for conservation or sustainable resource use.

In reality, reclamation of the Havelulotu and Fanga shoreline (south Ntiku'alofa) has progressed, particularly between the Power Station and the Valola Hospital. This has created.areas of the Ntiku'alofa shoreline on the lagoon with piecemeal reclamation, creating an uneven shoreline, causing local problems of eddies. This shoreline is unfortunately the leeward shore of the western arm of the, Fanga 'Uta lagoon, given that the prevailing winds are from the SE, which means that the lagoon tends to be choppy with wave fetch, across the lagoon. With disturbance of the mangrove margin here, the shore has lost protection against waves, and sediment has become unstable, contributing to turbidity problems in the lagoon. The shoreline is the vicinity of the Power Station is the narrow Fangakakau lagoon, where any coastal reclamation restricts and reduces tidal flushing of the enclosed western arm of the Fanga'uta lagoon. This may well reduce the ability of tides to naturally remove any pollution in the western lagoon.

During Cyclone Cora (26 December, 1998) new houses on landfill along this shoreline experienced severe problems with waves and inundation, which caused many owners to regret clearing the mangroves that used to protect the shore.

The development of this shoreline has already occurred. Ellison in (TENTP WP 17) described steps to make the best of the present situation are:

1. Provide sewerage facilities and enforce in law that lagoon shore houses do not discharge sewage and wastewater into the lagoon. The lagoon is shallow and poorly flushed, and these discharges contribute to decline in fishing resources, and are a threat to public human health.

2. Even up the shoreline so that it is smooth. It would be best to remove extensions that stick out beyond the natural shoreline, and not allow new headlands into the lagoon to be made. These reduce the natural flushing of the lagoon, and cause local problems with eddies. The narrow Fanga Kakau lagoon is particularly important to maintain a smooth, open shoreline, as through here tidal flushing occurs for the enclosed western arm of the Fanga'uta lagoon.

3. Ensure that no further mangrove reclamation occurs on other shoreline areas of the Fanga'uta lagoon. This means halting the registration of allotments in mangrove zones, the government taking back the allotments that have been registered in mangrove zones, and active replanting and rehabilitation of mangroves in degraded areas so that the protective function of mangroves is restored to Tonga.

4. Replant mangroves on the lagoon margin, a narrow fringe of trees is all that is possible owing to the pushing of fill across the inter-tidal zone, but a few trees will provide some protection from waves and wind, and prevent erosion.

MANGROVE REHABILITATION

Ellison, the Mangrove Specialist Advisor for the TEMPP reviewed suitable rehabilitation methods from available information and literature, to formulate a strategy appropriate for the Tongan species and conditions. This project is maybe the first attempt at mangrove rehabilitation in the Pacific Islands, the nearest mangrove replanting to Tonga has occurred in Eastern Australia (Field, 1996a). Review was carried out of the following steps:

- Identify the objective of mangrove replanting
- Remove the stress that caused mangrove decline
- Decide on approach to reforestation, either natural regeneration, propagule/ seed planting, or seedling planting
- Consider issues of danger of genetic change to unique Tongan characteristics
- Issues of seed collection
- Wilding collection and transplanting
- Propagule/ Seed planting
- Nursery Practices
- Site selection
- Monitoring

Identify the objective of mangrove replanting

The objective of mangrove replanting must be defined, as this controls the methods and materials to be adopted. The objectives of mangrove replanting elsewhere in the world have included timber production or silviculture (Malaysia, Bangladesh, and Pakistan); enhancement of coastal protection (China, Cuba), but most commonly is for the objective of restoration of degraded areas (Field, 1996b: 238).

The objective of mangrove replanting in Tonga is to restore the degraded mangroves, for the purpose of enhancement of coastal protection against storms, sea-level rise and erosion, and provision of natural products such as fish, crabs and dyes/ wood.

Remove the stress that caused mangrove decline

Replanting of mangroves will only be successful if the stress that caused the mangroves to decline is removed. The reason for mangrove decline in Tongatapu has been established by Ellison in (WP 5, 1998) to be over exploitation/ clearance by people, and subsequent disturbance by pigs that prevents natural seedling establishment.

Decide on the approach to reforestation.

