PROCEEDINGS OF THE PACIFIC REGIONAL WORKSHOP ON MANGROVE WETLANDS PROTECTION AND SUSTAINABLE USE

THE UNIVERSITY OF THE SOUTH PACIFIC MARINE STUDIES FACILITY, SUVA, FIJI

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ORGANISING COMMITTEE

South Pacific Regional Environment Programme (SPREP)
Ms Mary Power
Ms Helen Ng Lam

Institute of Applied Sciences
Ms Batiri Thaman
Professor William Aalbersberg

Editing: Professor William Aalbersberg, Batiri Thaman, Lilian Sauni
Compiling: Batiri Thaman, Lilian Sauni

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PACIFIC REGIONAL WORKSHOP

MANGROVE WETLAND PROTECTION AND SUSTAINABLE USE

Marine Studies Centre, USP Suva, June 12 – 16, 2001

Objectives:

- To review and promote the recommendations of the Regional Wetlands Action Plan (RWAP) for the Pacific Islands (1995) to regional and national agencies responsible for mangrove wetland conservation and management.
- To prioritise the updated Actions in the RWAP from both the national and regional perspective
- To develop and promote funding proposal(s) for highest priority regional and national actions.

Expected Outcomes

- Review of the status and value of mangrove wetlands in the Pacific region
- Review of current management initiatives and institutional arrangements in Pacific Island Countries (PICs).
- Priority list of actions to support the wise use and management of Mangrove Wetlands in countries in the region.
- A strategy to be used to target technical and financial support from regional organisations and the donor community.
- Updated Regional Wetlands Action Plan.

SUMMARY REPORT

WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

The workshop generally concluded that, while the specifics of mangrove degradation vary from country to country, the underlying causes are similar and have not changed or improved significantly since the Regional Wetlands Action Plan was developed. Urgent action is needed to focus attention on this issue and implement remedial action at the community level.

The underlying cause of mangrove degradation is predominantly the shift from a subsistence-based economy to a commercial-based (market-driven) economy. With this shift comes population growth, social changes, and the exploitation of natural resources for commercial purposes. New needs, aspirations and wants are also being created. Consequently, Pacific island countries are facing new challenges of balancing their economic development goals with those of conservation of their natural resources. Attaining this balance is essential given the limited natural resource endowments and economic opportunities in the islands, high population growth rates generally, and their vulnerability to natural disasters such as hurricanes and cyclones.

The strongest message to come out of the workshop was that the process of engaging communities in managing their resources is still not working well in the Pacific and that the project/donor-funding process is fundamentally flawed in this regard.

Whilst the threats and management actions were prioritised (Tables 1 and 2), the workshop discussions focused on the "how to" rather than the "what to" do in relation to developing and implementing natural resource management plans/programs, in the Pacific island context, rather than developing a specific proposal.

Conclusions

1. Despite modernisation and development, many coastal communities throughout the Pacific remain dependent on mangrove ecosystems and the services and products they continue to provide for their well being and economic livelihood, mostly through non-market based or subsistence exploitation. Because of their long association with mangroves, communities have a wealth of traditional empirical and scientific knowledge on the direct and indirect benefits of the mangrove ecosystem.
2. Even if these benefits provided by mangroves could be replaced, the expense would be far too great for most Pacific island rural and urban communities to absorb.
3. The environmental goods and services provided by mangrove systems in the Pacific are being used unsustainably by a range of stakeholders, without regard to the external costs that their actions impose upon the ecosystem and upon others who also depend upon this ecosystem. The "total economic value" of mangrove ecosystems must be taken into account in determining use types and levels, including all direct and indirect uses and benefits.
4. For resource use to be modified, the economic and socio-cultural interests of all parties must be taken into account. The incentives to change or modify behaviour must be carefully considered. In addition to measures to minimise environmental damage, specific measures need to be undertaken to address the particular constraints that poor resource-users face. Attempts to change resource use and promote sustainable mangrove management must consider the development needs of those communities that depend on these resources for their livelihood and survival needs.
5. The need to harmonise diverse stakeholder concerns and find shared interests that can be built upon to achieve environmentally sustainable mangrove management is of primary importance.

6. Management action must be multi-sectoral with representation of all primary stakeholders, especially local communities.
7. In order to work towards more sustainable mangrove management, key gaps in data/knowledge need to be addressed. Management needs to be based on good science. Sound data on biological and human-environment indicators is needed to guide policy and set parameters for sustainable resource use.
8. There is a real need to strengthen and enforce the rules and regulations governing the extraction and use of mangrove resources at the national and local level.
9. The region needs a stronger focus on mangrove wetland management.

Recommendations

Recommendations are in the form of guiding principles to develop national/local action programmes and priorities rather than simple action statements.

Over-riding principles

- *We must find the balance between economic 'development' and 'protection' (sustainable use)*
- Projects must be relevant to the area and the community (i.e. have a context/area-specific outcome-focused approach) taking into account all the relevant factors at the site:
  - *Ecological and economic factors will define the project/management boundary*
  - *Social, institutional and political characteristics will define the appropriate approach.*

GuidingPrinciples

1. Develop a **common philosophy** on what needs to be done
   - Must be founded in a partnership between government and 'communities'
   - All levels of government, private sector and relevant 'communities' should be involved.
2. Combine **'traditional' and 'modern'** information/management approaches/models and tools.
3. Management actions must be **sustainable**
   - Essential that they meet local income needs,
   - Adopt an integrated ecological-social-economic analytical framework,
   - Encourage a change in attitudes/behaviour/action/practices of all relevant stakeholders,
   - Develop strategies in partnership between community/government/NGOs, (and the private sector),

– Develop strategies appropriate to the local context,

   - Identify innovative options (rather than readily adopting developed country approaches/technologies),
   - Develop long term strategy/planning (including ecosystem zoning),
   - Address attitudes and resource use conflict,
   - More efficiently use existing government regulations (laws, informal, 'norms'); and

- Encourage more efficient and cost effective use of resources currently utilised.

4. Adopt **Participatory Learning and Action (PLA)** approach to develop context specific strategies (as compared with a consultative process)
    - Develop common visions, interests and strategies,
    - Provide pre-project funding to facilitate community-based involvement in project development and planning; and
    - Include conflict resolution processes in project development.
5. Obtain **appropriate information/data/knowledge** to support:
    - awareness and understanding (for public and government),
    - advocacy,
    - site specific management (at government and/or community level),
    - strategy based on ecological, economic, institutional, social and political; and
    - considerations.
6. Change the project development and funding process
    - change the project development process,
    - a change in donor funding process,
        - ***need support for pre-project community interaction/engagement with managers, researchers, and government for****;*
            - identification of issues,
            - identification of needs, aspiration and wants; and
            - identification of appropriate IGAs (Income Generating Approaches) and 'protection' options.

Table 1: Threats to Mangrove Wetlands in the Pacific Islands

(L for Low Threat, M for Medium Threat, H for High or Severe Threat)

COUNTRY	TONGA	NEW CALEDONIA	PALAU	FSM	PNG	SOLOMON ISLANDS	FIJI	SAMOA	AMERICAN SAMOA	VANUATU	MARSHALL ISLANDS
Overfishing		M	H	H	L	H	M	M	H	H	L
Coastal development		H	H	H	L	M	H	H	M	M	L
Watershed alteration / coastal sedimentation		H	H	M	M	M	M	M	M	H	M
Dumping/improper waste disposal		H	H	H	M	H	H	H	H	M	M
Reclamation		H	H	H	L	M	H	H	L	H	L
Aquaculture ponds		M	M	L	L	L	L	M	L	L	
Sewerage		H	H	M	L	H	L	M	L	M	M
Pesticide runoff		M	M	H	L	L	L	M	L	L	M
Animal waste		M	M	L	L	L	L	H	H	L	L
Industrial waste		H	L	M	L	M	M	H	L	L	L
Oil and hazardous waste spills		M	H	L	M	M	M	M	L	L	M
Alien species (e.g. from ballast water)		H	M	L	L	L	L	M	L	L	H
Collection of firewood		H	L	M	L	H	H	M	L	H	
Logging		M	L	L	L	M	L	M	L	M	L
Bio-prospecting/natural products		L	M	L	L	L	L	H	L	L	M
Global warming and sea-level rise		L	M	M	L	M	L	H	L	L	
Cumulative Impacts									H		
Dredging			M	M							

Table 2: Priority Management Actions

(L for Low Priority, M for Medium Priority, H for High Priority)

COUNTRY	TONGA	NEW CALEDONIA	PALAU	FSM	PNG	SOLOMON ISLANDS	FIJI	SAMOA	AMERICAN SAMOA	VANUATU	MARSHALL ISLANDS
Monitoring programs	H	H	M- H	L- M	L- M	M	M- H	H	M	L- M	M
Accurate maps and Geogrpahic Information System (GIS) database	L	H	H	M	M	L	L- M	H	H	L- M	M
Socio-economic valuation	L	M	H	M- H	L- M	L	M	H	M	M	M
Awareness and education efforts for mangrove conservation	H	H	M	H	L- M	M	H	H	H	H	M
Biological information needed for management	M	H	H	M	L	M	H	H	H	L- M	H
Lack of agency capacity	M	M	M- H	M- H	H	L	H	H	M	M	L
Lack of stakeholder participation	M	H	L- M	M- H	H	M	M- H	H	H	M- H	L
Lack of public support for regulations	M	H	M	M	L	L	M	M	H	M- H	L
Lack of enforcement	H	M	H	H	M	L	M	H	H	H	L
Lack of political will to support management	H	H	M	M- H	H	M	M	M	H	M- H	L
Breakdown of traditional values	M	M	M	M- H	L	M	H	H	H	M- H	L
Restoration	H	H	L- M	L- M	M	L	L	H	M	M	L
New industries for mangrove resources	L	H	L- M	H	L	L	L	M	M	L- M	L
Lack of alternative sources of income	H										
Lack of government support for wetland management	H										
Identify one agency with mangrove responsibility									H		

TECHNICAL REPORTS

Session I

The Value of Mangrove Ecosystems

THE VALUE OF MANGROVE ECOSYSTEMS: ECOSYSTEM SERVICES & FUNCTIONS

Dr Joanna Ellison, University of Tasmania

Introduction

This paper reviews the value of mangrove ecosystems to the Pacific island region, in terms of general ecosystem services and functions provided. The values of mangroves include improvement of near-shore water quality, land building, coastal protection from storms, coastal protection from sea-level rise, a habitat for specialised species, resources for tourism and community education, and conversion uses. The specific values provided in the sectors of Fisheries (including the role of mangroves in sustaining food-chains), Forestry (including wood supplies) and Cultural and Ethnobiological values (including medicinal uses) are reviewed in detail by other authors later in this workshop section, so are excluded in this general overview.

Improvement of near-shore water quality

Mangrove ecosystems are most extensive on sheltered coastlines, where sediment deposits create extensive inter-tidal areas, such as the deltas of river. In these areas, mangroves have a role in stabilising sediment and trapping contaminants. This buffering role causes water offshore in lagoon or shallow reef areas to be reduced in contaminants and suspended sediment. This enhances the health and productivity of seagrass, coral reef and other benthic communities adjacent to mangroves.

In the mangrove intertidal area, suspended sediment carried from the river catchment is flocculated in brackish water of sediment particles and the reduced velocity of water movement through the root systems promotes sediment to fall out of the water column. Furukawa and Wolanski (1996) and Furukawa et al. (1997) demonstrated that a combination of vegetational friction on water movement and sediment flocculation promotes sedimentation within mangrove swamps. Scoffin (1970) showed that the roots of *Rhizophora mangle* can significantly reduce the velocity of tidal water, and provide a better sediment binding capacity compared with a variety of sea-grasses and algal mats.

Increased sedimentation in mangrove areas relative to unvegetated mud banks has been shown in several studies. Spenceley (1982) from a study of inserted pegs in mangroves on Magnetic Island, off Townsville (Queensland) found higher sedimentation rates among mangrove roots than in the open. Young and Harvey (1996) used artificial pneumatophore roots to show a positive correlation between root density and sediment accretion.

The offshore water quality benefits of mangrove ecosystems are demonstrated by Allen's (1998) review of the introduction of mangroves to Hawaii. Three species were introduced in the early 1900's on Molakai, and mangroves have now spread and established on all the large islands. There has been a positive influence on water quality by the capacity of mangroves to retain sediment. In one extreme case on Oahu, 10 cm of sediment was deposited under mangroves in 16 months. Allen shows an example from Molakai, where turbidity is lower on coral reefs adjacent to mangroves than reefs with no adjacent mangroves. The mangroves also serve as a sink for high nitrate and phosphate levels coming off the land.

This role of mangroves in providing a pollution buffer is explained by Saenger, McCinchie and Clark (1990). Anaerobic bacteria present in mangrove sediments generate sulphide which react with metal leachate to form insoluble metal sulphides. These are trapped in the sediments and so removed from intertidal water. Furthermore, quantities of copper, lead and zinc may be directly absorbed by mangrove plants.

Several stratigraphic studies in mangrove areas of the Pacific have demonstrated the depths of

sediment trapped. Figure 1 shows sediment depths under mangroves fringing Kosrae in the Federated States of Micronesia. The radiocarbon dates demonstrate that most of this sediment was deposited in the later Holocene, indicative of human-induced catchment disturbance. Stratigraphic studies also demonstrate the value of mangrove ecosystems as land builders.

Land building

Sediment trapping by mangroves, by the processes described above, causes land building under mangrove ecosystems, mainly the creation of more intertidal land area. This is demonstrated at Low Isles on the Great Barrier Reef, which was mapped by the Great Barrier Reef Expeditions to show that the area of continuous mangrove increased by 67 per cent from 22 ha in 1929 to 36.5 ha in 1973 (Stoddart et al., 1978; Stoddart, 1980).

The increase of intertidal land is of use in providing greater storm protection to dry land, inshore of mangrove areas.

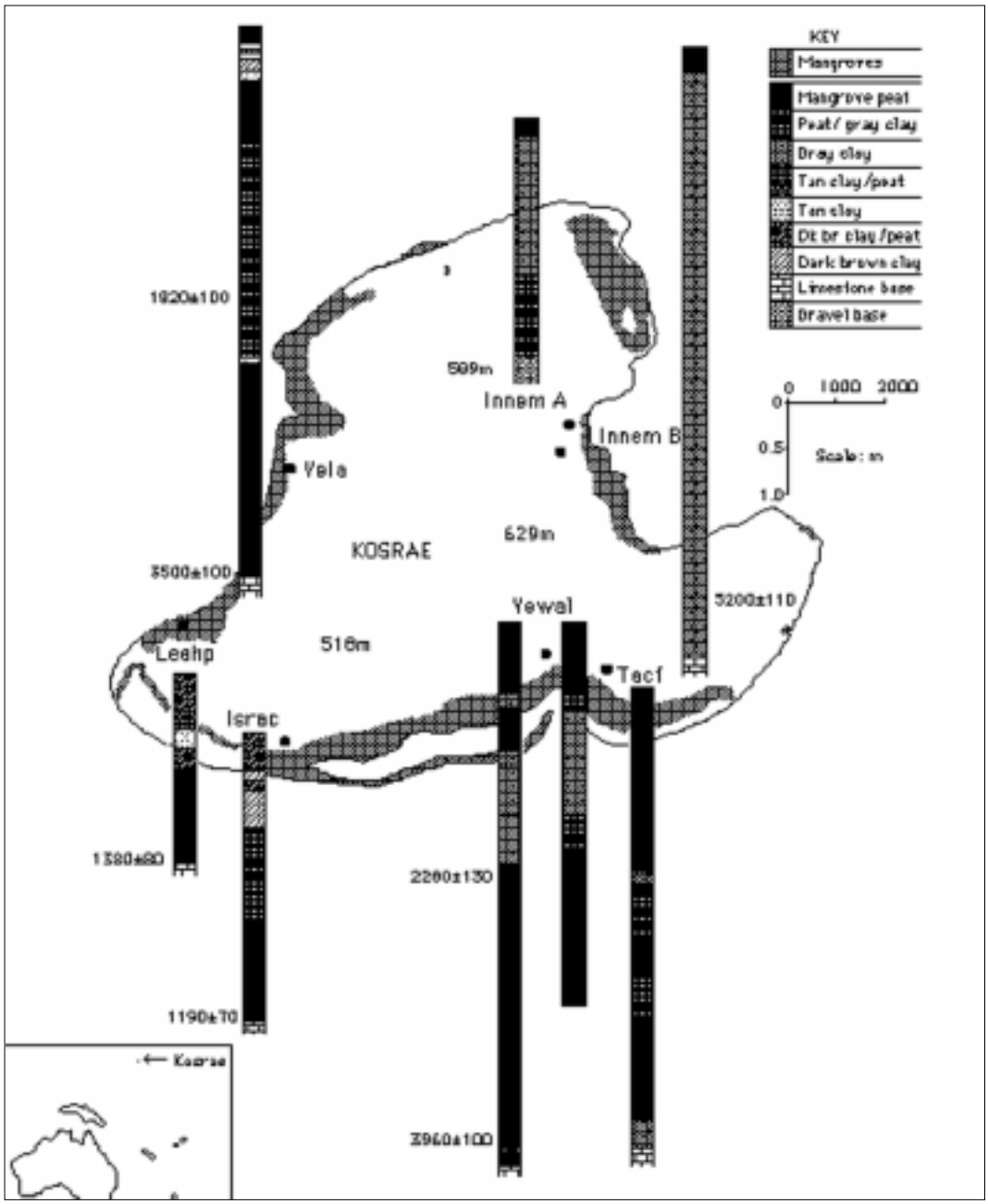

Figure 1. Sediment depths under mangroves of Kosrae, FSM. Source: Ward (1988) and Ellison & Stoddart (1991).

Coastal protection

Mangroves provide a value in protecting the land from waves and tidal surges, that may occur during tropical cyclones and other storms. This is well known by boat owners throughout the tropics and sub-tropics, who take their craft up mangrove creeks when a storm is threatening the coastline. When Cyclone Tracey hit Darwin in 1973, only twosailing boats survived unscathed. These took shelter up a mangrove creek. In Cairns, the procedure to be followed by boat owners in Cairns Harbour is to go up the mangrove creeks of Trinity inlet.

The protection is caused by two mechanisms, reducing both the wave and wind energy. First, wave energy is reduced by the wave dissipation through the gradual intertidal gradient that mangroves promote. Furthermore, the frictional barriers of intertidal root systems and intertidal mud banks trapped under mangroves, forces storm waves to spill not plunge in break. Hence wave energy is dissipated as the waves traverse the mangrove fringe. Second, the intertidal forest margin lifts onshore winds up, hence buildings on the foreshore are protected against strong winds by a margin of mangrove trees.

An example is provided from the Havelulotu and Fanga shoreline (south Nuku'alofa) of Tongatapu, Kingdom of Tonga. During Cyclone Cora (26 December, 1998) new houses on landfill along this shoreline experienced severe problems with waves and inundation that caused many owners to regret clearing the mangroves that used to protect the shore ('Akau'ola, Director of Fisheries, personal communication). This realisation is not new. From over 10 years ago, Prescott (1989: 41) described the regret of a resident at Ha'alaufuli in removing mangroves from in front of his lagoon shore house. He had to replant mangroves in front of his house for protection from strong winds and wave-splash.

While mangroves cause sediment accretion and land building, removal of mangroves can cause coastal erosion. Mimura and Nunn (1998) reported from Nabila village on the west coast of Viti Levu, Fiji, an account from a long-time resident Timoci Tuwai. He said the foreshore was once covered with mangroves, but in the 1930's-1940's the mangrove swamp was cleared. This was followed by coastal erosion, and now the shoreline is 10-15 metres inland of where he remembered it.

Protection of the shoreline from inundation due to sea-level rise

Because mangroves have the ability to raise their substrate surface, they may be able to keep up with slowly rising sea-level. This would continue the values of mangroves reviewed in this paper, and protect the inland of islands from direct impacts of sea-level rise, particularly salinity intrusion into fresh water lenses.

However, mangroves are likely to be severely impacted by more rapidly rising sea-level (Ellison, 2001). The Intergovernmental Panel on Climate Change (2001) predicts a global rise in sea level of between nine and 88 cm by 2100, and mangroves are one of the more sensitive ecosystems should this eventuate.

Habitat for specialised species

Mangrove communities form a specialised habitat for a variety of organisms, including several species of fish and birds that are confined to this habitat. This is demonstrated for the Pacific islands using Papua New Guinea and Tonga as examples.

The fish communities of mangroves in the Purari delta are described by Haines (1979), listing 49 species from 24 families in the freshwater reaches of the river and delta. Liem and Haines (1977) list 143 species from 48 families from the estuarine areas of the Purari-Kikori delta, of which 63 fish species are described as being estuarine, 59 as marine, and 15 as riverine. Studies in the Solomon

Islands (Blaber and Milton, 1990) and New Caledonia (Thollot, 1987) have shown significant fish stocks in association with mangroves. The mud crab (*Scylla serrata*) lives and breeds in mangrove habitats, and is an important food and commercial resource.

Two species of crocodile are found in Papua New Guinea (PNG), the Freshwater Crocodile (*Crocodylus novaeguineae*) prefers a fresh habitat, but may be found in brackish waters such as the Fly delta. The Saltwater Crocodile (*Crocodylus porosus*) occurs in brackish areas such as estuaries and mangroves. Palau, the Solomon Islands and Vanuatu are the only other Pacific islands with records of *Crocodylus porosus.*

Mangroves of PNG are habitats to a number of internationally endangered species, such as flying foxes (fruit bats). There is an endemic subspecies of the Mangrove Monitor *Varanus indicus spinulosus* with limited distribution in the Solomon Islands.

Mangroves are also habitat to numerous and diverse bird species. Scott (1993) catalogues some of the principal mangrove swamps of the Pacific islands, and lists seabirds and waterbirds as well as foraging forest birds that frequent the mangroves of many Pacific island countries. In Tonga for example, mangrove waterbirds include the Wattled Honeyeater (*Foulehaio carunculata*), Pacific Reef Heron (*Egretta sacra*), Pacific Black Duck (*Anas superciliosa*) and the Great Crested Tern (*Sterna bergii*). Migrants include the Pacific Golden Plover (*Pluvialis fulva*), Wandering Tattler (*Heterosceles incanus*) and Bar-tailed Godwit (*Limosa lapponica*) (Scott, 1993).

In general, very little is known about the population ecology of rare species that inhabit mangroves in PNG or other Pacific islands, hence their status is difficult to assess and improve.

In the Pacific island region, a total of 34 species of mangroves occur, and three hybrids (Ellison, 1999). These are of the Indo-Malayan assemblage (with one exception), and decline in diversity from west to east across the Pacific, reaching a limit at American Samoa. This means that each island group in the Pacific has a unique assemblage of mangrove species, possessed by no other island group. Relative competition between the species present may result in mangrove forest types found nowhere else in the world. An example is provided by the mangroves of Tonga. There, most species that normally favour the upper intertidal elevations of the mangrove range are absent (such as *Nypa fruticans*, small flowered *Bruguiera* species, and *Ceriops*). *Excoecaria agallocha* is usually a sub-dominant / occasional species in upper zone mangroves, but due to lack of competition in Tonga it forms extensive stands of the one species. In my experience, this is not found elsewhere in mangroves worldwide, and is caused by the unique assemblage of mangrove species in Tonga.

Tourism resources and community education

Mangrove ecosystems, with their specialised flora and fauna, and attraction of forest combined with seawater provide a strong attraction for educational and ecotourist groups. The inaccessibility caused by the muddy substratum has been combated in several locations by boardwalk construction, to allow visitors to walk through the mangroves without getting dirty, and without disturbing the mud.

The unusual adaptations of mangrove flora, the role of the mangrove forest in the marine food chain, and the visible fauna of crabs, mudskippers and birds are especially worthy of tourism use and public education. Interpretive signs, fixed along a boardwalk, which identify individual tree species, explain their specialised aerial root and salt tolerance adaptations, and traditional usage by local communities would provide self-guided tours for visitors. Interpretive signs have been successful on mangrove boardwalks in Australia (Cairns airport), New Zealand (Waitangi Reserve) and the USA (Everglades National Park).

Access to mangroves for visitors can also be provided by boat, though at low speed because boat wakes can erode mangrove substrates. In the Federated States of Micronesia (FSM), traditional

outrigger dugout canoes are used by the Enipein community to take tourists through the mangroves of the Enipein marine park. Tour guides give explanations of the social significance of mangroves, and explain and provide traditional food and *sakau*. The development is highly appropriate in that no impact on the mangroves occurs, a large number of people in the community are involved and benefit, and it serves to educate local people about the ecological, social and commercial value of the pristine mangrove ecosystem.

Other uses

In the Pacific islands, on islands with mangroves, population centers are usually located close to the mangrove areas. Hence the mangroves frequently become overused and degraded (Ellison, 1999). Mangroves are used as rubbish dumps, filled and constructed upon, or over harvested leading to ecosystem decline.

Conclusion

This review has shown the values of mangroves provided in the areas of improvement of near-shore water quality, land building, coastal protection from storms, coastal protection from sea-level rise, habitat for specialised species, and resources for tourism and community education. The coastal protection and land-building functions are particularly important in low and smaller island environments of the Pacific islands, where inland areas are subject to marine influence. The function of improvement of water quality is particularly important in the Pacific islands where coral reefs occur close to the coastline, and where communities are dependent on reef resources for subsistence and tourism income. The specialised species that occur in mangroves are part of their attraction to tourists and other visitors, which has potential for further development in many Pacific island countries.

These values are in addition to the values of mangroves for fisheries, forestry and cultural uses reviewed later in this workshop section. Increasingly, Pacific island governments and communities are realising the range of values of healthy mangrove ecosystems, and are repairing past damage with active management, community education, and rehabilitation (such as replanting).

References

Allen, J. A., (1998). Mangroves as alien species: the case of Hawaii. *Global Ecology and Biogeography Letters* 7, 61-71.

Ellison, J.C., (2001). Possible impacts of predicted sea-level rise on South Pacific mangroves. In Noye, J. and Grzechnik, M. (editors), *Sea-Level Changes and their Effects.*_World Scientific Publishing Co., Singapore.

Ellison, J. C., (1999). Present status of Pacific Island mangroves. In *Marine/ Coastal Biodiversity in the Tropical Island Pacific Region: Volume II. Population, Development and Conservation Priorities,* Eds L. G. Eldredge, J. E. Maragos and P. L. Holthus, Pacific Science Association/ East West Center, Honolulu. P. 3-19.

Ellison, J. C. & Stoddart D. R., 1991. Mangrove ecosystem collapse during predicted sea-level rise: Holocene analogues and implications. *Journal of Coastal Research* 7, 151-165.

Furukawa, K. & Wolanski, E., (1996). *Sedimentation in mangrove forests. Mangroves and Salt Marshes* 1, 3-10.

Furukawa, K., Wolanski, E., & Mueller, H., (1997). Currents and sediment transport in mangrove forests. *Estuarine, Coastal and Shelf Science* 44, 301-310.

Haines, A. K. (1979). An ecological survey of fish of the lower Purari river system., Papua New Guinea. *Purari River (Wabo) Hydroelectric Scheme, Environmental Studies* 6. Office of Environment and Conservation, Waigani.

IPCC, 2001: Climate Change 2001: The Scientific Basis. Summary for Policymakers; A Report of Working Group I of the Intergovernmental Panel on Climate Change, (http://www.unep.ch/ipcc).

Kare, B. D. (1995). A review of research on barramundi, reef fish, dugong, turtles and spanish mackeral and their fisheries in the Torres Strait adjacent to Papua New Guinea. *Science in New Guinea* 21, 43-55.

Liem, D.S. & Haines, A.K. (1977). The ecological significance and economic importance of mangrove and estuarine communities of the Gulf Province, Papua New Guinea. Purari *River (Wabo) Hydroelectric Scheme Environmental Studies* 3, 1-35.

Mimura N. & Nunn, P. D., 1998. Trends of beach erosion and shoreline protection in rural Fiji. *Journal of Coastal Research* 14, 37-46.

Moore, R. (1982). Spawning and early life history of barramundi (*Lates calcarifer*) (Bloch) in Papua New Guinea. *Australian Journal of Marine and Freshwater Research* 33: 647-61.

Prescott, F. (1989). *The management of mangrove resources in Tonga.* Unpublished M.Sc. Thesis, University of Sydney.

Saenger, P., McConchie, D. & Clark, M. (1990). Mangrove forests act as a buffer zone between anthropogenically polluted areas and the sea. In Arakel, A. V. (ed.), *Proceedings of the Coastal Zone Management Workshop*, Yeppoon, Queensland, pp. 280-299.

Scoffin, T. P., (1970). The trapping and binding of subtidal carbonate sediments by marine vegetation in Bimini lagoon, Bahamas. *Journal of Sedimentary Petrology* 40, 249-273.

Spenceley, A. P. (1982) Sedimentation patterns in a mangal on Magnetic Island, nr. Townsville, North Queensland, Australia. *Singapore Journal of Tropical Geography* 3, 100-107.

Stoddart, D.R. (1980) *Mangroves as successional stages, Inner Reefs of Northern Great Barrier Reef*. J. Biogeog ., 7, 269-284.

Stoddart, D.R., McLean, R.F., Scoffin, T.P. & Gibbs, P.E. (1978) Forty five years of change on Low Wooded Islands, Great Barrier Reef. *Phil. Trans R. Soc. London* B.284, 63-80.

Young, B. M. & Harvey, L. E. (1996) A spatial analysis of the relationship between mangrove (Avicennia marina var. australasica) physiognomy and sediment accretion in the Hauraki Plains, New Zealand *Estuarine, Coastal and Shelf Science,* 42, 231-246.

Ward, J. V. (1988). Palynology of Kosrae, Eastern Caroline Islands: recoveries from pollen rain and Holocene deposits. *Review of Palaeobotany and Palynology* 55, 247-271.

THE VALUE OF MANGROVES AND MANGROVE ECOSYSTEMS: CULTURAL AND ETHNOBIOLOGICAL IMPORTANCE[1]

Batiri Thaman[2] and Randy Thaman[3]

Introduction

For centuries mangrove ecosystems have contributed to the socio-economic and ecological wellbeing of coastal communities in Asia, Africa, Australia, the Pacific Islands, the Caribbean and South America. Mangroves are valued for the wide range of ecological services and products they provide, as well as serving as sites for human settlement and development (Hamilton and Snedaker 1984; Tomlinson 1986). Despite modernisation and development, many coastal communities throughout the world remain dependent on mangroves for their wellbeing and economic livelihood, often through non-marketed exploitation.

Coastal communities in the western Pacific, in particular, have a very high cultural and economic dependence on mangrove ecosystems and the services and products they continue to provide (Table 3). As a result of their long association with mangroves, such communities have a wealth of traditional empirical and scientific knowledge on the direct and indirect benefits of the mangrove ecosystem. Forestry products from mangroves include firewood, materials for construction, boat-building, woodcarving, tools, fishing equipment, medicines, foodstuffs, dyes, body ornamentation and a wide range of other products. Mangrove fisheries are a critical source of subsistence protein and cash income to many coastal communities. Table 3 is an attempt to list some of the more common uses and benefits of mangroves in the Pacific islands. Even if these benefits provided by mangroves could be replaced, the expense would be far too great for most Pacific island rural and urban communities that depend on mangrove ecosystems for much of their subsistence wellbeing and a proportion of their cash incomes. Table 3 also gives an indication of the incredible store of knowledge that local communities have about mangrove ecology and the ultilisation and cultural significance of mangrove resources. This knowledge must be seen as central to any programme to conserve or promote the sustainable utilisation of mangroves in the Pacific islands.

This summary paper is an attempt to stress the importance of gathering both qualitative and quantitative information on the community utilisation of mangrove ecosystems in the small island countries of the Pacific islands.

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[2] Scientific Officer, Institute of Applied Science, The University of the South Pacific, Suva, Fiji Islands.

[3] Professor of Pacific Islands Biogeography, The University of the South Pacific, Suva, Fiji Islands.

Table 3: Ecological and cultural functions of mangrove products and mangrove ecosystems to local communities in the Pacific islands.

ECOLOGICAL		
Shade	Nutrient Cycling	Water Purification
Erosion Control	Soil Improvement	Solid Waste Removal
Wind Protection / Windbreaks	Animal / Plant Habitats	Weed / Disease Control
Protection from Salt Spray	Spawning Ground	Protection from Sea-Level Rise
Flood / Runoff Control	Wild Animal Food	
CULTURAL/ECONOMIC		
Timber (commercial)	Brooms	Prop or Nurse Plants
Timber (subsistence)	Parcelisation/Wrapping	Staple foods
Fuelwood / Firewood	Abrasives / Sandpaper	Supplementary Foods
Boatbuilding (canoes)	Caulking	Wild snack / Emergency Foods
Sails	Insulation	Spices/Sauces
Tools	Decoration	DomesticatedAnimal Food
Weapons/Hunting	Body Ornamentation	Non-alcoholic Beverages
Containers	Cordage / Lashing / Rope	Alcoholic Beverages
Woodcarving	Glues / Adhesives	Stimulants
Handicrafts	Plaited Ware	Preservatives
Fishing Equipment	Fibre / Fabric	Meat Tenderiser
Floats	Dyes	Human Medicines
Toys/Playthings	Beads	Animal Medicines
Switch for Children/ Discipline	Hats	Scents/Perfumes
Brush/Paint Brush	Mats	Aphrodisiacs
Musical Instruments/Drums	Baskets	Fertility Control
Cages/Roosts	Commercial / Export Products	Abortifacients
Tannin	Ritual Exchange	Recreation
Oils	Poisons	Magico-religious
Toothbrush	Insect Repellents	Totems
Toilet Paper	Deodorants	Subjects of Mythology
Fire Making	Embalming Corpses	Sacred Sites
Sunscreen	Privacy/Meeting Sites	Illumination/Torches

Source: Adapted from Thaman and Clarke 1993.

Qualitative case studies of ethnobiological use of mangrove ecosystems

The following boxes summarise some of qualitative studies on ethnobiological use of mangroves in the Pacific islands.

Case Study - Federated States of Micronesia

In FSM mangroves are used for housepoles, fencing, posts (*Xylocarpus granatum*, *Rhizophora apiculata*, *Sonneratia alba*), handicrafts (*X. granatum*), canoes, roof thatch from the nypa palm (*Nypa fruticans*), ornaments, and medicines. Shellfish, finfish, crabs, birds, and bats are also consumed. Mangrove areas are also converted into sites for settlements (Devoe 1994).

Case Study - Tonga

In Tonga, mangroves are exploited for construction, firewood, and medicine. The major cultural use is the extraction of dye from the bark of **tongolei** (*Bruguiera gymnorrhiza*) for painting tapa (bark cloth). Medicine is prepared from the bark of lekileki (*Xylocarpus granatum*) to treat internal injuries. The flowers of **hangale** (*Lumnitzera littorea*) are used for garlands (Prescott 1989).

Case Study - Samoa

In Samoa, the main traditional use of the mangrove ecosystem is for the harvest of mangrove crabs, fish, and prawns for subsistence consumption. **Togo** (*Bruguiera gymnorrhoza*) is used for tool making, boat building and sometimes firewood. The bark, in the past, was used to extract dye for tapa making and tannins to preserve fishing nets and lines. Mangrove plants are also collected for medicine (*Bruguiera*), decorations and scenting oil. Mangrove areas also provide areas for bathing and washing (Schuster 1993).

Case Study - Vanuatu

In Vanuatu, mangroves are a source of fuelwood, building materials, fish, crabs, and shellfish. Villages situated within the mangroves on smaller islands are almost entirely dependent on mangroves for firewood and building materials. Common finfish caught include mullet, rabbitfish, and goatfish. The mangrove crab *Scylla serrata* is also commonly caught (Bani 1993).

Case Study - Papua New Guinea

In PNG, mangrove areas are used for timber (*Rhizophora, Bruguiera* and *Ceriops*), tools, thatching materials (*Nypa*), firewood, medicines, fish poison (*Derris*), food (*Bruguiera* seeds), and to harvest fisheries products and wildlife. Wildlife harvested for subsistence include birds, pigs, possums, and crocodiles. Commerical uses include tannin extract (*Rhizophora* sp.) from mangrove bark and the sale of crocodile skins. Mangrove crabs, fish, and clams are also sold. Communities also swim in mangrove areas (Rau 1984).

Case Study - Fiji

In Fiji, coastal communities are still largely dependent on mangrove areas for a wide range of subsistence and commercial forestry and fisheries products.

Forestry Products

Mangrove forests are utilised for firewood, construction materials, medicine, food, dyes, fishing equipment, and cash income. Villagers in the rural areas utilise mangrove products to a greater extent as compared to those in urban areas.

For firewood, the preferred species used is **dogo** (*Bruguiera gymnorrhiza*). Other species frequently used include **tiri wai** (*Rhizophora samoensis*)**, dabi** (*Xylocarpus granatum*)**, sagale** (*Lumnitzera littorea*)**,** and **ivi** (*Inocarpus fagifer*). Mangrove materials are still used for construction but most commonly for the construction of kitchens, toilets, or temporary sheds. Preferred species used in construction are **dogo, dabi, sagale, tiri** (*Rhizophora* spp.)**, misimisi** (*Scirpodendron ghaeri*)**, soga** (*Metroxylon* sp.)**,** and **borete** (*Acrostichum aureum*). Use of fishing gear made from mangrove materials is still widespread, particularly in the rural areas because of the increase in sales of fisheries products. Fishing gear made from mangrove materials include **dai ni mana** (mud lobster traps)**, lawasua** (crab trap)**,** and **lawa** (nets). Various other products are also made from mangrove wood, for example knife handles, boat poles, fishtrap poles or supports, clothesline poles, taro planting sticks and pig fences.

Medicines prepared from mangrove related species are still widely used by Fijian communities in both urban and rural areas. Species most widely collected are **dabi, tiri (titi)**(the aerial roots)**,** and **verevere** (*Clerodendrum inerme*)**.** Some of the medicines and the illnesses they cure are listed in Table 4.

Table 4. Common illnesses and the mangrove associated species used to cure them

Illness	Cure
Arthritis	Sinu (Excoecaria agallocha) leaves
Asthma	Verevere (Clerodendrum inerme) leaves
Cancer	Dabi (Xylocarpus granatum) bark, sagale bark
Eye infection	Dilo (Calophyllum inophyllum) leaves
Flu symptoms	Verevere leaves, dabi bark and leaves,
High blood pressure	Sagale (Lumnitzera littorea) bark
Open wounds	Wa bosucu (Mikania micrantha) leaves, vutu siriwai (Barringtonia racemosa) leaves
Pneumonia	Dabi bark and leaves
Scabies, skin diseases	Wa duva (Derris trifoliata) leaves and roots, kura (Morinda citrifolia) leaves
Sprains	Vau (Hibiscus tiliaceus) leaves
Thrush of the mouth	Titi ni tiri (Rhizophora aerial roots), tavola (Terminalia catappa) leaves, bark, and fruit

Mangrove materials are also used for cordage, the most frequently used being the **titi ni tiri, wa lai** (*Entada phasioloides*)**, wa midri** (*Stenochlaena palustris*), and **vau** bark. The utilisation of mangrove dyes and varnish is fairly uncommon now. The most common species used was **dogo** (*Bruguiera gymnorrhiza*)**.** Garlands, oil scents, decorations, toys, and handicrafts are also made from mangrove materials. In some villages food is also collected from the mangrove forest, e.g., young leaves and shoots of the ferns **wa midri** (*Stenochlaena palustris*) and **borete** (*Acrostichum aureum*). Fish poisons, mainly **wa duva**, collected from mangrove areas are used rarely now because its use is banned by the government. Spiritual uses, include the leaves of **sinu, vasa, vesi wai,** and **vulokaka** to scare away evil spirits.

Fisheries Products - Fiji

A range of mangrove-related species including molluscs, crabs, prawns, and 70 species of finfish are commonly caught for subsistence or to sell at local markets (Lal *et al* .1983).

Commonly caught crabs in Fiji are **qari** (*Scylla serrata*)**, kuka** (*Metapograpsus messor* and *Sesarma erythrodactyla*) and **lairo** (*Cardisoma carnifex***)** which are caught using crab nets or hand collected. These three species are also commonly sold. Commonly caught prawns are **ura** (*Macrobrachium lar*), **moci** (*Palaemon concinnus*) and **kadikadi** (*Macrobrachium equidens*)**.** These species are also sold. Mangrove lobster, **mana** (*Thalassina anomala*), is also caught in the mangroves using snares or by hand and sold. Commonly collected shellfish include **dio** (*Crassostrea mordax*)**, sici ni veidogo** (*Littorina scabra*)**, drivi** (*Vulsella vulsella*)**, kuku** (*Modiolus agrapetus*)**,** and **civaciva** (*Pinctada martensi*) . These are very rarely sold and used only for subsistence. Commonly caught finfish are **qitawa** (*Therapon jarbua*)**, ki** (*Upeneus vittatus*)**, kaikai** (*Leiognathus equulus*)**, kake** (*Lutjanus eherenbergi*)**, matu** (*Gerres macrosoma*)**, damu** (*Lutjanus argentimaculatus*)**, kurukoto** (*Eleotris melanosoma*)**, kawakawa** (*Epinephelus dameli*)**, nuqa** (*Siganus vermiculatus*)**, kabatia** (*Lethrinus harak*)**, kanace** (*Valamugil seheli*)**,** and **molisa** (*Liza melinoptera*). In the rural communities many households sold fish but in urban areas they are often consumed by the household or given away. Some fish species are also used as fish bait. Sharks, rays, sea cucumbers, and eels are also found in mangrove creeks. Most mangrove-associated fisheries apart from mangrove lobsters and eels are collected by women.

Other products obtained from mangrove areas include honey, flying fox, duck, mongoose, wild pigs, and coconut longhorn beetles.

A Pacific-wide study of the ethnobotany of Pacific island coastal plants shows the frequency of usage for specified purposes of the 140 plant species commonly found among Pacific island coastal and mangrove vegetation associations (Table 5). Over half of these species are either true mangroves or mangrove associates. The analysis in Table 5 shows that there are some 75 different purpose/use categories for these coastal plants, with the total frequency of usage for 140 plants being 1024, ranging from no reported uses for only two species to as many as 125 for the coconut (Cocos nucifera) if distinct uses within categories (e.g., tools with distinct functions or medicines that treat different illnesses or injuries) are counted.

Table 5: Frequency of the usage for specified purposes of 140 widespread Pacific island coastal and mangrove plant species.

Purpose / Use	Ferns x/10	Herbs x/17	Grasses /Sedges x/11	Vines/ Lianas x/14	Shrubs x/26	Trees x/62	Total x/140
Medicinal / Health	6	15	7	11	23	51	113
General Construction	-	-	-	-	6	54	60
Body Ornamentation	6	8	3	7	12	26	62
Firewood / Fuel	-	-	-	-	8	43	51
Ceremony / Ritual	3	4	-	5	6	23	41
Cultivated / Ornamental	4	3	-	2	10	20	39
Tools/Toolmaking	-	-	-	-	4	33	37
Emergency / Famine Foods	4	5	2	2	4	18	35
Boat / Canoe Building	-	-	1	-	3	30	34
Dyes / Pigments	-	-	-	2	4	24	30
Magic / Sorcery	1	6	1	1	6	14	29
Fishing Equipment	-	1	2	-	8	17	28
Cordage / Fibre	2	2	2	6	3	10	25
Games / Toys	-	-	1	4	4	16	25
Supplementary Foods	2	2	-	2	3	14	23
Scenting Oil / Perfumery	1	1	1	1	6	11	21
Fertiliser / Mulching	1	2	2	1	4	11	21
Weapons / Traps	-	-	-	-	6	14	20
Woodcarving	-	-	-	-	1	18	19
Food Parcelisation	3	1	-	3	1	11	19
Animal Feed	1	4	-	3	2	9	19
Legends / Mythology	-	-	-	-	3	15	18
Handicrafts	1	1	3	2	1	9	17
Clothing	-	1	3	-	1	9	14
Musical Instruments	-	-	-	-	1	13	14
Cooking Equipment	-	-	-	-	1	12	13
Fish Poisons	-	-	-	3	4	4	11
Export / Local Sale	-	1	-	-	2	8	11
Adhesive/Caulking	-	1	-	1	-	9	11
Fire by Friction	-	-	-	-	1	8	9
Soap/Shampoo	-	1	-	3	3	2	9
Containers	-	-	-	-	1	7	8
Repellents/Fumigants	-	-	-	-	2	6	8

Table 5 (Continued): Frequency of the usage for specified purposes of 140 widespread Pacific island coastal and mangrove plant species.

Purpose / Use	Ferns x/10	Herbs x/17	Grasses /Sedges x/11	Vines/ Lianas x/14	Shrubs x/26	Trees x/62	Total x/140
Wild Animal Foods	-	-	-	-	3	5	8
Tannin/Preservatives	-	-	-	-	1	6	7
Antitoxins	-	1	-	1	1	4	7
Living Fences/Hedges	-	1	-	-	1	5	7
Staple Foods	-	1	-	-	-	5	6
Drinks/Beverage	-	1	-	2	1	1	5
Strainers/Filters	-	-	2	-	-	3	5
Toilet Paper	-	-	-	-	1	4	5
Land Reclamation	-	-	-	-	-	5	5
Calendars/Clocks	-	-	-	-	-	5	5
Contraceptives/Abortifacients	-	-	-	-	3	2	5
Thatching/Roofing	-	-	-	-	1	3	4
Illumination	-	-	-	-	-	4	4
Combs	-	-	-	-	-	4	4
Animal Cages/Roosts	-	-	-	-	-	4	4
Oils/Lubricants	-	-	-	-	-	3	3
Brushes	-	-	-	-	-	3	3
Fans	-	-	-	-	-	3	3
Corks	-	-	-	-	-	3	3
Fishing bait	-	-	-	-	-	3	3
Other Uses*	-	-	2	-	5	27	34
TOTAL	35	63	32	62	161	671	1024
NO USES	-	1	1	-	-	-	2

* Other uses include stimulants/teas, flavouring/spices, ear cleaners, splints, aphrodisiacs, hair remover, masticants/chewing gum, abrasives, tooth brushes, cigarette wrappers, coconut climbing bandages or harnesses, measuring tapes, fireworks, windbreaks, sand screens, ladders, walking sticks, tethering posts, punishment/torture, communication/language, and computation or counting.

In terms of specific uses, the most widely reported uses were for medicine, general construction, body ornamentation, fuelwood, ceremony and ritual, cultivated or ornamental plants, toolmaking, food, boat or canoe making, dyes or pigments, magic and sorcery, fishing equipment, cordage and fibre, games or toys, perfumes and scenting coconut oil, fertilizer and mulching, woodcarving, weapons or traps, food parcelisation, subjects of legends, mythology, songs, riddles, and proverbs, domesticated and wild animal feed, handicrafts, cooking equipment, clothing, fish poisons, items for export of local sale, adhesives or caulking, and musical instruments, all of which were reported for at least eleven species (Table 5). The analysis, however, is based on traditional uses, many of which, as stressed below, have lapsed or are only employed in emergency, because modern technology has pre-empted them or the younger generation has lost the traditional knowledge associated with their value or use.

The most useful mangrove associated species, all with seven or more reported uses, are listed in Table 6. There is some usage overlap between categories, such as supplementary and emergency foods and medicinal plants, magical, ceremonial and body ornamentation plants, or plants used for handicrafts, woodcarving, cordage, and clothing. Moreover, the list does not include the more

strictly ecological functions of coastal plants, such as shade, protection from wind, sand and salt spray, erosion and flood control, coastal reclamation, animal and plant habitats, and soil improvement, all of importance to Pacific societies.

Table 6: Mangrove and mangrove associated species (with Fijian vernacular names) of particular cultural utility based on an analysis of the uses of 140 widespread coastal littoral and mangrove species (Note: not including a wide range of ecological functions or uses).

Scientific Name	Fijian Name	Uses
Cocos nucifera	niu	125
Hibiscus tiliaceus	vau	57
Pandanus tectorius	vadra	53
Calophyllum inophyllum	dilo	43
Cordia subcordata	nawanawa	40
Scaevola taccada	vevedu, dredre	32
Pemphis acidula	gie	30
Thespesia populnea	mulomulo, wiriwiri	26
Rhizophora spp.	tiri	25
Tournefortia argentea	roro ni bebe, kau ni yalewa, evo	23
Premna serratifolia	yaro, araro	22
Morinda citrifolia	kura	22
Terminalia catappa	tavola, tivi	21
Ficus tinctoria	mati, baka	21
Erythrina variegata	drala, rara	19
Inocarpus fagifer	ivi	18
Lumnitzera littorea	sagale	17
Bruguiera gymnorrhiza	dogo, lailai	16
Nipa fruticans	-	14
Barringtonia asiatica	vutu, vutu rakaraka	14
Mammea odorata	vetau,	14
Intsia bijuga	vesi, vehi	13
Vitex spp.	dralakaka, vulokaka, mulokaka	11
Entada phasioloides	walai, watiqiri	10
Cerbera manghas	vasa, rewa	10
Clerodendrum inerme	verevere, aria	10
Cassytha filiformis	walutumailagi, wa lawa	10
Polypodium scolopendria	vativati	8
Metroxylon spp.	soga	7
Ipomoea pes-caprae	wavere, lawere	7

These few examples from the analysis of the utility of the plants of Pacific island coastal and mangrove ecosystems shows the cultural sophistication and storehouse of empirical knowledge possessed by Pacific island societies in relation to their mangrove resources. The depth of this knowledge becomes almost incomprehensible to the ordinary urban planner, economist or scientist who has lost touch with the natural world and subsistence living systems. In short, the term mangrove "biodiversity" for the communities who depend on it and know it, particularly rural Pacific island peoples with only limited opportunities for generation of cash incomes, takes on immense meaning. However, the economic, cultural and ecological value of biodiversity is rarely acknowledged in development plans, project documents, or aid proposals, despite the fact that the products and benefits provided by it would be, as suggested above, extremely expensive or impossible to replace with imported substitutes.

Qualitative studies such as these provide detailed information about the utilisation of mangrove products, and useful information about communities dependent on mangrove areas. However, information on the quantities of products obtained and how frequently they are harvested are usually not obtained.

Quantitative case studies on the value of mangrove ecosystems

Quantification of community utilisation of mangrove products permits the levels of exploitation to be estimated, the dependency of communities on mangrove resources to be determined, and economic valuation of mangrove products to be carried out. A limitation is that detailed information on the cultural aspects of community utilisation is often not documented. Few quantitative studies on the utilisation of mangrove products have been carried out in the Pacific islands. Two of these are summarised in the box below.

Eley (1988) surveyed 27 women in PNG, and concluded that the mean volume of wood used in a day's cooking was 0.44 cubic feet per day, or approximately 350.4 cubic feet (99.32 cubic metres) of wood per year per family.

Lal (1990 in Devoe 1994) estimated that 105 cubic metres of mangrove wood were consumed per year for cooking in underground ovens on Kosrae, Federated States of Micronesia.

Valuation of cultural/community use of mangroves

The valuation of mangrove benefits is extremely important for decision-making in mangrove management. Environmental valuation involves estimating monetary values for resources and is a link between economic and ecological analyses in considering sustainable development (Thurairaja 1996). Barbier (1994) identifies three main benefits derived from mangrove ecosystems: direct uses, indirect uses and non-use. Direct uses include both commercial and non-commercial consumptive uses, for example the harvesting of timber and fisheries products (including subsistence uses) and non-consumptive uses such as recreation.

Although it is difficult to value subsistence use of mangrove products to communities because some do not have a market value, its valuation is critical in determining the true (cash + non-cash) economic value of the ecosystem in developing countries where this benefit is still widespread (Barbier 1993). Cultural values of mangroves are also difficult to value and thus are often ignored (Paw and Chua 1991).

Most of the literature deals almost exclusively with the valuation of the commercial uses of mangroves and to a lesser extent with the social value of mangroves, for example for recreation. However, little work has been done to determine the subsistence value (in money terms) and the cultural significance of mangroves to local communities (Hamilton and Snedaker 1984). This may be a result of the lack of a systematic methodology for valuing some of the products or because of the declining value of subsistence utilisation of mangrove ecosystems in some countries. Additionally, a continued reliance on a purely conventional economic analysis does not adequately assess the diverse benefits provided by mangroves and may result in their true value being underestimated (Watling 1985). In some cases the documentation of the extent of use may be the only option where an economic analysis cannot be carried out (Barbier 1994).

Value of community use in Fiji

An attempt has been made to determine the economic value of mangrove products to five communities in Fiji using market prices or substitute prices minus the gathering costs. The total value of all mangrove products used per week per household was then calculated (Table 7). All values are in Fijian dollars as of January 1998.

Table 7: Minimum, maximum, and mean total value for all mangrove products per household per week.

Village	Number of households	Minimum ($)	Maximum ($)	Mean ($)	Standard deviation ($)
Kinoya	20	1.88	190.69	50.29	48.57
Tamavua-i-Wai	20	0.01	121.41	30.65	36.24
Daku	20	10.76	359.59	192.17	97.22
Nadoria	19	0	243.27	115.03	72.18
Sawa	18	55	387.97	222.08	93.86
Urban villages	40	0.01	190.69	40.47	43.45
Rural villages	57	0	387.97	175.9	97.95
All villages	97	0	387.97	120.06	104.18

The average value for a household was then extrapolated to yield estimates of the average value of mangrove products to a village (Table 8). This study indicates that mangroves are indeed important to these communities, but particularly to rural communities associated with mangroves.

Table 8: Total economic value of mangrove products to each community per week.

Village	Number of households	Mean value of mangrove products per household per week ($)	Total economic value of mangrove products to each community per week ($)
Kinoya	65	50.29	3268
Tamavua-i-Wai	40	30.65	1226
Daku	48	192.17	9224
Nadoria	34	115.03	3911
Sawa	18	222.08	3997
Mean			4325

Change over time of community utilisation of mangrove products

The exploitation of mangrove products has intensified in some areas, for example where population densities have increased. Increasing pressure is put on mangroves for fuelwood and subsistence food production, and due to the increasing commercialisation of, and expanded urban market for, high-value products, such as crabs, prawns, and mangrove lobsters. However, in many areas, many uses of mangroves are decreasing. Factors that contribute to the diminishing importance of subsistence use include the decreasing demand for mangrove products such as mangrove firewood, materials for construction, tools, boats, fishing equipment, and medicines due to readily available substitutes, an increasing availability of wage employment, less time to collect, declining abundance of some species, and, in urban areas and among the younger generation, due to a loss of traditional knowledge in the preparation and use of certain products.

Significance of information on traditional use to mangrove management

Detailed studies of the traditional utilisation of mangroves can contribute to sustainable mangrove management through the:

1. Valuation of the Resource: Detailed information on the subsistence and commercial value of mangroves to indigenous communities can provide an economic basis for improved management

of mangrove resources through ensuring sustainable utilisation and protection of the current state of "subsistence affluence" (Fisk 1972). Mangrove ecosystems of traditional importance could then be better protected from threats such as overexploitation, pollution, reclamation and excessive commercial exploitation. Such information could also assist in determining the level of compensation owing to local communities that hold customary fishing rights to mangrove areas targeted for alternative development. The assessment of the social impacts of proposed mangrove development projects on local communities is another application of such information (Johnson 1992).

2. Assessment of the Resource: This information is important for determining if community use of certain mangrove resources could adversely affect the future sustainability of utilisation of a mangrove area.

3. Mangrove Management Plans and Policies: Quantitative and qualitative information on the use of mangrove resources can also be applied to the development of management plans and environmental legislation to insure that they are compatible with local usage and customs. This would make management plans and legislation more relevant to local situations and practices, and thus more effective in protecting the resource (Ruddle and Johannes 1985; Fong 1994).

4. Documentation of Traditional Knowledge: Documentation of subsistence resource-use strategies is, in itself, a means of documenting and preserving invaluable traditional cultural knowledge which is rapidly disappearing as a result of modern education, economic development, and the passing away of the few older people who currently serve as the last remaining repositories of in-depth traditional knowledge (Johannes 1989).

Conclusion

Qualitative and quantitative studies on the use of mangrove resources by local rural and urban communities and the valuation of these services and uses can help to provide better insight into the current importance of mangrove ecosystems to user communities and to the nation. This could then enable planners and decision-makers, including leaders at the community level, to have a better appreciation of the true economic and cultural value of mangroves to local indigenous communities and thus promote a more culturally and ecologically sustainable strategy for the use of mangrove ecosystems in the future.

References

Barbier, E.B., (1993). Sustainable use of wetlands. Valuing tropical wetland benefits: Economic methodologies and applications. *The Geographic Journal* 159 (1):22-32.

Barbier, E.B., (1994). Valuing environmental functions: Tropical wetlands. *Land economics* 70 (2):155-173.

Devoe, N. (1994). Mangrove exploitation and conservation in the Federated States of Micronesia. *ISLA: A journal of Micronesian studies* 2 (1):67-82.

Eley, T.J., (1988). *Hunters of the reefs: The marine geography of the Kiwai, Papua New Guinea*. Phd dissertation, University of California, Berkeley.

Fisk, F.K., (1972). Motivation and modernization. *Pacific Perspectives*. 1 (1):21-33.

Fong, G., (1994). Case study of a traditional marine management system: Sasa Village, Macuata Province, Fiji. *FAO Field Report* RAS/92/105 No. 94/1. Rome, FAO.

Hamilton, L.S. & Snedaker, S.C. (eds.). (1984). *Handbook for mangrove area management*. UNEP and East-West Centre Environment and Policy Institute, Honolulu.

Johannes, R. (1989). Traditional ecological knowledge: A collection of essays. Introduction. In Johannes, R. *Traditional ecological knowledge: A collection of essays*. ICUN The World Conservation Union , Gland, Switzerland.

Johnson, M. (1992). Research on traditional knowledge: Its development and its role. In Johnson, M. (ed.). *Lore: Capturing traditional environmental knowledge*. International Development Research Centre (IDRC), Ottawa. Pp3-27.

Paw, J.N. & Chua, T.E. (1991). *An assessment of the ecological and economic impact of mangrove conversion in South-east Asia*. In L.M. Chou, T.E. Chua, H.W. Khoo, P.E. Lim, Paw, J., Silvestre, G., Valencia, M., White, A. & P.K. Wong (eds.) *Towards an integrated management of coastal resources. ICLARM Conference Proceedings 22.* National University of Singapore, Singapore; National Science and Technology Board, Singapore; International Centre for Living Aquatic Resource Management, Manila, Philippines. Pp 201-212.

Prescott, F., (1989). *The management of mangrove resources in Tonga.* A thesis submitted in partial fulfillment of the Degree of Masters of Arts, University of Sydney, Sydney.

Rau, M., (1984). Traditional uses of mangroves in Central Province. In Morton, J.R., Aisi, G, Brough, E. & Salter-Duke, B. (eds.), *The role of science and technology in the development of Papua New Guinea: The policy dimensions. 1984 Waigani Seminar, September 2-7, University of Papua New Guinea, Waigani. Background papers*. Vol. 2. University of Papua New Guinea, Waigani, Port Moresby. Pp. 20-28.

Ruddle, K. & Johannes, R.E. (eds.) (1985). *The traditional knowledge and management of coastal systems in Asia and the Pacific.* UNESCO, Jakarta.

Soepadmo, E., (1987). Towards compatible Use of the Mangroves. In Field, C.D. and Dartnell, A.J. (eds) *Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management*, Proceedings of the Research for Development, Seminar held at the Australian Institute of Marine Science, Townsville, Australia, pp170 – 182.

Thaman, B., (1998). *Community utilisation and valuation of mangrove resources in Fiji*. MSc Thesis. James Cook University of North Queensland.

Thaman, R., (1992). Batiri kei Baravi*: The ethnobotany of Pacific Island coastal plants*. Atoll Research Bulletin No. 361.

Thaman, R. & Clarke, W.C. (1993). Pacific Island agroforestry: Functional and utilitarian diversity. In Clarke, W.C. and Thaman, R. (eds.). *Agroforestry in the Pacific Islands: Systems for Sustainability*. United Nations University Press, Tokyo.

Tomlinson, P., (1986). *The botany of mangroves*. Cambridge University Press, Cambridge.

Watling, D., (1985). *A mangrove management plan for Fiji (Phase 1).* South Pacific Commission and Fiji Government.

MANGROVE /FISHERIES CONNECTIONS IN TROPICAL AUSTRALIA

Anne Clarke, Queensland Fisheries Service, Australia

Introduction

In this paper I discuss the value of mangrove areas to fisheries in tropical and subtropical areas. The life cycle connections between targeted fish species and mangrove areas, in particular, will be highlighted, stressing the importance of mangrove areas not just to fish traditionally associated with mangroves but for some fish species usually caught further offshore.

Fisheries management has traditionally meant looking at resource extraction - at fishing itself i.e. setting limits to sizes, catch size, seasons, number of boats/licenses etc. In Queensland, Australia, fisheries management is approached in several ways.[1] Not only is fisheries resource extraction managed but also the actual areas of fisheries resource production i.e. fisheries habitat. This management approach can be reduced down to 'input' and 'output' controls.

The importance of habitat to fisheries productivity has been formally recognised in Queensland, at least since the first fisheries legislation in 1914 when mangroves were given statutory protection as their timber was being used to collect oyster spat for culture purposes. The key underlying tenet of fish habitat management is that if there is no fish habitat there is no fish. An entire section of the Queensland Fisheries Service (19.3 FTES) and specific provisions of the fisheries legislation (the *Fisheries Act 1994*) are now devoted to fisheries habitat management.

The basic components of fish habitat are;

- Good quality water,
- Food/nutrients for the fish, the plants and other animals; and
- The plants and substrates such as mudflats, sand bars and rocky foreshores that provide the actual structure within which the fish move, shelter and access food resources.

Each of these is an important component of the fish habitat system. In this paper I focus on the last component of fish habitat - the role of mangroves within the greater habitat system.

Mangrove habitat functions

The role of mangroves in primary productivity.

Mangroves and associated marine areas are among the most naturally productive in terms of primary productivity in the world (Harrison, 1967). The nutrients provided by mangrove vegetation form the basis of the food chain. Small organisms break down this vegetation. Larval fish and crustaceans feed upon those organisms, which in turn become prey for larger fish, birds and marine mammals.

The seeds (propagules) and leaves of the mangroves provide food for crabs. Crabs, most often sesarmid crabs, drag the seeds and other vegetative matter into their extensive holes. The activity of the crabs is vital to the functioning of the mangrove complexes as they are largely responsible for the constant turning of the marine soils - bringing deep soils to the surface and "ploughing" organic matter into the mangrove mud. Most [80 per cent] seed and leaf litter is recycled by crabs within successive high tides.

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[1] The Queensland Fisheries Service also has carriage of research and management of aquaculture and restocking into natural environments and artificial impoundments

Apart from their vital role influencing the functioning of mangrove ecosystems, sesarmid crabs constitute a key component of the extensive intertidal food chain that forms the diet of larger fish and birds. Research has indicated that sesarmid crabs are not only vital in incorporating nutrients into the marine substrates but act also as the main food of targeted fish species e.g. *Lutjanus argentimaculatus* (snapper), *Epinephelus coioides* and *E. malabaricus* (groupers) effectively short circuiting the food chain. It appears, now, after studying the gut contents of these fish, that a substantial part of the mangrove productivity sequestered by sesarmid crabs may be exported from mangrove ecosystems as a result of subsequent offshore migration of these fishes (Sheaves and Maloney, 2000) when as adults they move to reef areas on spawning runs.

The role of mangroves as structure for fisheries

Another valuable role that mangroves perform is providing the physical structure within which fish and other marine plants can carry out their life cycle functions.

Small fish, juvenile fish and larval fish utilise the shelter from predators that mangrove roots afford, as larger fish cannot always access the shallower waters. Larval and juvenile fish also feed upon the micro-organisms, algae and molluscs associated with mangrove roots or the mud around their base.

Mangrove roots can also provide the perfect hide for ambush predators such as some lutjanids and barramundi that sit and wait for prey in them.

The role of mangroves as stabilisers and buffers for fisheries

Mangroves not only provide a three dimensional matrix within which fisheries species carry out specific functions - they themselves function to maintain the conditions to support fisheries productivity.

One of these functions is to absorb land-sourced nutrients and fine sediments. Mangroves are great scavengers of nitrogen and phosphorous (Clough *et al* 1983). Increased farming and other developments along the coast has led to a sharp increase in the presence of these nutrients through the use of fertilisers and soil disturbance. Excess nutrients and sediments are carried in stormwater into streams, rivers and estuaries. Offshore from mangrove areas are usually reefs. The reef environment is relatively nutrient poor. Corals, however, have evolved in this environment. If excess nutrients find their way out to the reef, nutrient loving algaes can outcompete and eventually smother corals (Gilmour, 1999), particularly if herbivorous fish are being removed. An established coastal mangrove community can help reduce this risk.

Mangroves can also physically trap and hold terrestrial sediments. Sediment laden stormwaters moving through mangrove areas slow as they spread through the channels and roots systems. As these waters slow suspended solids settle. Mangrove roots “grab” sediments and nutrients to stabilise and extend the coastal delta areas in which they occur.

Mangrove sediments also have the ability to sequester heavy metals, radioactive isotopes and other poisonous chemicals in their anaerobic muds (Lugo and Brinson, 1978; Saenger and McConchie, 1990) as well as buffering landward areas from the impacts from cyclones, storm surges and floods.

An added stabilising benefit from mangroves is regulating water temperatures, especially along mangrove lined waterways. Overhanging mangrove branches shade the water, thereby maintaining favourable conditions for fish by lowering water temperatures and increasing saturation levels of oxygen.

Specific mangrove fisheries connections

In Australia, around 75 per cent of the targeted fish species utilise estuarine areas for at least some part of their life cycle (Blamey, 1996). In peninsula Malaysia, about 32 per cent of the total fisheries landings consists of species directly dependent on mangrove ecosystems (Soepadmo, 1985).

Mangroves at low tide reveal the above ground roots used by fish for shelter and predation. Mud banks at their base provide ideal crab and mollusc habitats.

Fish species commonly associated with mangroves

Fish species commonly associated with mangrove areas include;

- Mullet e.g. family Mugilidae, including the species *Mugil cephalus*,
- Herrings e.g. families Clupeidea/Chanidae, including boney bream (*Anodontostoma chacunda)*, milkfish (*Chanos chanos)* and the "mangrove sardine" (*Kerklotsichthys quadrimaculatus)*,
- Bream e.g. family Sparidae, including *Acanthopagrus spp*.,
- Mussels and oysters and;
- Mudcrabs e.g. family Portumidae, including species S*cylla serrata*.

Mullets and herrings are often targeted as food and as bait. Bream are a key target species for recreational and commercial fishers. Mussels and oysters as well as mud crabs form prey for other fish as well as being targeted for human consumption.

Mackerel and mangroves

Spanish mackerel *(Scomberomorus commerson)* are often caught through trolling offshore. This species, however, is reliant on mangrove areas for the early stages of its life cycle. Adult mackerel spawn offshore at about two years or more. The pelagic eggs hatch and travel in the plankton as larvae inshore. Mackerel juveniles of less than 10 centimetres are found in shallow inshore waters of high turbidity. These habitats can be of lower salinity and presumably higher productivity as well as greater shelter (Mc Phersen, 1988). At this stage these juveniles are feeding on small prawns and herrings. At about 15 - 40 centimtres (cm) the juveniles move into more open water habitats to feed on pelagic forage fish before maturity.

Barramundi (*Lates calcarifer*) and mangroves

Another very well known targeted fish species (at least in northern Australia, New Guinea and the Solomons) is the barramundi (*Lates calcarifer).* Barramundi spawn on the tidal flats. The larval fish drift into the mangroves and will stay in this habitat until they reach about 10 centimetres (cm). During the wet season, when waterways are in flood, juveniles move upstream into freshwater habitats. Here barramundi find reasonable refuge, usually a freshwater hole, and settle in for the dry season - eating any other fish, including each other, that might also be in residence. Barramundi juveniles spend at least two to three years in freshwater before moving out of the their freshwater shelters to enter the fishery at 58cm (Russell *et al* 1985).

Lutjanids and mangroves

The commonly targeted lutjanid *Lutjanus argentimaculatus* may travel significant distances during their life cycle. The adults "broadcast" spawn at offshore reefs between October and March (Southern Hemisphere wet season). The pelagic eggs hatch and drift as larvae in the plankton. At about 16 to 20 millimetres (mm) they move into the mangrove habitats. Gut content analysis has shown that juveniles eat crabs, bivalves and small fish such as empire gudgeon larvae (Sheaves *et al*, 2000). A significant proportion of these juveniles will move up stream into the freshwater areas (much like the barramundi). This species has been found as far as 125 km inland. These lutjanids will move out of these juvenile habitats at >400 millimetres (mm) (four to six yrs old) at the onset of maturity.

Other species of lutjanids also utilise the mangrove habitats for their juvenile stages; for example the fingermark (*Lutjanis johnii*).

Spangled emperor (*Lethrinus nebulosus*) and mangroves

This member of the "emperor" family is yet another commonly targeted species utilising mangrove areas. The spangled emperor is typically associated with inshore seagrass and mangrove habitats. The juveniles of this species typically feed on bivalves. All age classes of this species show a preference for soft bottoms for food intake with a daily migration from resting habitats (mangroves) to feeding grounds (seagrass beds) (Egretaud, 1992).

Mud crab (*Scylla serrata)* and mangroves

The common mud crab life cycle involves moving offshore to spawn. Larval crabs make their way back towards shore. Juveniles grow to maturity in mangrove areas (Brown, 1993).

Prawns and mangroves

Other crustaceans that require mangrove areas as part of their life cycle are some members of the prawn family. One of the main commercially targeted prawn species in northern Australia doing so is the banana prawn (*Penaeus merguiensis*). Banana prawn adults move offshore to spawn forming huge "boils" of animals that prawn fishers identify and target with their nets. The larvae move into the plankton and settle out in mangrove habitats to grow into juveniles (Haywood et al.,1993).

Painted crayfish (*Panulirus ornatus)* and mangroves

This is a fishery that one usually wouldn't associate with estuarine areas - the painted crayfish. There are several species in this genus. *Panulirus ornatus* is the most commonly targeted in Australia. After hatching offshore in summer, the larval crayfish move towards the estuarine areas and settle out (Dennis *et al* 1997). Juveniles are found in algae growing over wood in turbid water (eg. from the bottom of boats in marinas, off boat piles and oyster aquaculture furniture) adjacent to mangrove habitats (*pers comm* Linton, 2001).

Commercial fisheries and other values of mangroves

The figures attached as Appendix 1 have been compiled for commercial fish species reliant on estuarine areas. These figures do not however take into account the many other essential functions that mangrove areas provide to the human race. These include the following qualitative values:

ORGANIC PRODUCTIVITY

- high primary productivity,
- high secondary productivity (e.g. commercial and sports fisheries),
- high export of nutrients and;
- high wood production.

BIOTIC VALUES

- serve as fisheries nurseries, bird rookeries and refugia for terrestrial animals and
- gene banks for haline and euryhaline plant and animal species

WATER

- stores flood waters

BIOGEOCHEMICAL VALUES

- high capacity to recycle nutrients
- high storage of organic matter and CO_2 sink
- net oxygen production
- many biochemical cycles are closed by reducing N,C,S,Fe etc in anaerobic muds

GEOMORPHOLOGICAL VALUES

- high potential for erosion control
- protection of coastlines against storms, tides and winds
- high potential as land builders

OTHER VALUES

- natural laboratories for teaching
- importance as natural and cultural heritage

(adapted from Lugo et al 1978)

Costanza et al (1997) has calculated the value of mangrove wetlands viewing these functions as "services". He states that a hectare of mangroves is worth US$9,900 per year not just in fish production but also nutrient recycling, carbon sinking, coastal protection etc. This value compares with those annual values/ha for sea grasses (US$19,000), for swamps/floodplains (US$19,580), for estuaries (US$22,800), for wetlands (US$14,800) and for coral reefs (US$6,100). Given the key links between different tidal and wetland habitats and the frequent migrations fish undertake between these habitats, management of mangroves ensures maintenance of these links.

Management of mangroves

Mangrove habitat management is essential to the sustainability of many fisheries for a variety of reasons. Management includes protecting these habitats from anthropogenic impacts. The impacts of coastal development on mangrove habitats and the fisheries they sustain can be minimised by:

(1) putting aside important spawning and nursery habitats as Marine Protected Areas;

(2) ensuring adequate riparian buffer zones between coastal development and intertidal fish habitats;

(3) preventing unnecessary impacts through legislative controls and rigorous environmental impact assessments; and

(4) restoring or replacing coastal wetlands wherever possible - perhaps as offsets to developments on a case by case basis.

The message at the end of the day is that if we wish our fish stocks to be sustainable both for this generation and future generations - it is important that the habitat upon which fisheries species rely, is also managed sustainably.

References

Blamey, R., (1996). *Economics and evaluation of coastal wetlands* Fisheries Division Information Series, Department of Primary Industries, Brisbane Queensland.

Brown, I., (1993). Mangrove Crabs In *Nearshore Marine Resources of the South Pacific*. Ed Wright, A., & Mill, L. pp 609 – 642.

Clough B. F., Boto K. G., & Attwill, P. M. (1983). Mangroves and sewage: a re-evaluation In *Biology and Ecolgy of Mangroves* Ed H.J Teas Dr W. Junk Publishers. The Hague pp 151-161.

Costanza R., (1997). The value of the world's ecosystem services and natural capital. In *Nature* Vol 381 pp253 260.

Dennis, D.M., Skewes, T. D. & Pitcher, C. R., (1997). Habitat use and growth of juvenile rock lobsters, Panulirus ornatus In *Marine Freshwater Research*, CSIRO Cleveland Australia pp 663 – 670.

Egretaud, C., (1992). Study of the major biological traits of Lethrinus nebulosus especially its diet in Ouvea Lagoon (New Caledonia*)* In *Mem. Stage Sci. Mer. Biol. Mar. Noumea*. Publisher: Orstom, Noumea .

Gilmour, J., (1999). Experimental investigation into the effects of suspended sediment on fertilisation, larval survival and recruitment in a scleractinian coral *Marine Biology*, 1 35:451 – 465.

Harrison, G., (1967). Conservation of the marine life of mangrove swamps, estuaries and coastal streams In *Caring for Queensland, Australian Conservation Foundation*, 27 – 30.

Haywood, M.D.E. & Staples, D.J., (1999) Field estimates of growth and mortality of juvenile banana prawns (Penaeus merguiensis). In *Marine Biology.* Berlin, Heidelberg [MAR. BIOL.], vol. 116, no. 3, pp. 407-416, 1993.

Linton, L, (2001). Personal communication regarding professional experience in the collection of juvenile painted crayfish for aquaculture research purposes. Queensland Department of Primary Industries (Fisheries), Cairns, Australia.

Lugo, A.E. & Brinson, M.M., (1978) Calculations of the Value of Salt Water Wetlands', Greeson, P.E., Clark, J.R., & Clark, J.E., *Wetlands Functions and Values: The State of Our Understanding*, American Water Resources Association, Minnesota.

McPherson, G., (1988). Proceedings of *SPC Workshop on inshore fisheries resources* Noumea, New Caledonia South Pacific Commission 15-25 March p11 18.

Russell, D. J. & Garrett, R. N. (1985). Early life history of barramundi, Lates calcarifer (Bloch), in north-eastern Queensland Australian In *Journal of Marine and Freshwater Research* **36,** 191-201.

Saenger, P. & McConchie, D. (1990) *Heavy metal distribution in urban mangrove ecosystems*. Paper presented at Queensland University 28/11/90, 38pp.

Sheaves M. & Molony B. (2000). Short Circuit in the mangrove food chain In *Marine Ecology Series - Marine Ecological Program Service* Vol 199, pp 97 – 109.

Soepadmo, E, (1985). Towards compatible Use of the Mangroves, Field, C.D. and Dartnell, A.J. (eds) *Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management*, Proceedings of the Research for Development, Seminar held at the Australian Institute of Marine Science, Townsville, Australia, pp170 – 182.

APPENDIX 1: Economic value ($US) of Pacific commercial fisheries reliant on estuarine systems

			1998 M/T	1998 GVP US$
American Samoa	Snapper, Jobfishes	Lutjanidae	4	12,720
	Emperors	Lethrinidae	0	0
	Carangids	Carangidae	1	1,590
	Tuna Like Fishes	Scombroidei	330	612,150
TOTAL				626,460
Australia	Barramundi	Centropomidae	17000	6,700,000
	Snapper, Jobfishes	Lutjanidae	1431	4,550,580
	Clupeoids	Clupeoidei	7959	10,545,675
	Narrowed Bar Sp Mac	Scomberomorus	1635	4,332,750
	Seerfishes	Scomberomorus	666	1,235,430
	Tuna Like Fishes	Scombroidei	11	20,405
	Mackerel like	Scombroidei	649	1,203,895
	Blue Swimming Crab	Portunus pelagicus	6009	15,923,850
	Banana Prawn	Penaeus merguiensis	3711	23,601,960
	Giant Tiger Prawn	Penaeus monodon	3650	23,214,000
	Western King Prawn	Penaeus latisulcatus	105	667,800
	Penaeus Shrimp	Penaeus	17082	108,641,520
TOTAL				200,637,865
Fiji Islands	Snapper, Jobfishes	Lutjanidae	1155	3,672,900
	Emperors	Lethrinidae	1731	5,504,580
	Narrowed Bar Sp Mac	Scomberomorus	1455	3,855,750
	Marine Crabs	Brachyura	255	675,750
TOTAL				13,708,980
Guam	Snapper, Jobfishes	Lutjanidae	3	9,540
	Emperors	Lethrinidae	1	3,180
	Carangids	Carangidae	1	1,590
	Tuna Like Fishes	Scombroidei	1	1,855
TOTAL				16,165
Kiribati	Snapper, Jobfishes	Lutjanidae	1980	6,296,400
	Emperors	Lethrinidae	2000	6,360,000
	Clupeoids	Clupeoidei	3380	4,478,500
TOTAL				17,134,900
New Caledonia	Snapper, Jobfishes	Lutjanidae	40	127,200
	Tuna Like Fishes	Scombroidei	150	278,250
	Mackerel Like Fishes	Scombroidei	100	185,500
	Marine Crabs	Brachyura	20	53,000
TOTAL				643,950
Papua New Guinea	Barramundi	Centropomidae	400	1,300,000
	Banana Prawns	Penaeus merguiensis	600	3,816,000
	Kuruma Prawns	Penaeus japonicus	0	0
	Giant Tiger Prawn	Penaeus monodon	200	1,272,000
TOTAL				6,388,000
Solomon Is	Banana Prawn	Penaeus merguiensis	5	31,800
TOTAL				31,800
Tonga	Tuna Like Fishes	Scombroidei	15	27,825
TOTAL				27,825

LINKING MANGROVES AND FISHERIES: TOWARDS A TROPHIC MODEL OF THE MANGROVE COMMUNITY OF DARWIN HARBOUR, NORTHERN AUSTRALIA

Julie Martin, NTU Darwin

Introduction

Darwin Harbour, in Australia's Northern Territory, supports one of the largest and most diverse mangrove communities in Australia. The harbour itself is about 255 km^2 in area and the mangroves fringing it occupy more than 200 km^2. The harbour is the centre of a thriving recreational fishing industry and a substantial commercial fishery operates in nearby open and coastal waters. The rapidly growing city of Darwin is situated on the north-eastern side of the harbour and strategic plans indicate that future development may eventually extend around the entire harbour. Although relatively little mangrove habitat has been affected to date the habitat is subject to increasing pressure. Most of this is associated with land reclamation for residential and commercial uses, although aquaculture is also a rapidly developing industry.

Mangroves are thought to play a key role in the productivity of coastal zones, providing feeding and nursery habitats for recreational and commercial fish species. Given our existing understanding of tropical mangrove ecosystems, the mangroves of Darwin Harbour must play an important role in this ecosystem, although a detailed understanding of how they contribute to the system and to the ecology of the fish fauna is still being developed. Since there is little doubt that the growth of Darwin will result in at least some further reductions in the mangrove habitat, it is vitally important that the potential impact of different amounts and types of clearing be better understood.

Trophic model

Ecopath with Ecosim (EwE) is an ecosystem modelling programme that uses data for each species or component of the ecosystem to produce a trophic model that allows analysis and interpretation of the flows and biomass in the system. The original ECOPATH (Polovina, 1984) has been modified and enhanced over several years (Christensen and Pauly, 1992; Walters, Christensen and Pauly, 1997; Walters, Pauly and Christensen, 1999) and detailed descriptions of the program can be found in a number of publications (e.g. Christensen and Pauly, 1992; Christensen and Pauly, 1993; Walters *et al.* 1997).

This presentation illustrates an attempt, using EwE, to estimate the trophic flows among the various components of the Darwin Harbour ecosystem with a view to exploring hypotheses about the effects of mangrove removal on ecosystem functioning. Given the uncertainties involved in much of the information used in modelling these flows, the results should be interpreted cautiously until further validated. In summary, the aims of this project are to:

- Review and standardise existing information about the ecosystem components of Darwin Harbour;
- Construct a preliminary mass-balance trophic model of Darwin Harbour using the Ecopath with Ecosim (EwE) modelling approach and software;
- Determine areas in which further research is required to improve the model; and
- Examine the usefulness of the model as a management tool.

Mass balance concept

The model comprises producers, consumers and at least one detritus group. Each consumer group consists of either one species or a group of species having similar habitat preferences, diet and predators. The underlying mathematics of EwE are based on the "mass-balance" concept. That is, for each living group in the system, input must be balanced by output. EwE uses a system of simultaneous linear equations to balance biomass production and loss for each functional group in the ecosystem during the specified time period.

The Master Equation of the EwE model, which defines the parameters required for each component of the ecosystem, is:

$$B_i\left(\frac{P}{B}\right)_i \cdot EE_i = Y_i + \sum B_j\left(\frac{Q}{B}\right)_j \cdot DC_{ji}$$

where:

B = biomass (i = prey, j = predator)
$(P/B)_i$ = production/biomass ratio of (i)
EE_i = ecotrophic efficiency of (i) (proportion of production consumed by predators within the system, usually estimated by EwE)
Y_i = fisheries yield (or export) of (i)
$(Q/B)_j$ = consumption/biomass ratio of (j)
DC_{ji} = diet composition (fraction of i in diet of j)

Balancing the model

The Darwin Harbour model consists of 21 functional groups; 3 producers, 17 consumers and 1 detritus group. Data is entered for 5 of the above parameters for each functional group. The model is balanced using the ecotrophic efficiency (EE) values. The EE is a measure of that part of the production that is retained within the system and therefore must be <1. Balancing the model requires modifying the data until input equals output for each functional group (that is, EE's < 1). Depending on the data source, some values will be more flexible than others. For example, the diet matrix is often the LEAST accurate of all data input, so changes are usually made there first.

Model outputs

Once the model is balanced, various outputs can be used to explore the form and function of the ecosystem. These include a box diagram showing trophic levels of each group and the trophic links between each group, trophic transfer efficiencies, cycling within the

ecosystem, and mixed trophic impacts which include direct, indirect, positive and negative impacts. In addition, the balanced model can be run through the simulation modules, Ecosim and Ecospace.

Ecospace

Ecospace is a spatially explicit model developed as a policy evaluation tool which allows manipulation of habitats as well as fishing pressure. Using Ecospace, various management options, such as a reduction of mangrove biomass, can be simulated to examine the effects on catch rates and the biomass of all the components in the ecosystem. Ecospace requires the addition of several habitat related parameters such as habitat definition, habitat preferences for each functional group and movement rates.

In the example presented for this workshop, the defined habitats were mapped onto the grid of cells and a scenario set up in which half way through the simulation time period, 20% of mangroves were replaced by land, effectively removing them from the available habitat. Using the time plot (which tracks biomass over time), biomass for each component was observed to drop once the mangroves were removed and results indicated that the reduction of biomass ranged from about 4% to 25% loss.

It should be noted that the model generated in this exercise could only be regarded as a "first cut", useful in that it consolidates information about some of the species or groups of species in Darwin Harbour. It has several limitations which, at present, restrict its use as a means of management, mostly due to the preliminary nature of the model and the lack of data. The model has, however, presented a way of determining what further information is needed and how it should be collected, so that future projects have a framework in which to sit to provide the most useful information to decision makers. Rather than providing quantitative predictions, it should be seen as a tool for hypothesis generation and a way of initially evaluating policy options for more detailed study.

Also note, the description of the modelling software, Ecospace in particular, has been simplified to fit the time constraints of the workshop. Further information about the software and its application should be sought before attempting to construct and interpret models.

References

Christensen, V. and D. Pauly (1992). ECOPATH II - A software for balancing steady-state ecosystem models and calculating network characteristics. *Ecological Modelling* 61: 169-185.

Christensen, V. and D. Pauly, Eds. (1993). *Trophic models of aquatic ecosystems*. ICLARM Conference proceedings 26. Manila, ICLARM.

Polovina, J.J. (1984). Model of a coral reef ecosystem. Part 1. The ECOPATH model and its application to French Frigate Shoals. *Coral Reefs* 3: 1-11.

Walters, C.J., V. Christensen and D. Pauly (1997). Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. *Reviews in Fish Biology and Fisheries* 7: 139-172.

Walters, C., D. Pauly and V. Christensen (1999). Ecospace: Prediction of mesoscale spatial patterns in trophic relationships of exploited ecosystems, with emphasis on the impacts of marine protected areas. *Ecosystems* **2**(6): 539-554.

ECONOMIC VALUATION OF MANGROVES AND DECISION-MAKING

Padma Lal, Graduate Studies in Environment Management and Development
Australian National University, Canberra, ACT 0200, Australia

Abstract

Degradation and loss of mangroves continue despite they being recognised as being valuable to humans. This has generally been attributed to the mangrove resources being public goods, and as such they are used for 'free'. Economists have always argued that only when people bear the true economic cost of using natural resources they will have incentives to use them in an efficient manner. Resource managers and conservationists have also recently begun to acknowledge the importance of economic values in encouraging sustainable use and management of resources. Economists, managers, and many international organisations and government and non-government agencies are now encouraging countries to adequately take into account environmental values in economic decisions. One way of doing this is by encouraging economic valuation of resources for which markets do not exist and consider this in decision-making.

This paper briefly summarises, using microeconomic principles, why economic considerations are relevant to individuals and the role economic value information can play, at least theoretically, in increasing efficiency and sustainability of mangrove use. In the presence of missing markets, economic valuation information on non-market goods could ideally help correct market failures. The paper argues that in practice, however, there are a number of difficulties in using only economic valuation information in making decisions about wise use of mangroves. Its relevance is questioned particularly in the light of minimal ecological information available in the region and the limitations of benefit-cost analysis based decision-making. The appropriateness of a total reliance on economic valuation based decision-making is questioned, before proposing an alternative decision-making process in which economic valuation based decision-making is still relevant, but at a second tier level.

Importance of mangroves

Globally, according to the World Resource Institute, more than 50 percent of mangroves have been lost in recent times (World Resources Institute, 1996). They continue to be lost at an alarming rate. In the Asia-Pacific region, for example, an average of about one percent per annum of mangrove area loss has been reported. Amongst the causes of mangrove destruction, conversion to agriculture, aquaculture and housing development have been most significant. Internationally, agriculture has been the principal cause of wetland loss (Finlayson 1999). Even in the Pacific, in places like Fiji, agriculture has been the main cause of mangrove reclamation, with about 86% of all mangrove reclaimed being for sugar cane and rice farming (Lal 1990a). In some cases, commercial logging, cutting of wood for domestic purposes, and illegal fishing and hunting have also led to cutting of wood for domestic purposes, and illegal fishing and hunting have also led to

the destruction of wetlands in Asia–Pacific (Dugan 1990). In many Pacific islands, subsistence and semi-subsistence timber and fuelwood harvest have also led to significant losses and degradation ((Lal, 1991 #381), (Ropeti and Folinga 2001). Other threats to wetlands in the Pacific include reclamation for urban development and pollution from land-based activities.

Mangrove losses have been occurring at an alarming rate despite general acceptance of the role that mangroves play in maintaining the productivity of the coastal ecosystem and despite many concerted efforts to curb the destruction. It is generally accepted that mangrove ecosystems are highly productive, dynamic and complex. They provide four types of ecological services – (i) converting solar energy, nutrients and water through primary and secondary productivity processes and food chain interactions into fauna and flora; (ii) providing physical habitat and refuge for various fish and non-fish at different stages of their life cycle; (iii) storing and filtering sediment and nutrients, recycling nutrients and maintaining the quality of the aquatic system; and (iv) maintaining the biological order in the system ((Hamilton and Snedaker 1984); (Twilley 1993); (Gilbert, 1998 #74).

In the Pacific islands, as elsewhere in the world, mangrove ecosystems produce many goods and services which are directly or indirectly valued by local communities, these comprise what economists call total economic value. Total economic value is the sum of the direct and indirect use values and non-use values (Table 1)

Table 1: Goods and services supported by mangrove ecosystems in the Pacific				
TOTAL ECONOMIC VALUE (TEV)			***ECOLOGICAL PROCESS VALUES***	***CULTURAL FUNCTION VALUES***
USE VALUES		NON-USE VALUES	'Ecological glue' - Primary value of aggregate life support functions	Cultural 'glue' value – (*vanua, fenua)*
DIRECT USE VALUE **Extractive uses** • Fish and non-fish • Fuelwood • Agriculture • Medicine • Dye • Housing scaffolding • Timber for construction **Non-extractive use** • Ecotourism • Swimming	**INDIRECT USE VALUES** • Nutrient filtering • Flood control • Storm buffer • Shoreline stabilisation • Microclimatic stabilisation • Biodiversity maintenance • Education and research	• Bequest • Existence		
• **Source: Adapted from (Barbier 1989)**				

In addition to these values, for many Pacific Islanders, wetlands are part of their customary tenure based *vanua or fenua* which form the basis of their emotional, spiritual, ecological and economic well being. *Vanua* in Fiji, for example, defines amongst other things the duty of care that people have towards each other, the future generation and the environment (Vuki et al. 2000). Associations with their *vanua or fenua* provide the local people with cultural identity about who they are. These provide what (Lal and Young 2000) have called a flow of cultural process values - sense of cohesiveness, belongingness, customs and obligations about reciprocity, characteristics which have been encapsulated in the term 'Pacific Way' (Tupouniua 1980).

There are also ecological process values (Perrings 1995) associated with the: maintenance of biodiversity and "genetic library"; regulation of ecosystem processes and functions; maintenance of resilience; and maintenance of ecological processes and functions between ecosystems (supporting other systems through the production and export of organic matter and plankton) (Moberg and Folke 1999). Many of these keep the whole system and have functions that have secondary value, the primary values of the ecosystem being for example the food chain relationships and nutrient flow.

Humans thus value mangrove ecosystems for the goods and services, the ecological process values and the cultural function values they support. But not all of these values are captured in market prices and thus market mechanisms cannot be relied on to produce efficient use. Efficiency in use is defined by economists as an outcome when a resource is allocated to that activity which values it most (Layard and Walters 1978). Normally, where goods are traded, and thus have market values, market mechanisms can be relied upon to allocate resources in the most efficient manner.

One of the necessary conditions for market mechanisms to result in the efficient use of a resource is that the good be privately owned, or at least the use rights are held privately. Usually private property rights are found for goods which when consumed by one person, others can be precluded from deriving any direct benefits. Markets are common for such goods.

Mangroves as public good

For many of the goods and services, ecological processes and cultural functions of mangroves, markets are missing because they are a public good. Public goods exist, such as environmental scenery or ecological processes, where one person's enjoyment from it does not preclude others from deriving benefits at the same time. Since property rights provide the owners rights and duties (Bromley 1991), they structure incentives and shape human interactions (North 1990).

Property rights over the mangrove ecosystem are often missing because it is a real challenge to define property rights over them. The rights over the terrestrial component of the system can, and often are, easily demarcated, fenced, enforceable and enforced. As a result, in many countries, particularly in former British colonies in the tropics, wetlands above spring high water mark are often included in private land titles. The aquatic system

on the other hand does not lend itself to easy division, demarcation and enforcement. Consequently, wetland areas and resources below the high water mark often remain as public good and owned by the state (Munro-Faure 1991). In the absence of adequate property rights, markets for many of the goods and services provided by mangroves are missing, and thus these goods and services are treated as free. Where goods are 'free', people do not have any incentive to consider the costs of using them and thus they do not bear their true economic costs. When all costs are not fully borne by those using the resource, it is undervalued (Freeman 1999) and generally overexploited, degraded and abused. The net result is excessive conversion and loss of mangrove resources (Dixon and Lal 1994); (Lal 1990a); (Turner and Jones 1990) because only those costs and benefits of goods for which markets exist are considered in market-based decision-making.

Even though governments are the custodians of public goods, they, too, have encouraged the 'over use' of mangroves by ignoring the economic value of those resources for which no market values are present. Consequently, throughout the world, excessive reclamation and conversion of the terrestrial component of the mangrove ecosystem to alternative uses, such as agricultural, aquacultural development, and urban development, is observed.

Private vs Communal rights

Property rights over mangroves need not be defined only in terms of private property. Communally held rights can also operate effectively, provided the rules and regulations over communally held resources are clearly defined, well understood and enforced (Ostrom 1990); (Pinkerton 1989). For complex ecosystems such as wetlands it is also important that the rights for individual subcomponents only be recognised. Ideally rights must exist over the whole ecological system – ecological processes, environmental functions as well as goods and services generated by the wetlands, because often these are inseparable. The total environmental value of the mangrove ecosystem is more than the total economic value of the goods and services. It also includes, as discussed above, ecological process values as well as cultural function values.

Where the use or 'ownership' rights over the entire system exist they have been instrumental in reducing the rate of wetland losses. In Fiji, where remnants of indigenous rights can be found, no distinction is often made between the land and aquatic components and the underlying ecological processes. Traditional clans, or *mataqalis*, communally have claim over a *vanua*, or the physical resources and the environment, which together encapsulates 'nature', including the mangroves (Batibasaqa et al. 1999). During a brief period in the early eighties, the rate of reclamation was reduced considerably once the government shifted its stance about the nature of the indigenous claims over the coastal resources. The government partially accepted traditional claims over the coastal resources (area between spring high water mark and the seaward limits of fringing reefs), just as the nature of the indigenous ownership of the land was undisputed. While the state was still declared as the rightful owners, the *mataqali* were seen as custodians. With this recognition came large claims over the value of the expected loss of

fisheries resources and their source of livelihood as a result of mangrove reclamation. Such claims reduced the rate of reclamation; at one stage the engineer in charge of the reclamation on behalf of the government exclaimed, in response to the *mataqali* demands, that it (reclamation) was no longer 'worth the hassle' (Ernest pers comm, 1983).

However, this recognition of indigenous rights did not last very long and the government changed its position. The exact nature of the *mataqali* rights is confusing (Lal 1983), (Waqaraitu 1994). Traditional clans are recognized as communal owners of the coastal areas, but the government also declares that these rights are ususfructus only, and are not recompensable (Lal 1990a). Such an ambiguity affected the entitlements the *mataqalis* could claim. The traditional owners could not adequately exercise their 'ownership' rights and demand adequate compensation for the loss of mangroves due to reclamation or waste disposal, with *mataqali's* receiving compensations orders of magnitude lower than what could be legitimately claimed for at least direct goods lost through reclamation. One could argue that much of the reclamation in Fiji might not have occurred if the communal rights were recognized as compensable rights, encouraging a market for mangrove resources to develop. This would have encouraged users of mangroves to fully consider the true costs of the resources, giving then incentive to use the resources efficiently. In the absence of private property rights and thus market values, ideally economic valuation can play an important role in influencing those making decisions to explicitly consider economic values of all goods and services supported by mangroves, regardless of whether market values exist or not.

Role of economic values

Economic valuation information is valuable to decision-markers that are trying to encourage efficient and sustainable use of mangroves. Economic value information is generally used in three broad ways:

- Advocacy
- Choice between alternative uses
- Internalisation of externalities

1. *Advocacy*

In an environment where economic paradigm dominates many decisions and economic development is often the primary goal, use of economic valuation information is commonly advocated. Generally when non-economists promote the relevance of economics and economic values, they seem to have advocacy in mind, as the following quote from ICLARM suggests. Economic values, ICLARM notes, will help to 'prove to

decision makers in developing countries that improved management and conservation of coral reefs pays off' and help prioritise options (ICLARM 2001). They note that throughout the world, the ecosystem goods and services supported by coral reefs and other natural systems have been 'given too little weight in policy decisions' and that this neglect 'may ultimately compromise the sustainability of humans'.

The Ramsar Bureau, under the Ramsar Convention, has encouraged economic valuations of wetlands (Rubec 1999). The South Pacific Regional Environment Programme (SPREP) in their Action Plan recognises the need to promote natural resource economics 'to assist environmental officials and national and fiscal planners in taking stock of economic implications for environmental impacts' (SPREP 2000: 18). SPREP strongly recommends island nations "conduct or sponsor research on economic values of wetland ecosystems and species of the Pacific Island region, and direct results to national land-use planning/management plans and conservation organisations" (SPREP 1999:12). The underlying assumption is that by using economic value information one would be able to make strong arguments over the conservation of the in situ values of wetlands, particularly when faced with demands for conversions of mangrove areas for non-compatible uses largely on economic grounds.

Decision-makers, individuals, communities and governments, alike are often more readily convinced about the benefits of use or conservation of natural resources if they have available to them quantitative measures of their benefits and costs. It is easier to compare the economic value of the goods and services supported by the natural systems with those of development projects when there is a common nummerraire, than when one has to compare the monetary contribution of development with non-monetary measures of the contribution natural resources make to a country's well being.

The power of numbers cannot be undervalued, even if only crude estimates are available, as was the experience in Fiji. A rough estimate of the economic value of mangrove resources was the single most powerful piece of information that convinced the Minister responsible for land development to place a moratorium on the large scale reclamation of mangroves in 1983. Despite their in situ uses for subsistence and commercial fish harvests as well as firewood and other non-timber products being well recognised, mangrove resources were being reclaimed at a rapid rate, mainly by the government in an effort to 'produce new lands' for agricultural or industrial use. It was only after research helped to produce, albeit incomplete, information about the value of in situ uses of mangrove ecosystem that the Government of Fiji became convinced enough to place a temporary moratorium on large scale reclamation of mangrove resources, thus curbing the rate of destruction of the valuable resources.

There are different levels of economic information that can be used for advocacy. Proactive decision could be made at the national level when a government is choosing national or regional level policies or projects that may have significant national level impacts because of inter sectoral linkages. For small activities or developments, partial analysis of net economic contribution is generally used, as discussed below.

2. Choice between alternative uses

When choosing between alternative uses using economic paradigm, a comparison of their economic contribution is made and the activity chosen is that which produces the highest net economic benefit. A choice is made using criteria such as net present value (NPV), benefit cost ratio (BCR), internal rate of return (IRR), or cost effectiveness analysis (Sinden and Thampapillai 1995) (Table 2).

Table 2: Benefit cost analysis	
Criteria	Decision
1. Benefits > Costs; ie NB >0	Accept the project
2. $NB_1 > NB_2$	Accept Project 1
3. Quantitative estimates of $NB_1 > NB_2$	Accept project B only if the intangibles considered to be outweigh the difference in quantitative estimates
4. Cost effectiveness Benefits assumed to be the same but the costs differ. Choose between options based on minimum costs. If $C_1 > C_2$	Choose activity 2

A project with higher economic net value is chosen unless of course there are compelling reasons for accepting the project with a lower net social benefit. Some of the compelling reasons could be that the project with lower net social benefit was more socially desirable because of equity reasons. Or alternatively the economic value of the intangible goods and services of the project with the lower net social benefits was considered to be high enough to suggest the project had the highest net social benefits, after incorporating the non-market benefits and costs. Under potential Pareto criteria, as long as a project generates net economic benefits and developers could potentially compensate those who stand to lose as a result of the development, efficiency in resource use results.

Internalising externality costs and efficient resource use

Any mangrove land-based activity often produces some impact on the aquatic subsystems, affecting fisheries and other uses. Such externality costs, in the absence of property rights over the whole ecosystem, would then normally be borne by a third party or the society. For mangrove land to be efficiently used, developers who wish to reclaim mangroves would, according to the 'impactor pays principle', pay for the all externality costs. If after paying for the externality costs and all other costs, development still results in a positive net economic benefit, society will be better off (Panayantou 1995). If after considering the externality costs, a development is no longer economically viable, it will not proceed and society will still be better off.