There are several approaches to mangrove reforestation that can be adopted.

a) Natural regeneration
This is a non-active technique that protects the mangrove area from the original stress, and allows natural regeneration to occur. In Tonga, this would mean stopping human usage of the degraded mangrove area for a period of not less than 5 years, and fencing it from pigs. The advantages of natural regeneration are that the resultant mangrove forest tends to be more natural, and it is less labour intensive. There is a cost involved with the fencing.

b) Propagule/ Seed planting
This involves active planting of mature seeds in areas that are too degraded for natural regeneration to occur. This is usually due to lack of suitable propagules. If propagules are present but not establishing, then this is because the disturbance stress is still active (e.g. pigs).

c) Seedling planting
This involves active planting of seedlings in areas that are too degraded for natural regeneration to occur. The seedlings can be obtained either from wild sources elsewhere (wilding transplanting) or can be raised in a mangrove nursery.

Danger of genetic change of unique Tongan characteristics

Although a mangrove species may have a wide range internationally, areas of its range become genetically isolated and develop special varietal characteristics or ecological practices. This has been well demonstrated for the mangrove species *Avicennia marina* (Duke, 1992). The mangrove varieties across the Pacific islands have not yet been studied in any depth, but interesting differences have been noted. The *Rhizophora mangle* in Tonga is unique in flower structure from that which occurs in Hawaii, and the large mono-specific areas of *Excoecaria agallocha* in Tonga are found nowhere else in the world, it is usually a sub-dominant forest species. It is important to preserve these genetically unique characteristics of species from island group to island group.

This means that mangrove seeds used for replanting should be harvested from a place as close as possible to where they will be replanted. Import of mangrove seeds or seedlings from another country should not occur. Transport of seeds between islands should not be permitted, for example, mangrove seeds from Tongatapu should riot be planted in Ha'apai or Vava'u, each island group must use seeds collected locally for planting.

Some mangrove replanting practices have had no consideration of the natural biogeographical characteristics of mangroves, freely bringing in mangroves from all over the world, such as Saudi Arabia (Kogo and Tsuruda, 1996).

Species selection

Replanting in Tonga is best at first to concentrate on the naturally more common species, as shown in Table 5. The rare species have been rare at least for most of the 20th century (Yuncker, 1959). There is probably an unknown limiting factor why the rarer mangrove species are not common in Tonga. Trying to extensively replant a normally rare species is working against nature (Ellison 1999).

Table 5 Mangrove species with high replanting priority in Tonga.

Scientific name	Tongan name	Reasons for replanting priority
Rhizophora mangle	Tongolei	Both species are useful in shoreline protection, sediment sabilisation, and as fisheries habitat. Seaward zone degraded in many areas.
Bruguiera gymnorrhiza	Tongo ta'ane	Landward zone species now rare in Tonga owing to over exploitation of its bark, used in dying tapa.
Excoecaria agallocha	Feta'anu	Landward zone. Mangrove forest dominated by this species is unique in the world of Tonga, caused by absence of competitor species. Sadly, the best example, at Sopu, was cut down due to a planning mistake in the early 1990's. Replanting required in all landward mangrove areas, with *Bruguiera.*

Seed collection

Rhizophora and *Bruguiera* seeds are viviparous (already germinated) so have to be replanted within a few weeks. They cannot be dried and stored like normal seeds and they do not remain viable because they are already germinated before they leave the parent tree. This is an adaptation mangroves have to their wet and saline habitat.

Excoecaria seeds are not viviparous, and several occur in each fruit. The seeds retain their viability for about a month, and can either be sown directly onto suitable areas, or can be raised in nurseries.

Seeds for planting or for raising in nurseries must then be collected. This must be when they are ripe, which in Tonga is probably late summer (Jan-March). Mangrove phenology in Australia shows this to be the most common fruiting time at Tonga's latitude. If seeds are collected too young, they will not germinate (Hong, 1996).

Rhizophora stylosa seeds are ripe when a yellow ring develops at the top of the hypoycotyl, and the top swells. *Rhizophora mangle* hypocotyls are ripe when a (cotyledonary) collar or ring develops at the tip (Banus and Kolchmainen, 1975) and should be 20 em long, evenly coloured, with a reddish-brown tip. *Bruguiera* seeds are ripe when the hypocotyl changes color from green to brown, they do not. develop an abscission collar. If the hypocotyl does not come off from the parent tree with a slight pull, it is not ripe.

Seeds can either be collected from the tree, or beneath the tree. Seeds are usually in better condition if collected from the tree, with less physical damage or Insect/ fungal

infestation. They must be unblemished, free from insect attack, and handled carefully in transport. The seeds must not be allowed to dry out, but if kept in moist conditions this makes them vulnerable to insert or fungal attack. It is best to transport and store them in small horizontal bundles covered with banana leaves/ palm fronds or sacking. The baskets commonly woven in Tonga from palm fronds are ideal.