Therefore, to control the reclamation of mangroves causing a decline in mangrove dependent fishes and a loss of forest products, information about the economic value of the impacts is relevant and a 'tax' or fee on those causing the impact would be levied. Such payments would ideally reflect the true economic cost of the loss in forest products and fisheries output.

Efficiency can also be improved when users of public goods such as fisheries pay (resource rent) for the resource and not treat them as 'free goods'. For extractive uses of renewable resources, the appropriate fee is equivalent to resource rent. By getting the

fishermen to pay for the use of public goods, especially if the charges closely reflect the level of resource rent expected from the fishery, they will be encouraged to use the resources in an optimal manner (Tietenberg 2000). This is rarely done in developed countries, let alone in developing countries.

Similarly, where public goods are used for recreational purposes, charging recreational users fees could also make improved efficiency in use. Users will be made to explicitly take into account the economic cost of using public goods. User or tourist fees would ideally reflect the net benefits they derive, that is the consumer surplus, over and above what they pay to visit a site (Geen and Lal 1993).

Economic valuation issues

Economic values can, theoretically at least, help rationalise the use and management of mangroves. In practice, however, there are major valuation issues that need to be carefully considered before decisions solely based on economic paradigms are sufficient.

Advocacy and impact assessment
For advocacy often crude estimates of economic impacts may suffice, since economic-wide impacts are difficult to determine because of a lack of clear understanding about key inter-sectoral linkages in a society. To determine the national level value of mangroves, national level economic impact assessment of change in gross domestic product (and national employment) are appropriate (Perman et al. 1999). Such assessments require a variety of economy-wide models, including input-output models and computable general equilibrium. Such models are not only data hungry but also require a good understanding of inter sectoral linkages within an economy and the environment-economy interactions.

Very few countries in the Pacific have such predictive models. Where they are found, such as in Fiji and Papua New Guinea, the economy-environment linkages are absent, thus making it very difficult to provide an appropriate level of information about the economy-wide impacts of the expected loss of natural resources and to compare it with the economy-wide benefits that a development could provide. As a proxy, often input-output tables, where available, could be used, but I-O models tend to over-estimate impacts. Once again very few countries have input-output tables in the Pacific. A third or fourth best option is to obtain, however crude, quantitative or even qualitative

information about potential impacts. It is recognised that there is always a danger in using crude information as other factors may play a major role and governments can be susceptible to the ‘principle agent’ problem.

Advocacy and total economic valuation
When advocating the importance of mangroves, total economic contribution made by the resource could suffice. Economic contribution of a resource is captured by net economic value measures. Net economic values are determined by the supply and demand of a good or service. In essence, the economic value of a use or non-use reflects the consumer surplus and producer surplus associated with the supply and consumption of the goods

and services. When estimating in situ economic values associated with any natural system, including wetlands, ideally consumers' willingness to pay (consumer surplus) for each of the goods and services and net producer surplus estimates, are aggregated to derive total economic value estimate. Where the supply of natural resources does not incur costs (such as wild fishery or coral reefs), producer surplus may be zero and the appropriate valuation will involve estimating consumer surplus only (Costanza et al. 1998). Total economic value is determined by summing the net values of each direct and indirect use and non-use associated with mangroves (Table 1). Different valuation techniques based on revealed preferences and expressed preferences can be used to measure these values, summarised in Table 3. Appendix 1 provides a brief descriptions of techniques commonly used in wetland valuation.

All the non-market valuation techniques rely on the presence of markets for some goods and services to provide the appropriate context for valuing non-traded goods and services. Thus economic values of mangroves vary between countries and even within a country depending on the nature of the socio-economic and institutional context, including property rights regimes applicable to mangrove ecosystem, as well as local ecological characteristics.

Table 3. Methods of valuing goods and services supported by mangrove ecosystem

Goods and services		Measurements	Methods (examples)
Fisheries – fish and non-finfish harvest for commercial and subsistence	Direct use values - extractive	Net Economic Value of fisheries output 'with and without' mangrove	Production method ((Gilbert and Janssen 1998), (Ruitenbeck 1992); (Lal 1990a); (Naylor and Drew 1998), ((Barbier 1994); (Ronback 1999); (Sathirathai 1998))
Forestry – timber, firewood		The net value of the products	Production method ((Lal 1990a); (Sathirathai 1998); (Barbier 1994)
Dyes		The net value of the products	Production method
Tourism	Direct use values -non-extractive	• Tourism consumer surplus • tourism producer surplus	• Contingent valuation method (CVM)/Travel cost method (TCM) • Hedonic method • Production value approach
Education		• financial benefits • social benefits	• Benefits arise through education programme expenditures • CVM
Biological support	Indirect values	Biological functions	• Change in productivity approach • Percentage dependence technique • Contingent valuation method ((Naylor and Drew 1998)
Physical protection		Coastal protection	• Change in productivity approach • Percentage dependence technique • Replacement cost technique (Lal 1990a; Sathirathai 1998)
Global life support		Carbon storage function	Benefit transfer approach (Sathirathai 1998)
Existence values	Non-use values	Satisfaction on the existence for future generations	CVM; choice modeling
Option values		Expected values for future uses	CVM; choice modeling
Ecological Process values		???	??
Cultural function values		???	?? (perhaps CVM and opportunity cost approach – see Lal and Young (2000)
Adapted from (Barbier et al. 1997)			

Economic valuation of mangroves in the Pacific is almost non-existent (exceptions being (Lal 1990a) and (Naylor and Drew 1998)). Globally, the production method is commonly used to determine economic values of extractive uses, such as forestry and fisheries (eg. (Gilbert and Janssen 1998), (Ruitenbeck 1992); (Lal 1990a); and (Ronback 1999)). For indirect uses such as storm buffer or nutrient filtering services, replacement cost method is commonly used (eg (Lal 1990a), (Sathirathai 1998)). Naylor and Drew (1998) used CVM to determine the value locals placed on the protection and use of mangrove ecosystem as a whole in Kosrae.

Marginal economic valuation

As discussed earlier, when making choices between alternative uses, the appropriate valuation measure is the marginal net economic contribution the alternative uses are expected to make. Similarly, one needs to estimate the marginal economic value of the externality costs of land based activities if internalisation of externality is to be achieved.

To determine marginal change in the in situ values of mangrove resources, one needs to have a good understanding about the dynamics of the ecological system. Not only that, the link between human activities and their impacts on the goods and services produced by the ecosystem needs to also be known. Environmental processes, structure and goods and services supported by mangroves depend on a complex interplay of factors, including the area of mangrove forest, the level of carbon fixed by the mangroves and the extent of organic carbon and nutrients exported from mangroves (Robertson and Duke 1990.) (Gilbert and Janssen 1998) suggest that the quality of the mangrove cover also has a direct influence on the productivity and physical structure of wetlands. The better the mangrove cover, the better the performance of ecological process and environmental functions. The ability of the mangroves to maintain coastal water quality is also an important determinant of the systems' productivity (Marten and Polovina 1982); (Pauly and Ingles 1986) and (Ronback 1999).

Environmental production by mangrove ecosystems shows large spatiotemporal variation throughout the tropics (Gilbert and Janssen 1998). Though much has been written about ecological relationships (eg (Robertson and Blaber 1992); (Matthes, 1988 #92); (Morton 1990); (Robertson and Duke 1990.); (Odum and Heald 1972), the actual functional relationship between mangrove area and the quality of mangroves, the underlying ecological processes, and primary and secondary productivity, are not known for most areas, or known with considerable uncertainties. There is non-linearity in the relationship between mangroves and the goods and services they support (Pauly and Ingles 1986). There also exists a great degree of uncertainty and a lack of understanding about the spatial and functional relationship between mangrove areas and associated ecological and environmental functions (Ronback 1999); and (Gilbert and Janssen 1998).

To overcome this problem, many different approaches have been used to determine the economic impact of changes in wetland areas and the goods and services produced by the underlying ecological processes and the environmental functions. For example, (Nickerson 1999); (Barbier and Strand 1997) and (Lal 1990a) assume a proportionate linear relationship between the area of mangroves and the mangrove dependent species harvested. Others such as (Sathirathai 1998) use a static optimisation Cobb-Douglas model and an assumption of direct non-linear proportionate relationship between the

quantity of crabs harvested and level of fishing effort, keeping the area of mangroves constant. Such model assumptions are often based on economic theories and thus caution needs to be exercised when using such value estimates, as they can be over or underestimated.

In some extreme cases, where there are thresholds and discontinuities in the relationship, it is possible that loss of mangroves beyond a certain threshold can lead to a collapse in the whole system. In such a situation, the value of the products or ecological processes will not be captured by the standard valuations techniques.

Property rights and mangrove valuation

It is also possible that economic values estimated using non-market valuation techniques may also not represent the 'true' economic values because of the presence of policy distortions and immature markets. Valuation techniques no doubt depend on people's willingness to pay relative to other traded goods. Local market conditions and regulatory policies and rules determine the values of resources. Where immature markets exist or markets for goods and services cannot be easily identified, market prices may not fully reflect the opportunity cost of using the resources. Property rights regime is an important determinant of costs and benefits considered by private individuals and socially.

Since the social, economic and institutional characteristics vary from country to country large variations can be found in the economic values of goods and services (Table 4). Even within a country, economic values can vary depending on the number of substitutes available.

Table 4. Diversity in the economic value of goods and services supported by mangroves in selected countries (US$/ha/yr).

	Fiji (Lal 1990a)	Indonesia (Ruitenbeck 1992)	Philippines (Gilbert and Janssen 1998)	Kosrae (Naylor and Drew 1998)
Forestry	6	67	251	178
Fisheries	100	117	60	461
Biodiversity		15		
Erosion		3		
Nutrient filter (Human waste treatment)	2600			
Total				426-640

Consequently, before economic valuation of mangroves can be attempted, which itself can be costly (Barbier et al. 1997), local sociopolitical and institutional conditions need to be contextualised and the functional relationship between mangrove cover and goods and services determined. This requires R&D, which not many countries are often in a position to undertake in the short term. Moreover, purely economic arguments, as often advocated by neoclassical economists, cannot be used in circumstances where subsistence, semi subsistence and commercial economies co-exist, markets are not in equilibrium and thus the 'true' economic values are not known, or known with a great degree of uncertainty.

In places such as the Pacific, even where economic valuation information suggests a mangrove area should be conserved, this may not be a desirable outcome when locals do not have any other source of income (Lal and Keen 2001). In such circumstances, decision based on purely economic valuation information may not be superior to decisions made using other assessment methods.

In the absence of good information and the presence of uncertainties, there is a growing acceptance of the need for the 'precautionary approach' (Costanza 1987) and stipulating safe minimum standards (Bishop 1978), ecological threshold effects, or macroenvironmental standards (Lal 1990b). The need to adopt a precautionary approach is emphasized particularly where the development is irreversible. (Barbier 1994) suggests that economic marginal valuation approach and the use of benefit cost analysis as a decision making tool may be relevant only when a development is likely to affect the environment within the bounds of the 'safe minimum standard' criteria.

Other approaches to support decision-making in the face of uncertainty, include community participation, mediation and negotiation, and adaptive management (Dover 1999). In many instances a combination of these approaches are required if the presence of incomplete information and uncertainties in scientific knowledge are to be fully acknowledged. A more comprehensive approach is required if one also is to recognise the possibility of local community's management objectives to differ from those of the centralised government decision-makers. Usually government's focus on social welfare maximisation does not coincide with the objectives of the locals, for whom mere survival and short term income generation may be the primary goal. One such decision-making process is the IAMDP proposed by (Lal et al. 2001)[5].

Integrated Adaptive Mangrove Decision-making Process (IAMDP)

Operationally, a four-phased IAMDP is proposed: the subsystem identification phase, the reflective phase, the action phase and finally the adaptive learning phase (Figure 1). This process is a slight variation of the ADMP framework presented in Lal et al 2001, which the following section draws on.

Phase one — subsystem identification

Three assessments are carried out in this phase.

Stakeholder assessment – identifying key resource owners, users and managers, existing patterns of decision-making and the contexts of interaction between stakeholders, whose individual and collective decisions determine environmental outcomes.

Institutional assessment - providing an assessment of the rules and regulations that underpin activities within the ecosystem, and of other institutions that may indirectly affect the system. This stage will also identify traditional institutions that may be relevant as well as different management instruments used by the different agencies, including indigenous communities.

[5] This process is based on Lal's mangrove project in Kosrae (Lal 1989). A more generic model, ADMP, is detailed in Lal et al 2001.

Resource assessment uses traditional science and indigenous knowledge to provide a preliminary inventory of the relevant biophysical environment and ecological flora and fauna; an assessment of the natural processes and dynamics that underpin the current status of the environmental quality and resources at appropriate spatial and temporal scales; and an assessment of the functional processes and interaction between key components of the natural system that shape the environmental reality.

Phase two — reflective phase

The key objective of this phase is to identify priority problems and a common vision; the overall management approach and assessment frameworks to be adopted; and research needs and disciplinary focus, using participatory action research and dialectic decision-making processes. Researchers play an active role in this process, working with other stakeholders and providing their technical and analytical skills to help understand the effects of human activities on the natural dynamics, within the legal and institutional contexts, that underpin the observed reality.

Problem identification and common vision
A clear understanding of the underlying management issues and a general agreement about the desired future is critical in any decision-making process that attempts to arrive at a preferred path for development and management. There are three main categories of mangrove use and management issues. The first relates to the choice between alternative uses that may affect area of mangrove conserved and an acceptable level of economic development. The second concerns decisions about the appropriate rate of forest and fisheries harvests and the third is about implementation of key management strategies and instruments to achieve the desirable outcomes.

The stakeholders, with their different perspectives, together will: define the problem statement, arrive at a common vision about the desired outcome; and identify the desirable management approach (es) and the set of management criteria that will be used to select between alternative policy options and/ or management strategies. Information generated in individual disciplines and across disciplines, and indigenous knowledge should be integrated to develop detailed descriptive and causative inferences about the:

- nature and scope of the specific problem, issues or concerns;
- existing value systems of, and pattern of interaction between owners/custodians, users and managers;
- interactions between the natural, economic and social systems and possible cause and effects and linkages between human activities and ecological functions and processes; and
- spatial and vertical boundaries of relevant interactions relevant to the issue on hand, based on ecological and/or economic considerations.

Management approach and assessment framework

Once the stakeholders mutually recognize the nature of the issue and agree on their shared responsibility, arriving at some broadly shared vision about management approaches is another major challenge. The choice of assessment framework/ criteria is another issue stakeholders would need to agree on. If there is perfect information about the effects of human activities on the ecological processes and economic values, and if the integrity of the underlying ecological processes is not threatened, market mechanisms can then be used to encourage an optimal allocation between competing uses. This assumes market values reflect all the costs and benefits and that perfect information is freely available.

However, there are often imperfect information and uncertainty over actual outcomes causing market failures. There may also be a case of resources for which property rights cannot be assigned resulting in 'missing markets'. In such situations of missing markets and/or market failure, market based mechanisms cannot be relied on to encourage efficient or ecologically-sound outcomes. In such circumstances, it is useful to develop an evaluative framework that could help stakeholders to systematically assess the various impacts and agree on some way of objectifying the impact of their decisions in a consistent and acceptable manner. Multidisciplinary researchers help identify different analytical frameworks that could be relevant and work with the communities to develop an appropriate analytical framework for their particular context.

Phase three — action phase

In this phase, stakeholders formulate the typology of management strategies that will best resolve the resource problem knowing what motivates and influences individual decision-maker's action. This will dictate the nature of the management strategies, including the use of command and control based strategies, market based instruments, community based management strategies, and/or moral persuasion, to be considered and at which scale these need to be implemented. This phase has two tiers because of the scale issues involved and the degree of uncertainty.

As discussed above, in the presence of imperfect information and uncertainties over actual outcomes, BCA as a decision-making tool is not suitable. Choice about the best use of resources would need to be made using other decision-making processes and using a set of criteria, including economic net returns, determined by the stakeholders. Precautionary approach is advocated, particularly where irreversible outcomes are likely.

The actors, communities and government agencies, help define the needs and aspirations and future use scenarios through a consultative process. At the medium to large scale, i.e. the resource use and management districts or economic biomes, stakeholders could decide on broad resource use districts. A biome is an area of natural system where organisms, including humans exist, and their biophysical environment interact dynamically and within which there is a balance between inflow and outflow of material and energy (Cassells et al. 1991). Or it can be a subarea, which can be distinguishable as a subsystem, with a definable boundary. Ecological principles and processes guide the delineation of the boundary, since they determine the extent and the level of

environmental impacts and outcomes of any activity. The interaction between ecological, economic and social factors and processes identified earlier will determine the actual boundary of the ecobiome (that is economic biome), and will reflect the spatial and inter-temporal interconnectedness in the system.

The designated ecobiomes define a hierarchy of characteristics, including acceptable quality of a wetland area. They also by default define the stakeholders that have the rights and responsibilities over use and management of the resource, and whose inputs are relevant. The characteristics of the individual ecobiomes will thus also define the binding constraints about the upper limit of acceptable change, or the acceptable minimum standard of environmental quality. These ecobiomes form the basis for developing more specific action oriented management strategies in the second tier.

At tier two, the benefit cost analytical framework could be used to choose between alternatives within an ecobiome, regardless of whether the benefits and costs of alternatives can be quantified or not. Within these ecobiomes, decisions can be made about the rate of harvest of mangrove-based goods and the rate of use of the ecological services. Where the management concern is about the rate of harvest of fish or forest products or the assimilative capacity of coastal waters as a pollution sink, the bioeconomic models, incorporating the ecological functional relationships could be used. In the ADMP it is recognized that strategies should incorporate incentive mechanisms for change[6], meet a specific target and/or self-regulate, allowing stakeholders the flexibility of adopting strategies for which the benefits are commensurate with the costs and risks, within the agreed safe minimum environmental and social constraints.

Conflict and conflict resolution

In any multi stakeholder and multi disciplinary environment conflicts of interests, values, and disciplinary approaches are inevitable. This is despite everyone having good intentions, having an open mind, having an agreement about the desired outcomes, required management approach and evaluation framework, etc. Conflicts and disagreements are often unavoidable, not least because of personality differences, which need to be resolved. Difference may arise also because of the complexities (Antunes and Santos 1999) caused by:

- several activities producing a single outcome;
- multiple impacts of a single activity;
- inter-connectedness within and between land-based and aquatic components of the ecosystem;
- indirect and synergistic or cumulative effects; and
- non-linearity in relationships.

In the face of uncertainty, incomplete understanding and different value systems, stakeholders together with researchers should pool their knowledge. Stakeholder will also need to have an open mind, be flexible and willing to arrive at some consensus or at least

[6] Management instruments may include legislation, agreements, market-based strategies, institutional changes, and/or education (Panayantou 1995); (Dover 1999).

recognize the differences, which can, in phase three, be analyzed, compared and discussed to arrive at some form of consensus, using dialectic process.

Many different models of conflict resolution are available, however, bargaining and dialogue (Dorcey 1986) have been considered to be superior to authoritarian decision making for complex problems involving uncertainty and competing values. Buckles and Rusnak (1999) also argue that conciliation, negotiation and mediation is likely to produce a 'win win' solution rather than litigation and other confrontational modes of conflict resolution. DSS developed in the next phase could help in the resolution of conflicts particularly over values, management approaches and strategies.

Phase four — adaptive learning phase

It is important to treat the process of examining prospective management strategies as a series of management policy *experiments*, highlighting the element of surprise in the search for sustainable development (Janssen and Goldsworthy 1996); (Holling and Berkes 1998); (Lee 1999). The management strategies or user actions selected in phase three are implemented and monitored in an iterative manner (Figure 1). Each iteration shows why strategies worked or failed. The results of management experiments or user actions indicate the extents to which the problems are manageable and to which strategies need to be treated with caution. Regardless of the interpretation of the results, this phase becomes one of adaptive learning also know as experiential learning .

This learning process is central to the IAMDP. May (1992) provides a typology of learning: instrumental policy learning about the viability of specific instruments or programs; social policy learning about social constructions of policy problems, the scope of policy or about policy goals; and political learning where stakeholders become more knowledgeable about policy process and negotiating skills.

Application

An iterative process, involving resource owners/users, researchers/facilitators and the government, underpins the integrated adaptive mangrove decision-making process proposed here. An inter-disciplinary research team drawn from key biophysical disciplines, including ecology, from social sciences including social anthropology and economics, would act as resource persons as well as backstopping analysts. Similarly, recognizing that the current management is split among many different government agencies, the involvement of key government actors from the major ministries, such as forest, fisheries, lands, and marine, is also critical. Such interaction could be encouraged through National Mangrove Management Committees or other similar organizations, suited to the local conditions.

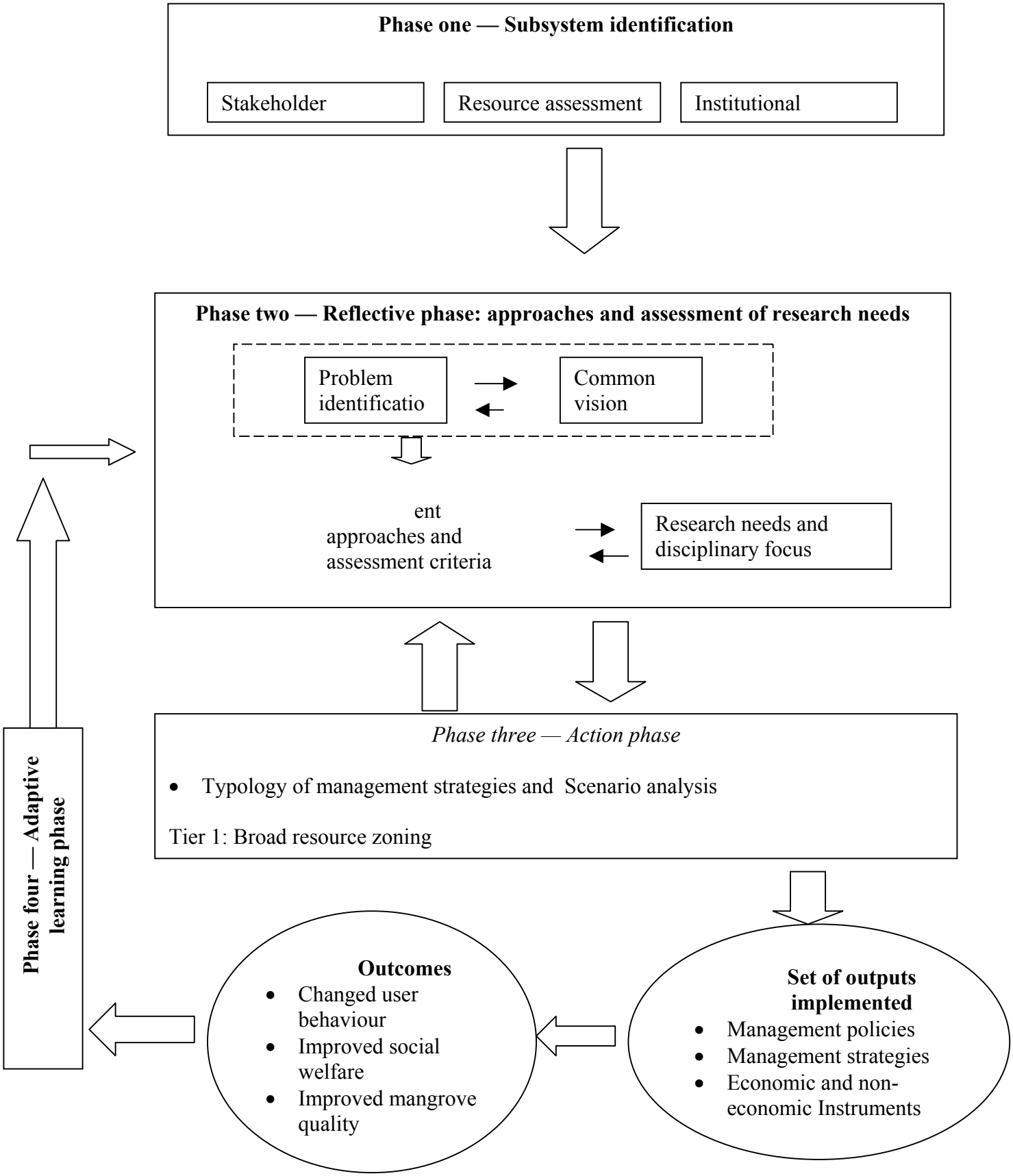
Whatever the nature of the organizational interaction, they collectively must be given the responsibility and legislative power to make informed decisions, and not just act in an 'advisory' capacity, as is commonly the case in many countries. They must also be provided with the appropriate level of resources to not only develop and implement but also to enforce a mix of command and control rules as well as instruments which provide appropriate incentives to the users. A package of institutional rules and regulations are essential because of the complex nature of the ecosystem, spatial and ecological inter-connectedness within the mangrove ecosystem, the link between ecological productivity

and economic production, the link between human actions and ecological system's responses, and the feedback loop.

Overall, the process is guided by constructivist philosophy underpinned by rigorous transdisciplinary research and active stakeholder participation. In such a system, economic valuation information is important but decisions are not solely based on them. The process is adaptive in nature and decision-making dialectic to reflect the different views and objectives of the different stakeholders, the presence of incomplete information and, at times, poor understanding about the dynamics of various subsystems and the interactions between them. Such acknowledgement also necessitates regular monitoring and fine-tuning of management in an iterative manner.

It is important to recognize that such an iterative decision making process involving key stakeholders is often time consuming and may result in conflicts within and between key actor groups. However, localised experiences elsewhere in the management of coastal areas (see various case studies quoted in (Buckles 1999) have demonstrated that a carefully thought out process can be highly successful. This requires a systematic process in which dialogue and regular discussions are a prerequisite as is the openness and preparedness of the different stakeholders to make concessions (Oviedo 1999). Furthermore, as more information becomes available and the understanding about the dynamics of the system improves, management policies could evolve and adjustments made to the mix of instruments used to manage the mangroves. This adaptive management is an essential element of the IAMDP.

Figure 1. Integrated Adaptive Mangrove Decision-making Process (IAMDP). (Adapted from Lal et al. 2001)



Conclusion

Economic valuation information can in ideal circumstances help improve resource use efficiency and conservation. However, the nature and the level of detailed information required depends on its expected use. For advocacy purposes, and particularly when large areas are involved, total economy wide value of mangroves is relevant. But few countries in the Pacific have the resources to develop the relevant national economic models or collect the required level of intersectoral data needed for such models. For many countries, the second best option could be to determine the total economic value of mangrove ecosystems by summing the net economic value of each of the goods and services. However, it needs to be explicitly noted that TEV does not capture all values associated with natural systems, including ecological process values and cultural function values.

When choosing between alternative uses within an economic framework, marginal economic value contribution of the alternative uses are compared and that use which generates higher net economic benefits is chosen. To make such comparisons, marginal economic benefit, net of all costs, is estimated. This requires not only an understanding about the ecological dynamics and the functional relationship between goods and services produced by mangroves and valued by humans, but also the interaction between human activities and their impacts on the mangrove ecosystem. Such information is often unavailable or available at high costs.

In the presence of incomplete information and uncertainties, economic valuation based decisions may not be all that appropriate. A combination of institutional and benefit cost analytical framework involving all relevant stakeholders may be required while also recognising the need for precautionary approach when irreversible outcomes are possible. An integrated adaptive mangrove decision-making process (IAMDP) is one such process that can be used for mangrove use and management. In such a process, economic valuation information is relevant, but its usefulness and the level of detail valuation required, will depend on the extent of knowledge about the ecological understanding of the system and its interaction with human activities. It also depends on the extent of economic information already available and the level of uncertainty that prevails. Ultimately, what the information will be used for and specific ecological-social and institutional context and the decision-making process to be used will dictate the level of detailed economic information on mangroves required. A stakeholder based decision-making process within an economic paradigm can be improved as more information becomes available and the understanding about the dynamics of the system improves. Stakeholders would adjust management policies and the mix of instruments used to manage the mangroves would evolve over time and become more sophisticated as better information becomes available.

Valuation Techniques

All non-market valuation methods rely on using prevailing market prices as reference points to derive economic values for goods which are not traded. Two categories of non-market valuation are commonly used, in addition to benefits transfer, to estimate values.

Revealed preference methods

Revealed preferences are methods where actual choices made by individuals are used to derive market values of a resource. There are several different methods that fall under this category; only the key ones are summarised below.

*Production method***:** Goods and services produced by the environment are transacted in the market place and can be used to estimate the economic value. Thus, for example, the value of forest products harvested, net of costs, can be estimated. To adequately use this technique, the physical changes in environmental characteristics on the marketed goods due to the proposed activities would need to be traced. Therefore, for example, a researcher estimates the quantity of different species of fish caught that are dependent on mangroves, and that may be affected if an area of mangrove were to be reclaimed. This, together with the price at which they are sold commercially, can be used to estimate the economic value, net of costs of fishing, to estimate net benefits of commercial fisheries supported by a unit area of mangroves. Market price can also be used as a proxy for estimating the economic value of subsistence fisheries.

Substitute or proxy method

In the case of non-marketed goods and services, such as dyes and medicinal values, the value of similar products, or close substitutes, sold in the market place can be used as surrogate market price. If there are apparently no marketed substitutes, then other methods may be used, including indirect opportunity cost, where the cost of the time spent collecting and preparing dyes or medicines could be used as a proxy.

Preventative expenditures

This approach allows one to estimate the value of a resource by determining how much people are prepared to pay to prevent its loss from occurring. Or alternatively, how much would it cost to replace the goods and services, once lost. Thus for example, after mangroves are reclaimed, one may need to establish a seawall to prevent the erosion of the coastal areas. The cost of the seawall could be used as equivalent to the value of the storm buffering services provided by the mangrove forests. A similar approach can be used to determine the nutrient-filtering services valued by humankind, where the cost of establishing a solid-waste filtering device is used as a proxy.

Similarly, the cost of preventive measures taken to avoid getting affected by pollution is used as a proxy for the cost of pollution. Thus for example, in the event of ground water pollution, if local communities were forced to drink bottled water purchased from supermarkets, or installed home water-treatment plants, or obtained water from alternative sources, then the costs of these preventive measures could be used to estimate the cost of pollution.

Change in earnings methods

Where human health is affected by, say, air or water pollution, the economic cost of pollution is estimated using the loss in earnings approach, plus the cost of medical expenses. This approach does not however capture the chronic health effects, which may

not result in actual loss in earnings. Nor does it reflect the true cost of pollution on society. Where human life may be lost, value of human life is estimated using insurance premiums people are willing to pay.

Hedonic method
This method relies on people's willingness to pay for a good, which often depends on its characteristics. Thus for example, the price that is paid for a house not only depends on its size, but also on its location, e.g. whether it is in a highly polluted area, or near an industrial site where there is excessive air pollution. Economists use such information to determine the economic value of, for example, air pollution, or environmental aesthetics.

Travel cost method
The recreational and aesthetic value of mangroves could be estimated using how much people are willing to pay to visit a site. Note that this method relies on the actual expenses incurred by the recreational user to derive a market demand for the resource and from which an appropriate economic value for the recreational experience is estimated. The actual expenditure itself is not equal to the economic value of recreational experience. Alternatively, access fees charged to enter national or marine parks could be used to measure the visitor's willingness to pay for the park. This, multiplied by the number of visitors, would give the economic value of the national park.

Expressed preference methods
This category of valuation is based on what people express as their willingness to pay for some environmental goods. This is often also called the "hypothetical valuation" method because respondents are given hypothetical scenarios and asked to indicate how much they would be willing to pay to either avoid the loss or to gain some improvement in the resource. This approach is called the "contingent valuation" method (CVM). Instead of asking people to directly express how much they would be willing to pay, other techniques such as the "choice modelling" approach (also known as "contingent ranking" method) have also been used. In the choice modelling approach, respondents are asked to consider and rank different scenarios that the researcher describes using a set of attributes, plus a cost associated with each scenario. Using the respondents' ranking, the researcher then estimates the value of a marginal change (improvement or loss) in the habitat or its use. Hypothetical valuation techniques are generally used to determine the value of intangible goods and services, such as bequest or existence value, changes in biodiversity value or changes in the ecological health of an ecosystem.

Benefit-transfer method
Where all else fails, benefit-transfer estimates have been argued by some to offer potential to estimate economic values. Benefit transfer is effectively using values estimated from previous economic studies conducted elsewhere and applying them to current site. It is important, however, to note that care needs to be taken when using this approach. It is important to ensure that, when using value estimates derived for other sites, there is close similarity between the characteristics of the two sites and the respective policy environments. In addition, there must be sufficient similarity in the stages of economic development, and the supply and demand conditions. Source (Lal and Keen 2001). For more details see (Freeman 1999).

References

Antunes, P. and Santos, R., 1999. 'Integrated environmental management of the oceans', *Ecological Economics,* 31(2):215-26.

Barbier, E.B., 1989. *The Economic Value of Ecosystems: 1- Tropical Wetlands, 89-02,* London Environmental Economics Centre, London.

Barbier, E.B., 1994. 'Valuing Environmental Functions: Tropical Wetlands', *Land Economics,* 70(2):155-73.

Barbier, E.B., Acreman, M. and Knowler, D., 1997. *Economic Valuation of Wetlands: a guide for policy makers and planner*, Ramsar Convention Bureau, Gland, Switzerland.

Barbier, E.B. and Strand, I., 1997. 'Valuing mangrove-fishery linkages: a case study of Campeche, Mexico.' , *IDRC supported Environmental and Resource Economics Course.*, EEPSEA Program, Singapore.

Batibasaqa, K., Overton, J. and Horsley, P., 1999. '*Vanua:* Land, People and Culture in Fiji', in J. Overton (ed.), *Strategies for sustainable development: experiences from the Pacific*, University of New South Wales Press, Sydney:100-8.

Bishop, R.C., 1978. 'Endangered species and uncertainty: the economics of a safe minimum standard', *American Journal of American Economics.,* 57:10-8.

Bromley, D.W., 1991. *Environment and Economy: Property Rights and Public Policy*, Basil Blackwell, Oxford.

Buckles, D. (ed.), 1999. *Cultivating Peace- Conflict and Collaboration in Natural Resource Management,* IDRC, Ottawa.

Buckles, D. and Rusnak, G., 1999. ' Introduction', in D. Buckles (ed.), *Cultivating Peace- Conflict and Collaboration in Natural Resource Management*, IDRC, Ottawa:1-12.

Cassells, D., Hamilton, L.S. and Saplaco, S.R., 1991. 'Understanding the role of forests in watershed protection', in R.A. Carpenter (ed.), *Natural Systems for Development: What Planners Need to Know*, Macmillan Publishing, New York:52-98.

Costanza, R., 1987. 'Social traps and environmental policy', *Bioscience,* 37:407-12.

Costanza, R., Ralph, d.A., Groot, R.d., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., V.O.Neill, R., Paruelo, J., Raskin, R., Sutton, P. and Belt, M.V.D., 1998. 'The value of the world's ecosystem services and natural capital', *Ecological Economics,* 25(1):3-15.

Dixon, J. and Lal, P.N., 1994. 'The Management of Coastal Wetlands: Economics Analysis of Combined Ecological-Economic Systems', in P. Dasgupta and M. K.G. (eds), *The Environment and Emerging Development Issues*, Oxford University Press, Clarendon:

Dorcey, A.J.H., 1986. *Bargaining in the Governance of Pacific Coastal Resources: Research and Reform.*, Westwater Research Centre, University of British Columbia., Vancouver.

Dover, S., 1999. 'Public policy and institutional R&D for natural resource management: issues and directions for LWRRDC', in C. Mobbs and S. Dover (eds), *Social, Economic, Legal, Policy and Institutional R&D for Natural Resource Management: Issues and Directions for LWRRDC*, Land and Water Research and Development Corporation, Canberra:78-105.

Dugan, P.J., 1990. *Wetland Conservation - a review of current issues and required action*, IUCN, Gland, Switzerland.

Finlayson, C.M. and Davidson, N.C., 1999. 'Global review of wetland resources and priorities for wetland inventory', http://ramsar.org/key_guide_nwp_htm (22/12).

Freeman, A.M.I., 1999. *The measurement of environmental and resource values: theory and methods*, Resources for the Future, Washington DC.

Geen, G. and Lal, P., 1993. *Charging Users of the Great Barrier Reef Marine Park*, Australian Bureau of Agricultural and Resource Economics (ABARE), Canberra.

Gilbert, A.J. and Janssen, R., 1998. 'Use of environmental functions to communicate the values of a mangrove ecosystem under different management regimes', *Ecological Economics,* 25(3):323-46.

Hamilton, L.S. and Snedaker, S.C. (eds), 1984. *Handbook for Mangrove Area Management,* Environment and Policy Institute, East West Centre, Honolulu, Hawaii.

Holling, C.S. and Berkes, F., 1998. 'Science, sustainability and resource management. Linking social and ecological systems, management practices and social mechanisms for building resilience.', in B. F. and F. C. (eds), *Linking Social and Ecological Systems*, Cambridge University Press, Cambridge:342-62.

ICLARM, 2001. 'Preliminary announcement- International Consultative Workshop on Economic Valuation and Policy Priorities for Sustainable Management of Coral Reefs"' , , ICALRM.

Janssen, W. and Goldsworthy, P., 1996. 'Multidisciplinary research for natural resource management: conceptual and practical implications.', *Agricultural Systems,* 51:259-79.

Lal, P. and Keen, M., 2001. *Economic considerations in community based project planning and implementation,* South Pacific Regional Environment Programme, Apia, Samoa.

Lal, P., Lim-Applegate, H. and Scocimarro, M., 2001. 'INRM or Adaptive decision-making process (ADM Process) - a case of focus, attitudes and approach', *Conservation Biology,* 52(2):11.Available *[online] URL: http://www.consecol.org/vol5/iss2/art11.*

Lal, P. and Young, E., 2000. 'The role and relevance of Indigenous cultural capital in environment management in Australia and the Pacific' in E.H. Commission (ed.), *Heritage economics: challenges for heritage conservation and sustainable development in the 21st century,*, Environmental Heritage Commission, Canberra.

Lal, P.N., 1983. *Institutional Aspects of Mangrove Management in Fiji.,* Fisheries Division, Suva, Fiji.

Lal, P.N., 1990a. *Conservation or conversion of mangroves in Fiji - an ecological economic analysis*, Environment and Policy Institute, East West Centre, Honolulu.

Lal, P.N., 1990b. *Macroenvironmental standards approach to resource allocation and management: the case of Kosrae's coastal wetlands, 91/1,* National Centre of Development Studies, ANU, Canberra.

Layard, P.R.G. and Walters, A.A., 1978. *Microeconomic Theory*, McGraw-Hill, New York.

Lee, K.N., 1999. 'Appraising adaptive management,', *Conservation Ecology,* 3(2):3 Available *[online] URL: http://www.consecol.org/vol3/iss2/art111.*

Marten, G.G. and Polovina, J.J., 1982. 'A comparative study of fish yields from various tropical ecosystems', in D. Pauly and G.I. Murphy (eds), *Theory and Management of Tropical Fisheries*, ICLARM and CSIRO, Manila:255-85.

May, P., 1992. 'Policy learning and policy failure.', *Journal of Public Policy,* 1(2):331-54.

Moberg, F. and Folke, C., 1999. 'Ecological goods and services of coral reef ecosystems', *Ecological Economics,* 29:215-33.

Morton, R.M., 1990. 'Community structure, density and standing crop of fishes in a subtropical Australian mangrove area', *Marine Biology,* 105(385-394).

Munro-Faure, P.W., 1991. *The Marine Resource and its Management: Attitudes and Approaches to the Leasing and Licensing of Tides and Submerged Lands,* The College of Estate Management, Reading.

Naylor, R. and Drew, M., 1998. 'Valuing mangrove resources in Kosrae, Micronesia', *Environmental and Development Economics,* 3(4):471-90.

Nickerson, D.J., 1999. 'Trade-offs of mangrove area development in the Philippines', *Ecological Economics,* 28(2):279-98.

North, D.C., 1990. *Institutions, Institutional Change and Economic Performance*, Cambridge University press, Cambridge, UK.

Odum, W.E. and Heald, E.J., 1972. 'Trophic analysis of an estuarine mangrove community', *Bulletin of Marine Science,* 22:671-737.

Ostrom, E., 1990. *Governing the commons: the evolution of institutions for collective action*, Cambridge University Press, Cambridge.

Oviedo, P., 1999. 'Conflict management in conservation and sustainable resource management', in D. Buckles (ed.), *Cultivating Peace - Conflict and Collaboration in Natural Resource Management*, IDRC, Ottawa:163-84.

Panayantou, T., 1995. *Economic instruments for environmental management and sustainable development*, Harvard University, Cambridge.

Pauly, D. and Ingles, J., 1986. 'The relationship between shrimp yield and intertidal (mangrove) areas: a reassessment.' , *IOC/FAO Workshop on Recruitment in Tropical Coastal Dermersal Communities*, Paris, UNESCO.

Perman, R., Ma, Y., McGilvray, J. and Common, M., 1999. *Natural Resource & Environmental Economics*, Pearson Education TlD, New York.

Perrings, C., 1995. 'The economic value of biodiversity', in V.H. Heywood and R.T. Watson (eds), *Global Biodiversity Assessment*, Cambridge University Press and UNEP, Cambridge:823-914.

Pinkerton, E. (ed.), 1989. *Cooperative Management of Local Fisheries: new directions for improved management and community development,* University of British Columbia Press, Vancouver.

Robertson, A.I. and Blaber, S.J.M., 1992. 'Plankton, epibenthos and fish communities', in A.I. Robertson, and Alongi, D.M. (ed.), *Tropical Mangrove Ecosystems.*, American Geophysical Union, Washinton DC:172-224.

Robertson, A.I. and Duke, N.C., 1990. 'Mangrove fish-communities in tropical Queensland, Australia: spatial and temporal patterns in densities, biomass and community structure', *Marine Biology,* 104:369-79.

Ronback, J., 1999. 'The ecological basis for economic value of seafood production supported by mangrove ecosystem', *Ecological Economics,* 29(2):235-52.

Ropeti, E.T. and Folinga, T., 2001. 'Mangrove Wetlands in Samoa' , *South Pacific Regional Environmental Workshop on Mangrove Wetland Protection and Sustainable Use*, Suva, Fiji.

Rubec, C., 1999. 'Guidelines for developing and implementing national wetland policies', *Ramsar,* http://ramsar.org/key_guide_nwp_htm (16/12).

Ruitenbeck, H.J., 1992. *Mangrove management: an economic analysis of mangrove options with a foucs on Bintuni Bay, Irian Jaya., 8,* Environment Management and Development in Indonesia Project (EMDI), Jakarta and Halifax.

Sathirathai, S., 1998. *Economic valuation of mangroves and the roles of local communities in the conservation of natural resources: case study of Surat Thani, South of Thailand,* Economy and Environment Program for South East Asia (EEPSEA), Singapore.

Sinden, J.A. and Thampapillai, D.J., 1995. *Introduction to Benefit-cost Analysis*, Longman Australia Pty Ltd, Sydney.

SPREP, 1999. *Regional Wetlands Action Plan for the Pacific Islands,* South Pacific Regional Environment Programme, Apia, Samoa.

SPREP, 2000. *Action Plan for Managing the Environment of the Pacific Islands Region 2001-2004,* South Pacific Regional Environment Programme (SPREP), Apia, Samoa.

Tietenberg, T., 2000. *Environmental and Natural Resource Economics*, Addison-Wesley, Sydney.

Tupouniua, S. (ed.), 1980. *The Pacific Way,* South Pacific Social Sciences Association, Suva, Fiji.

Turner, R.E. and Jones, T., 1990. *Wetlands: Markets and Intervention Failures*, Earthscan Publication, London.

Twilley, R.R., Bodero, A. and Robadue, D., 1993. 'Mangrove ecosystem biodiversity and conservation in Ecuador', in C. Potter. C.S., J.I. and Janezewski, D. (ed.), *Perspectives on Biodiversity: Case Studies of Genetic Resource Conservation and Development*, American Association for the Advancement of Science, Washington, DC:105-27.

Vuki, V., Naqasima, M. and Vave, R., 2000. 'Status of Fiji's Coral Reefs' , *SPC Coral Reef Initiative*.

Waqaraitu, S., 1994. 'The delimitation of the traditional fishing grounds: the Fiji experience', in G.R. South, D. Goulet, C. Tuqiri and M. Church (eds), *Traditional Marine Tenure and Sustainable Management of Marine Resources in Asia and the Pacific*, International Ocean Institute, South Pacific, Suva, Fiji:79-84.

Session III

Mangrove Wetland Mangement

development and spread the benefits of the lagoon as fairly as possible, we have developed a multi-use zoning plan, based on scientific information and the voice of the communities. Eight different usage types are identified within the lagoon's main ecosystem boundaries (Figure 1, Table 1). All of these have been designed to allow for indefinite or sustainable use of the lagoon and its resources, and depend on the cooperation of all parties involved. The eight proposed zones are:

Zone 1:	Lagoon Entrance Fisheries Area
Zone 2:	Lagoon Subsistence Fisheries Area
Zone 3:	Conservation Areas
Zone 4:	Sustainable Mangrove Use Area
Zone 5:	Village and Agricultural Uses
Zone 6:	Village Special Resource Use Areas
Zone 7:	Urban Use Area
Zone 8:	Special Public Use Areas.

ENVIRONMENTAL MANAGEMENT PLAN FOR FANGA'UTA LAGOON SYSTEM

Prepared by: Netatua Prescott, Ursula Kaly, Paula Taufa, Lupe Matoto, Sione Tukia Lepa, Taniela Faletau, 'Asipeli Palaki [*]
Edited by: Ursula Kaly, David Lloyd, Roland Lubett, Netatua Prescott, John Hibberd

Planning for the Future of the Fanga'uta Lagoon System

The Fanga'uta lagoon system is critically important for the environmental and economic health of Tongatapu.

The environment is the source of our natural wealth. Our economic, social and cultural development depends on it. In Tongatapu, Fanga'uta Lagoon forms a large part of this natural wealth providing food, materials, income and homes for Tongans. The health of the lagoon's ecosystems is vitally important if we are to continue benefiting from the lagoon in the future.

In 1998, a project commenced to help protect the natural resources of Tongatapu for future generations to use. The Tonga Environment and Planning Project (TEMPP) has worked with Department of Environment (DoE) to look at the health of the Fanga'uta lagoon system. DoE, in collaboration with other ministries, NGOs and the community, has reviewed these studies and developed strategies for protecting the lagoon's values, while allowing for its many important uses. These strategies have been brought together in this Environmental Management Plan (EMP). The Draft EMP was circulated to communities, ministries and NGOs; and their views, concerns and suggestions were gathered in a series of meetings around Tongatapu. It is with all those inputs that this EMP was produced. At Local Community meetings the following concerns were raised over the future of the Lagoon System

- Catching smaller and fewer fish
- Rubbish and litter
- Loss of mangroves
- Erosion threatening peoples' properties
- Loss of seagrass
- Sedimentation and muddy water
- Pollution
- Loss of species and habitats

The Environmental Management Plan

The Environmental Management Plan described here has been designed to improve the existing conditions in the lagoon and ensure that it can provide for the maximum use of goods and services in the future. The EMP is a guide for action by Government, and by individuals taking responsibility for their own environment. To provide guidance for

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[*] *Based on earlier contributions by:* Siale 'Akau'ola, Kasaline 'Ahoafi, Jackie Alder, Richard Chisholm, Stuart Dever, Joanna Ellison, 'Ulunga Fa'anunu, Timote Fakatava, Taniela Faletau, John Hibberd, Ursula Kaly, Timote Kaufusi, Sione Tukia Lepa, Uepi Lea, David Lloyd, Roland Lubett, Viliami Manu, Mary Marsh, Lupe Matoto, John Morrison, Poasi Fale Ngaluafe, Will Oxley, 'Asipeli Palaki, Sally Perry, Netatua Prescott, Garry Spiller, Tatafu Moeaki, Paula Taufa, Pita Taufatofua, Havila Taukolo, Seventeen Toumo'ua, Maliepo Toma, Lelea Tu'itupou, Sonasi Tupou, 'Akapei Vailea.

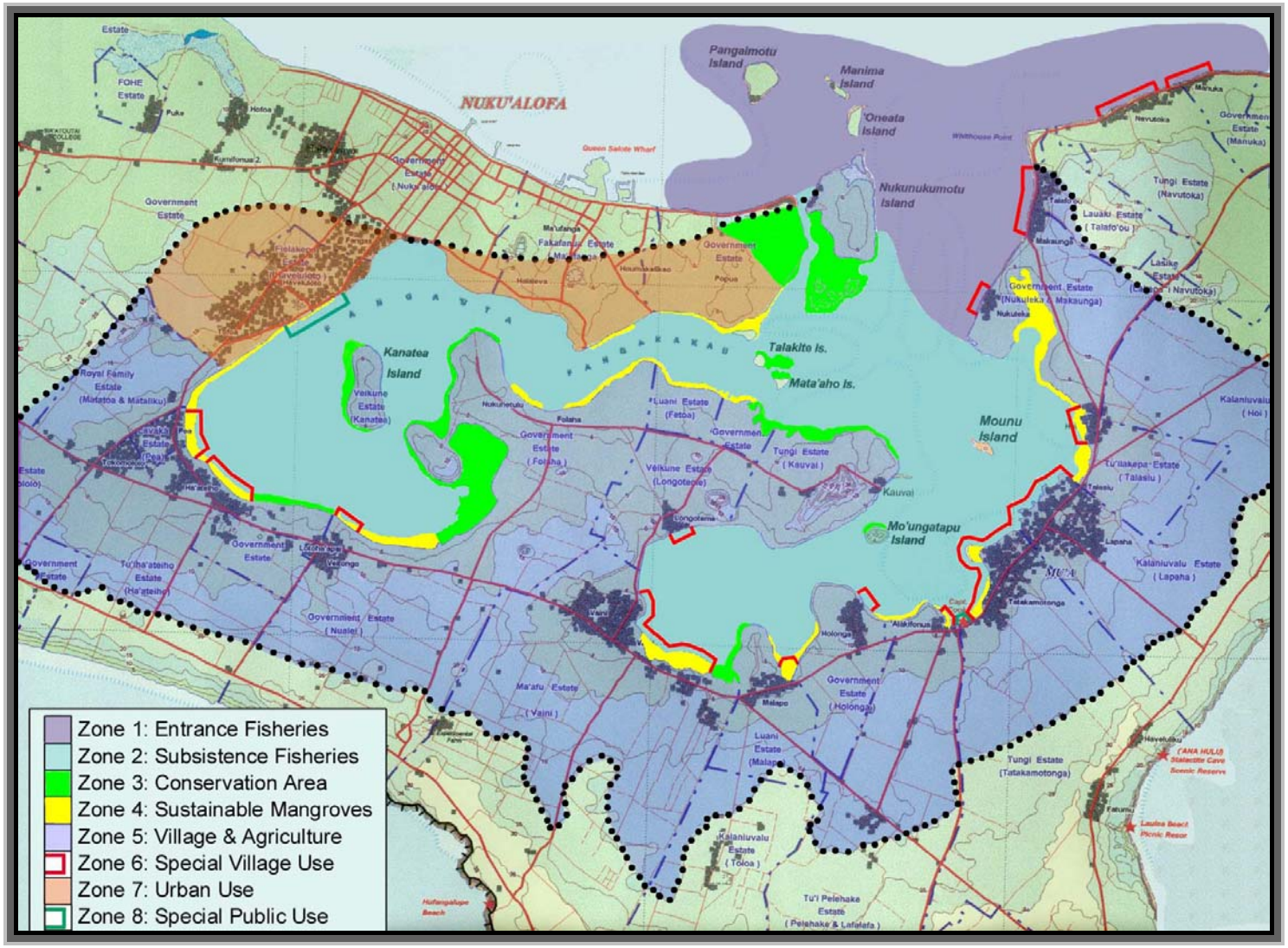


Figure 1: Fanga'uta EMP Map.

The map shows the main ecological boundaries for the lagoon, including the watershed and mullet spawning grounds. Also shown are the eight management zones proposed for the EMP.

Table 1: Summary of activities permitted in each of the eight zones defined for the Fanga'uta Lagoon EMP.

MHWM=Mean High Water Mark.

Activity	Zone 1 Mouth Fisheries	Zone 2 Lagoon Fisheries	Zone 3 Mangrove Conservation	Zone 4 Mangrove Use Area	Zone 5 Village & Agriculture	Zone 6 Village Special Use Area	Zone 7 Urban	Zone 8 Public Special Use Area
Land allocation below present MHWM	✗	✗	✗	✗	✗	✗	✓	✗
Commercial Fishing / Aquaculture	✓	✗	✗	✗	N/A	✗	N/A	✗
Subsistence Fishing	✓	✓	✗	✓	N/A	✓	N/A	✗
Mangrove removal	N/A	N/A	✗	✗	N/A	✗	N/A	✗
Seagrass removal	✗	✗	N/A	N/A	N/A	✗	N/A	✗
Mangrove use (wood, handicrafts, medicine)	N/A	N/A	✗	✓		✓	N/A	✗
Mangrove rehabilitation	N/A	N/A	✗	✓	N/A	✓	✓	✓
Reclamation	✗	✗	✗	✗	✗	✗	✓	✓
Seawalls	✗	✗	✗	✗	✗	✗	✓	✓
Dredging / sand & gravel extraction	✗	✗	✗	✗	✓	✗	✓	✗
Anchor and boat disturbance	✗	✗	✗	✗	N/A	✗	✗	✗
Buildings	✗	✗	✗	✗	✓	✗	✓	✗
Rubbish dumping	✗	✗	✗	✗	✗	✗	✗	✗
Industry	N/A	N/A	✗	✗	✗	✗	✓	✗
Tourism	✓	✓	✗	✓	✓	✓	✓	✓
Recreation	✓	✓	✗	✓	✓	✓	✓	✓
Research	✓	✓	✓	✓	✓	✓	✓	✓

Zone 1: **Lagoon Entrance Fisheries Area (Purple Zone)**

This covers the area between the southeastern tip of Nukunukumotu Island and Nukuleka, out through the mouth of the lagoon and towards Manuka along the northern coast. Its focus is to allow for subsistence and limited commercial fishing, and aquaculture (this is aquaculture that does not require feeding of stock). At the same time, this zone is designed to preserve the migration routes of all fishes that spawn outside of the lagoon, and those whose juveniles use the lagoon as a nursery. Activities that could damage the habitats in this region of the lagoon, such as dredging, reclamations and reef or seagrass damage, have been prohibited to help ensure that fishes continue to use the area to migrate. Mullet are protected in Zone 1 between 15 May and 31 July and may not be caught by any method. This means that fence or arrow traps must be disabled during the closed season. Gill nets are limited to 50m in length and a mesh size of 75mm.

Zone 2: **Lagoon Subsistence Fisheries Area (Light Blue Zone)**

This zone covers the entire water area of the lagoon, except for the mouth and the area to the east of the mouth that encompasses the migration of mullet, the lagoon's most prized fishery. The areas of water beneath mangrove trees are included in this zone. Within this zone, no commercial fishing is allowed, but subsistence fisheries are allowed. However, there is a proposed moratorium on all fishing for one year (30 April 2001-30 April 2002) before these regulations take effect, and no fishes, shellfish or jellyfish may be collected from any part of the lagoon during this period. After the expiry of the moratorium, fishers may take fishes, shellfish and jellyfish at any time of the year, except for mullet.

Mullet can be taken at any time of the year, except during a closed season between 15 May and 31 July. Arrow or fence traps are also not permitted within this zone between 15 May and 31 July. Although gill nets are allowed, they must be no longer than 50m and have a mesh size of 3 inches. The minimum size limits for fishes are shown in Table 2.

Table 2: Minimum recommended size limits for selected fishes in the Lagoon System.

Columns 3 and 4 show the way that average sizes of fish have changed between 1986 and 2001 (WP49). The values in the last column are from Fishbase (www.fishbase.org) and represent the theoretical average size at which fishes should be caught for a maximum sustainable harvest. Note that these sizes are a few centimetres larger than the size fishes must attain before they can reproduce (Column 5).

Name	Scientific name	*Average Size 1986 (cm)*	*Average Size 2001 (cm)*	*Size at first maturity (cm)*	*Size for max Sustainable harvest (cm)*
Fate (Snapper)	*Lutjanus kasmira*	20	15	19	20
Haku (Alligatorfish)	*Tylosaurus crocdilus*	60	60	77	100
Kanahe (Mullet)	*Valamugil seheli*	30	25	34	39
Kanahe / ‘Unomoa (Mullet)	*Liza macrolepis*			34	39
Kavakava (Grunter)	*Terapon jarbua*	15	15	22	23
Koango (Emperor)	*Lethrinus nebulosus*	40	30	37	44
Ma’ava (Rabbitfish)	*Siganus argenteus*			18	19
Manini (Surgeonfish)	*Acanthurus triostegus*			15.5	16
Matu (Silverbiddy)	*Gerres oyena*			18.5	19
Mu (Bream)	*Gymnocranius*			21	23
Ngatala (Grouper)	*Epinephelus merra*			19	20
Nue (Drummer)	*Kyphosus cinerascens*			27	30
O (Rabbitfish)	*Siganus spinus*			15	16
Sipesipa (Ponyfish)	*Leiognathus spp.*	30-40	15-20	15	15
Tangafa (Napoleon wrasse)	*Cheilinus undulatus*			111	155
Tanutanu (Emperor)	*Lethrinus harak*	30	20	29	33
‘Unomoa / Fua (Mullet)	*Mugil cephalus*	20-55	15-50	55	68
Vete (Goatfish)	*Mulloidichthys flavolinetaus*			19	20

Zone 3: Conservation Areas (Green Zone)

This zone encompasses the most important patches of mangroves remaining in the lagoon, near Nukuhetulu and at Nukunukumotu Island, plus those in some smaller patches around the lagoon. It also includes a few terrestrial areas around Siesia. The purpose is to create areas of mangrove forest that are set aside to function fully as fish habitats and as part of the lagoon’s cleaning system. Apart from recreation and research, each to be carried out without any harm to the mangrove system, no fishing, collecting or harvesting of wood, mangrove roots or medicines are allowed in these areas. Mangrove rehabilitation is not recommended for these areas, largely because they will not require it. It is important that incidental damage to these areas does not occur from pigs, or developments elsewhere in the lagoon. EIAs accompanying development projects should specifically address any risks to the Zone 3 mangroves or coastal forests.

Zone 4: Sustainable Mangrove Use Areas (Yellow Zone)
All remaining mangrove areas in the lagoon are classified in Zone 4. This zone allows for sustainable use of the mangrove resources, including use for wood, dyes and medicines. It also allows for the collection of fishes and other animals within the mangroves. The key is that the mangroves should be used in such a way that they are not damaged beyond their ability to recover and grow. Collection of wood or materials for dyes and medicine should be carried out so that only 10% of a tree is damaged each time. Wood and bark should be collected from branches, not the main trunk of the tree. Collections of leaves and flowers may be from any part of the tree. It would be useful to establish a new tradition of tying a biodegradable marker around each tree that is harvested for mangrove products. A maea string (made from the outer bark of the tapa tree, the hiapo) could be tied around a tree to let others know that it has had bark, roots or other parts taken from it. This could be used as a signal to let other people know that this tree needs to be rested to ensure it is used sustainably. When the maea rots and falls away, the tree would be ready for another harvest. All mangroves should be protected from damage by pigs. Planting of mangrove trees is encouraged to ensure replacement of any trees lost or damaged in the past.

Zone 5: Village and Agricultural Uses (Blue Zone)
This zone covers most of the lagoon system watershed. It allows for village settlements as well as agricultural uses of the land. The focus of lagoon management in this area is on minimising the movements of nutrients, mud, sewage and chemicals into the lagoon via the groundwater, any drainage systems or run-off. It is also focused on proper rubbish disposal.

All land within the watershed should be well planted with trees, grasses or crops as much of the time as possible, to ensure that the soil is stabilised and in the best condition for dealing with any accidental sewage overflows or pollution from other sources. Each village could work at ensuring that all of its land is covered by vegetation, and if it needs to be opened for a development (housing, agriculture), that the time without cover is kept to a minimum. For villages and landowners with hilly land, this is especially important, particularly close to the lagoon itself.

Farmers should try to find out about organic systems of land management and minimise the use of chemical fertilisers and pesticides in this zone. This could be a gradual process, undertaken with the assistance of the Agriculture Department. Those that do use chemicals on their land should inform themselves of the correct rates of application so that there is minimum waste and losses into the groundwater, which eventually finds its way into the lagoon.

The correct handling of sewage within this zone is important. Septic systems will continue to be used, and must be well designed and maintained to ensure that they do not leak sewage effluent into the groundwater. Septic tanks need to be pumped once every 2 years to eliminate the sludge that can otherwise clog the system and cause sewage to overflow. If any other systems are introduced, they must treat the sewage until it is harmless in terms of bacteria and nutrients. It is recommended that people building new homes, particularly in low-lying areas, consider composting toilets or other systems.

There should be no further reclamations or seawalls built in this zone. These destroy an important part of the life-support system of the lagoon (beaches and mangroves). Human

developments should be kept entirely on land, and not allowed to extend into the mangroves or other tidal areas.

All rubbish should be properly disposed of in the official Tapuhia dump, and areas on the fringes of the lagoon cleaned up. Rubbish should no longer be burned or buried at home, or used as landfill for low-lying pieces of land. All hazardous wastes such as oil and chemicals are to be recycled or disposed of properly and not dumped anywhere on the ground within this zone.

Domestic animals, particularly pigs, are to be restrained by fencing to prevent them causing damage on the lagoon foreshore.

Zone 6: Village Special Resource Use Areas (Red Zone)
This area has been specially allocated at the request of some of the village communities. The Village Special Use Zone is specific to each village and sets aside exclusive use of the lagoon's resources in the area bound by the shoreline in front of a village and out to a line 50 m into the lagoon from Mean Low Water Mark (MLWM). This does not prevent people from that village using other parts of the lagoon, except for the Special Use Zones belonging to other villages. The zone crosses into Zones 2 and 4, the rules of which are to be observed by people with access to Zone 6. People who are not resident in the village adjacent to each special use zone, may not fish there, use the mangroves, use any other resources or pollute the area.

Domestic animals, particularly pigs, are to be restrained by fencing adjacent to this zone to prevent them causing damage on the lagoon foreshore.

The presence of this zone does not restrict "outsiders" from accessing the lagoon through the zone. It only restricts resource use.

Zone 7: Urban Use Area (Orange Zone)
This zone covers about half of the urban area of Nuku'alofa. It allows for urban settlement, industrial uses, and limited reclamations and seawalls. The reclamations and seawalls are limited to those areas already damaged in the past, and which do not involve further losses of mangroves (other than small patches with <5 trees which are replaced by plantings elsewhere). Those areas between existing reclamations that have so far not been modified may be brought into alignment to smooth out the shoreline. The seawalls that bind them should be of environmentally friendly designs and shapes, and preferably be placed behind any mangroves or beaches.

Any rubbish dumped in the past on the fringes of the lagoon is to be cleaned up and disposed of in the dump at Tapuhia. Rubbish is no longer to be burned or buried at home or used as landfill in low-lying areas. Drainage channels are to be constructed so that they carry storm water and run-off out to sea and do not dump it into the lagoon. All sewage systems are to be well-designed and maintained, with adequate sludge removal and treatment of effluent, so that these do not find their way into the lagoon. If at a later date, a reticulated sewerage system is developed for Nuku'alofa, this will be accompanied by a full EIA and must dump the wastes well away from the lagoon management area.

All government departments, industrial areas and businesses are to be responsible for ensuring that chemicals, oils and other wastes do not find their way into the lagoon

through any of the pollution pathways (see above). Recycling and proper disposal of wastes is critical in Zone 7.

Effort is to be made to cover as much land as possible with vegetation to minimise sedimentation and run-off into the lagoon. Wherever possible, it is recommended that a nature strip of trees and grasses be developed on the shores of the lagoon.

Domestic animals, particularly pigs, are to be restrained by fencing to prevent them causing damage on the lagoon foreshores.

Zone 8: Special Public Use Areas

Zone 8 has been included to allow the public of Nuku'alofa access to the foreshores of the lagoon system for recreational, educational and other purposes. It extends from the P.I.E. Shop to the Ambassador Night Club at Tofoa. Its main purpose is to be used for picnics and recreation while preserving the natural ecosystems present. Other 'Special Public Use Areas' could be added later.

Strategies for Action

The EMP includes many actions designed to be implemented in the short, medium and long term. If these actions are carried out by all concerned, significant environmental and community benefits will result.

The following section outlines suggested strategies for action, identifying first the overall approach, then the key groups or stakeholders involved, followed by the roles or functions of these groups in working towards the objective.

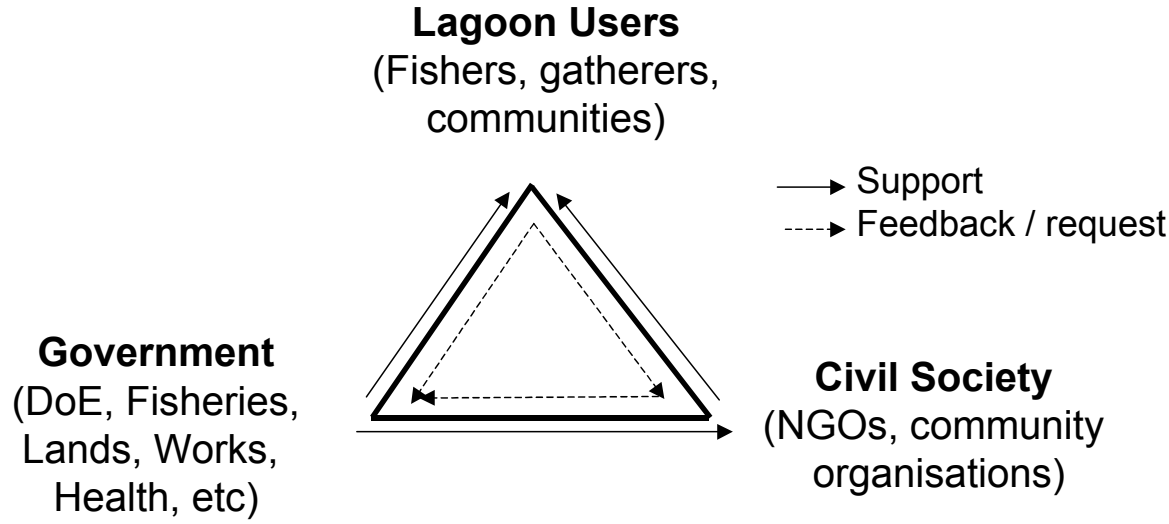
These strategies have been defined through a series of consultations with lagoon communities, both before and after formulation of the draft EMP. Meetings were held in a total of 14 villages to acquire local knowledge on the lagoon environment and gauge responses to the draft. Specific recommendations were also made by departments[7] and NGO representatives[8]. These responses are summarised in Table 4.

The Plan has been designed "*to improve the existing conditions in the lagoon and ensure that it can provide the maximum use of goods and services in the future*". This can best be achieved by a three-way partnership between government, civil society, and lagoon users (Figure 2).

[7] Ministry of Education; Ministry of Fisheries; Ministry of Works; Tonga Water Board; Ministry of Health; Ministry of Agriculture & Forestry; Ministry of Labour, Commerce and industries; Ministry of Marine & Ports; Tonga Visitors Bureau; Central Planning Department.

[8] Langafonua, Tonga Trust and 'Aloua ma'a Tonga.

Figure 2: The three-way partnership model of local development



Key Groups Involved

The key groups involved in designing the EMP and who will ultimately manage it fall into the categories of Lagoon Users, Civil Society and Government, as shown in Figure 2 and will play complementary roles including the following.

Lagoon Users (fishermen, shellfish and jellyfish gatherers, mangrove bark users, lagoon communities and settlements): Formulation and implementation of village activities, monitoring, policing, lobbying, networking.

Civil Society (NGOs, churches, community-based organisations): Facilitation of village action plans, education, awareness-raising, advocacy, conflict resolution, community mobilisation and development.

Government:
Department of the Environment: Co-ordination, technical expertise, monitoring, information, resourcing, backup of other agencies carrying out planned activities, promotion of the Strategy for Action through various messages/media.

Other Government agencies**:** Policy support, provision of expertise, monitoring, regulatory framework, policing in support of communities, media work.

Co-ordination, Policy and Resource Support

Co-ordination
Plan implementation should be coordinated and overseen by a Lagoon Management Task Force. This could be the continuation of the TEMPP Project Implementation Committee, but with a revised composition to reflect the three-way partnership:

- Government agencies (one senior representative from each involved)
- NGOs

- Representatives chosen on a rotating basis from lagoon communities. As these communities will be the main groups affected by the progress of the action strategy, it is vital that they have a substantial voice in the coordination process.

This Task Force should meet regularly, at least every two to three months. Its main roles are to:

- Ensure political and executive support for the action strategy;
- Decide on priority activities and responsibilities in Plan implementation;
- Monitor progress; and
- Seek funding from all avenues including the private sector.

Activities needing more hands-on management should be handled by *ad hoc* committees or working groups of three to five members, which can meet as often as required. The members would be selected by the Task Force.

Legislation and Regulation

Enforcement of regulations, and delegation of powers to local communities, have been key recommendations of both Government and communities. Government departments will be charged with the task of ensuring an appropriate regulatory environment, and with enforcing both existing and new regulations.

Village-Level Activities

Communities and Groups

Local environmental improvement activities are the *cutting edge* of the Strategy. The base-level actors in this process are the small, common-interest groups of society: tapa makers, shellfish gatherers, vegetable farmers, boat owners, women's groups, sports teams. These groups are capable of carrying out mini-projects such as sanctuaries, community-based management, mangrove replanting and care, rubbish disposal, waste oil disposal, recycling, tree planting or beautification. Women's groups are likely to take a lead in this type of activity.

Although community control is the foundation of an effective lagoon rehabilitation programme, it would be a mistake to just "hand over" activities to communities or groups and expect automatic results. Local groups need a few pre-conditions in order to flourish:

- The initial activities they undertake should be simple and low-cost, with humanly and ecologically achievable benefits within 12 to 18 months of start date.
- There needs to be a clear understanding by all concerned (groups, the community, NGOs and Government) of the functions and the rights of each group.
- They need to be able to see and enjoy the benefits of their effort, in other words, have 'ownership' of the mini-projects.
- They need constant support, both technical and organisational. Some modest level of material assistance in cash or kind may also be necessary.

- Activities need to be based on sound ecological principles and the guidance afforded by environmental monitoring to ensure that the results of actions do in fact improve the way humans interact with and benefit from the lagoon.

The interdependence of the lagoon ecosystems requires that these group activities are coordinated at a village or community level. Such coordination will act to ensure that the efforts of one group will not be undermined by the actions of another. An example might be where mangroves planted by a women's group are dug up by roaming pigs. Several villages and government departments have independently made the suggestion that some village-level committee should be formed to carry out this coordinating role, setting local priorities and rules in much the same way as the Lagoon Management Task Force. This committee or its officers would also exercise any delegated policing powers over the lagoon environment.

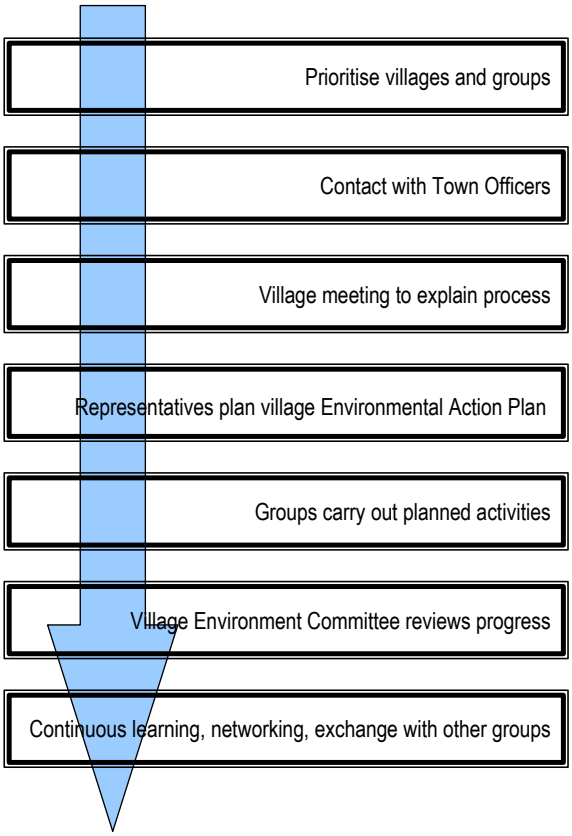
NGOs as Community Facilitators

Tonga is fortunate in having several mature NGOs experienced in village-level work, as well as church-based organisations with considerable capacity, if maybe not the same level of experience. It is recommended that these NGOs or organisations should form the primary contact with the village. Government is best equipped to play a "backstop" role, collaborating with the NGOs, helping them to build their own capacity, but leaving the practical village work to them.

These NGOs should play a catalytic role in local communities, encouraging the formation of small groups or the involvement of existing groups in rehabilitating the lagoon environment.

NGOs should facilitate the development of small groups, their growth in self-reliance, and in skills of analysis, planning, decision-making and problem-solving. Leadership of groups also needs to be promoted, as well as the functioning of village environmental committees if they are formed. These skills and attitudes are best developed through a participatory process such as Participatory Learning and Action (PLA), which can help the groups to discuss local environmental issues, identify a feasible activity and plan for its implementation. Figure 3 illustrates a possible method and the steps in this process.

Figure 3. A method of participatory interaction with the community level



TECAN: A Village-level movement

Village level work will stand the best chances of success if it is given an *identity* such as TECAN, with its own logo and membership. This movement could then have representatives, meetings, competitions and other activities that would give it a life of its own and maximise the sustainability of government and NGO initiatives.

Information, Education, Communication

Information, education and communication (IEC) programmes have the following objectives, to:

- Inform people about the start or progress of a campaign
- Persuade people to change behaviour
- Raise awareness of issues so affected groups can make informed decisions
- Improve understanding of issues by students, decision-makers or technical staff

IEC programmes involve all stakeholders, with a variety of messages to different target groups, using a variety of media. It is vital for these stakeholders to collaborate in the design and implementation of the programme.

For example, it may be seen as important to reach community leaders and figures of authority who will be a major influence in shaping attitudes. The IEC programme will identify certain messages to carry to these leaders, maybe in one-on-one conversations or

in a formal workshop. Communities themselves can also be trained to run their own awareness programmes.

Monitoring

Monitoring is vital to the success of the EMP. Monitoring should cover not only the health of the environment, but also the human side of the plan. This includes the numbers of people, changes in behaviour, participation levels and achievements of various groups and communities.

The newly-formed national Environmental Monitoring Team has begun the monitoring of the Fanga'uta Lagoon system providing vital information on its ecological condition and some of the issues affecting it. The results obtained from this work will help the Lagoon Management Task Force and others to adjust their strategies as required to ensure a sustainable future for the lagoon and the people who are its stewards.

Suggested Programme of Action

1. Secure political support for the EMP
2. Convene the Lagoon Management Task Force
3. Appoint working groups to manage the various functions
4. Canvass broadly among civil society organisations seeking their participation
5. Groups plan working strategies: legislation, funding, IEC, community work
6. Workshops building rapport between civil society and community leaders
7. Communities selected for first stage of environmental action plan development
8. NGOs work with communities

Table 4: Fanga'uta Environmental Management Plan: Implementation strategies and responses.

Zone	*Responses from Government*	*Responses from Communities*	*Agencies / groups involved*
Zone 1: Lagoon Entrance Fisheries Area	• MOF involved in the Management Plan • Enforce existing laws • Educate the public and raise public awareness of the proposed fishing restrictions • Enforce community-based management • Police catch limits and net sizes (Proposal is for 3 inch nets) • Employ village volunteers to report on exploitative activity in their particular areas	• Proposal to totally prohibit small mesh nets from coming into the Kingdom • Mouth of the lagoon is too distant, also has very strong current • This zone extends too far – should stop short of the lagoon mouth. Extend Zone 2 further.	• Ministry of Fisheries • Communities • NGOs • Commercial fishers
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 2: Lagoon Subsistence Fisheries Area	• Moratorium on fishing for one year • Enforce fisheries closures (commercial fishing, mullet, fish traps and moratorium) • Set limits on fishing gear (Gill nets <50m long, 3" mesh) • Establish, enforce and educate on minimum fish sizes • Educate public and raise awareness of the proposed fishing restrictions • Prevent clearing, anchor and boat damage of seagrass • Educate on the importance of seagrass for sustainable fisheries • Stop seagrass decline caused by pollution, seawalls, dredging and runoff	• One whole year moratorium is probably not feasible unless a substitute income activity is promoted for fishermen (3 villages) • Most fishermen do not have plantations so their only livelihood is through continued lagoon fishing • Some areas should be closed to boats to encourage recovery of seagrasses • Will regulations on fishing gear restrict length of fish fences? • Village fisheries management committees should be formed to prepare local management measures and to control outsiders fishing near the village fishing grounds.	• Ministry of Fisheries • Communities • NGOs
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 3: Conservation Areas	• Government makes decision to withdraw leases already in mangroves • Government initiates a compensation programme for those relocated • Identify existing deficiencies in current policy and improve them • Enforce existing policy • Important to enlighten, if not train, people on the merits of the EMP so they can return to	• Government should state clearly who is responsible for land allocation • Compensate or relocate those already allocated blocks • Employ village volunteers to report on exploitative activity in their particular areas • What is proposed as compensation for those already holding land in Zone 3? • Fully support the zoned conservation areas	• Ministry of Lands, Survey and Natural Resources • Department of Environment • NGOs, communities

	villages and encourage better stewardship • Stop further subdivision and development of residential land into the lagoon	• Government must put an end to further subdivision into the water	
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 4: Sustainable Mangrove Use Area	• Prevention of mangrove clearing • People in government and in the communities must learn to work together for the greater good. People are our most important resource for implementing the EMP and only through them can anything be successful • Education campaign on methods of sustainably using mangroves	• There should be a strong mangrove replanting scheme – will restore the ecosystem and encourage sustainable use • Every property should have at least a 50m mangrove fringe at its seaward edge	• Ministry of Lands, Survey and Natural Resources • Department of Environment • NGOs • Communities
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 5: Village and Agricultural Uses	• Promotion of organic farming and use of environmentally friendly materials for agriculture • Incorporate organic farming practices into school curriculum • Promote replanting of trees through proper management of tree nurseries • Encourage revegetation and vegetation retention on agricultural allotments • Encourage fencing to stop pigs damaging lagoon foreshore and mangroves	• Septic tanks are the main problem • What does the plan propose to do with those with outdoor toilets? • Rubbish dumping to be banned, enforceable by fines • Encourage fencing of pigs to prevent them damaging foreshore and mangroves • Decrease imports like disposable nappies, plastic bags • Would like to learn more about composting	• Department of Environment • Ministry of Agriculture & Forestry • Ministry of Health • NGOs • Communities
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 6: Village Special Resource Use Areas	• Create legal basis for special village use areas • Have a clear government policy for community based management • Continual meetings with the community to become aware of the proposed scheme and the merits of abiding by the proposals in the plan • This is essential for public awareness and must be accompanied by training workshops • Push to pass proposed regulations for the lagoon	• Full support for this concept but need to know more about enforcement and how it will work in practice • Zone 6 is too small for each village • Proposal to have an environmental committee in every village • Nobles, District/Town Officer and village communities and groups should be involved in the process of developing and implementing the EMP • We need very strong regulations that will be enforced and carried out	• Department of Environment • Ministry of Fisheries • Ministry of Lands, Survey & Natural Resources • NGOs • Communities

	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 7: Urban Use Area	• Incorporate the Town Planner in the implementation phase of the plan • Work with community leaders to be committed to the cause. They in turn can lead the rest of the community by example • Encourage proper disposal of garbage, oils, chemicals • Improve operations of sewage / septic systems • Cleanup foreshore	• Stop further reclamation and seawall development in lagoon • Stop further subdivision and development of tidal land in the lagoon	• Ministry of Health • Ministry of Works • Department of Environment • Ministry of Lands, Survey & Natural Resources • Chamber of Commerce • Private Sector, especially oil companies, processors
	Responses from Government	*Responses from Communities*	*Agencies / groups involved*
Zone 8: Special Public Use Areas	• Identify and protect key locations to enable public access to foreshore and lagoon by all residents of Tonga and visitors • Identify additional suitable areas, obtain approval and manage through local communities to improve stewardship of the area	• Havelu Village wishes to manage its own special village area and be able to control the use by others	• Ministry of Works • Department of Environment • Ministry of Lands, Survey & Natural Resources • Havelu Community Leaders • Local entrepreneurs and groups in Havelu.

List of communities consulted

1. Ha'ateiho
2. Havelu
3. Hoi
4. Holonga
5. Longoteme
6. Malapo
7. Manuka
8. Navutoka
9. Nukuhetulu
10. Pea
11. Popua
12. Talafo'ou
13. Vaini
14. Veitongo

AMERICAN SAMOA GOVERNMENT'S AMERICAN SAMOA COASTAL ZONE MANAGEMENT PROGRAM WETLANDS MANAGEMENT

Mary Midkiff & Peniamina Siatunu'u

Introduction

In recognition of the unique and important attributes of wetlands in American Samoa, the American Samoa Government (ASG) has developed a comprehensive wetlands management plan to provide a policy framework to manage wetlands resources. The management plan is intended to assist ASG promulgate rules and regulations for American Samoa Coastal Management (codified under 24 ASCA, Chapter 5). Of primary importance is to establish a mechanism for achieving a policy of "no net loss" of wetlands. These goals and objectives can only be achieved if:

- The people of American Samoa appreciate the economic and ecological values of wetlands and give consideration to these values in their actions.

- There is a broad understanding of the human activities that affect the land and water on which wetlands depend.

- The territory successfully integrates wetland protection and regulatory programs with other social goals and the user participation process.

The American Samoa Coastal Management Program (ASCMP) is the lead agency for wetland policy, management, and enforcement and is a section within the Department of Commerce. ASCMP follows the United States federal definition of wetlands as stated in Section 404 of the Clean Water Act that defines wetlands as:

Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFR Part 328.3 (b)).

This definition is applicable to American Samoa. It emphasizes that hydrology, vegetation, and saturated soils must be present in a wetland. Wetlands in American Samoa include mangrove swamps, freshwater and coastal marshes, springs, streams, and some cultivated areas such as taro fields.

Characterization of Wetland Resources

Wetland habitat can be salt water, fresh water, intermittent, riparian, wetlands forests and artificially created environments. Wetlands in American Samoa include marshes and swamps as well as cultivated and ruderal areas, all of which can occur in fresh and saltwater conditions. Wetlands support many plant species, some of which are only found in wetlands, while others occur at the fringe and may be associated with upland habitats.

A. Swamps

Swamps are wetlands dominated by trees and are found in both salt and fresh water areas. Saltwater swamps are also called mangrove swamps after the dominant trees. The common plants of mangrove and freshwater swamps include the oriental mangrove

(*Bruguiera gymnorrhiza*), red mangrove (*Rhizophora mangle*), beach hibiscus (*Hibiscus tiliaceus*), puzzlenut tree (*Xylocarpus moluccensis*), Tahitian chestnut (*Inocarpus fagifer*) and falaga tree (*Barringtonia samoensis*).

B. Marshes

Freshwater and saltwater marshes are characterized by herbaceous vegetation such as sedges, grasses and ferns, rather than woody shrubs and trees found in swamps. Saltwater marshes occur along coastlines and often become established in mangrove swamps that have been disturbed or cut off from the sea. Freshwater mashes occur naturally in shallow, slow moving, or standing waters where soils are saturated by a high water table. The dominant vegetation of marshes includes grasses and sedges such as *Paspalum* spp. and *Cyperus* spp., water chestnut (*Eleocharis dulcis*), *Ludwigia* spp., Job's tears (*Colx lacryma-jobi*), and the marsh fern (*Cyclosorus interuptus*).

C. Ruderal and Cultivated Wetlands

Ruderal wetlands are usually created in disturbed areas such as ditches, ponds, or disturbed mangrove swamps. Freshwater marshes have fertile soils and so have traditionally been converted to taro cultivation. The commonly cultivated taro plant in American Samoa is *Colocasia esculenta*. The fern, *Christella harvey*, and wild ginger (*Zingiber zerumbret*) can invade cultivated wetlands, ditches, and ponds.

Inventory and Status of Wetlands in the Territory

Wetlands in the Territory are being lost or degraded by urban growth and development as a direct result of increasing population. American Samoa's population has increased at an annual rate of 3.7 percent, according to the most recent census data (1980-1990). The rate at which the Territory has lost wetlands is similar to the population growth rate. Between 1961 and 1990, 4.6 percent of American Samoa's wetlands have been lost each year.

The population of American Samoa is expected to double within the next twenty years and pressures on wetland areas will only increase accordingly. As the population increases, so does the desire for land for housing, stores, offices, roads, and utilities. These needs represent a demand for the scarce flat areas, such as those occupied by wetlands. Given the island's topography, development is fairly well confined within a narrow band of land between the lower slopes and the ocean.

While a variety of federal and Territorial laws and regulations relate to wetlands protection, enforcement is inadequate and there is little comprehensive legislation to protect these valuable resources. Many land-filling activities, especially on Tutuila Island, result in piecemeal losses of wetlands that are either exempt from current regulation or occur without due process or permit review.

Compounding the problem associated with regulation and enforcement are cultural forces and a general shift in social attitudes by Samoans. Under the Samoan land tenure system, wetlands are perceived as land owned by the village. The perception of western public rights is not culturally appropriate in Samoan culture, thus the concept of public good conflicts with village interests. Samoans see the use of their land as subject to the decisions of their matai and village councils, not the federal or Territorial governments.

While some residents may be familiar with resource protection they feel compelled to remain silent when higher ranking residents make land use decisions that negatively impact wetlands but are traditionally within their decision making authority. Samoan communal and subsistence land use practices are also eroding fdue to increasing western influences and the shift to a cash economy. Furthermore, the general public does not have enough information about where wetlands are located, their biological and social functions, the regulatory requirements surrounding wetland areas, and the activities that damage the wetland's fragile ecosystems.

Gains and Losses in Tutuila and Aunu'u

Most of the wetland sites on Tutuila Island have experienced some loss over a thirty-year period between 1961 and 1991. The total wetland acreage for Tutuila Island has been reduced from 488.12 acres in 1961 to 350.93 acres in 1991, a loss of 137.19 acres in just this time period alone. Almost ten years later, we predict this value has doubled in 2001. Nuuuli has suffered the greatest loss of wetlands, approximately 61 acres, representing a 33% decline since 1961. Tula appears to have lost 8 acres, representing a 58% decline. Leone has lost over half of its wetlands since 1961. The freshwater marsh in Vaitia seems to have increased slightly (+ 0.45 acres). This is probably the result of the abandonment of taro cultivation which has allowed surface waters to flood a wider area.

The wetlands on Aunu'u Island appear to have increased slightly from 11.76 acres in 1961 to 11.93 acres in 1991, a difference of 0.17 acres. The wetland areas associated with the Pala Lake, the taro fields, and the Aunu'u Crater appears unchanged from 1961. The school swamp seems to have increased slightly (+ 0.17 acres). This reason is not known.

Causes of Decline

The main cause of the loss in wetlands is development. Clearing and filling to accommodate village homes, pigpens, and commercial buildings has encroached into wetland areas. Trash and other debris is dumped into the wetlands and, in some instances, covered with volcanic ash soils. Wetlands in the United States mainland are often lost through clearing and draining for agricultural use. However, this has rarely been the case in American Samoa, most of the wetlands have been lost from clearing and filling for development.

Present Land Uses In and Around the Wetlands of Manu’a

The steep topography of the Manu'a Islands dictates development patterns on the islands. Communal land ownership and cultural life philosophy also influences land practices. The lifestyle of the people has traditionally been characterized by subsistence agriculture and fishing. The fact that wetlands have not been filled for development, unlike Tutuila, is a strong statement about the high value the villagers place on these areas for agriculture and their willingness to preserve their wetland characteristics.

The Manua’an wetlands are presently used to provide food for the villagers. Most of the wetlands are used, at least in part, for taro cultivation, although banana, breadfruit, papaya, and pineapple are also grown around the fringes of the wetland. Freshwater eels are caught in the Luma and Olosega wetlands. Other agricultural products include the use of pandanas trees for mats and some medicinal plants. As far as we are able to determine

no pesticides or herbicides are used directly in the wetlands, but the watershed above the Luma wetland is an important agricultural area where some pesticides/herbicides may be used.

In Luma, Fusi, and Woto Marsh, agricultural pressures on the natural wetlands have been reduced by shifting taro production to upland sites such as the old airstrip on Tau Island and above the village on Ofa Island. The shift was precipitated by the cyclones of 1990 and 1991. This appears to be a permanent shift, since the upland sites are perceived as more reliable and less subject to flooding and other adverse weather conditions. Now that the villagers have made the investment to establish taro plantations in the upland sites, they are probably not likely to abandon them.

Village homes have been built around the fringe of the wetlands, but very little development is actually encroaching into the wetlands. A few piggeries are located around the wetlands but these are fewer than those observed on Tutuila. No public infrastructure (i.e., sewer, water, electrical, and telephone lines, roads etc.) has been built within the wetlands, except for a telephone line across the Luma wetland. Currently there is no pressure to build structures in any of the wetlands, nor are there any active plans for infrastructure development that would directly affect the wetlands. The village dumpsite at Fusi is an example of an infrastructure development that has altered a wetland. On Ofu, Woto Marsh may be threatened by a possible relocation of the airstrip and road.

Gains and Losses in Manu’a

Overall, there has been little gain or loss in the aerial extent of the wetlands of Manu’a. Slight losses appear to have occurred at Luma (1.24 acres, a 4.6% loss) and Olosega (1.39 acres, a 15.9% loss). The greatest loss has been at Fusi, on Ta'u, (3.38 acres, a 70% loss). It has been assumed that there has been no change in the wetlands at Va'oto Marsh in Ofu or at Lesi’u in Ta'u.

Table 1. Type and total acreage of wetlands in each village in American Samoa

WETLAND SITE	ACREAGE	WETLAND TYPES
Tutuila Island	**350.93**	
Nuuuli	122.90	Mangrove Swamp, Marsh, Ruderal, Cultivated, Streams, Lagoon
Leone	20.74	Mangrove Swamp, Marsh, Ruderal, Cultivated, Streams, Lagoon
Malaeloa	72.06	Freshwater Swamp, Marsh, Streams
Aua	9.18	Mangrove Swamp, Streams
Masefau	43.06	Mangrove Swamp, Marsh, Streams
Vaitia	34.05	Marsh, Mangrove Swamp, Cultivated Streams
Alofau	2.03	Mangrove (ruderal), Streams
Aoa	23.45	Mangrove Swamp, Marsh, Ruderal
Aloa	15.47	Marsh, Cultivated, Streams
Tula	7.99	Ruderal Marsh
Aunu'u Island	**111.93**	
Pala Lake	44.76	Mangrove Swamp, Lake
Taro fields	27.30	Cultivated
Crater lake	36.84	Marsh, Open Water, Stream
School Swamp	1.03	Mangrove Swamp, Ruderal

WETLAND	ACRERAGE	WETLAND TYPES
Tau Island	**35.84**	
Luma	25.80	Freshwater Swamp, Freshwater Marsh Cultivated Wetland
Fusi	1,45	Ruderal Wetland
Lesi'u	8.59	Freshwater Swamp, Cultivated Wetland
Ofu Island	**5.87**	
Woto Marsh	5,87	Freshwater Marsh
Olosega Island	**7.37**	
Village Wetland	7.37	Cultivated Wetland, Freshwater Marsh

Approach to Preparing a Wetlands Management Plan

The wetland management plan for American Samoa is based on the functional values of wetlands and their economic and cultural significance while, at the same time, striving to be accepted and enforced by the people themselves within their cultural system. It is our goal that through the wetland management plan, these values can be translated to the Samoan population and carried into the future with the cultural norms of society and with recognition of Samoan rights of self-determination.

The American Samoa Coastal Management Program has identified the following areas for future funding and technical assistance that will aide in the development of a wetland management plan. These include:

- A technical characterization of the existing wetland resources
- An investigation of wetland status and trends within American Samoa
- Identification of site specific opportunities for wetland restoration, rehabilitation, and creation actions
- An assessment of the economic importance of wetlands
- A survey of public agency involvement and village sentiment for wetlands management
- Development and discussion of an array of management options and tools, and
- Formulation of a recommended approach for wetlands management.

Educating for Wetlands Management

To effectively provide residents with the information needed to help them appreciate and protect their wetlands as a productive resource, ASCMP continues in the development of an Environmental Awareness Education Plan to include all water resources. This strategy is dynamic, as it is culturally sensitive and will have a unique approach to each audience. To be effective, the program will need significant input from primary residents, including village councils and residents.

The focus of the educational strategy is to provide information to those who are responsible for a) protecting or maintaining wetland areas, b) making decisions regarding the use of wetland areas, c) eradicating or degrading the wetlands, or d) establishing and maintaining local sanctions and rules. Target audiences include:

- Village Councils
- Pulenu'u for those villages
- Landowners adjacent to the wetlands
- Users (primarily farmers and those harvesting fish or plants from the wetlands)
- Elders of the villages concerned with preserving the traditional ways and cultural pride.
- Residents, children, and general public

Monitoring Wetlands

Three types of monitoring are necessary to maintain the management plan and to measure its success: wetland status and trend, wetland functions, and mitigation. Monitoring wetlands status and trends involves tracking changes in the amount and type of existing wetlands. Monitoring surveys should be conducted every 2 to 5 years to maintain zoning measures and other planning tools in the wetlands management plan. These monitoring surveys will contribute to future decisions regarding changes in enforcement, zoning, permitting or other planning measures.

Changes in the function of wetlands are just as important as the changes in the amount of wetlands. Wetland functions should be monitored to record changes and to increase knowledge about wetland ecology and function in American Samoa. Wetland functions involve plant and animal diversity, species composition and structure, productivity, water quality, and hydrology.

Current Situation

Presently the awareness of the importance of wetlands, its ecological functions and protection is not fully understood by the community. There is still much work to be done in this area. Decision making at the village level is crucial to wetland protection. Traditionally, land use and resource utilization decision are made in villages or at the aiga level and confirmed by the village council. Also American Samoa's traditional communal

ownership of land and natural resources is defined at the village level. Encouraging participation to protect wetlands is an ongoing process within the ASCMP program.

While village level participation is crucial, interest and awareness in wetlands management and protection should not be limited to residents of affected villages. A broader perspective must be obtained from residents who recognize that wetlands are a resource for all Samoans, not just those living on the edges of a wetland.

Due to population pressures much activity has revolved around permitting and enforcement activities and attempting to regulate and in some cases, prevent and discourage wetland-filling activities. This filling usually occurs on the edge of wetlands with the intent to create more land for personal use.

Current Public Awareness on Wetlands

ASCMP continues to promote the ecological and cultural importance of wetlands preservation to the public in a variety of mechanisms. May is wetlands month, and each year ASCNIP offers a variety of outreach and educational activities to create wetlands appreciation. Some of these activities involve creating songs, skits, dances, trivia contests, school lectures, TV spots and videos. Other mechanisms include Coastweeks, which is a two-week event filled with activities, field trips and presentations aimed towards promoting environmental awareness and conservation. A Religious Consciousness Project has been developed to target the religious leaders of the community on recognizing and preserving American Samoa's environment and understanding how land use practices and population will affect these resources in the future. ASMPS yearly Art and Tide calendar has been a tremendous success with much participation from schools on submitting environmental artwork along with traditional Samoan proverbs. A village of the year award, sponsored by the National Oceanic Atmospheric Administration, encourages villages to participate in environmental protection and awareness.

Mangrove Policy and Legislation

American Samoa Coastal Management Program Administrative Rules, revised July 7, 1997.

Section 26.0201 Adoption authority: The American Samoa Coastal Management Program administrative code is adopted pursuant to authority granted by the Department of Commerce under Public Law 21-35, the American Samoa Coastal Management Act of 1990, ASCA §§ 24.0501 et. seq.

Section 26.0202 Purpose: The provisions of this chapter govern the administration of the American Samoa Coastal Management Program. The Act mandates the establishment of a system of environmental review, along with economic and technical considerations, at the territorial level intended to ensure that environmental issues are given appropriate consideration in the land use decision-making process. The provisions of this chapter establish a consolidated land use permitting process, known as the Project Notification and Review System, including developmental standards, procedures for the designation, planning and management of Special Management Areas and procedures for determination of federal consistency. The provisions of this chapter are not intended to negate or otherwise limit the authority of any agency of the Territory, provided that

actions by agencies shall be consistent with the provisions contained herein. The provisions of this chapter are consistent with the Coastal Zone Management Act of 1972, as amended 16 USC §§ 1451 et. seq.

Section 26.0222 of the Administrative Code is dedicated entirely to wetlands management in American Samoa, this section provides a working definition, delineation, policy, jurisdictional limits, buffer zones, permitted and prohibited activities, permissible uses and violations.

Under section 26.0221 Special Management Areas are managed as areas that possess unique and irreplaceable habitat to American Samoa. Currently, the Leone Pala Lagoon and the Nuuuli Pala Lagoon have been delineated and designated as Special Management Areas.

Two candidates for Special Management Areas stand out for their unique character, the Malaeloa freshwater swamp and the Aunu'u Crater Lake Freshwater Marsh. ASCMP is working towards designating these areas for Special Management because both are large and relatively pristine areas that provide important fish and wildlife habitat and offer the best examples of freshwater wetlands in American Samoa.

The Malaeloa freshwater swamp supports large mature trees, including the rare lalapa. This species was once thought to be restricted to Leone and has not been reported from American Samoa for over sixty years. The expansive area of deep water within the wetland supports eels and other fish. These wetlands help control flood flows and protect downstream developments.

The Aunu'u Crater Lake is one of the most scenic areas in American Samoa. With the exception of the outlet culvert, this area is completely undisturbed. It supports a lush marsh communitv and provides a unique habitat for fish and birds, particularly the rare Australian gray duck. In addition, the crater bowl offers excellent recreational and educational opportunities for leisurely day hikes or for learning about the volcanic origins of the islands. Efforts have been made to make this a potential site to be included on the list of Wetlands of International Importance or the RAMSAR list.

EMPOWERMENT AND THE CHALLENGES OF INVOLVING LOCAL COMMUNITIES

Joeli Veitayaki

Introduction

The involvement of local communities is a prerequisite for the success of community-based intiatives (Chambers 1992). Although this seemed a foregone requirement, it was not intially done as local communtiies were only led by outsiders. This however is changing as people in communities throughout the developing world are staking their right to be involved in development activities affecting them. This is even more so in the Pacific Islands because of the way indigenous communities rely on environmental resources and their ownership of these resources. In addition, these communities need to be familiar with the need for contemporary management as some of the traditional management systems they have used up to now are no longer effective given the current capacity and resource use techniques. Little work has been done on better understanding how Pacific Islanders should be involved in resource management systems that incorporate the traditional and contemporary management systems. This incorporation is required because practices in local communities need to be made consistent with contemporary management practices. Furthermore, management practices in traditional communities need to be made appropriate to existing situations.

The involvement of customary resource owners in Fiji and the other Pacific Islands is intriguing because the effective involvement of local communities is dependent on how some of the pertinent issues discussed in this paper are addressed. Despite the sophistication associated with traditional wisdom, Pacific Islanders need to understand the complex interrelations between ecosystems that are inherent in nature. In addition, local custodians need to appreciate their rights and obligations under contemporary statutory management arrangements. On the other hand, people working with the communities need to appreciate the way people live and do things and how people's lives are affected by development initiatives. In an attempt to discuss some of the issues, this article will explore the need to empower local communities, the current status of empowerment and the challenges that need to be kept in mind. I will conclude with a number of proposals on how to formulate more effective resource management systems.

Rationale for Empowerment

The genuine involvement of people in the communities is a precondition for the success of all initiatives that involve them. This realisation came about after many early painful failures that were blamed on peoples' lack of interest, involvement and commitment. The quest to make development initiatives more successful has lead to the emphasis on community-based initiatives. This approach is suited to people in the Pacific because of their ownership of most of the resources and the importance of these resources to the people in the communities.

Community-based initiatives are now emphasised because they are cost-effective and are more appropriate. Experience has shown how knowledgeable people are about their resources (Johannes 1981). This intimate knowledge of local resources can be put to

good use when resources management methods are undertaken to ensure the sustainable use of environmental resources.