RhizophoralBruguiera seeds must be handled gently, particularly the plumule (spike) at the top of the hypocotyl.

Excoecaria seeds should fall in late summer, and can be collected from the mangrove mud surface beneath the parent trees. They are <1 cm in size, a fused 3 seeded pod.

Wilding collection and transplanting

Advantages of this method are: seedlings can be collected at any time through the year; they are suitable for higher energy sites; and success rates are usually higher than planting seeds (Latif, 1996).

Mangrove seedlings for replanting can be collected from large, mature mangrove ecosystems where natural regeneration is occurring. The mangrove mud must be firm, and seedlings can only be taken from within the forest. This is because sediment is removed with the seedling, so in a narrow, degraded or sea margin source site then erosion and degradation of the source area may occur.

Seedlings chosen for transplanting should be 0.5-0.8 m tall, with a straight trunk, an intact growing tip, and several leaf pairs. Avoid old seedlings, with over 15 leaf scars on the trunk, and those already developed prop roots or side branches. Older seedlings are less likely to survive transplanting, probably due to root disturbance (Hamilton and Snedaker 1984).

Seedling collection is best done at low tide. Seedling removal is best done using a length of 100 cm diameter PVC pipe. This is slid over the seedling, and cut into the mud around the seedling and pushed to 20-25 cm depth. Then the pipe is twisted and the seedling with a plug of sediment removed from the ground. A little water poured down the pipe, and shaking, will remove the plug out of the corer.
During transportation the seedling plug should be protected from drying out, and wind.

Propagule/ Seed planting

Seeds or *Rhizophora* and *Bruguiera* can be planted by inserting the tip into the mud, so that 1/3 to 1/2 of the propagule length is buried. This must be done gently.

Seed planting can only be done soon after the fruiting season, and mangrove seeds/ propagules cannot be stored for long.

Nursery Practices

Raising mangrove seedling & in nurseries before planting out can increase the survival and growth of mangrove planting. This allows the seedling to develop an healthy root system before planting. Propagules without woody thickening are more prone to crab attack (Chan, 1996). Another benefit of raising seedlings in nurseries, is that it provides an year-round supply for reforestation activities.

The propagule (seed) of *Bruguiera* is smaller than that of *Rhizophora,* so raising in nurseries will increase the planting success rate (Soemodihardjo et al., 1996). The seeds of *Excoecaria agallocha* are only 0.5 cm in diameter, so seedling raising in nurseries will greatly increase success of replanting.

Growing seedlings involves planting propagules in a mixture of sand and mangrove mud. Poly bags are best used, about 15 cm deep and 10 cm diameter, these can be easily relocated, and should have holes to allow drainage. Suitable bags are used in the Ministry of Forestry nursery at Tokornololo. Plastic containers with holes have also been used (Bohorquez, 1996). Seedlings should be watered once or twice a day with seawater mix. This suppresses fungal infections, and acclimatises the seedlings to saline conditions. Location of the nursery within a protected intertidal area means that watering occurs naturally, and the mangrove seedlings are better acclimatised to the mangrove conditions where they are to be planted. An upper intertidal area should be selected.

Walkways between seedling beds in the nursery are best made firm with wooden planks or matting for walking on. Excessive mud disturbance may cause silt deposition on seedling leaves. Seedling banks are best encased in wooden frames, to give them support at high tide.

To plant the small *Excoecaria* seeds, make a small indentation in the surface of the mud of the Poly bag with a finger tip, and drop the seed in, but do not cover the seed with mud (Siddiqi et al., 1993). Germination should occur in a few weeks. Seedlings should be raised in polybags for about 12 months, until seedlings reach a height of 30-50 cm. They were planted out with spacing of 1 m apart in Bangladesh, with 80% success after 12 months (Saenger and Siddiqi, 1993).

Site selection

In general, suitable species to be replanted are those that naturally occurred at the site before disturbance.

Mangrove species tend to occur in zones according to micro-elevation and frequency of inundation. Therefore, it is best to replant with the species that used to grow in the zone, i.e. *Rhizophora* on the seaward margin, and *Bruguieral Excoecaria* on the landward margin. Air photographs held.by The MLSNR can be used to show the former extent of mangroves, and the constituent zones.

Site preparation

If the site is infested with *Acrostichum* fern, then this has been found in replanting attempts elsewhere to be problematic (Field, 1996b: 235). It will need to be cleared, by cutting. Acrostichum will compete with newly planted seedlings, and reduce their success (Soemodihardjo et al., 1996).

If there are dead trees on the site, then these will have to be removed. This is because as dead trees rot over time, they become loose and roll with tides and waves, and can crush replanted seedlings.

Planting seedlings in the swamp

Planting can be done merely by digging a hole, taking the plastic bag off, and placing the seedling in the hole. It is very important that the mud level in the polybag becomes the same level as the mud in the mangrove swamp- if the seedling is buried deeper it will die (Ellison, in press). In loose substrates footprints are easily used for making a hole, digging tools are rarely necessary in the mangrove environment. Seedlings should be clumped in open areas at 1 meter intervals, as this provides mutual protection. The area should be protected from fenced from pigs, as these will push over young seedlings in their foraging activities.

Monitoring

Once the initial planting has been completed, it is important to monitor the progress of propagules or transplants. Replacement of individuals that die will be necessary. Problems that may reduce success could be debris, pig disturbance, crabs, fungi attack or storms.

Acrostichum may have to be cleared, if it grows up to compete with the seedlings.

If there is high seedling success rates, then replanted areas may need to be thinned after 5-7 years.

Identification of areas to be rehabilitated

The areas to be rehabilitated are identified from the mangrove survey and zoning activities described in Table 2.

Choice sites for rehabilitation with community participation

Three criteria must be satisfied in choice 6.f sites for rehabilitation with community participation:
1) The area has been identified as needing rehabilitation, zone 4 or 5 on human impact.
2) The area is not already subdivided and allocated into private ownership by individual people.
3) Where an area has been allocated, land holders must be willing to participate in rehabilitation programme, especially re-establishing mangroves on the seaward side
4) The local community is interested and enthusiastic on rehabilitation of mangroves.

Where to go from here - Some Recommendations

Resource assessment

The work commenced on mangrove area assessments (inventory and mapping) should be continued as a baseline for development of management plans. When more recent aerial photography becomes available, update the assessments already done based on the 1990 aerial images.

Establishment of National Mangrove Management Committee

A cross-sectoral task force (committee) should be established in Tonga to facilitate and coordinate management, research and monitoring of the mangrove resource.

Preparation of Management Plans

Mangrove Wetland Management Plans are required for mangrove areas. These should be developed in consultation with all interested parties. The broader the input to the process, the more likely the plan will succeed. There are no examples elsewhere in the Pacific Islands where this has been either attempted or achieved, though it is widely recognised as a future challenge in the region (1dechong et al., 1995). The need for this in Tonga is identified in NEMS Programme 4.9.1 (Thistlethwaite, Sheppard and Prescott, 1993). This recommendation from the Tonga NEMS was taken up by the TEMPP as one of its objectives.

There are no existing management plans for sustainable use of mangrove areas in Tonga. This has become a necessity with increasing pressures on mangrove resources and their resultant degradation. Mangrove management is, particularly difficult in areas zoned as Sustainable Usage Zones. Long-term use must be sustainable, so scientific monitoring is required to ensure that mangrove resources are not over used.

Planners need to quantify current and potential usage patterns of mangrove resources, both in direct and indirect products and in relation to other socioeconomic benefits (coastal buffer function, offshore food-chain connections, and ecotourism potential). Such evaluation would allow present and future needs to be met on a sustainable-yield basis from managed mangrove ecosystems. With this basis, ecological criteria can be established for levels of use in different areas, and incorporated into the management plan.

Such evaluation would allow present and future needs to be met on a sustainable-yield basis from managed mangrove ecosystems. With this basis, ecological criteria can be established for levels of use in different areas, and incorporated into the management plan. (Reference: Tonga NEMS Programme 4.9. L)

Determination of Sustainable Yield

Mangroves that are zoned as Sustainable Usage Zone should have exploitation managed on a sustainable yield basis, as is being implemented by the Ministry of Fisheries for marine resources.

The exercise of sustainable mangrove management has not yet been achieved in the Pacific Islands, and attempt to carry this out must be undertaken with sound theory (such as FAO, 1994), monitoring and review. The calculation of optimum sustainable yield from a mangrove resource can be achieved by exercises such as Bacon et al. (1988) Exercise 4.1 Calculating optimum sustainable yields for coastal resources.

The Birds and Fish Act declares mangroves of the Fanga'uta lagoon as protected from all damage in clause 7. (1) (iii) (see Section 1.5.1). It is possible within the existing law to have Sustainable Usage Zones by a licencing system. Under this law, people may, within the protected area, and with the prior consent in writing of the Prime Minister remove mangrove products. This would be a way of controlling mangrove usage, using the licencing practises presently operated by the Ministry of Fisheries as a model.