Sustainable development which is commonly defined as development that allows people today to meet their own needs without compromising the ability of people tomorrow to meet their needs, is now pursued in all corners of the Pacific region. Although it has been part of the rhetoric for over the decade since the Rio Conference, sustainable development is still to be achieved. It is because of this emphasis that local communities are being encouraged to play an active part in the utilisation of the natural resource in their areas. In promoting this stance, it is hoped that the communities would be in a better position to determine the sustainable level of use for the resource. It is believed therefore that if local communities are appropriately empowered, they would play critical roles in the sustainable utilisation of their resources.

Community-based initiatives are also promoted because of the revival of the value and relevance of the indigenous knowledge. It is hoped that community initiatives would employ traditional knowledge, which can effectively complement contemporary resource management methods. In the area of medicine, for instance, traditional healing power is now acknowledged and is being incorporated into the medical service in Fiji. The same can be done in areas such as food sources, social relations and resource management.

In spite of all these reasons why local communities need to be encouraged to determine their own development strategies, it also is important that outside input be incorporated. This is to ensure that the local communities learn and benefit from the experience of others and are not left only to learn from their own firsthand experiences. It can also assist the community to develop skills in collecting and analysing information that helps them judge the success of their initiativees and understand why. In addition many of the issues relating to the utilisation of environmental resources are new to local communities. It is therefore logical for local communities to receive advice and assistance from outside the communities. Recent experience has shown how effective local community initiatives have been with outside assistance. In Verata and Cuvu the people are testifying to the success of marine resources rehabilitation work that were undertaken with the assistance of externally funded non-government activities (BCN 1997; Tawake *et al*. 2001; Tawake and Aalbersberg 2001; Anon. 2002). This approach is now being attempted in several other areas in Fiji and the indications are that the activities would be successful in mobilising community action (Veitayaki *et al*. in press)

State of Empowerment

Community-based resource management is now widely practiced throughout the Pacific islands. Although different methods of empowerment are used, community groups are now playing a more active role in the use and management of their resources. In Samoa, an AUSAID funded project has enabled more than 60 villages to formulate marine resources management plans. These plans are the result of close consultation between the project officers and local communities. The people determine the management activities and also enforced them. Initial results indicate that the management activities are succeeding in reducing the threat on marine resources in the managed areas (King and Faasili 1997).

SPREP recently concluded a major Global Environment Funded project that involved the setting up of 12 conservation areas throughout the region. These conservation areas, comprisin g of some six marine-based ones, were established in an attempt to rpove that national parks do not work well in the Pacific. Earlier attempts to protect the biodiversity in the Pacific had been largely unsuccessful because in the earlier attempts at protection, the relationship of people and land was not considered. Land tenure in the Pacific rests with the communities, which makes it critical that the local communities are involved. In addition, it would be difficult to restrict the use of resources from the people that own these. The island governments hold little power over land, which traditionally rests with the local communities. Thus, the governments were unable to push the establishment of protected areas. The South Pacific Biodiversity Conservation Project (SPBCP) concept was based on the unique land and resources ownership situation in the Pacific and the need to encourage the collaborative participation of the local communities, NGOs and government agencies. These groups have to work together to establish and manage conservation areas that are based on the sustained use of local natural resources by the communities.

The objectives of the SPBCP were to:

- assist efforts by the local communities and governments to protect the biological diversity of the region,
- assist to establish and initially manage conservation areas that later will be managed by local communities, NGOs and government agencies
- protect the rich natural heritage of the region by conserving and sustainably managing its natural resources and biodiversity
- identify and address the most urgent threats to the region's biodiversity by protecting the region's plants, animals and ecosystems
- develop and advocate appropriate funding to support conservation and sustainable resource management activities
- strengthen local expertise and technical ability in planning and carrying out conservation programmes
- coordinate coastal management and planning activities in the region and,
- assist member countries to take all appropriate measures for reducing and controlling pollution and coastal erosion in the area covered by the SPREP Convention.

Previously, conservation needs in the Pacific were addressed by an emphasis on environmental education and awareness. The assumption was that greater understanding and awareness of the values of conservation would lead to positive conservation work. However, experience has shown that local resource owners live under trying socioeconomic conditions. They are often faced with the dilemma of choosing between immediate income from the use of resources that are unsustainable or delayed and less tangible benefit in the future through conservation activities. This was the main challenge to conservation in the South Pacific. The SPBCP concept acknowledges that conservation in the Pacific can be successful only if the needs of the local resource owners are accommodated. This is logical because conservation means preserving the resources for the future, whereas the people have to live here and now. It is therefore pointless to expect these people to conserve their resources if their immediate needs are not being met.

The challenges under SPBCP are to:

- find new and better methods of generating benefits within communities while maintaining resource use at sustainable levels and protecting biodiversity, and
- empower communities to plan, manage and monitor their own resources.

SPBCP is an attempt to make conservation projects more successful for existing sociocultural conditions. The biodiversity in most Pacific societies is threatened because of the socioeconomic changes occurring. The SPBCP approach attempts to simultaneously achieve the dual objectives of conservation and development. The search for alternative sources of income has greatly affected the declaration and development of the conservation areas. This is because the people's desire for income in the immediate future has to be addressed.

In Fiji, in the area of fisheries, different community based initiatives have been undertaken. For the licensing of all commercial fishers in the inshore areas of the country, the legislation requires that the owners of customary fishing grounds be consulted by people who seek to fish commercially in their areas. Government can only sign fishing licenses if the consent letter from the traditional owners of the fishing grounds is cited. Recent experience has shown that this arrangement can be abused particularly in areas where consent letters now represent the exchange of large sums of money. Such uncontrolled offers of license can hasten the depletion of fisheries resources because it extends the level of effort. This has resulted in the campaign to empower the owners of customary fishing areas to understand the long-term implication of their decisions. It is hoped that the owners of fishing areas will instigate management measures that would be more effective than what government is achieving through its management systems. In some instances the villagers have undertaken to reduce the number of licenses they allow for in their fishing grounds (BCN 1997;Tawake *et al*. 2001; Tawake and Aalbersberg 2001; Parks and Salafsky 2001; Veitayaki *et al*. in press).

Fiji has invested heavily in the demarcation and the settlement of its customary fishing area boundaries, which are now mapped and registered (Waqairatu 1994). The next logical step is to use science to help in the determination of the maximum allowable catch from different areas. This information will allow a more realistic way of determining the number of fishing licenses that can be offered to commercial operations within specific areas.

In some of the communities the state of the fishing grounds is poor and requires rehabilitation. In a number of places, the people have declared no take zones where the resources can be allowed some recovery time. The people have quickly embraced the idea that fishing effort needs to be reduced. The no take zones in Verata, Cuvu, Votua and in Gau are argued by the local people to quickly result in the recovery of the protected areas as well as adjoining ones (BCN 1997;Tawake *et al*. 2001; Tawake and Aalbersberg 2001; Parks and Salafsky 2001; Anon 2002; Veitayaki *et al*. in press).

In many of the coastal communities the effort is now to extend the resource management work. In Naboutini, Vunaniu, Korotogo, Namena and Saioko, villages in Fiji, the villagers are replanting and rehabilitating mangroves. Mangroves are critically important ecosystems whose values have only recently been appreciated. In the above named communities, the replanted and rehabilitated mangroves are assisting in the recovery of the fishing areas and are protecting the shorelines.

In some parts of Fiji traditional resource management practices are being used to enable the effective management of marine resources. In Tacilevu, the people have introduced a rotational system, which means that at any one time a portion of their fishing ground will be protected to allow the resources within to survive undisturbed for some time. In Sasa-Mali and Macuata, the chiefs of the district have decided to put in place a central licensing system. The system, which designated a chief from the three in the district to handle all consent applications within the district, would enable the chiefs to keep a better count on the number of licenses in their area. The chiefs also agreed that this scheme was a better way to ensure accuracy in the number of licenses. In Cuvu, the people have physically removed crown of thorns starfish from the reefs, have begun to culture corals and have designated no take areas (Anon. 2002). In all of these cases, the people are using their tradition to manage their fishing areas. However, in all the cases some outside organisation has been involved in mobilising community efforts. In all of these initiatives the communities have been assisted by Government departments, NGOs and institutions such as USP or AusAID.

Challenges

The empowerment of people in local communities is riddled with challenges that need to be addressed if the empowerment is to result in the desired long-term involvement of local communities. The challenges are in no particular order but need to be appropriately addressed if the empowerment is to be meaningful and lasting. Participation is critical to allow the identification of local priorities so that the development better reflects people's needs and wishes, mobilises local support for development and minimises the cost of public services by shifting the responsibility to local people and organisations. There is evidence that community development programmes actually cost less and are more successful to implement if the institutional framework is right. Although the process is time consuming intially, it is often more successful in the long run.

Development activities in Fiji have had inherent problems because the people have been ill prepared (Burns 1963:156; Belshaw 1964:122; Plange 1996:239). People need to be familiar with the requirements of the development activities and what is expected of them. Furthermore, they need to be trained in the appropriate new skills so that they can be as competent in these development activities as they have been with the traditional ones.

The top-down and externally-driven approach that is universally imposed on people and assumes they are ready to undertake development activities has not worked. The problems of development activities are related to two sets of factors. First is the people's lack of understanding of the requirements of the development activities in which they are involved. For example, people need to understand the objectives of the project and the reasons why they have to do certain things differently. Second is the lack of appreciation by outsiders of the influence and significance of the local social and cultural conditions in the areas in which they work. Policy makers and development agencies must appreciate the lifestyles in villages, people's value systems and their needs, including a minimum level of infrastructure and institutional support.

Community programmes must involve people in the development of policy, action plans and programme implementation strategies that empower them to work collectively towards a sustainable society and engender ownership of the local programmes (Keen 1994:55). This requires that the control and accountability for the development activity be taken from central authorities and given to community organisations. However, the inherent difficulties would exist if what the people are asked to do is new to them. Therefore, successful participation requires a two way process; with the understanding of local needs, building on the strengths of existing institutions, and defining changes that are needed to support community action (Narayan 1995:1).

Community-based development requires new institutions, which promote the:

- adoption of goals and processes which strengthen the capacity of a community to organise and sustain development and its benefits
- reorientation of bureaucracies to support community empowerment and investment in social capital through user participation in decision-making
- achievement of a match between what people in a community want and are willing to pay for and manage, and what development agencies supply .

(Narayan 1995:5).

Empowerment requires a rational and transparent decision making process. Good governance is required because people need to be comfortable and assured that their interests are foremost and that they are part of a network that is fair to all its members. Dynamic and enlightened leadership therefore is critical. Leaders need to be familiar with the responsibilities associated with community leadership. These leaders need to be well versed with the customary and the contemporary processes that they need to take advantage of. This requirement is crucial because leaders need to resolve conflicts as well as change and correct inconsistent ideas and practices people may have. Community leaders must be transparent, fair and lead by example.

People must be encouraged to act on issues that are important to them and their children. In the communities, people need to appreciate the value of self-reliance and determination. The people must realise that Government can not reach them all with its own programmes. People must therefore mobilise their own resources to serve their needs without wating for Government to do so. These initiatives are often the most successful because they relate to a need in the community. Such initiatives are also more appropriate because the people formulate them. To ensure long term commitment, local capacity needs to be enhanced to ensure that new hands can take over the initiatives from the current leaders. Indeed, the periodic change in leadership is necessary. The changes ensure that certain members do not hijack the initiatives and that the initiative is focussed in its objectives.

It is also crucial that appropriate compensation be paid to people who are taken away from their normal duties. People in communities have schedules and it is up to outsiders to compensate them when their initiatives are preventing the people from doing their normal work. Associated with this should be the acknowledgment by all outsiders of the disruption they cause to life in the villages. Outsiders always should remember how they affect local people's lives. Even in cases where the initiatives do not work peoples lives are being affected. At the same time it is generally felt that payment of community members for involvement in the project is not warranted as they should be willing to

participate because they see the long-term benefits to their community. Issues related to equitable and transparent sharing of benefits is critical to the success of these types of intiatives.

Effective Resource Management

Challenges and issues that need to be considered to allow for effective local community involvement include the provision for the people's source of livelihood. Local initiatives often involve some kind of change to the way people live. It is therefore critical that people's source of livelihood is catered for. Associated with this is the need for a source of income. Perhaps the largest pressure people in rural areas face today relates to income. This is why people in rural areas use their resources and is a central concern when people's source of income is affected in the management of the resource. Therefore, alternative or new sources of income should be introduced as parts of resource management arrangements.

Good, effective and transparent leadership is needed. This requirement means that people should be engaged in an effective and responsive consultative process. People should be accurately understood and this necessitates good consultation. In addition, people should be supported by positive reinforcements and incentives. These reinforcements and incentives will attract attention to the desirable changes that people need to bring about.

It is also important that community initiatives originate in the communities. This enhances ownership by people which would ensure that people are committed to it. It is also important that the technology level used is appropriate for the community. It would be ridiculous to offer any technology to people in the communities unless they can prove they are ready to use them. The technology used therefore should relate to what people require and need and this should be discussed during the consultation.

Successful community-based development is dependent on a number of factors such as the:

- use of appropriate strategies for encouraging participation
- existence of viable community groups
- appropriate fit of technology to the project and community needs
- effective agency outreach strategies, client responsive agencies, and enabling policies

(Govan 1997:196–7; Siwatibau 1997:42).

Development project plans need to incorporate these factors because no amount of planning, political will or funding will succeed if the plans are not based on realistic assumptions. For instance, any development plan that does not include a training and capacity building component assumes that people are already familiar with how business ventures operate. Experiences in villages however have shown this to be wrong. In many of the villages, people are only involved part-time in development activities. To base calculations on the fact that people put in full-time effort will be inappropriate in such cases.

The people involved in rural development projects should not only be provided with comprehensive training but should also be offered follow-up activities. This is why it is

critical that government provides training and extension services to all communities intending to be involved in a development activity. The participants at these training sessions should be selected properly using objective criteria. The trainees need to understand the nature of the project and how they fit into the picture.

A new, more flexible system of rural development funding is needed to avoid the introduction of unilateral projects and to reduce the emphasis on funding periods. The new system should provide practical support and encourage people in rural areas, including indigenous Fijians, to exploit emerging opportunities. The new system must empower people to look after their own affairs instead of being totally dependent on state initiatives.

The project cycle approach represents an attempt to involve the grassroots people in the formulation of the projects. The project cycle approach covers project identification, project formulation, project implementation, project monitoring and project evaluation (Australian International Development Assistance Bureau (AIDAB) 1988; Overseas Development Assistance (ODA) 1995; Hinds 1998). It also emphasises need identification, feedback and review mechanisms that have not been well addressed in past rural development project planning. The cycle begins when an idea for a project is developed and ends when the project is completed and the outcomes have been evaluated. The concept of the cycle is significant because the results of the final evaluation are incorporated into the design of later development projects. This is an improvement on traditional project design, where that linkage has not been made. As a result, earlier project experiences have not been scrutinised and used as the basis for planning better development projects. In contrast, the project cycle uses the iterative learning processes that quality development work entails (AIDAB 1988; ODA 1995; Hinds 1998). It is also a response to the realisation that development problems in the Pacific cannot be understood only in terms of economic issues. It is now recognised that it is just as important to put the projects in the context of historical and social and cultural traditions. The project cycle, if used properly, can ensure that development projects are relevant, appropriate and pragmatic.

The project cycle follows a process and is not restricted by the parameters of a pre-existing blueprint or model. The important thing is that the design may be altered during implementation as a consequence of the monitoring. This approach would enhance the incorporation of local social, cultural, ecological and economic conditions. The benefit of the process is that while the outcome cannot be fully known in advance, the interim progress can be evaluated and monitored. Such monitoring will assist in steering the project towards the desired outcomes.

Conclusion

Empowerment of local communities is needed to enable the genuine involvement of people in development activities affecting them. This approach is now widely practised in the Pacific Islands, especially related to marine resource management, where successes have been documented. To ensure that this approach is improved and maintained at a level required for the long term success of development initiatives in rural areas, some of the challenges discussed above should be considered. The suggestions made on how the challenges can be addressed should be useful in trying to make resource use more

effective. The involvement of people in local initiatives in the future can only auger well for the utilisation of natural resources in their jurisdiction. People own the resources and heavily depend on them. This is the reason why the empowerment is required and why local people need to be involved.

References

Australian International Development Assistance Bureau (AIDAB), 1988. *Country Programs*: *operation guide,* vol. II, AIDAB, Canberra.

Anon., 2002, Tourism initiative pays off marine life thrives on Yanuca. Sunday Times*, 13th January:5.*

BCN (Biodiversity Conservation Network), 1997. Summary Report on the 1997 Verata Tikina Marine Resource Monitoring Workshop, Ucunivanua. 22 April – 2 May.

Belshaw, C.S., 1964. *Under the Ivi Tree*: *society and economic growth in rural Fiji*, University of California Press, Los Angeles.

Burns, A., 1963. *Fiji*, Her Majesty's Stationery Office, London.

Chambers, R., 1992. Rural Appraisal: rapid, relaxed and participatory. International Development Studies (IDS) Discussion Paper 311.

ECOWOMAN, 2000. Participatory Learning and Action: a trainers guide for the South Pacific. ECOWOMAN and SPACHEE, Suva.

Govan, H., 1997. 'Building Upon local culture for Community Development', in B. Burt, and C. Clerk (eds), *Environment and Development in the Pacific Islands*, National Centre for Development Studies, The Australian National University and the University of Papua New Guinea Press, Canberra:185–200.

Hinds, L.O. (ed.), 1998. 'Special issue CIDA's regional oceans programme workshop', *Marine Policy The International Journal of Ocean Affairs*, 22 (6):437–543.

Johannes, R.E. 1981. *Words of the Lagoon. Fishing and Marine Lore in the Palau District of Micronesia*. London: University of California Press.

Keen, M., 1994. 'Empowering communities to act for the environment', in M. Keen (ed.) *Communities, Education and Sustainability: perspectives from Thailand and Australia*, CRES, Australian National University, Canberra:53–8.

King, M and U. Faasili, 1997. 'Community-based management of fisheries and the marine environment', in *Fisheries and Marine Resources, Marine Studies Technical Report* 98/3, papers presented at symposium, VIIIth Pacific Science Congress, July 13–19, The University of the South Pacific, Suva.

Narayan, D., 1995. 'Issues in community based development and key features of successful community based development', *Designing Community Based Development*, Environmental Department World Bank Paper 7.

ODA (Overseas Development Administration), 1995. *A Guide to Social Analysis for Projects in Developing Countries*, HMSO, London.

Parks, J and N. Salafsky (eds), 2001. *Fish for the Future? A collaborative test of locally-managed marine areas as a biodiversity conservation and fisheries management tool in the Indo-Pacific region: Report on the Initiation of a Learning Portfolio*. World Resources Institute, Washington DC, USA.

Plange, Nii-K., 1996. *The 'Science' of Society: exploring the links between science, ideology and theories of development*, Fiji Institute of Applied Studies in association with the Department of Sociology, University of the South Pacific, Suva.

Radrodro, E. 2000. 'UNDP to help Ba Province Marine Project', *The Fiji Sun* March 21:5.

Ruddle, K., 1994. 'Traditional Marine Tenure in the 90s' in South, G.R., D. Goulet, S. Tuqiri and M.Church (eds), *Traditional Marine Tenure and Sustainable Management of Marine Resources in Asia and the Pacific*. International Ocean Institute-South Pacific, Suva:6 – 45.

Siwatibau, S., 1997. 'Who controls development in the Pacific', in B. Burt and C. Clerk (eds), *Environment and Development in the Pacific Islands*, National Centre for Development Studies, The Australian National University and the University of Papua New Guinea Press, Canberra:34–45.

Tawake, A., J. Parks, P. Radikedike, W. Aalbersberg, V. Vuki and N. Salasfsky. 2001 (Fall). 'Harvesting Clams and Data: involving local communities in implementing and monitoring a marine protected area. A case study from Fiji', *Conservation Biology in Practice a publication of the Society of Conservation Biology*:32 -34.

Tawake, A., and W. Aalbersberg, 2001. Community-based Refugia Management in Fiji. Paper presented at the Pacific Science Inter Congress in Guam, June 1 – 6.

Veitayaki, J., in press. 'Cooperation Among Small Island Developing States in the Area of Marine Biodiversity: a case study of SPREP's South Pacific Biodiversity Conservation Programme'. Submitted to *Ocean and Coastal Management*.

——, in press b. Taking Advantage of Indigenous Knowledge: the Fiji case. Submitted to UNESCO.

——, *W. Aalbersberg and A. Tawake, in press. Empowering Local Communities: a case study of the University of the South Pacific.*

Waqairatu, S., 'The Delimitation of Traditional Fishing Grounds – the Fiji experience' in South, G.R., D. Goulet, S. Tuqiri and M.Church (eds), *Traditional Marine Tenure and Sustainable Management of Marine Resources in Asia and the Pacific*. International Ocean Institute-South Pacific, Suva: 79 – 84.

WWF (World Wildlife Fund for Nature) South Pacific Program, 1996. *Community Resource Conservation and Development: a toolkit for community-based conservation and sustainable development in the Pacific*. WWF South Pacific

Session IV

Mangrove Monitoring & Assessment

COMMUNITY-BASED MONITORING AND MANAGEMENT NETWORK FOR THE CONSERVATION AND WISE USE OF PACIFIC ISLAND MANGROVES[9]

Eric Gilman, Audubon Society, Honolulu

Introduction

A brief overview will be provided of a draft project proposal to establish a community-based mangrove monitoring and management network for the Pacific Islands region (Gilman et al., 2001). The overview focuses on identifying expected benefits of site-based and regionally coordinated mangrove monitoring and describes potential actions to establish and implement a monitoring network.

The *Sixth South Pacific Conference on Nature Conservation and Protected Areas*, held in 1997, called on the regional and international conservation community to share the responsibility of implementing the *1999-2002 Action Strategy for Nature Conservation in the Pacific Islands Region* (South Pacific Regional Environment Programme, 1999a). In 1998, the South Pacific Regional Environment Programme (SPREP) formed the Pacific Islands Roundtable for Nature Conservation to meet the Conference's mandate. At the 4th meeting of this Roundtable in 1999, participants considered how to address a component of the Action Strategy, which calls for the development of standardized and replicable methods to survey ecologically valuable natural resources (Objective 1, Key Action 1.11, South Pacific Regional Environment Programme 1999a). A group of wetland professionals volunteered to produce a Concept Proposal that describes a method to establish and implement a community-based mangrove monitoring system (Gilman et al., 2000). The Concept Proposal assesses the suitability of alternative wetland inventory, mapping, and assessment methods for the desired application (establishing a regionally coordinated, participatory, site-based mangrove monitoring programme in the Pacific Islands region), and identifies a process to establish the mangrove monitoring network. This team then used the Concept Proposal as a starting point to develop a full Draft Project Proposal (Gilman et al., 2001). SPREP and The University of the South Pacific (USP) are co-leads for completing the proposal and coordinating implementation of the project.

Monitor mangroves to address threats

Pacific island governments have recognized the value of mangroves and the need to augment conservation efforts (e.g., South Pacific Regional Environment Programme, 1999b). Despite numerous known values and uses, ranging from maintaining coastal water quality to protecting land from inundation during storms and sea level rise (e.g., see Lal 1990 and 1991, Lal et al. 1984, Thaman 1992, Thaman 1998, South Pacific Regional Environment Programme 1999b, Thaman 1999a), mangroves are degraded and under increasing pressure from coastal development. In most Pacific island countries, pressures of population growth and competing resource use are major threats to ecologically

[9] Adapted from (a) *DRAFT Project Proposal for Conservation and Wise Use of Pacific Islands Mangroves: Building Capacity and Awareness through a Community-Based Monitoring and Management Network* (Gilman et al., 2001); and (b) *Concept Proposal for Conservation and Wise Use of Pacific Island Wetlands by Building Capacity and Awareness through Community-Based Site Monitoring* (Gilman et al., 2000).

sustainable development and conservation of wetlands valuable to local communities, particularly where population increase rates are relatively high and land areas are small (Lal 1991, Scott 1993, South Pacific Regional Environment Programme 1999b). Additional threats to mangroves include: adverse effects from climate change and sea level rise (Ellison 1993 and 1996); insect infestation; short-term hypersalinity; short-term extreme high freshwater ponding (inhibits tree respiration) (Intari, 1990); filling for conversion for upland development and agriculture (Lal, 1990 and 1991; Ellison, 1999); clearing forested wetlands for aquaculture use; discharging nutrients, organic wastes, antibiotics, and other chemicals, increasing sedimentation loads (Ellison, 1999), increasing pathogen numbers, low dissolved oxygen, and increasing oxygen demand from aquaculture; altering hydrology and salinity by changing surrounding land uses that alter natural catchment areas; altering sedimentation rates and nutrient replenishment, for example by converting upland forests into urban environments and draining stormwater into wetlands; altering wave energy, currents, and water circulation, such as by dredging a boat channel near a mangrove stand, causing erosion of the mangrove's substrate; excessive harvesting of flora and fauna; oil spills and chronic oil and toxic metal contamination (Ellison, 1999); introduction of nonnative species of plants and animals; cultivation or disturbance by feral animals; fungal flora pathogens and other diseases (Olexa and Freeman, 1978; Teas, 1982); herbivory by crabs, insects, and other fauna; and pollution from chemicals and nutrients input via runoff and point sources (Gilman 1999). A monitoring network will help address the numerous threats facing mangroves.

Benefits of site-based mangrove monitoring

Participatory, site-based mangrove monitoring can provide numerous benefits to support mangrove conservation and sustainable management. Mangrove monitoring provides information useful for planning and management by providing baseline information to:

- Develop comprehensive management plans;
- Implement wetlands regulatory programs, such as by predicting impacts of alternative proposed wetland-use activities on wetland quality and quantity and determining mitigation requirements;
- Account for cumulative effects of wetland degradation (e.g., see Gilman 1998 and 1999);
- Develop effective wetland water quality standards (for instance, if managers observe a consistent decrease in water quality in a community's mangroves below designated thresholds, this advanced notice of a problem would help the community and managers to correct the problem); and
- Help managers identify suitable wetland rehabilitation sites, and develop guidelines to design rehabilitation projects.

Additional benefits of implementing a site-based, participatory mangrove monitoring program include:

- Increased public awareness of the ecological, social, and economic values that mangroves provide; and
- Increased capacity for in-country managers to train local community counterparts (such as landowners, resources users, and students), to conduct site-based monitoring. Local-level capacity to use monitoring data and trends analyses for site-based and national management applications will be developed.

Benefits of regional coordination

A regional wetlands monitoring programme will provide advanced notice to enable suitable management responses; enable standardization to facilitate assessments of regional-scale trends in wetland quantity and quality; provide a vehicle for broad dissemination of lessons learnt; and provide an affordable way to increase in-country capacity, local community involvement with monitoring, and public outreach:

- Advanced notice: A regional monitoring network can provide advanced notice to site managers of an impending problem so managers can avoid or minimise the problem before it becomes established or irreversible. For instance, if retreat of the seaward edge of a mangrove monitoring site is observed, comparison with regional tide guage records (e.g., Mitchell et al., 2000) could identify more rapid sea-level at that site. Identified response of mangroves to rising sea level in an impacted country could help identify appropriate management before problems occur elsewhere in the region;
- Regional status and trends estimates: Information from a regionally standardized mangrove monitoring network can be used to estimate the regional status and trends in mangrove quantity (area) and quality (ecological integrity, health, or degree of disturbance); and
- Broad application of lessons learnt: A regionally coordinated monitoring program allows for wide, regional, dissemination of lessons learnt at local levels. These lessons of effective and ineffective approaches to manage and monitor mangroves can also be used to improve the monitoring and management of other ecosystems and resources.

Mangrove monitoring principles

Site-based mangrove monitoring entails periodically collecting and analyzing inventory and assessment data to determine trends in the quantity and quality of wetlands. Temporal changes in wetland *quantity* can be measured by interpreting a time series of inventories and maps. A wetland inventory is the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities (Finlayson et al., 1999). Inventory methods define wetland location and size, with further information on their bio-physical features and management, and utilise on-the-ground surveys as well as remote sensing (aerial photography, synthetic aperture radar, or satellite imagery) (U.S. Fish and Wildlife Service 1990a, 1990b, and 1991; Finlayson et al., 1999). Wetland inventories and maps are not available in most countries and territories in the Pacific Islands (Hamilton and Snedaker 1984, Scott 1993, South Pacific Regional Environment Programme 1999b, Ellison 1999).

Temporal changes in wetland *quality* can be measured through periodic assessments of wetland functions and values. Wetland "functions" are the processes that link a wetland's structural components, or what a wetland does. The reduction of nitrate to gaseous nitrogen, storage of surface water, and maintenance of wildlife habitat are examples of wetland functions. Wetland "values" are the goods and services that result from functions performed by wetlands that are important to people. For instance, wetlands provide fish and wildlife consumed by people, reduce damage to property from storms and floods, and improve water quality (Mitsch and Gosselink, 1993; Gilman, 1999). While there are

numerous methods to measure wetland *functions* (e.g., see Kusler and Niering, 1998; Bartoldus, 1999), only a few methods have been developed to assess wetland *values*, including non-monetized scaling and weighting approaches (such as used in the U.S. Fish and Wildlife Service's Habitat Evaluation Procedure (1980)) and common denominator approaches that reduce values to some common term such as dollars (e.g., Mitcsh and Gosselink, 1993; Bartoldus, 1999) (see the review of wetland functional and value assessment methods in Gilman et al., 2000). Mangrove valuation techniques help assess economic value of goods and services bought and sold through markets and those for which no markets exits (Lal 1990, James 1991, Barbier et al. 1997). Assessing wetland values is complicated because: (a) it requires an understanding of the region's social context (who benefits from specific functions, how many people benefit, and how do they benefit); (b) many wetland values are not exchanged on the open market, making it difficult to assign an economic value to these goods and services; and (c) different people place different levels of importance on a wetland's functions (Mitsch and Gosselink 1993, Kusler and Niering 1998). The use of standardized wetland assessment methods in the Pacific islands has been limited (CNMI Wetland Assessment Team 1998, Ellison and Oxley 1998, South Pacific Regional Environment Programme 1999b, Thaman 1999b, Ellison 2000).

The Australian Institute of Marine Science's Survey Manual for Tropical Marine Resources (English et al., 1997) may be adapted for this project, and inventory and mapping will likely be based on on-the-ground surveys. Components of the participatory community valuation inventory method developed at USP by Dr. Randy Thaman (Thaman, 1999b) and components of other wetland value assessment methods (such as Lal, 1990; James, 1991; and Barbier et al., 1997) could be incorporated into the broader assessment method.

Methodology

The draft project proposal (Gilman et al., 2001) describes 21 relatively distinct steps to establish a networked mangrove monitoring programme in four countries. These potential activities would be completed in three-years. A pithy summary of these proposed activities follows:

- SPREP and USP form a five-member Project Coordination Team to coordinate the 3-year project. Four National Focal Points and four Site-Based Monitoring Coordinators implement the site-based aspects of the project;
- Synthesize and evaluate past and current mangrove management activities in the region, prepare country reports (in part, to describe current management framework and ability to manage the cumulative effects of mangrove degradation and consider site-specific functions and values, known status and trends information, information gaps, cause of past mangrove degradation, threats to mangroves, and inventory and assessment needs to monitor mangroves), and hold a scoping workshop to plan to address monitoring and management needs (this step is being addressed in the June 2001 SPREP mangrove management workshop for which this paper was prepared);
- Develop criteria to select four mangrove sites to be included in the monitoring programme. Selection criteria may include the availability of information on the site, representativeness of the site of the country's mangroves, degree of naturalness, site stability and level of protection, size and location, existing uses and other values, local community support and resources to engage the community in monitoring activities,

capacity of the local government and other organizations to support on-the-ground activities during the project period and to continue the mangrove monitoring programme after the initial three year project ends, and suitability for applying the monitoring protocol;

- The 13 project coordinators select the four sites for the monitoring programme and produce in-depth case studies of the four mangrove sites;
- Project coordinators select general inventory, mapping, and assessment methods that would subsequently be adapted locally for each mangrove site. The Concept Proposal identifies criteria to be used to select the monitoring methods (Gilman et al, 2000). Criteria include ability to be adapted to be implemented by local communities and students, ability to raise community awareness of wetland values, ability to fulfill prioritized planning and management needs, suitability for regional application, requires a realistic amount of technical and financial resources to implement, and is replicable and accurate;
- Develop draft monitoring guidebooks for each of the four mangrove monitoring sites, and verify the accuracy, consistency, and precision of these methods. The project coordinators would seek peer review of the draft inventory and assessment methods, and eventually final national guidebooks would be published;
- Project coordinators produce training manuals for each of the four monitoring methods;
- The project team conducts training workshops for in-country instructors;
- Trained national-level participants train end-users, such as local communities, landowners, students, local government personnel, and private consultants. This training would also include an awareness-raising component and recommendations for implementing regional and international conventions;
- The project team conducts additional training to develop local capacity to use monitoring data for improved mangrove management and conservation---such as explaining how monitoring data can be used for planning and management applications such as water quality and quantity management, comprehensive wetlands management planning, and decision-making in regulatory programs;
- SPREP and USP, in coordination with additional partners, would establish a permanent system for centralized coordination, including providing technical assistance, periodic refresher workshops, a regional repository and archive for data and specimens, and annual reporting on the status and trends of the regions' mangroves; and
- Follow-up case studies of the mangrove sites included in the monitoring program for the three-year grant period would be produced at the end of the project, in part, to evaluate the effectiveness of the effort. A follow-up workshop would be held to evaluate the project, disseminate lessons learnt, institutionalize needed changes to the approach (such as revising the assessment and inventory methods and training manuals), and select additional sites to be added to the monitoring programme.

Consistency with regionally and internationally accepted principles

The draft proposal for a community-based mangrove monitoring programme is consistent with regionally and internationally accepted principles for wetlands inventory, monitoring, conservation, planning, and management. The original impetus for developing the draft project proposal to establish and implement a mangrove monitoring network for the Pacific Islands region came from an effort to implement a component of the *Action Strategy for Nature Conservation in the Pacific Islands Region* (South Pacific

Regional Environment Programme, 1999a). The Draft Project Proposal was developed to also fulfill the call for action in the *Regional Wetlands Action Plan for the Pacific Islands*, involving 14 countries and 8 territories, endorsed by the South Pacific Regional Environment Programme, which calls for freshwater and mangrove wetland inventorying, mapping, and monitoring to produce requisite baseline information to develop management plans (South Pacific Regional Environment Programme, 1999b). The Draft Proposal was also developed to be consistent with guidelines developed under the Convention on Wetlands to establish and strengthen local communities' and indigenous people's participation in wetlands management (adopted as the Annex to Resolution VII.8 by the 7th Conference of the Contracting Parties, May 1999), Ramsar's recommendations regarding monitoring the ecological character of wetlands (Article 3, Recommenation 5.2, and Resolutions VI.1 and VII.10), Ramsar's Wise Use Guidelines (Recommendation 4.10 and Resolution 5.6), and Ramsar's Management Planning Guidelines (Resolution 5.7) (Ramsar Convention Bureau, 2000). Furthermore, the approaches for wetland inventory and monitoring being proposed will be fully compatible with those currently under development through the joint workplan between the Convention on Biological Diversity and the Ramsar Convention on Wetlands, and will therefore contribute to harmonization of information requirements between international Conventions (Convention on Biological Diversity Secretariat and the Ramsar Convention Bureau, 2000). Wetlands International has provided a letter of endorsement for the proposed project, and the Ramsar Convention Bureau has expressed its willingness to endorse the project as well.

Future steps

A potential next step might be for national mangrove management staff to discuss the general principles of the draft project proposal to determine what changes are necessary and assess if there is consensus for the proposed approach. Discussion is needed on how to improve the proposed methodology, determine selection criteria for mangrove monitoring sites, identify candidate monitoring sites, and discuss a timeline to complete remaining tasks to finalize the proposal. Additional planning activities might include finalising site selection criteria, selecting the four mangrove monitoring sites, receiving national endorsements of the project proposal, identifying the individuals who will implement the project (which includes a five-member project coordination team, four national focal points, four site-based monitoring coordinators, local community mangrove monitors, and USP graduate students). Additional pending steps include completing a budget (the focus of requested funding and proposed activities reflects the intent of the project to strengthen in-country capacity to monitor and manage mangrove wetlands. Resources are focused on supporting on-the-ground activities), revising and finalising the proposal, conducting fundraising, and creating a timeline to initiate and implement the project.

References

Barbier, E.B., Acreman, M., and Knowler, D. 1997. Economics Valuation of Wetlands: A Guide for Policy Makers and planners. Ramsar Convention Bureau, Gland, Switzerland.

Bartoldus, C.C. 1999. A Comprehensive Review of Wetland Assessment Procedures: A Guide for Wetland Practitioners. Environmental Concern Inc., St. Michaels, MD, USA.

Convention on Biological Diversity Secretariat and the Ramsar Convention Bureau. 2000. Joint Work Plan 2000-2001 of the Convention on Biological Diversity and the Convention on Wetlands (Ramsar, Iran, 1971).

CNMI Wetland Assessment Team. 1998. *Draft Hydrogeomorphic Functional Assessment Method for Depressional Wetlands of the Northern Mariana Islands*. Commonwealth of the Northern Mariana Islands Division of Environmental Quality, U.S. Army Corps of Engineers, USDA Natural Resources Conservation Service, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service. Saipan, Commonwealth of the Northern Mariana Islands, USA. 72 pp.

Ellison, J. 1993. Mangrove retreat with rising sea level, Bermuda. *Estuarine Coastal and Shelf Sciences* 37: 75-87.

Ellison, J. C., 1996. Potential impacts of predicted climate change on mangroves: Implications for marine parks. *Parks,* 6(2), 14-24. International Journal for Protected Area Management (IUCN).

Ellison, J. C. 1999. Present status of Pacific Island mangroves. *In Marine/ Coastal Biodiversity in the Tropical Island Pacific Region: Volume II. Population, Development and Conservation Priorities*, Eds L. G. Eldredge, J. E. Maragos and P. L. Holthus, Pacific Science Association/ East West Center, Honolulu. P. 3-19.

Ellison, J. C. 2000. How South Pacific mangroves may respond to predicted climate change and sea level rise. A. Gillespie and W.C.G. Burns Eds., *Climate Change in the South Pacific: Impacts and Responses in Australia, New Zealand, and Small Islands States*. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 289-301.

Ellison, J., and W. Oxley. 1998. *Draft Mangrove Baseline Survey Workshop. Tonga Environmental Management and Planning Project*. AUSAID and Government of Tonga. 15 pp.

English, S., C. Wilkinson, and V. Baker (Eds.). 1997. *Survey Manual for Tropical Marine Resources, 2nd Edition*. Townsville: Australian Institute of Marine Science.

Finlayson, CM, Davidson NC, Spiers AG & Stevenson NJ. 1999. Global wetland inventory - current status and future priorities. *Marine & Freshwater Research* 50, 717-727.

Gilman, E.L. 1998. Unknown adverse impacts to wetlands from the Corps' Nationwide Permit Program: Examples from the Commonwealth of the Northern Mariana Islands. *Coastal Management* 26(4): 38-60.

Gilman, E.L. 1999. Choosing appropriate instruments from the wetlands management toolbox: A planning process to improve wetlands conservation. *Wetland Journal* 11(3): 15-22.

Gilman, E.L., L. Apis-Overhoff, J. Ellison, M. Finlayson, R. Jaensch, B. Thaman, R. Thaman, and J. Veitayaki. 2000. *Concept Proposal. Conservation and Wise Use of Pacific Island Wetlands by Building Capacity and Awareness Through Community-Based Site Monitoring.* Prepared for the Pacific Island Roundtable for Nature Conservation. 19 pp.

Gilman, EL, J Ellison, M Power, B Aalbersberg, R Thaman, B Thaman, and J Veitayaki. 2001. *DRAFT Project Proposal for Conservation and Wise Use of Pacific Islands Mangroves: Building Capacity and Awareness through a Community-Based Monitoring and Management Network*. South Pacific Regional Environment Programme and The University of the South Pacific. 26 pp.

Hamilton, L.S. and S.C. Snedaker (ed). 1984. *Handbook for Mangrove Area Management*. East-West Center; International Union for the Conservation of Nature and Natural Resources; United Nations Educational, Scientific and Cultural Organization. IUCN, Gland, Switzerland. 123 pp.

Intari, T.S.E. 1990. Factors affecting the death of mangrove trees in the Pedada Strait, Indragiri Hilir, Riau, with reference to site condition. *Buletin Penelitian Hutan* (*Forestry Resources Bulletin*) 531:33-48.

James, R.F. 1991. *Wetland Valuation: Guidelines and Techniques*. PHPA/AWB Sumatra Wetland Project Report No. 31, Asian Wetland Bureau, Bogor, Indonesia.

Kusler, J. and W. Niering. 1998. Wetland assessment: Have we lost our way? *National Wetlands Newsletter* 20(2): 1, 9-14.

Lal, P.N. 1990. *Conservation or Conversion of Mangrove Ecosystems in Fiji: An Ecological Economic Analysis*. Environment and Policy Institute Occasional Paper No. 11. Honolulu, Hawaii: East West Center. Also published as Ecological Economic Analysis of Mangrove Conservation: A Case Study from Fiji. Mangrove Occasional Paper No. 6. UNESCO.

Lal, P.N. 1991. Mangrove Management Issues in the Pacific Islands. Islands/Australia Working Paper No. 91/3. National Centre for Development Studies. Australian National University.

Lal, P.N., K. Swamy, and P. Singh. 1984. Mangrove Ecosystem: Fisheries Associated with Mangroves and their Management. Mangrove Fishes in Wairiki Creek and their Implications on the Management of Resources in Fiji. In *Productivity and Processes in Island Marine Ecosystems*. UNESCO Report on Marine Science. Paris, France.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. Van Nostrand Reinhold, New York, N.Y., USA.

Mitchell, W., Chittleborough, J., Ronnai, B. and Lennon, G.W. 2000. Sea Level rise in Australia and the Pacific. *The South Pacific Sea Level and Climate Change Newsletter*, 5 (1), 10-19.

Olexa, M.T. and T.E. Freeman. 1978. A gall disease of red mangrove caused by *Cylindrocarpon didymum*. *Plant Dis. Rep*. 62: 283-5.

Ramsar Convention Bureau. 2000. *Ramsar Handbooks for the Wise Use of Wetlands*. Ramsar Convention Bureau, Gland, Switzerland.

Scott, D.A. 1993. *A Directory of Wetlands in Oceania*. The International Waterfowl and Wetlands Research Bureau, Slimbridge, U.K. and Asian Wetland Bureau, Kuala Lumpur, Malaysia. 444 pp.

South Pacific Regional Environment Programme. 1999a. *Action Strategy for Nature Conservation in the Pacific Islands Region 1999-2002*. Apia, Samoa. 44 pp.

South Pacific Regional Environment Programme. 1999b. *Regional Wetlands Action Plan for the Pacific Islands*. Apia, Samoa. 25 pp.

Teas, H.J. 1982. An epidemic dieback gall disease of *Rhizophora* mangroves in the Gambia, West Africa. *Plant Dis. Rep.* 66:522-3.

Thaman, Batiri. 1998. Community utilisation and valuation of mangrove resources in Fiji: case studies of Daku, Nadoria, and Sawa Villages and Kinoya and Tamavua-I-Wai peri-urban settlements, Fiji Islands. Unpublished M.Sc. thesis. James Cook University, Townsville.

Thaman, R.R. 1992. Batiri kei Baravi: The ethnobotany of Pacific Island coastal plants. *Atoll Research Bulletin* 361:1-62.

Thaman, R.R. 1999a. Coastal biodiversity and ethnobiology: An ecological, cultural, and economic safety net for Pacific peoples. Chapter 12 in Eldredge, L.G., Maragos, J.E., Holthus, P.F. and Takeuchi, H.F. (eds.), *Marine and coastal biodiversity in the tropical island Pacific Region. Vol.2. Population, development, and conservation priorities*. Programme on Environment, East-West Center and Pacific Science Association, Bishop Museum, Honolulu. Pp. 235-265.

Thaman, R.R. 1999b. Pacific Island biodiversity on the eve of the 21st Century: Current status and challenges for its conservation and sustainable use. *Pacific Science Association Information Bulletin* 51 (1-4): 1- 37.

U.S. Fish and Wildlife Service. 1980. *Habitat Evaluation Procedures (HEP)*. Division of Ecological Services. Report ESM 102.

U.S. Fish and Wildlife Service. 1990a. *Cartographic Conventions for the National Wetlands Inventory*. St. Petersburg, FL, USA, 73 pp.

U.S. Fish and Wildlife Service. 1990b. *Photo Interpretation Conventions for the National Wetlands Inventory*. St. Petersburg, FL, USA. 45 pp + Appendices.

U.S. Fish and Wildlife Service. 1991. *Wetlands Status and Trends in the Conterminous United States Mid-1970's to Mid-1980's*. Washington, D.C. 28 pp.

MANGROVE ASSESSMENT AND MONITORING METHODOLOGIES

Dr Joanna Ellison, University of Tasmania

Introduction

This paper reviews the mangrove assessment and monitoring methodologies, and the advantages Pacific island countries could gain from implementing mangrove monitoring. The focus here is on setting up a monitoring framework, field techniques that could be used, and examples from the region where these have been already used.

Background to mangrove monitoring

Coastal monitoring in the Pacific region has been discussed for some time, with the purpose being systematic measurements repeated over time that may show change in health of coastal ecosystems. This provides managers with information to enable sustainable status of coastal resources.

Ten years ago several expert groups identified the need for a global monitoring system of coral reef and mangrove response to climate change (IOC 1990; IOC 1991; UNEP/UNESCO 1993; UNEP 1994). Progress was made for coral reefs when the International Coral Reef Initiative (ICRI) was launched at the United Nations Global Conference on Sustainable Development of Small Islands Developing States in Barbados in 1994, bringing renewed emphasis on monitoring coral reefs. In 1995, ICRI called on many nations to commit themselves towards increasing research and monitoring of reefs to provide the data for effective management.

Mangroves have always lagged behind coral reefs in attracting scientific interest, popular interest and project funding. However, in Pacific island environments particularly, mangroves and coral reefs are closely located, and are interconnected through water movement and food-chains. This close connection was recognised by ICRI, leading to adoption of mangroves under the ICRI umbrella as associated systems. This occurred at the ICRI Pacific Regional Workshop held in Suva (27.11-1.12.1995), when the draft Regional Wetlands Action Plan (Idechong et al., 1995) was presented by SPREP. This Action Plan was later endorsed by Pacific Island governments, in response to the recognised need for greater effort and commitment to the conservation and sustainable use of wetlands (SPREP, 1999). The Regional Wetland Action Plan focuses on mangroves, but also included fresh water wetlands.

The Regional Wetland Action Plan (SPREP, 1999) defines actions to monitor mangroves in two sections. These are outlined below:

RWAP Section 3.3 Research and Monitoring
Objective: To collect information on mangrove ecosystems that can contribute to the management process.
Present status: Knowledge of Pacific Island mangroves is poor relative to other regions (SE Asia, Caribbean). Very few studies have been carried out that are of relevance to ecology and management. There are no mangrove monitoring programs in the Pacific region outside of Australia (AIMS).

RWAP Action: 3.3.1 Regional monitoring of health of mangroves

Develop a regional monitoring program to assess the status of mangroves in the PIR, evaluate the success of management and conservation actions and develop more effective management practices.

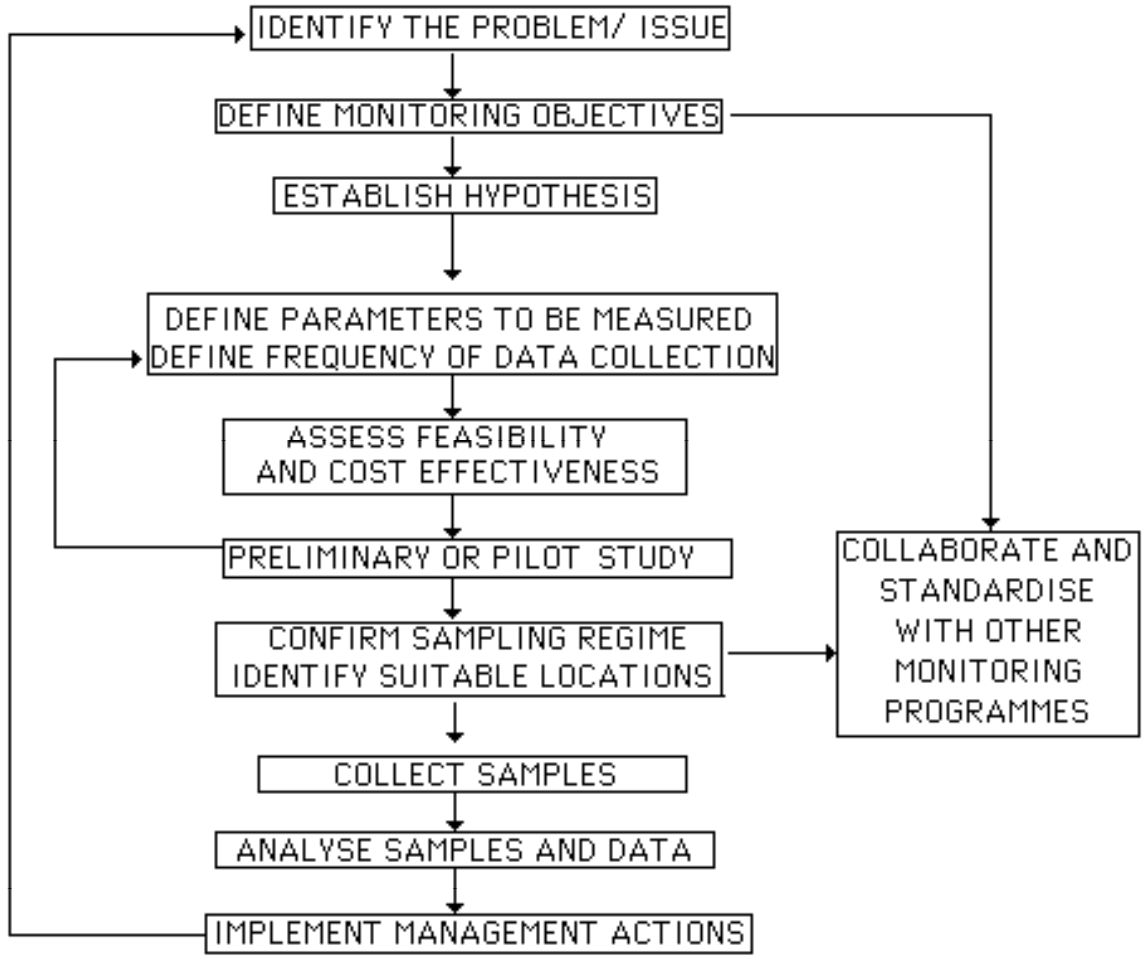
RWAP Action: 3.3.5 Mangrove response to sea-level rise predictions

Mangrove swamps, particularly those of low islands, are likely to be sensitive to rise in sea-level. PIC's should promote the development of a Global Mangrove Monitoring Network under the Coastal Zone Module of the Global Ocean Observing System. This could be combined with a regional effort for monitoring of mangrove ecosystem health (Action 3.3.1).