Brueuiera gymnorrhiza (Tongo ta'ane)

The mangrove species *Bruguiera gymnorrhiza* (Tongo ta'ane) has become particularly over-exploited in Tongatapu, so that it is presently rare. This is because its bark is used for the manufacture of the red dye in decoration of tapa, which has high ceremonial and cultural significance in Tonga. The growing rarity of this species and pressure on the remaining trees demands particular attention, or in a few years time there may be none left alive. This would be a tremendous tragedy for the mangrove ecosystem~ of Tonga, as well.as traditional tapa making ceremonies.

It will be necessary to adopt more careful bark stripping activities. Presently it is common to strip all bark within reach, from the mud level to above 2 meters in height. The bark has an important function. to the tree in conserving fresh water, and transporting water and food products between the roots and the leaves. With removal of such large areas of bark the, tree frequently dies. Research is needed on the best ways to remove bark from Bruguiera with minimum impact to the health of the tree. This could be an excellent advanced degree research project for a Tongan student to undertake. However, the following principles would probably improve the survival rate of trees:

- Do not remove bark below the tidal level. In the Fanga 'Uta lagoon this is around knee height on an adult person in the *Bruguiera* zone, higher outside the lagoon. The saline water has several impacts on a de-barked tree: removal of fresh water from the trunk tissue by osmosis; soaking the unprotected wood and causing it to rot; and introduction of fungal and bacterial infections.

- Leave connected strips of bark vertically on the trunk, so there is a roadway of live bark from the solid area below tidal level to the solid area out of reach above. This allows some undisturbed transport fibres to remain, to the tree can have some food and water movement through its tissues.

If the tree is able to survive the de-barking, then it will grow scar tissue and re-develop its bark. Keeping these trees alive will allow them to reproduce more young Bruguiera trees, prevent degradation of the mangrove area, and allow the tree to be used for obtaining of tapa dye in the future.

It may become necessary to place a (temporary) ban on the exploitation of *Bruguiera* bark for manufacture of tapa dye, unless these suggested actions to prevent its continued abuse are adopted. This could be similar to the 5-year ban on Beche-de-Mer export introduced by the Ministry of Fisheries, to allow the recovery of the species. With *Bruguiera,* a ban may be necessary on export of tapa that contains dyes using the species. This may be a painful necessity for Tonga at the present time, but it would be even worse to lose the species completely in a few years. Prescott (1989) from her survey 10 years ago found that this was unavoidable if unplanned and unsustainable levels of exploitation continued.

Fortunately, there are other plants available from which the dye for tapa can be made. Ha'ateiho villagers named two other plants that can be used: *Bischofi-a javanica* (koka) and *Aluerites moluccana* (tuitui). These are dry land plants, which are grown on tax allotments or in house gardens. However, most people prefer the quality of the mangrove dye (Prescott 1989: 66). This is because the mangrove dye gives the tapa a bright shining colour.

Mangrove Monitoring

A scientific monitoring system is required, that will enable ongoing assessment of the environmental health of the mangroves of Tongatapu. This will allow sustainable use of mangroves to be quantitatively monitored and evaluated, and environmental changes caused by external influences such as sea level rise to be distinguished (Ellison, 1998). Such a system is planned regionally under the SPREP Mangrove Action Plan (Idechong, et al., 19-95).

Mangrove monitoring includes:

- area mapping and survey of community structure, zonation and condition of mangroves (this has already been carried 6.11t).
- establishment of permanent plots for measurement of growth rates of trees, also mortality rates.
- monitoring of seedling growth rates
- monitoring of sedimentation rates, accretion or erosion.
- monthly mangrove litter analysis, for measurement of productivity and phenology of the mangrove trees.

Monitoring of mangrove ecosystem health will allow a mechanism by which sustainable use of the mangrove zoned for use can be evaluated. Mangrove swamps, particularly those of low islands, are likely to be sensitive to rise in sea-level. The Kingdom of Tonga National Environment Management Strategy identifies in Programme 4.4.1 a need for surveying and monitoring of climate-sensitive ecosystems (Thistlethwaite, Sheppard and Prescott, 1993). The mangrove-monitoring program proposed to be carried out as part of this project will address this need. The SPREP Regional Wetland Action Plan in Action 3.3.5 (1dechong et al., 1995) also identifies a need for regional monitoring of mangrove response to sea-level rise predictions.

Environmental Impact Procedures

Environmental impact procedures should be used to assess the potential impacts of proposed development projects on mangrove areas, and establish bonds or environmental levies to be applied to development projects to enable monitoring of impacts to be carried out. This was a mangrove management recommendation of Prescott (1989: 95).

No cutting of mangroves on the seaward edge of the mangrove zone should be permitted. This disturbs an important fish-breeding habitat, causes sediment erosion by waves on the edge of the lagoon, and weakens the remainder of the mangrove zone.

No Net Loss of Mangroves

Recognising the importance of the mangrove resource to Tonga, and its present degraded situation, any loss of mangrove area for any purpose should be compensated for by replanting of an equal area of mangroves at a suitable inter-tidal site at the cost of the developer. This is the present legislation in Queensland, and is a policy of the Pohnpei Mangrove Management Plan (Metz, 1996: D-64).

Community Education and Awareness.

Public awareness programs should be continued to improve the attitudes of people towards mangroves. This is not a short-term activity, but must continue particularly due

to the youth of Tonga's population. TV, radio and the printed paper and magazines should be used, as well as education programs and material in schools and colleges. Public goodwill towards mangroves is a requirement for successful rehabilitation and management.

Develop appropriate ecotourism ventures

There is considerable potential for use of the Folaha/ Nukt.ihetulu mangrove forest as an educational and ecotourism facility. A small visitor reception center could be constructed to house interpretive displays of mangrove ecosystem diversity in Tonga, species, identifications, special adaptations of species, and traditional usage of the forest.

ENVIRONMENTAL MANAGEMENT PLAN FOR THE LAGOON SYSTEM

(REFER MANAGEMENT PLAN FOR THE LAGOON SYSTEM)