Endorsements: Western Samoa NEMS Programme Profile 11.
The Kingdom of Tonga NEMS Programme 4.4.1.
Republic of the Marshall Islands NEMS Programs 1.1, 1.2.

An effective monitoring program is designed to address the objectives identified, such as identifying long-term change in mangrove extent and health, and is tested and modified through a pilot study. Stages in the design of a monitoring program that contributes to management outcomes are shown in Figure 1, adapted from Finlayson (1994).

Figure 1. Conceptual plan for development of a monitoring programme (from Finlayson, 1994)



What change occurs in mangroves that monitoring can show?

Monitoring is the ability to identify change in mangrove spatial extent, the health of the trees and the fauna, and other biological or physical aspects of the ecosystem. Mangroves inhabit a dynamic interface between terrestrial and oceanic factors and processes. Figure 2 is a simple model showing the factors that influence the extent and health of a mangrove ecosystem. Change in any of these factors may affect the mangroves.

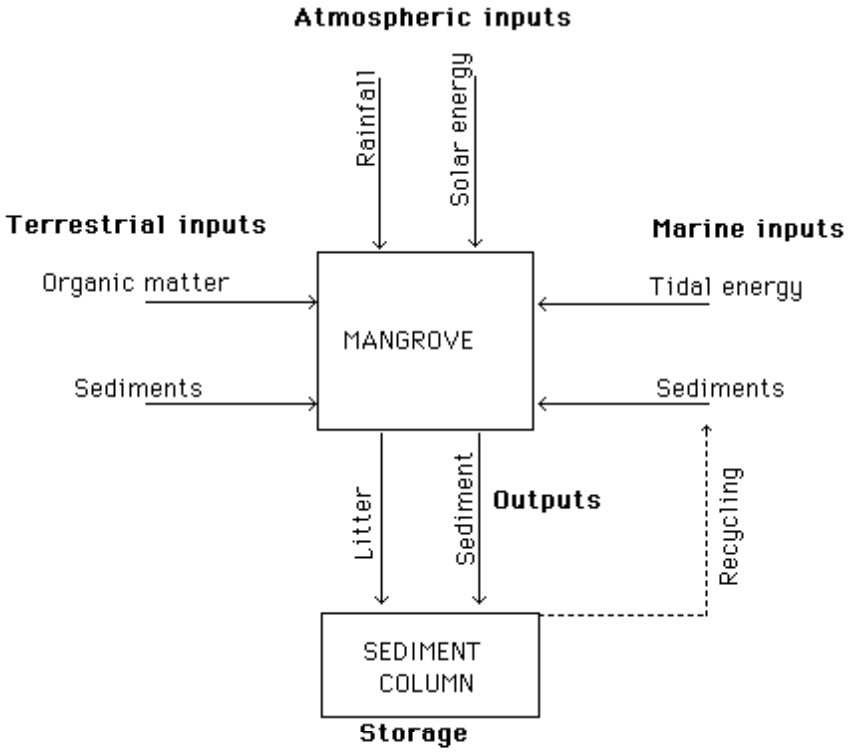


Figure 2. Mangrove ecosystem model, showing atmospheric, terrestrial and marine influences on mangrove extent and health.

Changes in factors that influence mangroves may be natural, or human-induced. Mangroves in the Pacific region are subject to extraction of products and other uses, thus it is important to ascertain that these uses are sustainable for future generations.

If monitoring identifies change in mangrove extent, then causes can be identified, and management actions incorporated to reduce stress to mangrove ecosystems. Many factors can cause mortality or reduced health of mangroves, both natural and human-induced.

Natural disturbances which have caused mortality in mangroves include physical damage from storms, sometimes combined with excess sedimentation, frost (Kangas and Lugo, 1990; Jimenez, Lugo and Contron 1985), hail (Houston, 1999), disease (Weste et al., 1982), restricted inundation (Hatton and Couto, 1992), and prolonged inundation. Human disturbances which have caused mangrove mortality include excess sedimentation (Ellison 1999), oil spills (Lewis, 1983; Duke et al. 1997), and changes to mangrove hydrological regime (Elster et al., 1999; Pollard and Hannan, 1994).

In summary, mangroves are killed or have reduced health due to:

- Sediment burial (suffocates roots)

- Sediment erosion (loss of structural support)
- Changed hydrological regime
  - -excess flooding
  - -exclusion of tidal water
  - -sea-level rise (increased inundation)
- Oil pollution (hydrocarbons)
- Storm damage
- Frost/ hail
- Pests - insects, fungi etc.
- Unsustainable use - over cutting/ stripping of bark
- And of course clearance/ landfill

These effects are usually local in scale, unlike the effects of climate change or sea-level rise.

Intertidal wetlands are expected to show a sensitive response to predicted climate change and sea-level response (Woodroffe 1990, Ellison, 2001). The nature of this response is complex, and subject to factors of environmental setting (Semeniuk 1994, Bacon 1994). Rise in temperature and the direct effects of increased CO_2 levels are likely to increase mangrove productivity, change phenological patterns (such as the timing of flowering and fruiting), and expand the ranges of mangroves to higher latitudes (Ellison, 2001).

Sea-level rise may cause substrate sediment erosion in mangrove ecosystems, increase salinity at landward zones, cause inundation stress, and promote landward migration of mangrove species zones combined with mortality in their present locations (Ellison, 2001).

What monitoring techniques can be used?

There are many attributes of mangroves that can be monitored, and many techniques that can be used to monitor change in these. Following the monitoring planning framework in Figure 1, it is necessary to identify what you want mangrove monitoring to achieve, who you want to do it (i.e community groups, schools, or ministry staff), and not blow out the budget with a huge wish list.
Examples of attributes that can be monitored:

- mangrove extent or area, species zones
- health of trees- forest biomass/ productivity/ growth
- forest recruitment and mortality
- sediment accretion or erosion
- fauna present
- water quality
- sediment quality- pollutant levels
- human impacts

Mangrove ecosystem monitoring has been developed in SE Asia and the Caribbean and examples can be taken from these regions as to how to address regional monitoring of mangroves. Use of standard techniques and contribution of data to a regional center allows results from sites to be compared for the interpretation of regional and local trends and influences.

In the Caribbean, the Caribbean Coastal Marine Productivity (CARICOMP) program has been developed to study and monitor the productivity of mangrove, coral and seagrass ecosystems (CARICOMP, 2000), producing a manual of standardised techniques and distributing field equipment packages. There are 29 institutions or government departments in 22 island or mainland countries (with a coast on the Caribbean) participating in the program.

In southeast Asia, the ASEAN-Australia Living Coastal Resources Project produced a manual of standardised survey techniques for monitoring the status of and changes over time of coral reefs, mangroves, soft bottom communities, seagrass beds and fish stocks (English, et al., 1997).

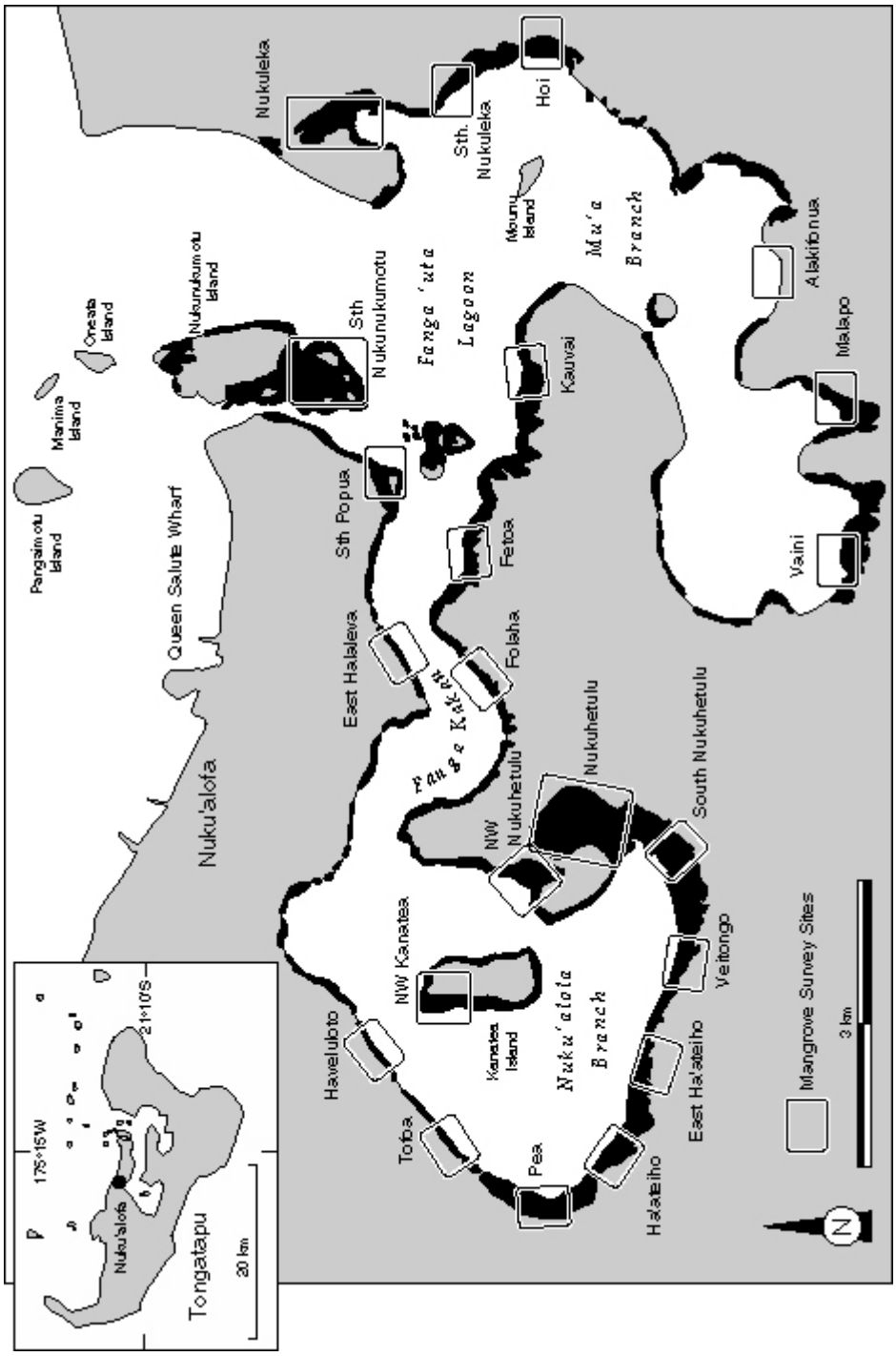
Baseline assessment

The first time a mangrove ecosystem is monitored provides a baseline assessment against which future change can be compared. These techniques can be used for assessment of mangrove extent, community structure and degree of human impact. In Tongatapu, Tonga, assessment of mangroves was required for allocation of zoning categories. Ellison and Oxley (1998) adapted the transect technique of English et al., (1997), and surveys were carried out by Ministry of the Environment staff.

Methods

Survey sites were selected from the central extent of each major embayment of mangroves in Tongatapu (Figure 3).

Figure 3.Tongatapu showing mangrove survey sites



At each site, walk a transect line into the forest using compass to ensure that the transect is perpendicular (90°) to the shoreline. Measure from the start of the landward mangrove edge, and note which species are in each zone, and whether these are abundant/ rare. Use the 100 m measuring tape to record the width of each species/ community zone along the transect, and record the distance of the seaward edge with lagoon water. Assess human impacts in each zone using criteria in Table 1, and record codes of types of human impact using Table 2.

Table 1. Codes used to record the impact of human pressure on mangrove ecosystems.

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 2. (Adapted from Table 3.5 English et al 1997) Codes used to describe the type of impact at a site.

Code	Type of Impact
BU	Bunding or dyking
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	Illegal cutting
MI	Mining activities
MU	Multiple impact. Note codes of multiple impacts in Remarks.
OT	Others eg. Pig foraging. Note this in remarks.
PP	Prawn and fish ponds
SC	Shell collecting
SS	Severe storm

Results

Results from the transect surveys are given in Prescott (this volume, Table 2). Subsequent to the field surveys, data was recorded on a database. Then transect data was extended to

characterise mangroves of the entire lagoon using these transects as ground-truthing points to allow interpretation of air photographs.

Mangrove zoning categories identified

Four mangrove zoning categories were allocated to the Tongatapu mangroves using this baseline assessment technique: Protection zones (areas of high diversity and undisturbed old-growth communities); Sustainable usage zones (for harvesting of mangrove products); Rehabilitation zones (for replanting) and Convertible zones (fragmented areas close to the city).

This example from Tonga demonstrates how a baseline survey can be implemented and used to make management decisions on mangrove zoning. The techniques used were not advanced enough to allow quantitative assessment of mangrove biomass and productivity. These techniques are reviewed below.

Assessment of mangrove productivity - Rapid plotless techniques

Angle counts/ Relascope

A rapid survey of mangrove community structure and biomass can be made using the Angle Count Cruising Method of English et al. (1997). This is a plotless rapid technique of estimating stand basal area (m^2/ ha). Use of a 1 factor prism allows determination of basal area in 14 m^2 ha^{-1}. So if 14 trees are "in" the sample, this means 14 m^2 ha^{-1} of trees can be estimated. If you incorporate girth measurement of trees within the sample, this allows stem densities per hectare also to calculated (stems ha^{-1}). Trees are sighted from a fixed point through a factor 1 wedge prism, through a 360^o sweep (Figure 4). Diameter of trees are measured at 1.3 m above the substrate surface (English et al., 1997).

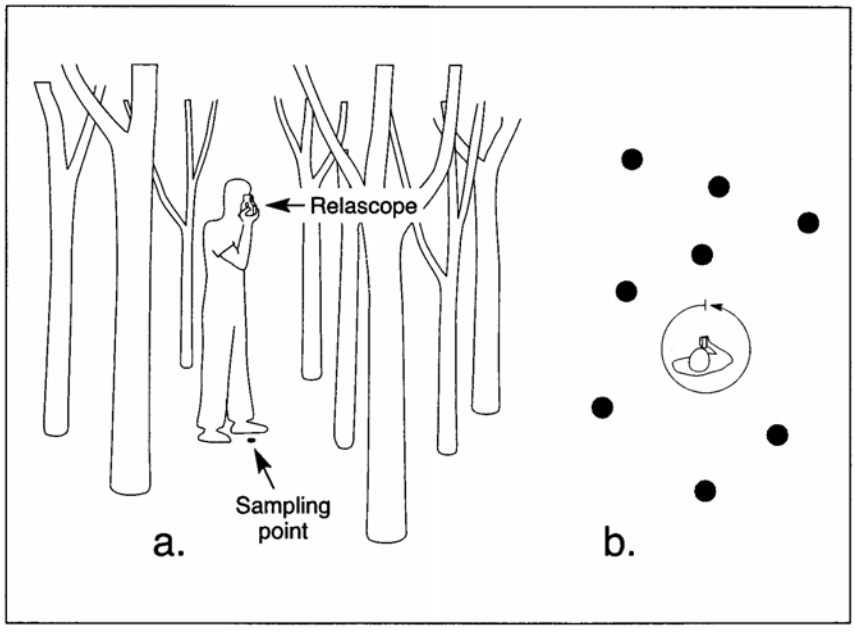


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Figure 4. Use of a relascope for rapid survey of mangrove basal area (from English et al., 1997.

Light attenuation/ Leaf area index/ Forest densiometer

Various techniques of estimation of forest productivity from the comparison of light levels outside the forest with the light levels under the forest canopyhave been developed for mangroves by Bunt et al. (1979). There is a close association between net primary production, the amount of light absorbed by the plant canopy, and canopy leaf area index. Leaf area index is defined as the total leaf surface area per unit ground-surface area measured in equivalent units, ie m^2. It is a parameter used to measure the photosynthetic capacity of plants and their role in gas, water, carbon and energy exchange (Araujo et al., 1997).

Examples of use

Examples of use of these techniques from the regioninclude that by Robertson, et al., (1993) who used angle counts and light attenuation to estimate mean net primary production rates for the three main mangrove zone communities identified in the Fly delta mangroves (Table 3).

Table 3. Areas of major mangrove forest types in the Fly Delta, estimates of forest productivity and daily production (From Robertson et al., 1991).

Forest type	Area (ha)	Productivity (KgC ha^{-1} a^{-1})	Daily production (Tonnes C)
Rhizophora-Bruguiera	31 500 26.7	841.1	(22.1)
Nypa	38 400 27.1	1 040.6	(30.7)
Avicennia-Sonneratia	17 500 19.0	332.5	(22.8)
Totals	**87 400**	**2 214.2**	

Boto et al. (1984) compared mangrove forest productivity of the Purari delta area with sites in Queensland and NW Australia, using light attenuation techniques. This study showed highest potential net primary production at sites in the Pie River estuary, comparable with levels recorded at pristine Hinchinbrook mangrove sites. All other sites from the Cape York peninsula and NW Australia gave significantly lower production estimates, showing the high productivity of southern PNG mangroves.

Permanent plots

None of the above techniques allow quantitative comparison over time of mangrove community structure, growth rates and biomass. This is because they are plotless techniques, hence the return to the exact sampling location and repeated measurement of the same trees is difficult. This is the advantage of permanent plots, where trees can be re-measured periodically, and changes recorded are indicative of larger areas of mangroves.

Methods

Permanent plots are established along a perpendicular transect through the center of the mangrove swamp. This methodology follows mangrove monitoring techniques used by the Caribbean Coastal Marine Productivity (CARICOMP) (2000) manual. One plot should be placed in each zone, with adjacent replicates.

In each plot, mangrove trees are identified with aluminium numbered tags, and their diameter/circumference and height measured. Tags can be nailed to trees with galvanised nails, and seedlings can be identified by placing the tag on aluminium wire (ie mig wire) and hung around the small mangrove stem. Girth of the tree is measured at breast height (1.3 m above the ground), and diameter determined. Where prop roots of *Rhizophora* converge above breast height (1.3 m), girth is measured above the uppermost intersection. Height can be measured using a telescoping survey pole. These data can be used to obtain mean height and mean diameter of the plot, and number of trees is used to calculate tree density, or stem density.

Basal area defines the space covered by a tree stem, and is a good measure of stand development, relating wood volume and biomass (Cintron and Shaeffer-Novelli, 1984). It can be calculated using the formula:

$$\text{Basal area } (m^2) = \frac{dbh^2}{4\,(10{,}000)} \qquad \text{(where dbh is in cm)}$$

Biomass can be determined by allometric equations. These are calculated by harvesting an area of mangrove, and determining dry weight of trees of different diameters. An example is the dbh to weight conversion of Golley et al. (1962) determined in Puerto Rico, which is recommended for use by the CARICOMP manual (2000).

$$\text{Biomass (g)} = \text{dbh (cm)} \times 3{,}390$$

$$\text{Mean stand biomass } (kg/m^2) = \frac{\text{Total biomass}}{\text{Tree density} \times 1000}$$

Examples of use

Examples of use of these techniques in the region can be found in the Federated States of Micronesia, where the FSM Forest service has permanent plots established since 1983 on Pohnpei, Yap and Kosrae (Devoe 1993). Plot remeasurement has shown average annual growth to be 6.9 m^3 per hectare per year, though with a great range between plots of 0.9-16.7 m^3 per hectare per year, which was indirectly caused by variation in exploitation and human impacts.

Cole at al. (1999) showed significantly faster growth rates for the mangrove species *Bruguiera gymnorrhiza* and *Sonnneratia alba* on Kosrae relative to Pohnpei, only 560 km apart. This may be caused by differences in cyclone periodicity.

Litter productivity

Litter is dropped mangrove debris, which is indicative of mangrove productivity. Data on litter fall has been widely collected in mangroves (Saenger and Snedaker, 1993) to quantify vegetative production and phenology (the timing of flowering and fruiting). This is a robust technique of determining mangrove health, through litter production.

Methods

In each plot at each site, several 1 m^2 litter catchers are hung below the mangrove canopy. These can be constructed of pipe/ wood frames and shadecloth or netting attached in a catch bag. These are emptied monthly. The catch is oven dried at 60°C for 2

days, then sorted into litter components of leaves, reproductive parts of each species, and wood, and then each component weighed.

Examples of use

Leach and Burgin (1985) analysed mangrove litter productivity and phenology from Motupore Island near Port Moresby (9°S), between January 1981-May 1982. The mangrove forest studied was *Rhizophora stylosa*, with sub-dominants of *R. apiculata* and *Sonneratia alba*, reaching a canopy height of only 10 m. They found a total annual litter fall of 14.3 tonnes dry weight ha^{-1} a^{-1}, with a marked seasonality in production, most falling during the wet season December- April. All three species flowered and fruited mostly in this period, and leaf production also increased. This is similar to patterns of litter production found in mangroves of north Queensland (Duke et al., 1981).

The total litter production was the second highest recorded in 35 studies from mangroves throughout the world reviewed by Saenger and Snedaker (1993). Comparing with forests of the same species at Hinchinbrook Island in Queensland (18°S), the total annual litter fall of *Rhizophora stylosa* forest was 9.3 tonnes dry weight ha^{-1} a^{-1}, *Rhizophora apiculata* was 10.9 tonnes dry weight ha^{-1} a^{-1} and *Sonneratia alba* was 7.9 tonnes dry weight ha^{-1} a^{-1}. This indicates that the mangroves of southern PNG are highly productive, and the figure obtained by Leach and Burgin (1985) is probably an underestimate for most mangroves of ths coast, owing to the low stature of forest they selected.

This is supported by Duke (1990) and Bunt (1995), who collected litter between 1982-1983 at a mangrove site near Port Moresby (NW of Motopure Island). Annual litter falls were 8.3 tonnes dry weight ha^{-1} a^{-1} for *Avicennia marina*, 18.8 tonnes dry weight ha^{-1} a^{-1} for *Rhizophora stylosa* and 9.5 tonnes dry weight ha^{-1} a^{-1} for *Ceriops tagal.* These were either higher than or close to the highest totals compared with those from Australian mangroves. These studies show that mangroves of the Gulf of Papua are among the most productive in the world, possibly owing to a combination of low latitude and low salinity.

Other physical/ biological measurements

Sedimentation or erosion rate.

Sedimentation stakes are very useful for long term monitoring of accretion/ erosion of the mangrove substrate, using stakes in permanent plots. The author has developed a design that fixes below the active root mat, so stakes are not lifted as the root mat grows. This can be a problem with shallow stakes, especially in peaty mangroves with a dense root mat.

Sediment type

Surface sediment can be analysed in each monitoring plot. One technique is to throw a 0.25 m^2 sampling square blindly ten times, and 1 ml of surface sediment collected from the center of the square. The combined sample for each site is then dried at 105°C for 24 hours, weighed, ignited at 550°C for four hours, and reweighed. This gives the percent organic matter in surface sediment, indicative of the amount of allochthonous inorganic sediment coming into the mangrove system, from marine or catchment sources.

Mangrove invertebrates

A range of techniques exist for research and monitoring of mangrove invertebrates, such as crabhole density or crab observation. One standard operation procedure that is very useful for community education and increasing perceived value of mangroves is collection of all invertebrates by a team of 4 villagers within a 25 m^2 area over a 15 minute period. The catch are then identified and weighed, and results can be compared between sites.

Water quality

There are standard techniques for the monitoring of water quality in natural waters, available under EIA procedures, Australian Waterwatch etc. The question is, what would be useful in the mangrove environment to indicate stress conditions. Monitoring for pollutants such as hydrocarbons, heavy metals or pesticides may not be useful at a long-term monitoring site as such events are usually of short duration and site specific impacts.

Mangrove trees are tolerant of a range of salinities and a range of (perhaps all) water turbidity conditions. They are not tolerant, however. of excess sediment burial, this is monitored using sedimentation stakes.

The CARICOMP program recommends one water quality measurement in mangrove monitoring sites, interstitial salinity. This is the sub-surface water surrounding mangrove roots at low tide, which is measured by digging a pit.

Remote sensing

Remote sensing has been used for assessment of very large mangrove areas in SE Asia. Techniques that give more information on mangrove community structure are being developed, but all these methodologies are fairly expensive and require considerable training for use and interpretation. Passive sources record reflected solar energy from the earths surface, the most basic of which is aerial photographs, while active sources emit and record their own sources of energy.

Lucas et al. (in press) investigated the use of aerial photographs, acquired in 1950 and 1991, for assessing the temporal dynamics of mangroves along the West Alligator River in Australia's Northern Territory. For both years, an unsupervised classification of the digital orthomosaic was applied to map mangrove extent. Digital Elevation Models (DEMs), or height maps, of the mangrove canopy were derived from stereo pairs. Field observations in 1998 and 1999 respectively provided ground truth for interpreting the derived datasets. The comparison of mangrove extent revealed a substantial movement over the 41-year period, perhaps in response to hydrological changes that have resulted in a landward extension of saline conditions. Changes in the height of mangroves were observed but were difficult to quantify due to the reduced quality of the 1950 DEM. The study demonstrated the viability of using time-series of aerial photography for monitoring and understanding the long-term response of mangroves to environmental change, including sea level rise.

Using Synthetic Aperture Radar data (an active remote sensing technique) combined with ground truthing information from transects and permanent plots, it is possible to spatially quantify the height, component biomass and community distributions of mangroves over

large areas. SAR has provided data giving a three-dimensional representation of vegetation canopies and allowing retrieval of vegetation biomass and structural components (Proisy et al., 1999). The resulting datasets can be used to generate a current baseline of mangrove extent, condition and regeneration stage. The spatial height and biomass estimates can be used to indicate the health, productivity and structural diversity of the mangroves, whilst the community distribution can be used to map present extents of the different mangrove species groups. Future surveys can indicate change in these parameters over time.

Conclusions

This paper has shown how monitoring of mangroves can show changes in extent and health of forests over time, which would allow Pacific island countries to be able to manage mangroves in a sustainable manner.

Baseline assessment of mangrove community zones and their condition can allow appropriate zoning for use, as demonstrated recently in Tongatapu. Quantitative measurement of mangrove biomass and productivity using permanent plots can show changes over time, which may be caused by over-exploitation or stress from disturbances such as sea-level rise. Comparison of sites within a regional monitoring system would allow these local or regional causes to be identified and addressed.

References

Araujo, R.J., Jaramilo, J.C. and Snedaker, S.C., (1997). LAI and leaf size differences in two red mangrove forest types in south Florida. Bulletin of Marine Science 60, 643-647.

Bacon, P. R., 1994. Template for evaluation of impacts of sea-level rise on Caribbean coastal wetlands. Ecological Engineering 3, 171-186.

Boto, K. G., Bunt, J. S. and Wellington, J. T. (1984) Variations in mangrove productivity in Northern Australia and Papua New Guinea. Estuarine, Coastal and Shelf Science 1:, 321-329.
Bunt, J.S., Boto, K.G., and Boto, G. (1979). A survey method for estimating potential levels of mangrove forest primary productivity. Marine Biology 52, 123-128.

Bunt, J. S. (1995) Continental scale patterns in mangrove litter fall. Hydrobiologia 295: 135-140.
CARICOMP (2000). Caribbean Coasatal Marine Productivity. A cooperative research and monitoring network of marine laboratories, parks and reserves. Caricomp Methods Manual Level 1. Manual of methods for mapping and monitoring of physical and biological parameters in the coastal zone of the Caribbean. University of the West Indies and Florida Institute of Oceanography.

Cole, T. G., Ewel, K. C. and Devoe, N. N., (1999). Structure of mangrove trees and forests in Micronesia. Forest Ecology and Management 117, 95-109.

Devoe, N. N. 1992. Mangrove assessments on Yap, Kosrae, and Pohnpei, Federated States of Micronesia. UNEP Regional Seas Reports and Studies 147: 1-19.

Duke, N. C. (1990) Phenological trends with latitude in the mangrove tree Avicennia marina. Journal of Ecology 78: 113-133.

Duke, N.C., Bunt, J.S. and Williams, W.T. (1981) Mangrove litter fall in Northeastern Australia. I. Annual totals by component in selected species. Australian Journal of Botany 29: 547-553.

Duke, Norman C., Pinzon M., Zuleika S., Prada T., Martha C. (1997). Large-Scale Damage to Mangrove Forests Following Two Large Oil Spills in Panama. Biotropica 29 (1), 2-14.

Ellison, J. C. (1999) Impacts of sediment burial on mangroves. Marine Pollution Bulletin 37:420-426.

Ellison, J. C. (2001). Possible impacts of predicted sea-level rise on South Pacific mangroves. In Noye, J. and Grzechnik, M. (editors), Sea-Level Changes and their Effects. World Scientific Publishing Co., Singapore. ISBN 981-02-3618-2

Ellison, J. C. and Oxley, W. (1998) Mangrove Survey Workshop. Tonga Environmental and Management and Planning Project. Sponsored by AUSAID and the Government of Tonga.

Elster C., Perdomo L.,Schnetter, M.-L. (1999). Impact of ecological factors on the regeneration of mangroves in the Cienaga Grande de Santa Marta, Colombia. Hydrobiologia 413, 35-46.

English S., Wilkinson C. and Baker V., 1997, Survey Manual for Tropical Marine Resources, Australian Institute of Marine Science, 2nd ed., Townsville, 390 p.

Finlayson, C. M., 1994. Monitoring ecological change in wetlands. In G. Aubrecht, G. Dick and C. Prentice Eds., Monitoring ecological change in wetlands of middle Europe. IWRB Special Publictation, Slimbridge, p. 163-180.

Hatton J.C. ; Couto A.L. (1992). The effect of coastline changes on mangrove community structure, Portuguese Island, Mozambique. Hydrobiologia 247 (1-3), 49-57.

Houston, W. A., (1999). Severe hail damage to mangroves at Port Curtis, Queensland. Mangroves and Salt Marshes 3 (1), 29-40.

Idechong, N., Ellison, J. and Jaensch, R., 1996. A Draft Regional Wetlands Action Plan for the Pacific Islands. International Coral Reef Initiative Pacific Regional Workshop Report (Suva, Fiji, 27 Nov-1 Dec 1995), p. 116-134. South Pacific Regional Environment Programme, Apia.

Intergovernmental Oceanographic Commission (1990). UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System of Coastal and Near Shore Phenomena Related to Climate Change. Intergovernmental Oceanographic Commission Report of Meetings of Experts and Equivalent Bodies 61.

Intergovernmental Oceanographic Commission (1991). UNEP-IOC-WMO-IUCN Meeting of Experts on a Long-Term Global Monitoring System of Coastal and Near Shore Phenomena Related to Climate Change, Pilot Projects on Mangroves and Coral Reefs. Intergovernmental Ocenaographic Commission Report of Meetings of Experts and Equivalent Bodies 69.

Jimenez J.A. ; Lugo A.E. ; Cintron G., (1985). Tree mortality in mangrove forests. Biotropica 17 (3), 177-185.

Jimenez J.A. ; Martinez R. ;Encarnacion L., (1985). Massive tree mortality in a Puerto Rican mangrove forest. Caribbean Journal of Science 21 (1-2), 75-78.

Kangas, P.C.; Lugo, A.E. (1990). The distribution of mangroves and saltmarsh in Florida. Tropical Ecology, 31 (1), 32-39.

Leach, G.J. & Burgin, S. (1985). Litter production and seasonality of mangroves in Papua New Guinea. Aquatic Botany 23: 215-224.

Lewis R.R. III (1983). Impact of oil spills on mangrove forests. In: Teas H.J. ed.: Tasks for Vegetation Science v.8, 171-183. Dr. W. Junk, The Hague.

Lucas R. M., J. C. Ellison, A. Mitchell, B. Donnelly, C. M. Finlayson, and A.K. Milne. (in press) Use of Stereo Aerial Photography for Assessing Changes in the Extent and Height of Mangrove Canopies in Tropical Australia. Wetlands Ecology and Management.

Pollard D.A. ; Hannan J.C. (1994). The ecological effects of structural flood mitigation works on fish habitats and fish communities in the lower Clarence River system of south-eastern Australia. Estuaries 17 (2), 427-461.

Prescott, N. (2001). Tonga Country Report. (This volume).

Proisy, C., Mougin, E., Fromard, F. and Karam, M.A. (2000). Interpretation of polarimetric radar signatures of mangrove forests. Remote Sensing of the Environment, 71:56-66.

Robertson, A. I., Daniel, P. A. and Dixon, P. (1991) Mangrove forest structure and productivity in the Fly river estuary, Papua New Guinea. Marine Biology 111: 147-155.

Saenger, P. & Snedaker, S.C., (1993). Pantropical trends in mangrove above-ground biomass and annual litterfall. Oecologia 96: 293-299.

Semeniuk, V., 1994. Predicting the effect of sea-level rise on mangrove in northwestern Australia. Journal of Coastal Research, 10, 1050-1076.

South Pacific Regional Environment Program (1999). Regional Wetlands Action Plan for the Pacific Islands. Apia, SPREP, 25pp.
UNEP/ UNESCO 1993. Impact of expected climate change on mangroves. UNESCO Report in Marine Science 61.

UNEP. 1994. Assessment and Monitoring of Climatic Change Impacts on Mangrove Ecosystems. UNEP Regional Seas Reports and Studies No 154, 62pp.

Woodroffe, C. D. 1990. The impact of sea-level rise on mangrove shorelines. Progress in Physical Geography 14, 483-520.

Weste, G., Cahill, D. and Stamps, D. J., (1982). Mangrove dieback in North Queensland, Australia. Transactions - British Mycological Society, 79 (1), pp 165-167.

COUNTRY REPORTS

Session I

Overview of Mangrove Wetlands in the Pacific Region

THE STATUS OF MANGROVES: GLOBAL, ASIA-PACIFIC, PACIFIC ISLANDS REGION

Wetlands International

Mangroves & mangrove ecosystems

- A **mangrove** is an (emergent) plant species that grows in intertidal waters, normally trees but including some shrubs, palms and ferns. It is tolerant to salt and brackish water and substrate with low oxygen levels.
- Tree species: eg. *Rhizophora, Avicennia, Bruguiera* spp.
- **Mangrove ecosystems** are based on mangrove plant communities (often forests).
- They occur mainly in tropical but also in sub-tropical and (in Southern Hemisphere) sometimes in temperate zones.

Mangrove distribution world-wide

- Largely confined between 30^{o} north and south of equator
- Notable exceptions; Bermuda and Japan (N), Australia, New Zealand and east coast South Africa (S)
- Widely distributed within these longitudinal confines
- Latitudinal development highest along the eastern coasts of Americas and Africa
- In Pacific Ocean, natural mangrove limited to western areas
- Absent from many Pacific islands

Global centres of diversity

- Two main global centres of diversity for mangroves termed the western and eastern groups
- Eastern group broadly corresponds to Indo-Pacific
- Western group includes African and American coasts of the Atlantic Ocean, Caribbean Sea and Gulf of Mexico and the Pacific coast of the Americas
- Quite different floristically with about five times the number of species in the eastern region vs the western region.

Global mangrove area estimates by region (sq km)

South and Southeast Asia	75,173 (41.5%)
Australasia	18,789 (10.4%)
The Americas	49,096 (27.1%)
West Africa	27,995 (15.5%)
East Africa and the Middle East	10,024 (5.5%)
TOTAL AREA:	181,077

Pacific Island Mangroves

- Pacific Island total mangrove area: 848,735 ha (2.4% of world's mangroves)
- Largest areas in PNG, Solomon Islands, Fiji and New Caledonia
- 34 species occur in this area and 3 hybrids
- All species of "eastern" or Indo-Malayan assemblage (with one exception)
- Decline in diversity from west to east across Pacific
- Eastern limit American Samoa (introduced to Hawaii and Tahiti)
- Mangrove Area of Pacific small in global terms but each island group has a unique community structure and are significant for human uses

Mangrove areas and diversity in the Pacific Islands Region

Country	#species	Area (ha)
Palau	13	4, 708
FSM	14	8, 574
PNG	33 (2)	200, 000
Guam	11	70
Northern Marianas	5	?
Solomon Islands	20 (2)	64, 200
New Caledonia	14 (2)	20, 250
Vanuatu	14	?2, 750
Marshall Islands	5	?
Nauru	2	1
Kiribati	4	?
Tuvalu	2	40
Wallis & Futuna	0	0
Fiji	8(1)	41, 000
Tonga	8	1, 000
Western Samoa	3	? 700
American Samoa	3	52
Niue	1	0
Tokelau	0	0
Cook Islands	0	0
French Polynesia	1	?
Pitcairn	0	0

Threats to mangroves in the Pacific Islands Region

- Conversion for **agricultural** or industrial land.
- Conversion for **urban** and tourism infrastructure.
- Disruption of **hydrology** due to road and transport.
- **Catchment** degradation - impact on freshwater inflows.
- **Over-harvest** of fish/crustaceans.
- Potentially, conversion for **aquaculture** ponds.
- Potentially, unsustainable **forestry** operations.
- **Sea level rise** - global warming.

Note: Very conservative estimate of 1% mangrove area loss per year for Asia-Pacific region (Ong, 1995)

Management strategies - in general

- **Community level action:**
  raise awareness of values and threats to values
  restore traditional harvest regimes
- **National level action:**
  plan for zonation of use of mangrove resources
  establish conservation areas
- **International cooperation:**
  address global warming causes
  focus resources and expertise on mangrove ecosystems

Acknowledgments

- Many of the data used are from publications produced by the International Society for Mangrove Ecosystems (ISME), notably the *World Mangrove Atlas* and *Journey Amongst Mangroves*. Used with permission.
- Other data are from *Mangroves, Ecology of Intertidal Forests* (Moloney & Sheaves 1995).
- Pacific Island mangrove species and areas data from Ellison, J.C., 1999. Status Report on Pacific Island Mangroves.

Session II

Status of Mangrove Wetlands in Pacific Island Countries

FIJI

By: Batiri Thaman, Aliti Vunisea, Alifereti Naikatini and Timoci Gaunavinaka

Background on Fiji's Mangrove Resources

Mangrove Area and Distribution

In the late 1980s the area extent of mangrove forests was calculated to be 38,543 hectares (of the original 41,000 hectares) (Watling 1985). Just over 90% of the mangroves are on Viti Levu and Vanua Levu, with the largest stands located in the deltaic areas of the Rewa, Ba, and Nadi Rivers on Viti Levu and the Labasa River on Vanua Levu (Ellison In Press a). The Ba, Labasa, and Rewa deltas combined support 28% of the national resource, however, they are lightly affected by development pressure (Gray 1993). The Suva-Navua mangroves and the Nadi Bay mangroves are, on the other hand, considered the most threatened because of their location (Watling 1985).

The mangroves of the Rewa delta are the most diverse and have been identified for urgent consideration in terms of sites important for biodiversity conservation. Those that need urgent conservation in terms of hydrological function are the mangroves of the Ba and Labasa Deltas (Singh 1996).

Mangrove Flora and Fauna

Fiji's mangrove flora is floristically simple consisting of four exclusively mangrove species, a unique mangrove hybrid, and four predominantly mangrove species. It is dominated by three 'true mangroves' from the family Rhizophoraceae: *Bruguiera gymnorrhiza* (**dogo** in Fijian), *Rhizophora stylosa* and *Rhizophora samoensis* (both **tiri**). The fourth true mangrove is *Lumnitzera littorea* (**sagale**). The sterile hybrid *R.*x *selala* (**selala**) is a cross between *Rhizophora stylosa* and *R.samoensis*. The predominantly mangrove species include *Xylocarpus granatum* and *Xylocarpus moluccensis* (both **dabi**), *Excoecaria agallocha* (**sinu**), and *Heritiera littoralis* (**kedra ivi na yalewa kalou**) (Pillai 1990, Watling 1985, and Smith 1981). The mangrove fern *Acrostichum auruem* (**borete**) is also widespread. In addition, there are many non-exclusive mangrove tracheophytes (Pillai 1990). The hybrid *Rhizophora* x *selala* is of some scientific interest because it is only found in Fiji, Tonga, and New Caledonia with Fiji having the greatest area of the hybrid (Watling 1985).

The mangrove fauna include a wide range of different marine organisms including crabs, prawns, a mangrove lobster, shellfish, fish, sharks, rays, eels, and other invertebrates, plus a smaller range of terrestrial animals that live in the forest, for example birds, flying foxes, mammals, and insects. Raj *et al.* (1984) provides a preliminary list of mangrove associated fauna, and Lal (1983) provides a list of the mangrove fish fauna.

Jurisdiction Over Mangrove Resources

Because mangroves are on the land-water interface, jurisdiction over them and their management is complex. Although terrestrial land may be owned by groups of indigenous Fijians, by government, or by others in the case of Freehold land, all intertidal and submerged land is owned by the state thus the state technically owns most mangrove areas (Department of Forestry 2001). However, Fijians have customary rights of use to

the living resources in these intertidal areas but not to the living resources on the land adjacent to it, if it is not owned by them. This has implications for mangrove utilisation by Fijians, as some species (e.g. land crabs) live within mangrove areas above the mean high water mark (Baines 1984).

Management of Mangrove Resources

Despite the considerable importance of mangroves to Fijian society, their sustainable management has only recently been given the attention it deserves, and currently faces many constraints. The present management system for mangroves was developed by Watling in 1985 and 1987, and includes legislation and zoning of mangrove areas. The mangrove zoning scheme comprises:

A. Mangrove Reserves: Primary Designation	1. Resource Reserves - allocated in areas of high species diversity and areas important to capture fisheries. 2. National Reserves - areas of major scientific, educational, and recreational interest.
B. Managed Resource Areas: Secondary Designation	1. Traditional Use Zone - areas required for the subsistence of Fijian communities, especially in rural areas. 2. Wood Production Zone - areas of potential for timber and firewood. Needs to be managed. 3. Shoreline Protection - required to protect roads, seawalls and agricultural land from the ocean, and coral reefs from pollution and sediment.
C. Development Zone: Tertiary Designation	1. Sewage Processing - areas used for the treatment of sewage. Research needs to be carried out on these areas as well as continual monitoring. 2. Aquaculture 3. Urban Development - Environmental Impact Assessment should be carried out prior to development 4.Tourism 5. Agriculture

This management plan has not been officially adopted (Lal 1991) and the current management of individual zones is probably inadequate. A Mangrove Management Committee, established in 1983, also exists and advises the Lands and Surveys Ministry on all matters concerning mangroves (Swarp 1992). Moreover, because the mangrove resource is poorly understood, most decisions on its utilisation appear to be made on an *ad hoc* basis and rely on inadequate information (Pillai 1985).

Research

The mangrove flora and fauna of Fiji have been fairly well researched. Various studies have been conducted on the mangrove flora of Fiji, mangrove-associated algae, and mangrove-associated fauna such as the fishes, mud crabs, penaeid prawns, the mangrove lobster, and the mangrove oyster. Few ecological studies have been carried out on Vanua Levu and almost none on the outer islands (Gray 1993). Investigations into the impact of pollution on mangroves are also lacking.

Current Awareness Activities

A number of workshops have been conducted recently related to mangrove conservation and use. In addition, there are a number of projects being carried out related to mangrove management, conservation, and monitoring.

Workshops

- USP has conducted workshops in Namatakula and Navutulevu on mangroves
- Wetlands International in January 2001 held a workshop in Suva on Field Survey Techniques for studying wetland biota
- WWF/MAFF recently conducted a workshop on Vanua Levu on Kuta and Wetlands
- Women in Fisheries Network conducted workshops and mangrove replanting in Tikina Namena
- GTZ
- FSP have conducted workshops in Nadroga
- National Trust

Projects

- USP- In Verata, one community conducts monitoring of mud lobsters in mangroves that they have set aside as part of their marine resource management plan. USP has also commenced a similar project at Votua, Ba. A mangrove area has been set aside as a tabu area by these communities and the plan is to monitor mangrove crabs within this mangrove area.
- OISCA has conducted extensive mangrove replanting projects in a number of communities along the coral coast.
- WWF has a Masi project in Tikina Wai on the Coral Coast. This project examines the use of mangrove bark as dye for tapa (bark cloth)
- USP/Govt./NGOs are seeking to establish the Muanikau mangroves and Children's Park as a Mangrove Conservation Area
- National Trust was involved in the set up of the Oceania part of the GLOMIS mangrove database. This database includes references on mangroves as well as personnel involved in mangrove research and management. National Trust also has developed a mangrove poster.
- FSP
- JICA

Recent Institutional Developments

Institutions Established

- A wetland working group was established in 2000 to deal with wetland conservation issues as well as the selection of a Ramsar Site.
- A Mangrove Management Committee established in 1983 still exists to advise the Lands and Survey Department on all matters concerning mangroves in Fiji.

Training Programs and Materials Developed

- A community training booklet on mangroves and other coastal ecosystems is being developed by the Women in Fisheries Network. This is in the process of publication for community level education throughout the region.
- Incorporation of awareness of mangroves into the school curriculum – classes 7 & 8 has been completed.

Present Monitoring Systems

Community-Based
- Verata: Communities are conducting their own biological monitoring of mud-lobster (USP supported)
- Tikina Wai, Nadroga: Community is monitoring the use of the mangrove (**dogo**) for dye for masi (WWF supported)

Government-Based
- Department of Forestry regulates "commercial logging" of mangroves (for poles and firewood)
- Department of Fisheries monitors the size of "mangrove crabs" sold at local markets

Involvement of Other Sectors

NGO's
- WWF – World Wide Fund for Nature
- Women in Fisheries Network
- OISCA
- JICA
- FSP –Foundation for Peoples of the South Pacific
- GTZ

Community Groups
- Verata District (Tailevu)
- Namena District (Tailevu)
- Wai District (Nadroga/Navosa)
- Votua (Ba)
- Nasoata Island (Rewa)
- Coral Coast communities

Academia
- USP – University of the South Pacific

Business Sector
- None specifically targeting mangrove conservation

Mangrove Legislation and Policy

In Fiji there is no single body of legislation or institution that deals specifically with mangroves. The Lands and Survey Department, however, has been the custodian of all mangrove resources of the country. Legislation depends on the departments that deal with the land, water, and the resources in or on mangrove areas (Lal 1983c). For example, although the Forestry Department is responsible for issuing and regulating licenses for the commercial felling of mangroves for firewood or timber via the Forestry Act, there is no legal framework covering illegal felling or overexploitation of timber for subsistence use (Watling 1985). The Fisheries Department is responsible for issuing licenses to fish in coastal waters via the Fisheries Act, while the Lands and Survey Department is responsible for foreshore land and reclamation of mangroves (Lal 1990). In addition, legislation dealing with pollution and reclamation of mangrove areas are haphazardly enforced.

An area of concern is that subsistence uses, unlike commercial uses, of mangrove areas have never been regulated by government or indigenous populations. This could be of importance since subsistence utilisation of mangrove-associated fisheries and wood is more widespread than commercial utilisation (Lal 1991).

In 1992, a National Policy concerning mangroves was under consideration by the Fiji government. It stated that:
Mangroves are an important national asset: Primarily as a resource base for capture fisheries, secondarily as a renewable source of products which contribute to the quality of life of associated coastal communities.
Recognizing this: The natural processes of the ecosystem should be preserved wherever possible thereby allowing the sustained harvesting of its renewable products and the preservation for future development options. Conversion activities should be minimised and permitted only in the national interest and after detailed socio-economic comparison with the expected loss to capture fisheries and other renewable uses (Swarp 1992).

However, at present there is a lack of a policy on wetland protection (Singh 1996).

Current Utilisation Patterns

Mangrove ecosystems in Fiji, in addition to their ecological and environmental roles, play a major role in the historical, cultural, and economic life of the Fijian people that live near the coast.

Fijian communities on the coast utilise mangrove forests as a source of food, for cash income, fuelwood, construction materials, tools, fishing equipment, medicines, and dyes amongst other things. In a recent study by Thaman (1998), it was found that these products are still being used, however, their importance is diminishing due to the use of alternative modern products, less time available to collect because of other commitments, and the loss of traditional knowledge in the preparation and use of these products.

Mangrove wood is commercially exploited for firewood and mangrove poles. Commercial exploitation is concentrated in the Rewa Delta, producing around 95% of the national total of commercial production. The estimated total area of mangrove actively managed for firewood production is estimated to be less than 50 ha and production has now declined to around 1,000 to 2,000 cubic meters per year. Currently there are 7 annual licenses in operation, 5 in the Rewa Delta and 2 in Navua (Department of Forestry 2001).

Mangrove ecosystems also support coastal subsistence, commercial, and recreational fisheries in Fiji. Mangrove fisheries are a critical source of subsistence protein, and a significant source of cash income for coastal communities, especially in rural areas, with a range of mangrove-related species commonly sold at local markets. Molluscs, crustaceans (crabs, mangrove lobsters, and prawns), and around 70 species of finfish are found or caught in mangrove waters (Lal *et al.* 1983, Lal 1991). Urban communities also utilise mangrove areas for subsistence and commercial purposes but not to the same extent as rural communities.

Mangrove areas are also extremely important to Fiji's sewage treatment program. Almost all of Fiji's municipal sewage plants are associated with mangroves, which are used as oxidation ponds, areas where solids are trapped and where effluent is discharged (Watling 1985). Rubbish dumps are also often situated near or in mangrove areas. However, these

two uses need to be more carefully planned and managed as they could result in serious community health problems (Baines 1984).

A further use of mangrove areas is for the location of settlements. All the major settlements of the Suva Peninsula are located around Suva's rivers or mangrove swamps, or where these once were. The location of Suva's poorer residents in these areas is explained by the low commercial value of the mangrove land, and a preference to locate near a river or mangrove area that could supplement them with food and cash earnings, and provide access to the ocean and reefs for those with boats.