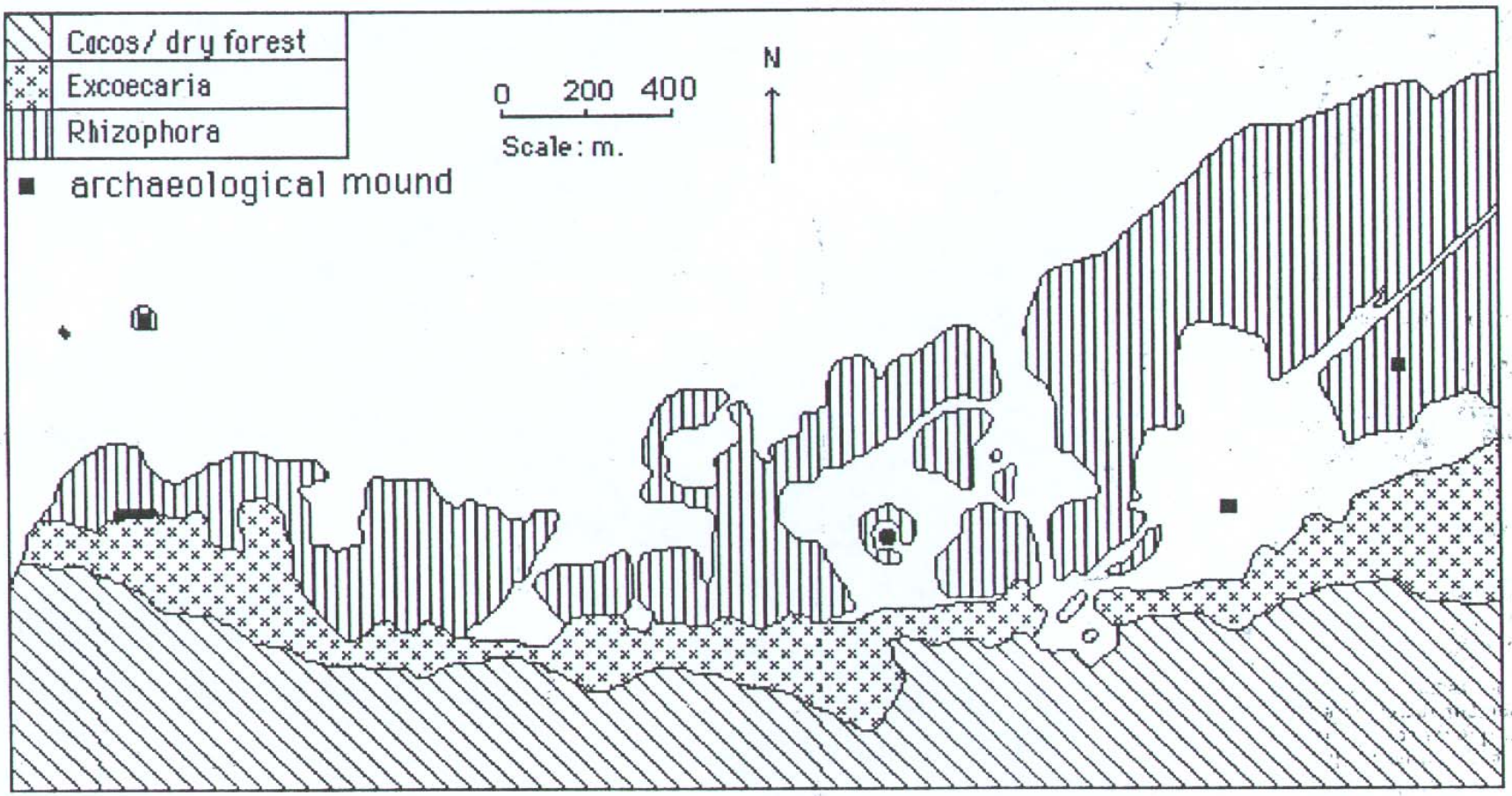

Figure 2. Mangrove zonation at Fatai, Tongatapu.

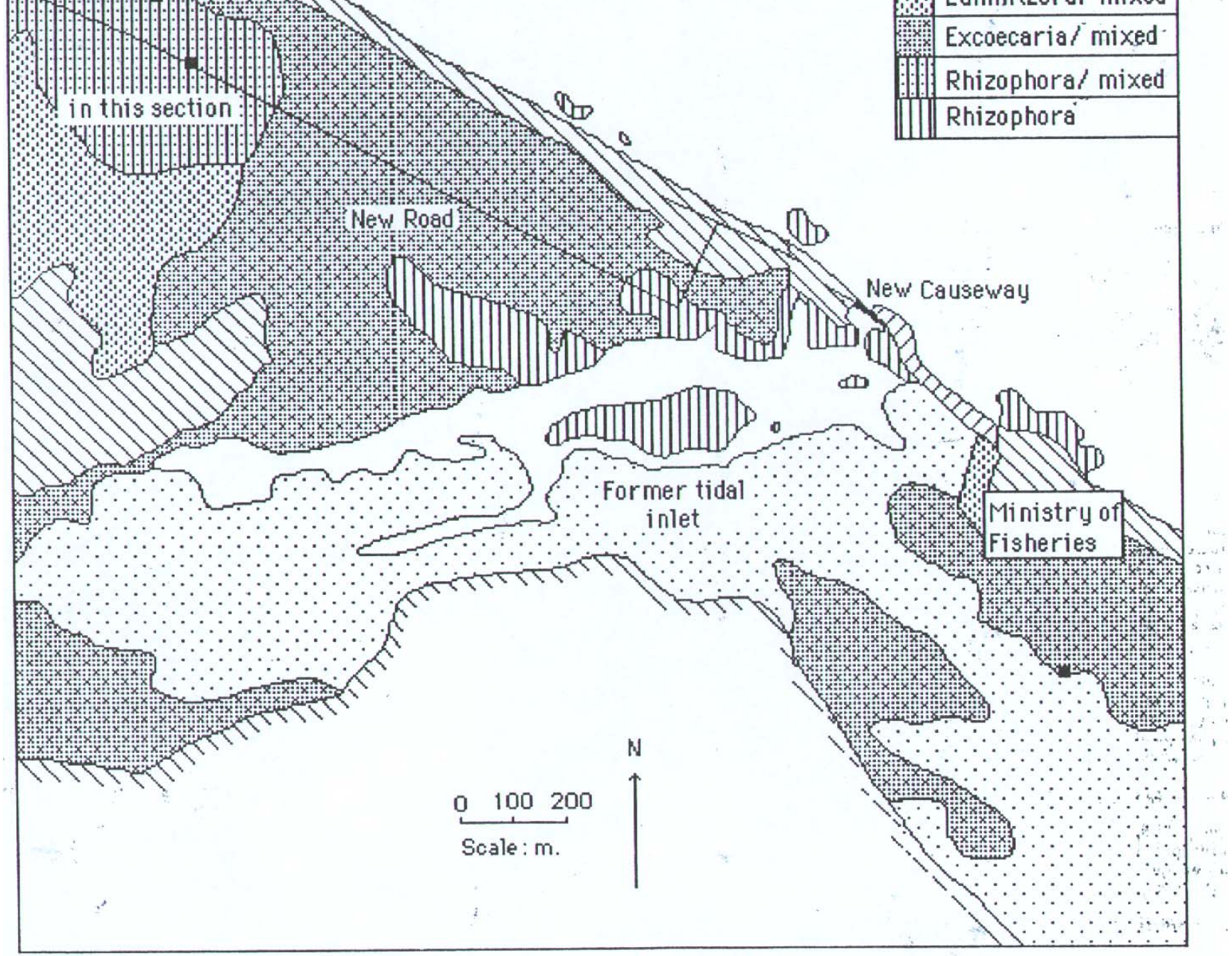

Figure 3. Mangrove zonation at Sopu/ Muifonua, Tongatapu.