Mangrove areas are also seen as valuable land for reclamation for agriculture, industry, residential areas, tourist hotels, and urban development. Applications for reclamation for residential, industrial, and other urban development have increased dramatically, especially in urban areas.

Additional values of mangroves are for use in scientific studies, recreation, tourism, and education.

Present Threats to Mangroves in Fiji

Although threats to the mangrove ecosystem in Fiji are currently limited, the resource is much smaller than in Asian countries and thus more vulnerable. Mangrove areas in urban and peri-urban areas are the most susceptible to threats which arise due to increasing urbanization and development activities. These threats include the expansion of squatter settlements within and bordering mangroves, high population densities that consequently lead to overexploitation of mangrove products, reclamation of mangroves because of commercial, industrial and residential demands for land, drainage activities, sand mining, pollution, and estuarine dredging for flood mitigation (Watling 1985; Pillai 1985; Singh 1996).

Over-exploitation for subsistence firewood use is present and visible but highly localised and limited in extent. It is most serious in the urban and periurban areas and in the drier western mangroves where the ability to withstand coppicing appears to be poor (Swarp 1992).

Although poorly executed large-scale reclamations, which had the greatest impact on mangroves in the past, have reportedly been stopped as official government policy, continuing small-scale reclamations are resulting in the same loss of valuable mangrove resources (Lal 1983). It has been estimated that more than 80% of the mangroves of the Suva Peninsula are thought to have already been reclaimed for urban development (Hamilton and Snedaker 1984), and 6% of the total area has been converted to other uses (Pillai 1988). In addition, extensive government-approved reclamations of mangroves associated with the Denarau Island and Vulani Island tourism developments in Western Viti Levu have been carried out.

No detailed monitoring of pollution in Fiji mangroves has been carried out although Lal (1984) reported observations of abnormalities in the mangroves adjacent to an electricity generating plant, which could have been near the mangroves of Kinoya village. Bryant (1994) reported that in the Suva area, 95% of the mangrove oysters collected from 8 sites exceeded World Health Organisation limits for faecal coliform levels probably originating from sewage effluent. In the urban areas, litter is often thrown into mangroves (Chape and Watling 1992).

Threats that affect mangrove areas, in general, include increasing populations near the coast, commercialization of mangrove products, lack of enforcement of regulations prohibiting unlicensed mangrove felling for commercial purposes, illegal cutting and fishing, hurricanes, and probable sea level rise.

References

Baines, G.B.K. 1979. Mangroves for national development: A report on the mangrove resources of Fiji. (Unpubl. Report)

Department of Forests. 2001. Mangrove production in the Southern Division Fiji. Department of Forests, Ministry of Agriculture, Fisheries, and Forestry, Suva.

Gray, A.J. 1993. Fiji. In Scott, D.A. (ed.). *A Directory of wetlands in Oceania*. IWRB, Slimbridge, U.K. and AWB, Kuala Lumpur, Malaysia.

Ellison, J.C. In Press (a). Present status of Pacific Island mangroves. In Eldredge, L.G., Maragos, J.E. and Holthus, P.L. (eds.). *Marine and coastal biodiversity in the tropical island pacific region: II Population, development and conservation priorities.* Pacific Science Association, East-West Centre, Honolulu.

Ellison, J.C. In Press (b). Systematics and taxonomy of Pacific Island mangroves. In Maragos, J.E., Peterson, M., Eldredge, L.G., and Bardach, J.E. (eds.). *Marine and coastal biodiversity in the tropical island pacific region: I Species systematics and information management priorities*. Pacific Science Association, East-West Centre, Honolulu.

Lal, P.N. 1983. Mangroves and secondary productivity: Fishes associated with mangroves in Wairiki Creek, Fiji. In Lal, P.N. (ed.). *Mangrove resource management. Proceedings of interdepartmental workshop 24 Feb, 1983, Suva, Fiji*. Technical report No. 5, Fisheries Division, MAF, Suva. Pp 13-31.

Lal, P.N. 1983b. Institutional aspects of the management of mangrove resources in Fiji. In Lal, P.N. (ed.). *Mangrove resource management. Proceedings of interdepartmental workshop 24 Feb, 1983, Suva, Fiji*. Technical report No. 5, Fisheries Division, MAF, Suva. Pp 56-65.

Lal, P.N. 1991. Mangrove management issues: Strategies adopted in the Pacific Islands. Islands/Australia Working Paper No. 91/3. National Centre for Development Studies, Australian National University, Canberra.

Lal, P., Swamy, K. and Singh, P. 1983. Mangroves and secondary productivity. Fishes associated with mangroves in Wairiki Creek, Fiji. In Lal, P. (ed.), Proceed. of an interdepartmental workshop, February 1983, Suva, Fiji. Fisheries Division Technical Report 5. Ministry of Agriculture and Fisheries, Fiji.

Pillai, G. 1985. Mangroves of Fiji: Their uses and management. Paper presented at the Research for Development seminar: The mangrove ecosystem. Australian Institute of Marine Science, 17-25 May, 1985, Townsville.

Pillai, G. 1990. *Mangroves of Fiji*. University of the South Pacific, Suva.

Singh, B. 1996. Fiji. In Jaensch, R. (ed.) *Wetland Conservation in the Pacific Island Region*. Proceedings of the Regional Workshop on Wetland Protection and Sustainable Use in Oceania. Port Moresby, Papua New Guinea, 6-10 June 1994. Wetlands International- Asia Pacific, Canberra, Publication No. 118.

Smith, A.C. 1981. *Flora Vitiensis nova. A new flora of Fiji (spermatophytes only)*. Vol. 2. Pacific Tropical Botanical Gardens, Lawai, Kauai, Hawaii.

Swarup, R. 1992. Country report Fiji. In Nakamura, T. (ed.) *Proceedings of seminar and workshop on integrated research on mangrove ecosystems in Pacific Islands Region Vol I*. Japan International Association for Mangroves (JIAM), Tokyo. Pp 90-135.

Thaman, B. 1998. Community Utilization and Valuation of Mangrove Products. Unpublished MSc Thesis. James Cook University of North Queensland, Townsville.

Watling, D. 1985. *A mangrove management plan for Fiji (Phase 1)*. South Pacific Commission and Fiji government.

PALAU

By: Theo Isamu and Alma Ridep-Morris

Inventory of the status of mangrove wetlands in Palau.

Extent
11,633.0 acres (4,708.0 ha)

General description

Mangrove wetlands in Palau constitute wetlands on high islands, coral islands and rock islands. These include the estuarine mangroves of high islands, embayments and rivers, and the intertidal coastal flat mangroves of low islands.

Palau's mangrove species are mostly confined to the intertidal coastal flats where they are generally subject to tidal overwash twice daily. Here they form a dense, virtually impenetrable continual forest cover ranging in extent from a few meters to one mile from the seaward to landward edge. Their distribution is roughly stratified by horizontal gradients that are aligned parallel to the shoreline. Stand structure ranges from single clumps to dense overstocked stands. Tree forms range from stunted and shrub-like plants to trees up to 70 feet in height and 40 plus inches in diameter (Metz, 2000).

Within Palau's mangrove habitat types, it has been confirmed that eighteen (18) mangrove species and associated species occur (Duke, 1999).

Genus Species	***Palauan Name***	***Habitat Zone***
1. *Acanthus ebracteatus*	Kollil	I
2. *Acrostichum speciosum*	Okuam	I
3. *Avicennia alba*	unknown	
4. *Bruguiera gymnorhiza*	Denges, Kodenges	I, F, R
5. *Ceriops tagal*	Biut	I, R
6. *Dolichandrome spathacea*	Rriu	I
7. *Excoecaria agallocha*	Ias	F
8. *Heritiera littoralis*	Ebibech	I, R
9. *Lumnitzera littorea*	Mekekad	I, R
10. *Nypa fruticans*	Toechel	I, R
11. *Pemphis acidula*	Ngis	F
12. *Rhizophora apiculata*	Bngaol	F, R, I
13. *Rhizophora X lamarckii*	Tebechel	F, R, I
14. *Rhizophora mucronata*	Tebechel	F, R
15. *Rhizophora stylosa*	Bngaol	F
16. *Scyphiphora hydrophyllacea*	Kuat	R, I
17. *Sonneratia alba*	Urur	I, F, R
18. *Xylocarpus granatum*	Meduulokebong	I,R

I = Interior F = Fringe R = Riverine

Mangrove wetland loss

Most of the mangrove wetland loss in Palau has occurred due to development and human activities, for example reclamation for residential development and aquaculture. The extent of wetland loss is unknown.

Institutional arrangements for mangrove wetland management

Institutions/Agencies
Bureau of Natural Resources and Development
(a) Division of Agriculture and Mineral Resources
(b) Office of the Conservation Area Support Officer
Environmental Quality Protection Board (EQPB)
Palau Conservation Society
Several State Governments (e.g. Koror State Government)
Palau International Coral Reef Center

In the National Government, the Division of Agriculture and Mineral Resources under the Bureau of Natural Resources and Development works on the development of the National Mangrove Management Plan. The Office of the Conservation Area Support Officer under the Bureau of Natural Resources and Development specifically works on the management, awareness programs, and monitoring of the Ngaremeduu Conservation Area, which is the largest and most biodiverse mangrove ecosystem in Palau. The Environmental Quality Protection Board deals with the establishment of national regulations and enforcement of these regulations.

Other institutions or agencies involved in the mangrove wetland management include the Palau Conservation Society (a non-government organization), which deals with awareness programs; the Koror State Government, which deals with establishing state regulations and enforcement of these state regulations; and the Palau International Coral Reef Center (a newly established center) that promotes research and public awareness programs.

Mangrove wetland policies and legislation

Legislations/Acts
There are several state legislations that are in place in the states of Aimeliik, Ngatpang and Ngaremlengui that protect and conserve the Ngaremeduu Conservation Area, which encompasses the largest mangrove ecosystem in Palau.

1. Ngaremeduu Conservation Area Act of 1999, Aimeliik State
2. Ngaremeduu Conservation Area Act of 1999, Ngatpang State
3. Ngaremeduu and Compact Road Mitigation and Conservation Area Act of 1999, Ngaremlengui State

Another legislation that is in place to set aside a mangrove area of the west coast of Ngaraard State as a conservation area is the:
- Ngaraard State Public Law No. 4-4

Regulations
Currently, the Environmental Quality Protection Board proposed the Marine and Freshwater Quality Regulations (Chapter 2401-11-09), which would enforce buffer zones

for the protection of coastal waters and mangroves. These regulations are pending approval from the Palau National Congress, the Olbiil Era Kelulau (OEK).

There is an Environmental Impact Statement Regulation that is in place and is enforced by the Environmental Quality Protection Board.

Management plans
A couple of management plans that are in place that deal with mangrove conservation in Palau are:

a) The Palau Mangrove Management Plan (2000)
b) Management Plan for the Ngaremeduu Conservation Area (2000)

Tenure ownership of mangrove wetlands in Palau

Most of the mangrove wetlands in Palau are state-owned. Under the Constitution of the Republic of Palau, all mangrove areas fall under the jurisdiction of the state governments. The National Government may provide strategies and policies that the National Congress may adopt into legislations, that can be used as guidelines for the states to adopt for the protection and management of their resources.

Community-based management structure in place

Traditional chiefs of each state impose traditional laws called "bul" in their respective communities, for the purpose of protecting and conserving their natural resources. The traditional chiefs may impose a "bul" on certain species of mangroves, including the ban of collection, or cutting of the resources.

An example of a community-based project that imposes mangrove management is the Ngaremeduu Conservation Area (NCA). The NCA is managed by the Conservation Area Coordinating Committee (CACC), which involves community members and traditional leaders, and patrolled by the Conservation Area Patrol Officers (CAPOs), working together to conserve and protect the resources of the NCA. The NCA involves the buffering of mangrove areas, of up to 50 feet from the mangrove edge inland.

Mangrove wetland monitoring system

There has been no defined mangrove wetland monitoring system in place in Palau. Scientists who come to study the mangroves in Palau have not necessarily used a particular mangrove wetland monitoring system to assess the health and status of the mangroves in Palau. This being the case, it is important to set up a mangrove wetland monitoring system that is carried out on a regular basis to help assess the health and status of the mangroves in Palau.

Current awareness on the importance of mangrove wetlands

Extent of public understanding of mangrove wetlands
In the past, many people thought of mangroves as mosquito-infested and smelly areas, and they did not realize the need to protect them. However, through public awareness

programs conducted by different environmental sectors, e.g. Bureau of Natural Resources and Development, Environmental Quality Protection Board, Palau Conservation Society, etc., awareness has been raised regarding the importance of conserving and protecting mangroves not only for present but also for future generations.

Mangrove wetland education in the school

There is currently an effort to strengthen the science and environmental programs in the education system, including mangrove wetland education programs. The Bureau of Education, in cooperation with the Public Schools, Palau Community College and various environmental sectors, are working together to set up a science curriculum that will involve hands-on science activities to gain knowledge of the environment of Palau.

Community involvement in wetland management

The Ngaremeduu Conservation Area is a community-based biodiversity conservation program that involves three states of Palau, namely Aimeliik, Ngatpang, and Ngaremlengui. The NCA program stresses the importance of community involvement in the projects. The management of the mangrove wetlands in the NCA incorporates buffer zones, protection of habitat, and seasonal collection of mangrove crabs to prevent overharvesting of these important delicacies of Palau. Traditional chiefs in the states also impose traditional law called "bul" to prevent overharvesting of certain species of mangroves for building materials or other purposes.

Campaigns/strategy for promotion of wise use of mangrove wetlands

Several school campaigns have been conducted by several environmental sectors to promote the wise use of mangrove wetlands throughout Palau. There was a huge campaign through the Annual Science Fair in 2000 to promote the protection and wise use of mangrove wetlands in Palau.

Involvement of other sectors in mangrove wetland policy development, management and monitoring

The development of the Palau Mangrove Management Plan which is the basis for wetland policy in Palau, involved various sectors including government agencies, NGOs, academics and other environmental sectors. Management of wetlands falls under the jurisdiction of the state governments, with assistance from the national government. There is currently no ongoing monitoring of the mangrove wetlands.

Current situation regarding use of mangrove wetlands

Mangrove wetlands are seriously being considered for better protection under the Palau Mangrove Management Plan (2000), which recommends the setting up of conservation and reserve areas under the Heritage Act, and the Environmental Quality Protection Board proposal for the Marine and Freshwater Quality Regulations (Chapter 2401-11-09), which enforces buffer zones for the protection of coastal waters and mangroves.

Several states are currently using or proposing to use some mangrove areas for aquaculture development. Palau is currently considering boosting the development of aquaculture in order to improve the economy of Palau. Before aquaculture develops in Palau, wetland policies should be in place for the protection and sustainability of mangrove wetlands.

Furthermore, eco-tourism is slowly being introduced as another means of generating money with minimal impacts to the environment. An ecotourism strategy for the Ngaremeduu Conservation Area has been established, but due to funding constraints, it has not been implemented. This project can become one of the best sustainably-managed mangrove area in Palau, once the communities involved see the benefits of protecting the mangroves asa tourist attraction and for future generations.

Status of adoption of multi-lateral biodiversity conservation conventions

Palau acceded to the Convention on Biological Diversity in 1999, and the National Biodiversity Strategy and Action Plan proposal has been accepted by GEF for funding. The Office of Environmental Response and Coordination was created by the President of Palau in January 2001 to address the Convention on Biological Diversity, the Convention on Climate Change, and the Convention on Desertification.

The accession process to the RAMSAR Convention is still pending, waiting for approval by the President of Palau in the near future.

THE FEDERATED STATES OF MICRONESIA

By: Andreas Paul and Ahser Edward

The Federated States of Micronesia (FSM) consists of 45 distinct islands scattered over a vast expanse of ocean between 1°N and 10°N latitude and 137°E and 168°E longitude. Most of these islands are low coral atolls except for four high volcanic islands. The four high islands represent most (92%) of the land area and serve as capital centers of the states. These high islands located from east to west are Kosrae, Pohnpei, Chuuk and Yap state. The population of the entire FSM is approximately 116,268 people with an average population growth of 2.1%.

The wetland areas in FSM primarily comprise of mangrove forest, swamp forest, freshwater marsh, ivory nut palm forest and saline marsh. Over 85% of the wetlands in FSM are mangrove, 65% of which is found is found on the main island of Pohnpei. Kosrae comes next with an additional 18%. Although Yap has a smaller area of mangrove forests, the mangroves are more developed and more diverse than Pohnpei and Kosrae. Recent studies on biological diversity have indicated that the diversity of the mangrove species increase from east to west with Malaysia and Indonesia having the highest number of species. On the islands of Pohnpei and Kosrae, the species distribution may differ, however, they may have the same number of species of mangrove trees. For example, in Kosrae, *Sonneratia alba* dominates the seaward margin of mangrove forest while on Pohnpei, *Rhizophora mucronata* is found there. Pohnpei may have one or two more species over Kosrae and recent studies show that since the two islands are so close together in geographical location, they may have the same species. Kosrae should be noted for the abundance of nepa, *Nypa fruticans.* Yap like Chuuk, has poorly developed mangroves but slightly greater species diversity than the islands located to the east.

Much of the wetlands in FSM are located on the main island states whereas wetlands on the low atolls are limited to cultivated taro *Colocasia esculenta* and *Cyrtosperma chamissonis* with limited fringing lagoonal mangroves comprised mainly of dwarf *Rhizophora mucronata, Bruguiera gymnorrhiza* and *Lumintzera littorea*. The table below shows the wetland areas in the FSM (in hectares).

	Kosrae	**Pohnpei**	**Chuuk**	**Yap**	**Totals**	**Percent**
Mangrove Forest	1,562	5,525	306	1,171	8,564	85.4
Swamp forest	345	214	0	155	714	7.1
Freshwater marsh	25	149	234	165	573	5.7
Ivory nut forest	0	137	2	0	139	1.4
Saline marsh	0	29	0	6	35	0.4

Wetland Loss

Over the last several decades, the main uses of the mangrove trees have been for timber and handicrafts and these uses were considered sustainable and non-destructive. As population increased and new lifestyles were introduced, the use of the coastal resources evolved. The loss of wetland areas, primarily mangroves, has been from the dredging of coral rubble from the adjacent fringing reefs. A large area of mangroves has been cleared

to access the adjacent reefs for coral rubble to be used for filling of roads. Land-filling for land reclamation contributes to mangrove loss and is sporadic in some areas of the Federated States of Micronesia.

Wetland Area Legislation

In the FSM, the individual states have exclusive jurisdiction over the management of natural resources. In Kosrae and Pohnpei States, submerged lands (those below the high tide mark) are public land and under the jurisdiction of the State Government. In Chuuk and Yap, water areas are privately or customarily owned. In Pohnpei, the 1987 Watershed Protection and Mangrove Management Act gives the State Forestry Division broad authority to manage mangrove areas. In Kosrae, legislation exists to prevent development along specified river drainages. Thus far this has not become a significant problem and there has not been a real need to enforce the law. Areas designated to be sanctuaries are located in Pohnpei and Kosrae.

Institutional Management

Organizations involved in the management of the wetland areas include:

US Federal Agencies
- Forest Service – provides technical assistance to state governments
- Soil Conservation Service – currently providing technical assistance to Pohnpei and Kosrae states

FSM Government
- FSM Department of Resources and Development – coordinate outside technical assistance for state agencies.
- Pohnpei Division of Forestry – manages the mangrove and watershed areas
- Kosrae Development Review Commission – overlooks the management of the mangrove and watershed areas

Academic Institutions
- College of Micronesia – Sea Grant Extension Services – assisting in the development of coastal resource management plans, parks and protected areas

Community Involvement

In Pohnpei and Kosrae, the communities have shown a lot of interest in protecting the mangrove forest. Some communities have started projects to designate nearby mangrove forests as sanctuaries. The Langer community is pushing that the Pohnpei legislature make it a law that the entire Langer becomes a sanctuary, including the mangrove forest fringing the island. In Kosrae, Utwe-Walung Marine Park was a community initiative.

In the FSM primary and secondary school systems, standards for teaching science have been developed. The next step is to write course outlines for these standards and by next year, these course outlines will be used in the schools. Mangrove management is one of the key issues that is emphasized in these curricula.

Recent work involves several NGOs and government agencies in implementing the Youth to Youth program. This program started with selecting over ten schools. Environmental awareness programs were taken to these schools. During the course of the project, the students were given talks and field trips. Towards the end of the project, students were asked to compose songs and develop skits from what they have learned from the talks and

field trips. Songs were sung and the skits were performed at the fair held during the Earth Day celebrations. Posters were also made and displayed in the classrooms for students from other schools to see. The winning ones are displayed at the airport.

Kosrae state has done some reforestation of mangroves involving the students in the elementary schools. Research, mainly inventories and mangrove productivity studies, have been recently conducted in Kosrae on diameter (growth) and collection of carbon dioxide. These recent studies were mainly carried out by US Forest Services.

The FSM has ratified the Convention for the Protection of the Natural Resources and Environment of the South Pacific (the SPREP convention) and has signed and ratified the Convention on Biological Diversity. FSM is not as yet a party to the UNESCO Man and Biosphere Program, Ramsar Convention or World Heritage Convention, nor has it signed or ratified the Convention on the Conservation of Nature in the South Pacific.

SOLOMON ISLANDS

By: Peter C. Ramohia[1] and Nathaniel da Wheya[2]

INTRODUCTION

Background

Solomon Islands (5-12^{o}S – 152-170^{o}E) stretches 1700 km northwest to southeast between Bougainville (PNG) and Banks group (Vanuatu) and is the third largest country in the South Pacific after PNG and New Zealand. It has a land area of 27,556 km^2 and an EEZ of 1.34 million km^2, twice that of Vanuatu and slightly larger than that of Fiji. The Internal Waters (12 mile Zone) is 0.3 million km^2 and this is where most mangrove areas and coral reefs occur.

The country is divided into 9 provinces plus Honiara municipality: (1) Malaita province (2) Guadalcanal province (3) Western province (4) Choiseul province (5) Makira/Ulawa province (6) Isabel province (7) Temotu province (8) Central province and (9) Renbel province. The 1999 national census put the total population of Solomon Islands at 408,358 with a population density of 14 persons per square kilometer and a population growth rate of 3.4% per annum.

The overwhelming majority of people live in coastal communities or villages engaging in the subsistence economy.

Tenure

The Customary Marine Tenure (CMT) system is an important part of the cultures of Solomon Islands and varies between different cultures. CMT has been described as complex and dynamic and recognized under Solomon Islands Constitution (Fisheries Act 1998). Under CMT, coastal areas (mangroves, lagoons and corals reefs) are owned by a kinship group. Owners are part of the coastal setting (or system) and any impacts on the system will have a bearing on them. Success or failure of projects or conservation efforts in coastal areas depends on the support of customary owners.

STATUS OF MANGROVES

A precise definition for the word “mangrove” may not exist but consequently, the term has been used to describe the community as a whole as well as the plants or trees growing in a mangrove habitat. The term “mangrove” now refers to the trees or plants which are restricted to the inter-tidal zone and the term “mangal” defines the community of which mangroves form an integral part. Many other plants are associated with mangroves but these are not exclusive to the habitat.

Status of Mangrove Wetlands in Solomon Islands

[1] Ministry of Fisheries and Marine Resources Honiara, Solomon Islands
[2] Ministry of Forest Environment and Conservation, Honiara, Solomon Islands

Woodroffe (1987), using Chapman (1970) which recognizes 55 species belonging to 11 families and 16 genera, listed 19 species of mangroves for the Solomons Islands. Oreihaka (1997) and the Pillai and Sirikolo (1997) (Oreihaka, 1997 presumably using the Pillai and Sirikolo 1997) identified 26 species from 13 families and 15 genera (Table 1), using the exclusive mangrove species of Sangar et al (1983), which recognizes 60 species drawn from 16 families and 22 genera. This indicates that the Solomon Island species represents 43% of the world's mangrove species. The report by Pillai and Sirikolo (1997) is the most up to date information on the mangroves of the Solomon Islands.

Recently, Mr. Dako Nating did a comparison study of the biodiversity of the mangroves of east Isabel and Laucala Islands as part of his Masters thesis, with emphasis on flora and fauna (mollusks and crustaceans).

Areas under Mangal in Solomon Islands

Hansell and Wall (1976) estimated the area covered by mangroves in Solomon Islands to be 64,200 hectares. A recent estimate, however, puts it at 52,550 hectares (Solomon Islands National Forest Resources Inventory, 1995). Mangroves account for approximately 3 % of the total land area of 27,556 km^2.

Mangroves are found on most islands of the Solomons. The distribution of major mangrove stands and species in Solomon Islands as reported by Pillai and Sirikolo (1997) is summarized below.

On Malaita, significant stands of mangroves are found at Lau Lagoon (North Malaita), Langa Langa Lagoon (West Malaita), Are Are Lagoon (Southwest Malaita), and Maramasike Passage (between Small Malaita and Malaita). Nineteen species of mangroves are recorded in the Langa Langa Lagoon with the dominant species being *Rhizophora apiculata, R. stylosa* and *Bruguiera gymnorhiza*. The mangroves of Malaita are dominated by *B. gymnorhiza* and *R. apiculata*. Other species reported on the island include *R. mucronata, Nypa fruticans, Ceriops tagal, Heritiera littoralis, Scyphiphora hydrophyllacea, Xylocarpus granatum, Cynometra ramiflora, Acanthus ebracteatus, Lumnitzera littorea* and *Sonneratia ovata*. *Acrostichum aureum* occurs sporadically.

On Guadalcanal, the mangrove stands are more or less confined to Marau Sound, situated at the eastern extremity of the island. Eleven species of mangroves are recorded in Marau with the dominant species being *Rhizophora stylosa, R. apiculata, Bruguiera gymnorhiza* and *Lumnitzera littorea*. Other mangrove species recorded in the area include *R. mucronata, B. parviflora, C. tagal, S. ovata, Excoecaria agallocha, X. granatum*, and *S. hydrophyllacea*. The marine fern, *A. aureum* occurs sporadically.

On San Cristobal (Makira) the mangroves are confined to Star Harbour and the Three Sisters Islands with the dominant mangrove genus being *Rhizophora*.

In the Western Province mangroves are found around Hawthorn Sound, the southern shores of New Georgia Island and in the Marovo Lagoon. Thirteen mangrove species are found in the Hawthorn Sound area with the dominant species being *R. stylosa* and *B. gymnorhiza.* Other mangroves of the area include *R. apiculata, R. mucronata, C. tagal, S. hydrophyllacea, A. ebracteatus, E. agallocha, L. littorea, H. littoralis, S. ovata* and *X. granatum.* Leary (1993b) reported the dominant species of the Marovo lagoon to be

Rhizophora spp with local concentrations of *L. littorea, H. littoralis, X. granatum* and *Bruguiera* spp.

The largest stands of mangroves on Santa Isabel are found around Western Santa Isabel, the Arnarvon Islands (Arnavon Marine Conservation Area), between San Jorge Island and the mainland, the Thousand Ships Bay, and the Ortega Channel. The dominant mangroves of Western Santa Isabel are *Rhizophora* spp and *Bruguiera* spp. *L. littorea* is also prevalent (Leary, 1993b).

On Choiseul, mangroves are found at the southeastern end of the island, including Waghena and Rob Roy Islands, as well as the northwestern end of the island. Leary (1993b) reported the dominant mangrove species of Eastern Choiseul to be *R. stylosa* and *R. apiculata* with local concentrations of *S. caseolaris* and *N. fruticans*. Other mangrove species which are found on the island include *Bruguiera spp, L. litto*rea and *X. granatum* .

In the Central Province, the largest stands of mangroves occur along the entire length of Mboli (Utaha) Passage separating the islands Nggela Sule and Nggela Pile (Florida Islands). Fourteen species of mangroves are recorded in the passage.

The mangroves of Temotu Province are dominated by *R. apiculata* and *B. gymnorhiza*. Other common species include *L. littorea, R. stylosa* and *H. littoralis*.

In summary, the Solomon Islands mangrove flora is dominated by *Rhizophora* and *Bruguiera. Lumnitzera* is also fairly common.

Table 1. Mangrove species of the Solomon Islands

Family	Species
Acanthaceae	*Acanthus ebracteatus* Vahl. 1791
	Acanthus ilicifolius L. 1753
Avicenniaceae	*Avicennia alba* Blume 1826
	Avicennia eucalyptifolia (Zipp. ex Miq.) Moldenke 1960
	Avicennia marina (Forsk.) Vierh. 1907
	Avicennia officinalis L. 1753
Combretaceae	*Lumnitzera littorea* (Jack) Voigt. 1845
Euphorbiaceae	*Excoecaria agallocha* L. 1759
Leguminosae	*Cynometra ramiflora* L. 1753
Meliaceae	*Xylocarpus granatum* Koenig 1784
	Xylocarpus moluccensis (Lamk.) Roem 1846
Myrsinaceae	*Aegiceras corniculatum* (L.) Blanco 1837
Myrtaceae	*Osbornia octodonta* F. Muell. 1862
Palmae	*Nypa fruticans* (Thunb.) Wurmb. 1781
Rhizophoraceae	*Bruguiera gymnorhiza* (L.) Lamk. 1797-8
	Bruguiera parviflora Wight & Arnold ex Griffith 1936
	Bruguiera sexangula (Lour.) Poiret 1816
	Ceriops tagal (Perrottet) C.B.Robinson 1908
	Rhizophora apiculata Blume 1827

	Rhizophora mucronata Lam. 1804
	Rhizophora stylosa Griff. 1854
Rubiaceae	*Scyphiphora hydrophyllacea* Gaertn. 1805
Sonneratiaceae	*Sonneratia alba* J. Smith 1819
	Sonneratia caseolaris (L.) Engl. 1897
	Sonneratia ovata Backer 1929
Sterculiaceae	*Heritiera littoralis* Dryand. in Aiton 1789

Source: Pillai and Sirikolo (1997)

Although not exclusive to the intertidal zone, the following plants have also been recorded in the mangal in Solomon Islands. These are, *Pemphis acidula, Dolichandrone spathacea, Hibiscus tiliaceus, Calophyllum inophyllum, Pandanus spp, Cocos nucifera, Acrostichum aureum, Barringtonia racemosa, Brownlowia argentata, Cerbera floribunda, Cerbera manghas, Clerodendrum inerme, Thespesia populnea,* and *Myristica hollrungii* (Table 2).

Table 2. Some important, non-exclusive species of shrubs and trees found in the mangal

Family	Species
Pteridaceae	*Acrostichum aureum* L. 1753
Lecythidaceae	*Barringtonia racemosa* (L.) Spreng 1826
Tiliaceae	*Brownlowia argentata* Kurz 1870
Apocynaceae	*Cerbera floribunda* K Schumann 1889
	Cerbera manghas L. 1753
Verbenaceae	*Clerodendrum inerme* (L.) Gaertn. 1805
Bignoniaceae	*Dolichandrone spathacea* (L.f.) K. Schumann 1889
Malvaceae	*Hibiscus tiliaceus* L. 1753
	Thespesia populnea (L.) Solander ex Correa 1807
Myristicaceae	*Myristica hollrungii* Warb. 1897
Lythraceae	*Pemphis acidula* Forst. 1776

Source: Pillai and Sirikolo (1997)

Mangrove Fauna

Despite only a few mangrove related studies being undertaken in Solomon Islands, it is obvious that the mangroves of the country are rich in biodiversity. Given the land area and proximity to Papua New Guinea, which lies in the biogeographic region where the main concentrations of mangroves occur, this is not surprising. Besides plants, bacteria, fungi, lichens and algae, almost all major groups of animals, from protozoa to mammalia are represented in the mangal.

In Solomon Islands a variety of resident organisms, eg barnacles, limpets, oysters, periwinkles, crabs and mudskippers (*Periophthalmus* spp*)* are closely dependent on mangroves for food or space. Additionally, non-resident fauna such as fish, insects, saltwater crocodiles, birds, bats visit the ecosystem from time to time in search of shelter, food and mates.

The mangrove swamps harbour many species which are of economic value and constitute an important human food resource. These include oysters, clams, gastropods, cephalopods and crustaceans such as the mangrove-lobster (*Thalassina anomala)*, commercially important prawns (e.g. *Penaeus* spp), the coconut crab *(Birgus latro),* the land crab (*Cardisoma spp*)*,* mud-crab (*Scylla serrata*) and hermit crabs (*Uca* spp).

Many of the fish species are economically important food fishes, for example snappers, mullets, rabbit fishes, jacks, emperors and groupers use the mangrove. 136 species of fish from 13 families from estuaries have been recorded to date in the Solomon Islands (Blaber & Milton, in Leary, 1993a). Sharks and several species of rays also enter mangal waters.

The saltwater crocodile, *Crocodylus porosus,* is the best known reptile occurring in the mangrove habitat and all the 5 species of turtles found in the Solomon Islands (the hawksbill (*Eretmochyles imbricata),* the green turtle (*Chelonia mydas),* the leatherback turtle (*Dermochyles coriacea),* the loggerhead turtle (*Caretta caretta),* and the Olive Ridley turtle (*Lepidochelys olivace)* visit mangal waters. The Mangrove Monitor, *Varanus indicus spinulosus* and a number of snakes, lizards, geckos are present in the mangal.

It may well be that some of the 173 resident species of birds of the country live in the mangal, or visit the mangal for food. Other avian species, for example shore birds and migratory birds may also exploit the mangrove habitat.

Mammals utilising Solomon Islands mangroves include bats, rats, and presumably the marsupial possum, *Phalanger orientalis,* not to mention humans. Sea-cows, *Dugong dugong,* also browse in waters associated with mangroves.

Uses of Mangroves of the Solomon Islands

As seen above, many living organisms rely on the mangrove ecosystem. Mangrove habitats also provide an array of uses to humans, directly or indirectly. On the subsistence level (in Solomon Islands), humans rely heavily on the mangrove and the animals associated with it for a variety of products including food, firewood, building materials and medicine. Table 3 present the main uses of mangrove plants in Solomon Islands.

Table 3. Uses of mangroves of the Solomons

Species	Uses
Acanthus ebracteatus	Used medicinally to cure boils; fuelwood
Acanthus ilicifolius	Fuelwood
Avicennia alba	Fruits are used as food; used medicinally to cure boils; fuelwood
Avicennia eucalyptifolia	As for other members of the genus
Avicennia marina	As for other members of the genus
Avicennia officinalis	As for other members of the genus
Lumnitzera littorea	Durable timber, used as construction and building material; stem is used for poling canoe; flowers used for decoration; fuelwood
Excoecaria agallocha	Used as poison, the latex of the plant is mixed with oil of *Cerbera* to catch fish; leaves used as medicine as an analgesic for body ache
Cynometra ramiflora	Fuelwood
Xylocarpus granatum	Bark is used medicinally for the treatment of diarrhoea and dysentry; dyes; construction and building material; fuelwood
Xylocarpus moluccensis	Used in furniture making; fuelwood
Aegicerous corniculatum	Fuelwood

Osbornia octodonta	Fuelwood
Nypa fruticans	One of the most useful mangroves: young seeds are edible and yields sugar/alcohol; young shoots are used medicinally; young leaves used for making skirts for "kastom" (custom) dancing and other traditional ceremonies; leaves are used for thatching, for making umbrellas, hats, mats, fish aggregating devices etc; leaf stalks are used as fuelwood (and arrows in the past).
Bruguiera gymnorhiza	Propagules are used as food; used medicinally, in the treatment of malaria; tannin for the manufacture of adhesives and leather (and in the past for the preservation of fishing nets/lines); charcoal; construction and building material; sapling is used for making spear handle; stem is used for making pestle (for crushing food prior to cooking); sharpened stem is used for husking coconut; fuelwood
Bruguiera parviflora	Construction and building material; sapling is used for making spear handle and for husking coconut; fuelwood
Bruguiera sexangula	Construction and building material; sapling is used for making spear handle and for husking coconut; fuelwood
Ceriops tagal	Durable timber, used as construction and building material; dyes; sapling is used for making spear handle and for husking coconut; fuelwood
Rhizophora apiculata	Tannin for the manufacture of adhesives and leather (and in the past for the preservation of fishing nets/lines); dyes for tapa -making; construction and building material; stem is used for making pestle (used for crushing food prior to cooking); sapling is used for making spear handle and for husking coconut; charcoal; fuelwood
Rhizophora mucronata	Tannin for the manufacture of adhesives and leather (and in the past for the preservation of fishing nets/lines); dyes; construction and building material; sapling is used for making spear handle and for husking coconut; fuelwood
Rhizophora stylosa	Dyes; sapling is used for making spear handle and for husking coconut; fuelwood
Scyphiphora hydrophyllacea	Fuelwood
Sonneratia alba	Fruits are used as food; used medicinally as internal and external medication; (making bows in the past); dye for tapa-making; pneumatophores are used as floats for fishing lines; fuelwood
Sonneratia caseolaris	As for other members of the genus
Sonneratia ovata	As for other members of the genus
Heritiera littoralis	Used medicinally for the treatment of diarrhoea and dysentry; durable timber, used as construction and building material; construction of canoes; fruits are used as toys for babies and infants; fuelwood

Source: Pillai and Sirikolo (1997)

THREATS TO MANGALS

Destruction of mangals is a global concern. Mangals are destroyed as the result of reclamation for urban development/settlement, conversion to salt pans, agriculture, aquaculture, sewage and toxic chemicals disposal (released into them), siltation (silt from land-based development smothers the roots of mangroves), and over-exploitation (they are over-exploited by traditional users for timber, firewood, food, medicine etc).

In Solomon Islands, mangroves are under increasing threat from activities such as logging, mining, reclamation for human settlement, waste disposal and over-exploitation by traditional users. In some parts of the country, (eg Are Are Lagoon) mangroves are the major source of firewood for households (domestic use) and for drying beche-de-mer and copra. Pillai and Sirikolo (1997) reported that mangrove trees are being logged in Marau Sound (Guadalcanal), Langa Langa Lagoon (Malaita) and possibly elsewhere in the country. Mangrove areas are increasingly being used for settlement as villages grow as the result of the increasing growth of coastal populations of the country. This is evident in Are Are and Lau lagoons on Malaita, around Western Isabel, Southeastern Choiseul and parts of Western Province (eg Marovo lagoon and around Munda/Noro area). Many log storage points used by loggers on Isabel are reclaimed mangrove areas.

The mangrove resources of the Solomon Islands will have to be utilized in a sustainable way or else it will be wiped out in the near future.

CONSERVATION AND SUSTAINABLE USE OF MANGROVE

Management and Legal Obligation

Solomon Islands is well aware of the important roles coastal resources play in the life of her people. As such, maintaining the benefits derived from coastal resources is paramount and the Government through its technical Divisions has drawn up appropriate policies and legislation to safeguard the development of resources. Furthermore, through its technical Divisions, the Government has also drawn up various programs that would protect the biodiversity, especially those that are of high commercial value and are prone to over-exploitation.

The Solomon Islands National Environmental Management Strategy (1993), is the blueprint for sustainable development in Solomon Islands and provides the foundation for implementing much of Agenda 21.

In line with Government policies (on marine resources) and the principles of sustainable development, sustainable management and conservation of coastal marine resources, Solomon Islands has enacted three legislations in 1998. These are the Fisheries Act 1998, The Environment Act 1998 and The Shipping Act 1998.

The Fisheries Act 1998 revised the laws relating to Fisheries and made provisions for the proper management and development of Fisheries in Solomon Islands. The Act highlighted several principles that the Minister has to take into consideration when exercising his powers and functions as provided for under the Act, one of which is that the Minister shall have regard to the principle that Solomon Islands fisheries resources shall be managed, developed and conserved so as to ensure resources are not endangered through over-exploitation but are utilized at a level that ensure their optimum sustainable yield. It also advocates the principle of sustainable development and applies the precautionary approach to conservation, management and exploitation of fisheries resources in order to protect the fisheries resources and preserve the marine environment. In this context, exploitation of fisheries resources in Solomon Islands shall be done through properly devised management plans. Marine Conservation Areas may be declared under this Act. Traditionally, some Solomon Islands communities impose temporal closures on coastal resources (within mangrove and adjacent coral reefs). The

closures are often referred to as taboo areas, reserves or conservation areas and are imposed by chiefs and based on traditional ownership or marine tenure (CMT).

One of the important aspects of the Act is that it recognizes the customary rights holders over or in relation to any area within Solomon Islands waters. As seen above, CMT system is an important part of the cultures of Solomon Islands. Through CMT, resource owners are part of the coastal setting (or system) and any impacts on the system will have a bearing on them.

Through *The Environment Act 1998,* Solomon Islands has matched its national policy on environment and conservation through the enactment of this legislation to promote sustainable development through sustainable management. The legislation is in compliance with our international obligations. The objectives of the Environment Act 1998 are that it shall make provision for and establish integrated systems of development control, environment impact assessment and pollution control. It shall also prevent, control and monitor pollution. The Act caters for national and regional environmental concerns.

Through *The Shipping Act 1998,* the protection of the marine environment and prevention of marine pollution from vessels will be regulated. Under this Act, the Marine Division would have the authority to prosecute violations of the Act. The Act incorporates various IMO Conventions.

The Solomon Islands does not have a specific Wetland Policy and legislation but the Ministry of Forest Environment and Conservation (MFEC) is the coordinating Government Agency for mangroves and wetland related matters. Through this Ministry, the Government has done preparatory work to nominate Lauvi Lagoon (technically a lake) on Guadalcanal for the RAMSAR site but the ethnic strife on Guadalcanal has halted further development.

On the other hand, Solomon Islands has signed the Kyoto Protocol and is a party to the Convention on Biological Diversity (CBD).

Community based conservation is increasingly becoming acceptable in Solomon Islands, as a result of combined efforts by the Government, NGOs like The Nature Conservancy and World Wildlife Fund for Nature (WWF) through education and awareness programmes. In Isabel and Choiseul Provinces, TNC is a major partner in the 6 years old Arnavon Marine Conservation Area and the WWF has been successful in helping communities in Marovo lagoon (Western Province) establish community managed conservation areas which include some mangroves areas. Education and awareness are important to make communities aware that they are stakeholders, and they must realise that conservation can bring them benefits.

Conservation and Sustainable use

The 10-point NEMS (National Environment Management Stategy) proposal provides an excellent framework for sustainable use and conservation of the biodiversity of the country, including mangroves.

If the Solomon Islands is to retain what remains of its rich mangrove biodiversity then it is essential that human activities affecting mangroves and their environment are managed properly. In other words, we must ensure that: all economic development - land or sea

based - is in harmony with ecological principles; environmental awareness is fostered in school children and the general public; research is carried out to determine accurately the total area under mangrove cover and an inventory of mangrove species diversity and richness is prepared; areas of high ecological, wilderness and cultural value are protected; waste management is improved and pollution of mangals is minimised; an environmentally sound coastal zone strategy is put in place; extensively damaged mangrove habitats are reforested; and traditional and non-traditional users of mangrove resources strictly adhere to the principle of sustainable use.

The Solomon Islands should adopt an integrated approach to physical planning/ economic development on the one hand, and environmental protection in the country, on the other. Such a strategy would require an appropriate legal framework of environmental law with built-in routine environmental impact assessment, together with the means for its enforcement.

For effective environment management it is imperative that the Solomon Islands public is well informed and supportive. This calls for mounting both formal and informal environmental education. Appropriate curricula at the primary, secondary and tertiary levels of education should be designed and implemented. Concommitantly community education be undertaken.

The mangrove resource database needs to be improved. Firstly, the areal extent of mangroves in the Solomons should be determined accurately. A comprehensive survey of mangrove species diversity and richness should be undertaken. Equally, all other mangal flora and mangrove fauna should be surveyed and documented.

The Solomons has unique flora and fauna. Destruction of mangrove habitats could lead to the extinction of rare plants and animals which inhabit the mangal. Loss of mangroves would be harmful also to many non-residents, such as insects, fish, reptiles, birds and mammals, including humans, who visit the mangrove environment in search of food, shelter etc. Mangrove ecosystems of ecological and scientific value should be protected. NEMS' proposal that, amongst others, the Marovo Lagoon, Lake Tenggano and Arnarvon Islands Group be declared as World Heritage Sites, is a step in the right direction. Similarly, the Marau Sound and other sites rich in mangrove biodiversity should be converted into marine parks and protected.
The Solomon Islands is increasingly becoming polluted with greenhouse gases, hazardzous chemicals, solid wastes and sewage, particularly around urban centres. Disposal of raw sewage into the sea in coastal villages and the lighting of grass fires around villages and towns are also contributing to an increase in the levels of pollution. The problem should be addressed through the vehicle of formal and informal education. Appropriate legal instruments will have to be designed and enforced.

References

Chapman, V.J. 1970. Mangrove phytosociology. Tropical Ecology 11: 1-19

Hansell, J.R.F and Wall, J.R.D.1976. Land resources of the Solomon Islands. Volume 1: Introduction and Recommendations. Land Resources Study 18, Land Resources Division, Ministry of Overseas Development, Surrey, England.

Leary, T. 1993a. Solomon Islands State of the Environment Report. SPREP, Apia, Western Samoa.

Leary, T. 1993b. *In*: Directory of Wetlands of Oceania. The International Waterfowl and Wetlands Research Bureau (IWRB) and Asian Wetland Bureau (AWB). pp331-361.

Oreihaka E., 1997. Freshwater and marine aquatic resources in SolomonIslands. Unpublished report for Fisheries Division, Department of Agriculture and Fisheries, Honiara, Solomon Islands, 60 p.

Pillai, G and Sirikolo, Q. M., 1997. Mangroves of the Solomon Islands. (In Prep.), IMR, USP.

Saengar, P., E.J. Hegerl and J.D.S Davie. 1983. Global Status of Mangrove Ecosystems. International Union for Conservation of Nature and Natural Resources. pp88.

Solomon Islands National Environment Management Strategy (NEMS). 1993. SPREP, Western Samoa. 160pp

Solomon Islands National Forest Resources Inventory, Vol 1-9. 1995. Ministry of Forest, Environment & Conservation, Honiara, Solomon Islands.

Woodroffe, C. D. 1987. Pacific Islands Mangroves: Distribution and Environmental Settings. Pacific Science 41(1-4): 166-185.

VANUATU

By: Trinison Tari[1] and William Naviti[2]

Introduction

Mangrove ecosystems of Vanuatu cover an estimated 2,500-3,500 ha, 0.2%-0.3% of the total land area (12,190 square kilometres). Sizable stands occur on only nine (9) of the eighty (80) islands in the archipelago - Hiu, Ureparapara, Vanualava, Motalava, Malekula, Epi, Emae, Efate and Aniwa. The largest stands, some 2,000 ha in total, occur in two localities at Malekula - the Port Stanley/Crab Bay area and the Maskelyne Islands/Lamap area. You can see on the map of Vanuatu, the presence of mangroves on these islands.

Inventory of the Status of Mangrove Wetlands in Vanuatu

Vanuatu has only about 2,500 ha of mangroves, with nearly 2,000 ha found in eastern Malekula. The remainder exists in small stands of 15-210 ha on other islands (Figure 1).

Figure 1. Area Distribution of the Main mangroves in Vanuatu Archipelago

Island	*Area of Mangrove (%)*	*Area of Island (%)*
Malekula	1,975 (78.0)	205,300 (1.0)
Hiu	210 (9.0)	5,280 (4.0)
Efate	10 (4.0)	92,300 (0.1)
Emae	70 (3.0)	3,280 (2.1)
Epi	60 (3.0)	44,500 (0.1)
Vanualava	35 (2.0)	33,100 (0.1)
Ureparapara	30 (1.0)	3,900 (0.8)
Motalava	25 (1.0)	3,100 (0.8)
Aniwa	15 (0.5)	800 (1.9)
Total	*2,460*	*391,560 (0.6)*

Source: David and Cilaurren 1988.

In Vanuatu, thirteen major mangrove tree species have been identified in eight families, for example *Rhizophora, Bruguiera, Ceriops, Sonneratia, Lumnitzera* and *Avicennia. Avicennia* and *Rhizophora* are the most common. The species are *Heritiera littoralis, Exocecaria agallocha, Xylocarpus qranatum, Ceriops tagal, Rhizophora sylosa, R. mucronata, R.. apiculata, Bruguiera gymnorhiza, B. parviflora, Avicennia marina, Sonneratia caseolaris, S. alba and Lumnitzera littorea.*

Mangroves in Vanuatu like in other countries of the South Pacific are an important source of fuel wood, building materials, medicine, fish, crabs and shellfish and are a critical component of subsistence fisheries. They are at risk from excessive firewood collection and in some places like Malekula and Efate they are at risk from planned development projects.

[1] Environment Unit, PMB 063, Port Vila, Vanuatu
[2] Fisheries Department PMB 045, Port Vila, Vanuatu

General Description of the Physical, Hydrological and Ecological Features of Mangrove Wetlands

Mangroves are bushes or trees that grow between the low tide and high tide mark. This region is called the intertidal zone. The word mangrove has two meanings: the individual trees as mangroves or the description of the whole community of mangrove trees. Mangroves mainly occur in the tropics on sheltered shores and in estuaries, but they can also grow on sand and volcanic soils.

There are two types of mangrove environments:

a) River environment: These occur along rivers and streams with a large freshwater input. There are usually many mangroves near the coast but as you move upstream the area is covered with more forest plants.
b) Marine environment: These occur along coastlines or in estuaries that have little freshwater input. Most of the water in marine mangrove systems comes from the sea. There is a change from mangroves to forest as you move inland.

Mangrove trees form part of a large ecosystem. The mangrove ecosystem is made of many parts.

- the mangrove trees themselves
- animals and plants living on the mangrove trees
- animals living under the bark and inside dead mangroves;
- animals and plants living on the surface of the surrounding mud and sand
- animals living under the mud and sand
- animals and plants living in the water surrounding the mangroves at high tide
- animals and plants living in associated streams and channels
- birds and flying foxes roosting in the mangroves
- birds feeding around the mangroves

Some of the mangrove animals and plants are also common in other areas such as coral reefs. However, some are found only in mangrove areas.

Has MangroveWetland Loss Occurred

Mangrove ecosystems in Vanuatu, as elsewhere in the world, are extensively utilised by man and valued for their in situ goods and services. As mentioned above, mangroves are an important source of fuelwood, building materials, medicine, fish, crabs and shellfish.