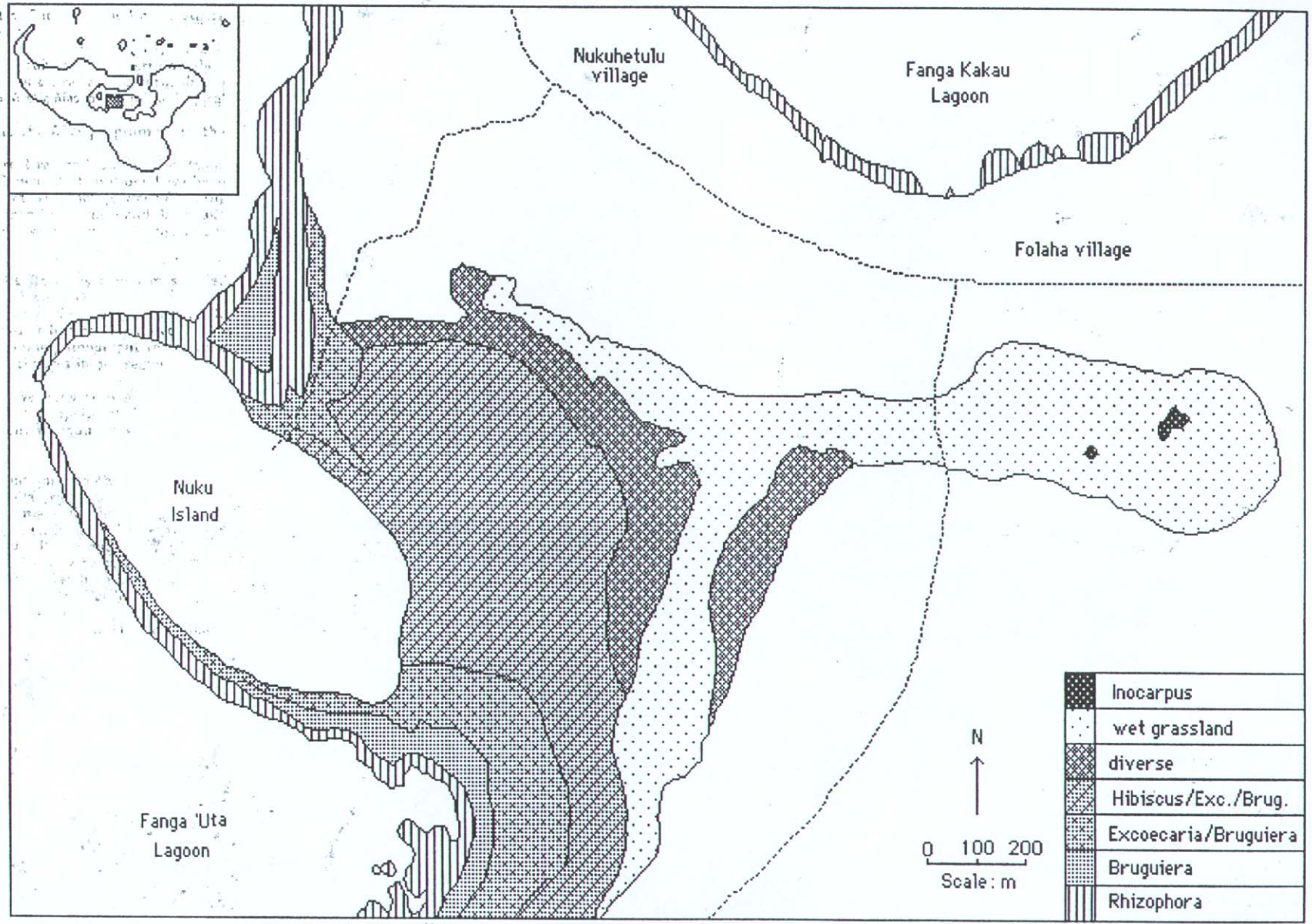

Figure 4 Mangrove zonation at Nukuhetulu, Tongatapu.

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