Some patches of mangrove forest such as on Efate and Malekula have been cleared and reclaimed in the past few years to cater for development projects such as tourism and wharf facilities.

The harvest of mangrove for fuelwood is becoming a common problem in Vanuatu. Villages usually situated within the mangroves on smaller islands are almost entirely dependent on mangrove for fuelwood and building materials. On smaller offshore islands such as the Maskelynes of South Malekula, an average of 15-24 bundles per month of mangrove wood per household is burned as fuelwood.

Harvest of mangrove dependent fisheries products for subsistence and semi-subsistence purposes is common too at the village level. Villages located within or in close proximity to mangroves rely on the mangrove ecosystem for their subsistence fishing. The common

finfish species targeted include the mullet species; rabbit fish - Siganidae species; goatfish - Mullidae species. David and Cilaurren (1988) noted that in the Maskelyne Islands 66 species belonging to 36 families of finfish were caught regularly from the mangrove areas.

The true mangrove crab, *Scylla serrata* locally known as "Caledonian Crab" or "basu" is caught in the estuarine area around the Port Stanley region and on the Maskelyne Islands. These are often caught specifically to supply restaurants and hotels in Port Vila and Luganville. Very few households are involved in the sale of the Caledonian crab.

The extensive usage of mangrove resource as mentioned above is a direct result of high population growth in relation to the very limited resources available, especially on small islands, and the need to accommodate development projects on the island.

Institutional Arrangements for Mangrove Wetland Management

A systematic system of management of mangroves does not exist in Vanuatu, a feature common to many Pacific Islands. However, currently, all mangrove management matters are taken care of by the Fisheries Department and the Environment Unit.

There has been very little research and training in the area of mangroves in Vanuatu. There is currently no local person who is trained to undertake researches on mangroves. A French Scientific Research Institute for Co-operative Development (ORSTOM) has undertaken some research on mangroves and the subsistence fishing uses with no local training. In 1988, a local by the name David Esrom with his expatriate colleague (Cilaurren) did a brief survey and report on mangrove usage in Port Stanley, Malekula. In 1998, the Environment Unit produced a poster on the usage of mangroves in Vanuatu that has been widely distributed especially to the mangrove communiteis. Apart from these, there has never been any extensive research on the mangroves of Vanuatu.

Mangrove Wetland Policies and Legislation

The Forestry Act 1982 and Fisheries Act 1982 provides for the management and utilisation of coastal forest products on a sustainable basis. Mangrove products are obviously included in the list of coastal products.

In 1991, under the traditional conservation practices, a Marine Reserve was established on Malekula. The area which is commonly known as Narong Marine Reserve, covers an area of approximately 160 hectares. All marine resources within the reserved areas are strictly prohibited for collection, consumption and damage at any time. This includes the exploitation of mangrove stands within the area.

Currently there are no formal mangrove wetland policies or legislation in Vanuatu. A National Mangrove Management Plan was formed in 1988 but no longer exists now. The government now relies on existing institutional mechanisms to address mangrove management issues arising from development on custom land.

Even though the government does not have a formal policy on commercial logging of mangroves, the Environment Unit and the Fisheries Department have adopted an informal policy of not allowing logging of mangroves or large scale reclamation of mangrove areas for alternative uses.

Tenure Ownership of Mangrove Wetlands

Mangrove wetlands are traditionally owned by the custom landowners. Any development on custom land requires the non-owners to obtain a lease from custom land owners. Negotiations of leases for tourism development, forestry, agriculture, etc. is handled by the Department of Lands. Proposals for physical development involving actual alienation of land for a period of time (such as hotel development) are deliberated by the Rural Alienated Lands Committee (RALC). Environment Impact Assessment (EIA) is only required for large-scale projects. However, EIA requirements are not currently based on any legislation. A lease is issued subject to restrictions stipulated by the Department of Lands and a number of covenants have been developed. Under the Land Lease Act 1983, one of the covenants included in the standard form of commercial lease is the provision that the commercial leasee agrees not to fell or otherwise destroy mangroves growing on the stated land.

Community-Based Management Structures for Natural Resource and Mangrove Wetland Management

Although destruction of mangroves is becoming a problem in the mangrove growing areas in Vanuatu, traditionally people and landowners of those areas know themselves that mangroves are very important to their livelihood. It is obvious that clearing of mangroves is done purposely for firewood, building materials, expansion of villages and easier access to the sea. Apart from these, the chiefs and the landowners will never allow people to clear the mangroves unnecessarily. In some areas the chiefs place a temporary ban on the mangrove wetlands to allow the mangroves and other related species which they depend upon for food, to recover.

Mangrove Wetland Monitoring System

Currently, Vanuatu does not have a mangrove wetland monitoring system in place yet. It is something that needs to be considered in the near future.

Awareness on the Importance of Mangrove Wetlands

In the past few years, the Environment Unit and Fisheries Department have done community awareness on mangrove wetlands. This is still an on-going programme. The target communities are the mangrove-related communiteis, and this is normally done through visiting and holding a meeting within the communities. Sometimes public awareness on mangrove wetlands is done through Radio Vanuatu for the general public. As mentioned earlier, a special poster on the usage of mangroves produced by the Environment Unit in 1998 has also been widely distributed to the mangrove-related communities and the general public.

Mangrove wetland education is an important subject to teach to young children. This subject is currently included in the environment studies curriculum so students from both primary and secondary schools in Vanuatu now learn about mangrove wetlands.
Examples of community involvement in wetland management are the Narong Marine Reserve and Uri Island Reserve, both of which are located in Malekula. In the early 1990s under the traditional conservation practices, these two marine reserves were established. Narong Marine Reserve covers an area of about 160 hectares.

Involvement of Other Sectors in Mangrove Wetland Management

Several NGOs in Vanuatu have done some general awareness in the mangrove-related communities on the importance of protecting the mangrove ecosystem, for example, FSP Vanuatu (Foundation for the Peoples of the South Pacific), World Vision, NKDT (National Community Development Trust) and WSB (Wan Smol Bag) Theatre. This awareness raising by the NGOs has contributed a lot to the overall management of mangrove wetlands in Vanuatu.

Current Situation Regarding Use of Mangrove Wetlands (agriculture, forestry, eco-tourism, aqua-culture)

Apart from fisheries products and mangroves exploited for household consumption and use, the mangroves of Vanuatu are not commercially exploited. Occasional requests for logging permits have been received by the Forestry Department and Environment Unit, but to date they have always been rejected.

Agriculture has not yet occurred to any significant extent in mangrove growing areas. In some localities the landward fringes have been converted for agricultural uses such as coconut plantations. In other areas, most notably the Maskelynes, some mangroves have been removed to allow for village expansion.

There is currently no conversion of mangroves to mining and aquaculture. There are potentialities for these to occur on Malekula in the near future when the need arises.

At present, development pressures on mangroves are small, partly because the main urban centres are away from the major mangrove resource. The largest concentration of mangroves in Vanuatu is found on the island of Malekula while major developments are on the islands of Efate and Espiritu Santo. Irreversible conversions of mangrove forests for urban development has only recently occurred, and is largely localised and on a very small scale. Tourism development is particularly on the south east of Efate.

Status of Adoption of Multi-lateral Biodiversity Conservation Conventions (RAMSAR Convention, Kyoto Protocol, and Convention on Biological Diversity)

Vanuatu signed the Convention on Biological Diversity (CBD) in 1992 and ratified it in 1993. As part of its obligation to CBD Vanuatu has produced a national biodiversity conservation strategy in November 1999 in which there is mention of the protection and sustainable use of mangroves. The Kyoto Protocol has already been signed and submitted to the UN Climate Change Secretariat. The RAMSAR Convention has not been signed yet but Vanuatu is in the process of formalising its accession. Vanuatu has signed and acceded to CITES and ITTO (International Tropical Timber Organisation), both of which have some provisions for the management of mangrove resources and other related species. The Forestry Department has also included in the Forest Policy a section on the protection and sustainable use of mangroves.

Marshall Islands

By: Mr Maity Bungitak[1]

Status of Mangrove Wetlands

There has not been any study conducted on mangrove wetlands in the Marshall Islands as far as our limited sources indicate. However, it is widely known that the majority of the islands and atolls in the Republic of the Marshall Islands have mangrove wetlands. The area of these wetlands is estimated to be in the range of five square meters to about 5 hectares. Most of the wetlands are inland and have small water passages leading from the lagoon to the wetland. Other wetlands are totally enclosed except for small holes at the bottom through which salt water flows during high and low tide.

These mangrove wetlands are home to three important crab species, several species of coastal fish, shrimps, mollusks and also sea birds. The crabs are a very important part of the islanders' diet and are very highly valued for their delicious meat. The most common of these crabs is the *Scylla* species and the brown pinkish crab. The S*cylla* crab spends most of its life under water crevices, while the other two usually dwell in dug holes near the mangrove area. The other species, the brown pinkish crab, is mostly hunted during high tide when they prefer to climb the mangrove trees and remain just above the water line.

The most common species of mangroves are the *Brugiera* species, the *Rhizophora* species, and the *Soneratia* species. Kone and coconuts also grow in the mangrove wetlands but mostly on the very edge of the area.

Mangrove Wetland Legislation

There is no existing legislation that directly deals with mangrove wetlands in the Marshall Islands. However, under regulations such as the historic preservation, earthmoving, and coastal management regulations, any activities within the wetlands would be controlled. Otherwise, there is no legal frameworks for the protection of the wetlands.

It is only recently that some people in the Marshall Islands are aware of the importance of mangrove wetlands to their socio-economic development as a result of awareness raising activities by the NGO groups in the Marshall Islands. For instance, the Jaluit Atoll Development Association (JADA) had worked with the senior community leaders on Jaluit Atoll to find ways to restore and to protect the mangrove wetlands on the atoll. They have held workshop meetings, community consultations, and awareness meetings. They have also helped in drafting some management guidelines for the protection and sustainable exploitation of the mangrove resources and on how to promote the mangrove areas for eco-tourism activities.

Tenure Ownership

The traditional leaders of the *bwij* (tribe) own the mangrove wetlands. There are usually three title owners of the land; the *Iroi*j (chief), the *Alap* (head of the tribe), and *Dri Jerbal* (the senior member of the tribe). Decision making with regards to the mangrove wetlands

[1] Monitoring Officer, Jaluit Atoll Conservation Project, Jaluit Atoll

usually involves these three titled land owners. In most cases, usually the *alap* gives permission to cut down mangrove trees for building homes.

Describe the Community-based Management Structures in Place

At present the *alaps* have established an organization to promote conservation of the mangrove wetlands and make it available for ongoing eco-tourism projects on their atoll. As a result, they have begun clearing walking trails around the mangrove forest for visitors. There is also a plan to reopen the two natural water channels that were closed about eighteen years ago when the road was built.

The *alaps* have also planned to establish entrance and license fees for those who want mangrove logs for home construction. Such fees would be used for the conservation and sustainable use of their mangrove areas.

There is a need for capacity building among the members in order to strengthen their organizational structure and their capability to exercise their authority in protecting the mangrove lands.

Monitoring System

Due to lack of awareness of the importance of mangrove areas, there is no monitoring system established in the communities. Only recently was the *alap* organization established. One of the reasons I am at this workshop is to learn what is necessary so that upon returning home I will start a monitoring program of the mangrove wetlands in my island.

Involvement of Other Sectors

Because the project is new, the only NGO that is presently involved is the Jaluit Atoll Development Association (JADA). The Jaluit Atoll Conservation project under the SPREP/EPA is also involved to some extent. Last month, two Japanese from Friends of the Earth visited the mangrove wetlands and showed interest to assist in its conservation and sustainable development for the eco-tourism project.

Current Situation

The mangrove forest is still in good condition. However, since the natural channels were blocked some eighteen years ago, there was an immediate decline in the population of mangrove crabs. Reef fish also declined. The sea birds that usually make nests on the mangrove trees are now very few and may soon disregard the area because of previous heavy logging. Now that the people in the community want to make changes to preserve the mangrove areas, there is hope that the trend may reverse. Also if public awareness is conducted in the communities, people will be more aware of the great need to preserve their mangrove areas.

Status of Adoption of Multi-lateral Conventions

RMI has ratified the Biodiversity Convention and the Kyoto Protocol.

NEW CALEDONIA

By: Francois Devinck[1] and translated by Caroline Viex[2]

Introduction

Mangrove wetlands in New Caledonia cover a total area of 200 km^2 (Thollot 1987), which is 1.2 % of the total area. Mangrove wetlands are mostly located on the west coast fringing over 79% of the coastline, and fairly uncommon on the east coast covering only 14 % of the coastline, where they are concentrated at the mouth of large rivers. Few mangroves are found at Pines, Loyalties and Belep Islands. It appears that the extent of mangroves has not been significantly reduced since 1987, apart from the greater Noumea area where analysis of SPOT Images indicates loss of over 200ha.

Four types of mangrove assemblages are found in New Caledonia:

- estuarine mangroves
- inner embayment mangroves
- lagoon mangroves
- coastal mangroves

Mangroves in New Caledonia are found to extend to the 1.2 meter contour below the high tide depth (sea level difference between high and low tide: 1.7 meter). Mangroves forest height ranges between 8 and 20 meters. No endemic plants have been found.
Table 1: Taxonomic list of New Caledonian mangrove trees and associated species (Veii, Lon, pers.comm).

Pteridophytes Pteridaceae	 *Acrostichum sp*
Angiospermes Acanthaceae Apocynaceae Avicenniaceae Bigotuaceae Chenopodiaceae Combreaceae Euphorbiaceae Leguminoseae Lytbraceae Meliaceae Rhizophoracese Rubiaceae Sonneratiaceae Sterculiaceae	 *Acanthus ilicifolius* *Cerbera manghas* *Avicennia* sp.aff.*officinalis* *Dolichrarulone spathulata* *Salicornia australes* *Gumnitzera littorea* *Lumnitzera raceosa* *Excoecaria agallocha* *Cynometra ramiflora* var. *bijuga* *Pemphis acidula* *Xylocarpus granatum* *Bruguiera gymnorrhiza* *Ceriops tagal* *Rhizophora apiculata* *Rhizophora lamarckii (*hybride F1 from *R.apiculataxR.stylosa)* *Rhizophora mangle* var. *samoensis* *Rhizophora selala (* hybride F1 from *R.manglexR. stylosa)* *Rhizophora stylosa* *Scyphipltora hydrophyllacea* *Sonneratia alba* *Sonneratia caseolaris* *Heritiera littoralis*

[1] Head of Environment, South Province, New Caledonia
[2] Assistant Project Officer, Coastal Management, SPREP.

Other plants
In New Caledonia, landward of the mangroves, other halophytes can be found (Virot, 1956; Baltzer, 1969) including:

- *Sporobulus virginicus*
- *Acrostichum aureum*
- *Salicornia australis*
- *Acanthus ilicifolius*
- *Exocoecaria agallocha*
- *Derris trifoliata*

A survey of Greater Noumea's mangrove avifauna, carried out in 2000 by Barre and Dutson, found 28 birds species some of which were endemic.

Threats and Impacts

There are two major categories of threats to mangrove systems in New Caledonia:

- Traditional threats due to extractive activitiese such as fishing and wood harvesting. , However, outside the wider Noumea area, thanks to the sparse populations, these threats are not serious. Mangrove crab populations in these areas have not decreased, and there appears to have been an increase in populations.

- Threats due to urbanization and economic development

Fifty percent of the population live in the Greater Noumea Area, that includes the cities of Mont Dore, Paita and Dumbea. In this area, urbanization and economic development are major issues. Landfilling and construction of seawalls represent the main threat to mangroves. Between 1960 and 1989, at least 230 ha of mangroves, out of the 666-797 ha first measured, have been destroyed in the Greater Noumea Area. Initially, as people migrated to the city, more traditional threats such as wood harvesting and rubbish dumping have increased. Now, landward mangrove areas such as salt marshes are used for shrimp aquaculture. To date, there appears to have been no adverse ecological effects on *Avicennia* and *Rhizophora* communities (IRD-ORSTOM). Despite the well known essential function of mangroves, the lack of space in cities leads, even now, to the filling of mangroves for developments such as main roads and public buildings. EIAs are not compulsory, but are often undertaken.

Institutional Arrangements for Mangrove Wetland Management

According to the Matignon Agreements, the three regions in New Caledonia have responsibility for managing their environment. The Environment Unit of the Natural Resources Management Division of the South Region is in charge of mangrove wetland management and conservation. Several research institutes such as IRD, University of New-Caledonia, Caledonian Agronomic Institute and some research consultancies have contributed to improving knowledge on mangroves and wetlands.

There are no specific legislations/regulations relating to mangroves. Mangrove management falls under the general regulation covering environment protection and their conservation is included in the town planning process.

In town planning, governed by the town council, mangroves are considered a "natural protected area". This means that mangroves have to be preserved and only development for public visitation can be undertaken. "Natural protected areas" are classified into three types. Mangroves are classified as 'ND' areas where any construction is forbidden. Most of the coast, called Coastal Public Area, is also classified as ND.

Town Plans cover Greater Noumea, (Noumea, Mont Dore, Paita and Dumbea) and several inland towns: Bourail and La Foa. These Town Plans are reviewable and can be modified every 5 years.

In general, regional regulations group together all legislative texts dealing with environment protection and sustainable resource use. Concerning mangroves, the main regulations that can be used for their management and conservation are those that:

- Define protected areas for which a research organisation or NGO must be consulted,
- Specific fishery regulations, notably, limits on nets size (75 meters) and forbiding the use of nets less than 100 meters from mangroves.

Note that several small mangrove areas are part of marine reserves like the Ducks Island or the Bailly Island reserve.

Tenure

Since 2000, the Public Coastal Area (81.2 meters inland from the highest tide level) which was the state responsibility, has become the responsibility of the region. Thus, the region's planning department, in consultation with the technical department, is in charge of giving permission for construction in the Public Coastal Areas. Permits are often given for "public interest" developments such as roads.

There is no specific community-based management structure (institutionalised or informal) for mangrove wetland management.

Mangrove Wetland Monitoring Systems

In 2001, a regional budget for the south region wetland inventory by aerial photos (SPOT) was estimated. The purpose of this survey is to identify and characterize mangroves and continental wetlands in order to carry out management and conservation plans for several priority areas.

Community Awareness

Mangrove protection has only become an issue quite recently, starting with the NGO initiative "New-Caledonian Nature Preservation Association". Since then, the Introduction to Environment Center and regions environment department have taken over from this first initiative. Several publications, films and school lecture programs have been developed.

A preliminary proposal for a "discovery pathway" is in process. This should lead to the selection of a site in 2001 where an educational and recreational pathway will be built.

A third NGO, "Racine" (roots) is also getting more involved in mangrove issues. Together with the two other NGOs, this association has taken many steps towards

mangroves protection such as guided tours, press meetings, and newspaper articles dealing with mangrove functions and importance, in order to make people sensitive to their importance.

Use Patterns

Mangroves are not considered an eco-touristic product yet. The “discovery pathway” tour, opening soon, should compliment other tours, for example, the Noumea aquarium tour.

Only back-mangroves areas (salted fields with Salicornia) are used for aquaculture with no apparent environmental impact

The socio-cultural importance of mangroves to people from the Greater Noumea area is difficult to assess because of a lack of data. Observations indicate that this ecosystem is used for several traditional activities such as subsistence and recreational fishing, medicinal plant collection, firewood and timber harvesting.

Conventions

Signatory to Ramsar Convention.

PAPUA NEW GUINEA COUNTRY REPORT

Status of Mangrove Wetland Protecton and Sustainable Use in Papua New Guinea

By: Tunou Sabuin[1]

Introduction

The ecological, environmental and socio-economic importance of mangrove forests is widely accepted by international agencies, governments, NGOs, scientists and tropical coastal communities alike. It is appreciated that mangrove ecosystems provide a unique and valuable range of resources and services, making them far more valuable than the sum of the products they generate. Nonetheless, responsibility for mangrove management historically has generally been assigned to sectorial institutions, normally Forestry Departments or Fisheries counterparts, or in urban settings to infrastructure or utility authorities.

Only to a limited extent have these institutions catered for the multiple functions of mangrove ecosystems. As early as the 1920s the Malaysian Forest Department, for example, recognized the legitimate needs of fishermen for various secondary products, but admitted them to be somewhat vexatious complications in an otherwise straightforward scheme for fuel and pole wood production (Watson, 1928).

From such beginnings, mechanisms for mangrove management have continued to be largely along sectorial lines. Inevitably, individual agencies have approached coastal resource management with prejudices that limit their priorities to those directly related to agency jurisdiction and goals.

Multiple use management, though much talked about, is still the exception in practice, rather than the rule. Tomlinson succinctly describes the problem in 1986: 'A forestry department will emphasize utilization that may degrade the resource, a fisheries department will emphasize conservation with minimum disturbance, and an agriculture department may advocate conversion and replacement by some putatively and more valuable resource. *This conflict is the background to mangrove management.*

In PNG, the management of multiple or mono cultural use of mangroves and the wetlands on economical scale remains strictly prohibited as far as the PNG Logging Code of Practice and environmental laws are concerned but has appreciated a somewhat multiple use system by the traditional users without set management guidelines and control mechanisms, simply because the lives of the coastal people of the river deltas and the waterways are greatly dependent on these fragile resources for food, shelter, transportation, shoreline and river protection, etc. from generation to generation.

The management plans and guidelines for multiple use of wetlands, particularly the mangroves by the traditional users remains to be seriously considered, as the pressure from the wetland owners in the Gulf of Papua and the Western part of PNG to exploit their fragile forests to generate cash has escalated in the last decade.

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[1] Field Services Division, National Forest Service, PNG

In the nation's capital, Port Moresby, the mangrove resources that occur in small patches are somewhat under threat. The population pressure from the nearby villages has forced the coastal communities to exploit this fragile and valuable resource to generate cash income through the sale of fuelwood to the city residents.

At the same time the toxic wastes from the city may also have caused harmful effects to these important resources, but no studies have been conducted to verify this statement. The National Botanical Gardens of PNG has attempted to re-afforest certain areas under serious threat, but the program had failed due to a funding problem and the lack of public awareness on its importance.

Fragile Forest Resource Information

The most extensive and luxurious mangroves and wetland resources are in the delta systems of major rivers in the Gulf of Papua and Province of Papua New Guinea.

There are about 14 fragile forest types as defined and described by the department of environment and conservation in PNG. The current area, as adjusted since 1975 is 26,280,554 hectares. It was also recorded that 1,019,499 ha was converted to agriculture and 394,636 ha was logged some decades ago (FIMS, NPS png, 1994).

From the above total, the mangrove forest area is 550,942 hectares for all the twenty (20) Provinces in PNG, and the fragile area described as wetland is 11,951,729 hectares (FIMS, NFS png, 1994).

Whilst PNG is blessed with its extensive and luxurious mangroves and wetland resources which are protected and conserved under the environmental laws and the PNG Logging Code of Practice, the WWF has seen fit to establish an agency called, the Kikori, Integrated Conservation and Development Project in the Kikori Basin of the Gulf of Papua.

This particular project has created concerns amongst the indigenous and government agencies; particularly because of its involvement in the Eco-forestry project development of wetland and mangrove harvesting involving 18 incorporated landgroups in the Kikori Basin.

However, in this presentation and throughout the workshop, I wish to focus on this particular project development and find a balanced equation between conservation and sustainable use from an economical point of view and what PNG and the other Pacific Island countries can do to accommodate the increasing pressure to sustain population growth and the expansion and diversification of national economies.

WWF'S Kikori Integrated Conservation & Development Project

WWF's Kikori Integrated Conservation and Development Project in PNG operates within one of the largest remaining tracts of undisturbed tropical rain forest in the southern hemisphere. The Kikori Basin covers an area of 2.3 million hectares and stretches from the extensive mangrove wetlands of the Gulf Province to the alpine grasslands of Doma Peaks in the Southern Highlands Province.

The operation started in 1994 and involved various village communities in the Kikori Basin to conserve their forest and aquatic resources while addressing their development needs. The project is promoting rural development and income-generating activities that contribute to the sustainable management of the area's natural resources.

The Kikori Basin which is characterised by numerous waterways, has always been the main means of transport for locals, barging of logs, shipping of merchandized goods, and the oil pipeline.

Due to the heavy use of the waterways within the Kikori Basin, the WWF has conducted 13 bio-diversity surveys and confirmed the extraordinary flora and fauna of the area, focusing on fresh water fish, reptiles, amphibians, aquatic insects, moths and butterflies.

Eco-forestry

On the other hand, WWF has established an Eco-forestry umbrella company, Kikori Pacific, which acts as a marketing agent and provides training for community-based eco-forestry groups in the Lower Kikori area.

Kikori Pacific is buying, milling and selling timber on a sustainable basis and continues to export timber to an international buyer in Australia. The Company is working closely with the 18 incorporated landgroups who have determined their boundaries excised from the original Forest Management Area, Turama Extension.

The actual program started in 1994 and initially established four (4) Eco-forestry enterprises to work with Kikori Pacific Ltd. These villages based companies are:

- Hope Forest Ltd
- Darken Lumber Investment Ltd
- Iviri Timber Investment
- Keboi Kerowa Investment Ltd

These projects are all aimed towards sustainable development by way of producing sawn timber for their own use, and generating cash income for the communities through proceeds of sawn timber sales to Kikori Pacific Ltd.

However, due to technical and financial problems experienced by most of these projects, the only maintained groups and individuals are from the Veraibari village. They are:

- Darken Lumber Investment Ltd
- Iviri Timbers
- Veraibari Village

Operational Areas

The operational areas are confined to the clan's tribal boundary, mostly along the main Kikori river system and the delta areas.

These areas are within the Turama Forest Management Area, categorised as block 1 and 2, which are defined as semi and permanent flood plains, hence are restricted for logging by the large-scale operator.

These fragile areas are being negotiated between the developer, the landowners and WWF, so that these wetland areas can be released back to the resource owners to develop by way of small-scale sawmilling operations with low impact. There has never been a concrete agreement between the parties and the state to date.

Sawn Timber Sales

The sawn timber produces have found comfortable markets, locally and internationally. The main species processed and marketed is *Xylocarpus* sp. or commonhy known as the mangrove cedar.

It was reported that the volume harvested and marketed is less significant. The hard data could not be accessed from WWF Eco-forestry enterprise despite numerous attempts.

Legal Implications

The operations of these Eco-Forestry Projects including Kikori Pacific Ltd do not have the legal cutting power called the timber authority, as far as the Forestry Act and Regulations are concerned.

Attempts over the issuance of timber authority have been made but were unsuccessful, due to the legal fact that areas applied for timber are under the Turama Forest Management Agreement Area (FMA).

The Eco-forestry projects are not licensed to operate, as far as the Act and Regulations are concerned, and this also include the Kikori Pacific Ltd. Attempts have been made to license these community based operators.

The areas, located in the river deltas, are legally within the boundary of the state acquired Forest Management Area, and the permit to operate this area has been issued to a different operator called, Turama Forest Industry (TH).

Economic Implication

The promotion of resource owner participation in the utilisation of their own forest resource is one of the objectives of the NFS in the Forest Resource Development Sector. However, this may not always be the case with the waterway and the river delta people, when one looks at the large-scale operations in the Gulf Province.

These 18 incorporated land groups have decided to withdraw from the large-scale timber concession area due to the fact that they have little say over the timber resources on dry land, unrestricted for harvesting. These people are still beneficiaries of the proceeds of sale from the large-scale operations in terms of 100% of 7% premium based on F.O.B. exports. At the same time they also receive indirect and direct monetary benefits from the delta infrastructure and the annual waterway funds, except for the timber royalties.

The Eco-forestry projects set-ups in the villages along the waterways and the river deltas have attempted to generate extra income from the sale of semi-processed product, particularly the mangrove cedar at K24.00 stumpage. However, when taking into account the escalating running costs of this type of operation, in terms of fuel and parts, perhaps the cash flow may be far from sustainable.

The extreme scenario is the travelling distance which one would find the furthest and most Mangrove Cedar harvested is from the Veraibe village some 15-20km down the river system and to the coast. The logs are normally floated with the river current, which sometimes take about a week to reach the centralized milling point at Kikori.

At the same time the waterway people greatly rely on the marine and aquatic food to sustain their living. The main supplies of local fresh water crabs, prawns and barramundi come from the Gulf and Western Province of Papua New Guinea.

Environment Implication

The environment regulations on the exploitation of mangrove and wetland timber resource will remain unchanged for the years to come.

Ironically, the current operation of Eco-Forestry Projects in the delta region, which concentrates on the harvesting of one type of mangrove species called the Mangrove Cedar is a total breach as far as the environmental laws and the Logging Code of Practice are concerned. This practice will definitely have an impact on the species in a long run, if not properly managed and regulated.

Mangrove cedar or *Xylocarpus sp.* does not exist in abundance in swamp areas, but is scattered or occur in small patches of less than 4 to 6 cu m/ha. The species occurs in almost pure stands along the riverbanks where there is tidal brackish water.

The regeneration of this species is quite poor in the area, as the tide level does not always allow the base of the standing tree free of water thus reduces to some degree the germination and survival rate of seeds and saplings. The seeds normally float and as the high tide comes in daily it sweeps them into the river system and away from their place of origin. It is assumed that the continuos floating of seeds greatly contributes to loss of viability and increased mortality. Those that are deposited on dry land have a better chance of survival.

Planning Implications

The Kikori Integrated Conservation and Development Project (KICDP) with its establishment have introduced Eco-Forestry Projects in the delta area of Kikori Basin. The aim to achieve sustainable development of the Forest Resources, through small-scale sawmills, is a good management approach at the community level. However, it would be better if it was applied on non-fragile areas, and place more emphasis on conducting applied research on the mangrove wetland in the Kikori Basin in conjunction with other government agencies to help assist in the formulation of a better management plan and guidelines for the sustainable use of these fragile resources.

At present there are no management plans and guidelines in place to accommodate this practice, simply because it contravenes the act and regulations of PNG.

Nevertheless, the KICDP has tapped into a number of projects related to the management of mangroves and the wetlands in the Kikori Basin and has redefined some of its objectives to enhance better management and sustainable use.

Some Related Projects Undertaken by KICDP

The KICDP has identified and conducted a number of environmental studies, directly and indirectly related to the wetland activities by the Eco-forestry projects as established under the Kikori Pacific Ltd.

These projects and activities include to:

- Establish environmental impact assessment protocols for Eco-enterprises, (this activity is completed but information is not available).

- Conduct environmental impact assessment for all Eco-enterprises, (impact assessment has been completed on all Eco-enterprises, with some monitoring programs and guidelines completed)

- Develop and implement monitoring programs of Eco-enterprises as needed.

- Collect environment baseline data on all Eco-enterprises.

- Complete the final technical reports of the baseline biodiversity surveys of Iviri, Keboi Kerowa and Darken eco-forestry areas when the remaining reports are received from the consultants.

- Conduct community-based environmental monitoring of eco-forestry harvest areas in the lower Kikori and provide regular feedback to landowners of eco-forestry operations.

- Complete the report on the establishment of bio-diversity-monitoring plots in Iviri, Darken and Keboi Kerowa Eco-forestry areas.

- Re-survey Iviri monitoring plots to monitor impact of harvesting *Xylocarpus* trees on biodiversity indicators.

- Implement post-logging environmental impact assessments (PHA) as timber is felled.

Some Objectives of the KICDP project (as redefined)

The redefined objectives and forward steps taken for better management:

- to create an enabling environment for biodiversity conservation in the Kikori catchment.
- Maintain communications with national and provincial government officials.

The Project Manager along with other WWF staff within the South Pacific region met with the Director of the Office of Environment and Conservation (OEC), and two of his staff to introduce WWF's new representative for the region, David Hulse, and to discuss WWF and OEC collaboration. Following this meeting, the Project Manager and the Conservation Science Coordinator met with the project's Desk Officer at OEC.

Project staff have also met with individuals at the National Museum and Art Gallery, the University of PNG, and the Forest Research Institute staff to keep them updated on

project activities, and to discuss ways to further improve collaboration between WWF the private sector and governmental agencies directly and in-directly involved.

The project's Eco-Forestry Officer continued to maintain dialogue with the Gulf Provincial Forestry Officer, Allanson Avae, on the state of the project's submission on community based eco-forestry. At the same a submission on the entire project and activities has been submitted to the Provincial Forest Management Committee (PFMC) of the Province to deliberate in its next meeting,

AMERICAN SAMOA COUNTRY REPORT

By: Ms. Mary Midkiff[1] and Peniamina Siatunu'u[2]

Introduction

In recognition of the unique and important attributes of wetlands in American Samoa, the American Samoa Government (ASG) has developed a comprehensive wetlands management plan to provide a policy framework to manage wetlands resources. The management plan is intended to assist ASG promulgate rules and regulations for the American Samoa Coastal Management (codified under 24 ASCA, Chapter 5). Of primary importance is to establish a mechanism for achieving a policy of "no net loss" of wetlands. These goals and objectives can only be achieved if:

- The people of American Samoa appreciate the economic and ecological values of wetlands and give consideration to these values in their actions.

- There is a broad understanding of the human activities that affect the land and water on which wetlands depend.

- The territory successfully integrates wetland protection and regulatory programs with other social goals and user participation process.

The American Samoa Coastal Management Program (ASCMP) is the lead agency for wetland policy, management, and enforcement and is a section within the Department of Commerce. ASCMP follows the United States federal definition of wetlands as stated in Section 404 of the Clean Water Act that defines wetlands as:

Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFR Part 328.3 (b)).

This is the U.S. legal definition of wetlands and is applicable to American Samoa. It emphasizes that hydrology, vegetation, and saturated soils must be present in a wetland. Wetlands in American Samoa include mangrove swamps, freshwater and coastal marshes, springs, streams, and some cultivated areas such as taro fields.

Since mangrove wetlands occupy most of the acreage in American Samoa, our wetland management plan is directly applicable to mangrove management and is considered one in the same.

Characterization of Wetland Resources

[1] Water Quality Specialist, American Samoa Coastal Management Programme
Department of Commerce, American Samoa
[2] Wetlands Village Conservation Officer, American Samoa Coastal Management Programme,
Department of Commerce, American Samoa

Wetland habitat can be salt water, freshwater, intermittent, riparian, wetlands forests and artificially created environments. Wetlands in American Samoa include marshes and swamps, as well as cultivated and ruderal areas, all of which can occur in fresh and salt water conditions. Wetlands support many plant species, some of which are only found in wetlands, while others occur at the fringe and maybe associated with upland habitats.

Swamps

Swamps are wetlands dominated by trees and are found in both salt and fresh water areas. Saltwater swamps are also called mangrove swamps after the dominant trees. The common plants of mangrove and freshwater swamps are the oriental mangrove *(Bruguiera gymnorrhiza),* red mangrove *(Rhizophora mangle),* beach hibiscus *(Hibiscus tiliaceus),* puzzlenut tree *(Xylocarpus moluccensis),* Tahitian chestnut *(Inocarpus fagifer)* and falaga tree *(Barringtonia samoensis).*

Marshes

Freshwater and saltwater marshes are characterized by herbaceous vegetation such as sedges, grasses and ferns, rather than woody shrubs and trees found in swamps. Saltwater marshes occur along the coastline and often become established in mangrove swamps that have been disturbed or cut off from the sea. Freshwater mashes occur naturally in shallow, slow moving, or standing waters where soils are saturated by a high water table. The dominant vegetation of marshes includes grasses and sedges such as *Paspalum spp.* and *Cyperus spp.,* water chestnut *(Eleocharis dulcis), Ludwigia spp.,* Job's tears (*Coix lacryma-jobi),* and the marsh fern *(Cyclosorus interuptus).*

Ruderal and Cultivated Wetlands

Ruderal wetlands are usually created in disturbed areas such as ditches, ponds, or disturbed mangrove swamps. Freshwater marshes have fertile soils and so have traditionally been converted to taro cultivation. The commonly cultivated taro plant in American Samoa is *Colocasia esculenta.* The fern, *Christella harvey,* and wild ginger *(Zingiber zerumbret)* can invade cultivated wetlands, ditches, and ponds.

TABLE 1. Type and total acreage of wetlands in each village in American Samoa

WETLAND SITE	ACREAGE	WETLAND TYPES
Tutuila Island	**350.93**	
Nuuuli	122.90	Mangrove Swamp, Marsh, Ruderal, Cultivated, Streams, Lagoon
Leone	20.74	Mangrove Swamp, Marsh, Ruderal, Cultivated, Streams, Lagoon
Malaeloa	72.06	Freshwater Swamp, Marsh, Streams
Atia	9.18	Mangrove Swamp, Streams
Masefau	43.06	Mangrove Swamp, Marsh, Streams
Vaitia	34.05	Marsh, Mangrove Swamp, Cultivated Streams
Alofau	2.03	Mangrove (ruderal), Streams
Aoa	23.45	Mangrove Swamp, Marsh, Ruderal
Aloa	15.47	Marsh, Cultivated, Streams Ruderal Marsh
Tula	7.99	
Aunu'u Island	**111.93**	
Pala Lake	44.76	Mangrove Swamp, Lake
Taro Fields	27.30	Cultivated
Crater Lake	36.84	Marsh, Open Water, Stream
School Swamp	3.03	Mangrove Swamp, Ruderal
Tau Island	**35.84**	
Luma	25.80	Freshwater Swam, Freshwater Marsh Cultivated Wetland
Fusi	1.45	Ruderal Welland
Lesi'u	8.59	Freshwater Swamp, Cultivated Wetland
Ofu Island	**5.87**	
Va'oto Marsh	5.87	Freshwater Marsh
Olosega Island	**7.37**	
Village Wetland	7.37	Cultivated Wetland, Freshwater Marsh

The Unique Character of American Samoa's Mangroves

The Samoan Island group is one of the only places in the world where both the oriental mangrove and the red mangrove grow together. The red mangrove *(Rhizophora mangle)* grows in tropical areas west of 0 degrees longitude. Found in West Africa, eastern Brazil, the Caribbean, Central America, and Florida, the distribution of the species then leaps across the Pacific Ocean to Samoa, Fiji, and New Zealand.

The oriental mangrove *(Bruguiera gymnorrhiza)* grows mostly east of the longitude mark. Typically, this mangrove is found in East Africa, the southern Indian coast, Malaysia, western and northern Australia, Micronesia, Fiji and continues to Samoa. The only other places where both species are found together are New Zealand, New Caledonia, Fiji, and some other Polynesian Islands.

While most of the marshes and swamps of American Samoa contain plants found commonly in other parts of the U.S., the mangrove wetlands, especially those that support mature forest, such as those in Nuuuli are uncommon. This is part of the reason American Samoa's mangrove wetlands receive so much attention from the U. S. federal government. They are unique and should be protected.

Inventory and Status of Wetlands in the Territory

Wetlands in the Territory are being lost or degraded by urban growth and development as a direct result of increasing population. American Samoa's population has increased at an annual rate of 3.7 percent, according to the most recent census data (1980-1990). The rate at which the Territory has lost wetlands is similar to the population growth rate. Between 1961 and 1990, 4.6 percent of American Samoa's wetlands have been lost each year.

The population of American Samoa is expected to double within the next twenty years and pressures on wetland areas will only increase accordingly. As the population increases, so does the desire for land for housing, stores, offices, roads, and utilities. These needs represent a demand for scarce flat areas, such as those occupied by wetlands. Given the island's topography, development is fairly confined within a narrow band of land between the lower slopes and the ocean.

While a variety of federal and Territorial laws and regulations relate to wetlands protection, enforcement is inadequate and there is little comprehensive legislation to protect these valuable resources. Many land-filling activities, especially within mangrove wetlands on Tutuila Island, result in piecemeal losses of wetlands that are either exempt from current regulation or occur without due process or permit review.

Compounding the problem associated with regulation and enforcement are cultural forces and a general shift in social attitudes by Samoans. Under the Samoan land tenure system, wetlands are perceived as land owned by the village. The perception of western public rights is not culturally appropriate in the Samoan culture and thus the concept of public good conflicts with village interests. Samoans see the use of land as subject to the decisions of their matai and village councils, not the federal or Territorial governments. While some residents may be familiar with resource protection they feel compelled to remain silent when higher-ranking residents make land use decisions that negatively impact wetlands but are traditionally within their decision-making authority. Samoan communal and subsistence land use practices are also eroding due to increasing western influences and the shift to a cash economy. Furthermore, the general public does not have

enough information about where wetlands are located, their biological and social functions, the regulatory requirements surrounding wetland areas, and the activities that damage the wetland's fragile ecosystems.

Gains and Losses in Tutuila and Aunu'u

Most of the wetland sites on Tutuila Island have experienced some loss over a thirty-year period between 1961 and 1991. The total wetland acreage for Tutuila Island has been reduced from 488.12 acres in 1961 to 350.93 acres in 1991, a loss of 137.19 acres in just this time period alone. We predict this value has doubled in 2001. Nuuuli mangrove wetland has suffered the greatest loss, approximately 61 acres, representing a 33% decline since 1961. Tula appears to have lost 8 acres, representing a 5.8% decline. Leone has lost over half of its wetlands since 1961. The freshwater marsh in Vaitia seems to have increased slightly (+ 0.45 acres). This is probably the result of the abandonment of taro cultivation which has allowed surface waters to flood a wider area.

The wetlands on Aunu'u Island appear to have increased slightly from 111.76 acres in 1961 to 111.93 acres in 1991, a difference of 0.17 acres. The wetland areas associated with the Pala Lake, the taro fields, and the Aunu'u Crater appear unchanged from 1961. The school swamp seems to have increased slightly (+ 0.17 acres). This reason is not known.

Causes of Decline

The main cause of the loss of wetlands is development. Clearing and filling to accommodate village homes, pigpens, and commercial buildings has encroached into wetland areas. Trash and other debris are dumped into the wetlands and in some instances, covered with volcanic ash soils. Wetlands in the United States mainland are often lost through clearing and draining for agricultural use. However, this has rarely been the case in American Samoa, most of the wetlands have been lost from clearing and filling for development.

Present Land Uses in and Around the Wetlands of Manua

The steep topography of the Manu'a Islands dictates development patterns on the islands. Communal land ownership and cultural life philosophy also influences land practices. The lifestyle of the people has traditionally been characterized by subsistence agriculture and fishing. The fact that wetlands have not been filled for development, unlike Tutuila, is a strong statement about the high value the villagers place on these areas for agriculture and their willingness to preserve their wetland characteristics.

The Manu’a wetlands are presently used to provide food for the villagers. Most of the wetlands are used, at least in part, for taro cultivation, although banana, breadfruit, papaya, and pineapple are also grown around the fringes of the wetland. Freshwater eels are caught in the Luma and Olosega wetlands. Other agricultural products include the use of pandanas trees for mats and some medicinal plants. As far as we are able to determine no pesticides or herbicides are used directly in the wetlands, but the watershed above the Luma wetland is an important agricultural area where some pesticides/herbicides may be used.

In Luma, Fusi, and Woto Marsh, agricultural pressures on the natural wetlands have been reduced by shifting taro production to upland sites such as the old airstrip on Tau Island

and above the village on Ofu Island. The shift was precipitated by the cyclones of 1990 and 1991. This appears to be a permanent shift, since the upland sites are perceived as more reliable and less subject to flooding and other adverse weather conditions. Now that the villagers have made the investment to establish taro plantations in the upland sites, they are probably not likely to abandon them.

Village homes have been built around the fringe of the wetlands, but very little development is actually encroaching into the wetlands. A few piggeries are located around the wetlands but fewer than has been observed on Tutuila. No public infrastructure (i.e., sewer, water, electrical, and telephone lines, roads etc.) has been built within the wetlands, except for a telephone line across the Luma wetland. Currently there is no pressure to build structures in any of the wetlands, nor are there any active plans for infrastructure development that would directly affect the wetlands. The village dumpsite at Fusi is an example of an infrastructure development that has altered a wetland. On Ofu, Woto Marsh may be threatened by a possible relocation for the airstrip and road.

Gains and Losses in Manu'a

Overall, there has been little gain or loss in the aerial extent of the wetlands in Manu'a. Slight losses appear to have occurred at Luma (1.24 acres, a 4.6% loss) and Olosega (1.39 acres a 15.9% loss). The greatest loss has been at Fusi, on Ta'u, (3.38 acres, a 70% loss). It has been assumed that there has been no change in the wetlands at Va'oto Marsh in Ofu or at Lesi'u in Ta'u.

Mangrove Policy and Legislation

United States Federal Agencies and Jurisdiction

A No Net Loss Policy has been established by President George Bush for wetlands and has directed the Domestic Policy Council to define and develop the necessary policies to achieve the goals of "no net loss". A memorandum of agreement between the Corps of Engineers (COE) and the Environmental Protection Agency (EPA) makes it a goal to achieve "no net loss" of wetlands, although it recognizes this is not possible in every case.

US. Army Corps of Engineers (COE)

Authority. The authority to regulate the discharge of dredged and fill material into wetlands is jointly shared by the COE and the EPA. The COE is authorized to issue Department of the Army permits for the discharge of dredged and fill material into wetlands under Section 404 of the Clean Water Act. The EPA can veto a permit issuance under Section 404 of the Clean Water Act.

The COE issues Department of the Army permits regulating construction in navigable waters of the United States under Section 10, River and Harbor Act of 1899. Both authorities apply to American Samoa wetlands.

Jurisdiction - The COE regulatory jurisdiction in American Samoa wetlands includes waters subject to the ebb and flow of the tide up to the mean high water mark, and all other waters that include lakes, ponds, rivers, streams, intermittent streams, mudflats, sandflats, grassbeds, wetlands and all other waters, including those separate from the ocean tributary system. Normal farming and silverculture practices are exempt from obtaining Section 404 permits from the COE.

In American Samoa wetlands on Tutuila, the COE regulates the discharge of dredged and fill material into the tidal wetlands, as well as those wetlands associated with tributary systems and wetlands isolated from the ocean and tributary systems. Important to the regulation of wetlands is the federal determination and jurisdictional definition of wetlands. Recently, the "Federal Manual for Identifying and Delineating Jurisdictional Wetlands" was developed for use by the COE, EPA, SCS, and US17WS. This manual standardizes methods for determining and delineating federal jurisdictional wetland boundaries.

US.Environmental Protection Agency (EPA)

Authority. Ultimate Authority for the Clean Water Act lies with the EPA. Under Section 404, the EPA has permit review and veto power over any permit issued by the COE. The EPA reviews all individual permit applications and certain, nationwide permits for evaluation of environmental impacts, alternatives, and mitigation and can veto permits that do not meet the 404(b)(1) guidelines. Under Section 402 of the Clean Water Act, the EPA has authority for issuing National Pollution Discharge Elimination System permits.

Jurisdiction: The EPA's jurisdiction over all waters of the United States, including wetlands is the same as the COE under Section 404 of the Clean Water Act. Under Section 301 of the Clean Water Act, the EPA also has jurisdiction over the discharge of any pollutants into the nation's waters through the National Pollution Discharge Elimination program. Although the EPA does not have jurisdiction under Section 10 of the River and Harbor Act of 1899, it reviews and comments on all Honolulu district Section 10 public notices in accordance with the provisions of the National Environmental Policy Act and Section 309 of the Clean Air Act.

American Samoa Coastal Management Program Administrative Rules 1997

26.0201. Adoption authority. The American Samoa Coastal Management Program administrative code is adopted pursuant to authority granted by the Department of Commerce under Public Law 21-35, the American Samoa Coastal Management Act of 1990, ASCA $$24.0501 et. seq.

26.0202. Purpose. The provisions of this chapter govern the administration of the American Samoa Coastal Management Program. The Act mandates the establishment of a system of environmental review, along with economic and technical considerations, at the territorial level intended to ensure that environmental considerations are given appropriate consideration in the land use decision-making process. The provisions of this chapter establish a consolidated land use permitting process known as the Project Notification and Review System, including developmental standards, procedures for the designation, planning and management of Special Management Areas, and procedures for determination of federal consistency. The provisions of this chapter are not intended to negate or otherwise limit the authority of any agency of the Territory, provided that actions by agencies shall be consistent with the provisions contained herein. The provisions of this Chapter are consistent with the Coastal Zone Management Act of 1972, as amended 16 USC$$1451 et. seq.

Section 26.0222 of the Administrative Code is dedicated entirely to wetlands management in American Samoa, this section provides a working definition, delineation, policy, jurisdictional limits, buffer zones, permitted and prohibited activities, permissible uses and violations.

Under section 26.0221 Special Management Areas are managed as areas that possess unique and irreplaceable habitat to American Samoa. Currently, the two mangrove areas, Leone Pala Lagoon and the Nuuuli Pala Lagoon have been delineated and designated as Special Management Areas.

Special Management Areas

Two candidates for Special Management Areas stand out for their unique character: The Malaeloa freshwater swamp and Faimulivai Marsh, the Aunu'u Crater Lake Freshwater Marsh.

Faimulivai Marsh, on Aunu'u, is an important wetland site because it is the largest, least disturbed and true herbaceous freshwater marsh in the Territory. This pristine and beautiful marsh offers important wildlife habitat for the Australian gray duck and is one of the most scenic areas in American Samoa. With the exception of the outlet culvert, this area is completely undisturbed. In addition, the crater bowl offers excellent recreational and educational opportunities for leisurely day hikes or for learning about the volcanic origins of the islands. Efforts have been made to make this a potential site to be included on the list of Wetlands of International Importance or RAMSAR list.

The Malaeloa freshwater swamp is the second largest wetland in the Territory (72 acres) and is considered pristine. This swamp supports large mature trees, including the rare 1alapa and gatae (*Erythrina fuss*). This species was once thought to be restricted to Leone and has not been reported from American Samoa for over sixty years. The expansive area of deep water within the wetland supports eels and other fish. These wetlands help control flood flows and protect downstream developments.

ASCW is working towards designating these areas for Special Management because both are large and relatively pristine areas that provide important fish and wildlife habitat and offer the best examples of freshwater wetlands in American Samoa.

Approach to Preparing a Wetlands Management Plan

The wetland management plan for American Samoa is based on the functional values of wetlands and their economic and cultural significance and at the same time, striving to be accepted and enforced by the people themselves within their cultural system. It is our goal that, through the wetland management plan, these values can be translated to the Samoan population and carried into the future with the cultural norms of society and with recognition of Samoan rights of self-determination.

The American Samoa Coastal Management Program has identified the following areas for future funding and technical assistance that have aided in the development of a wetland management plan, these include:

- A technical characterization of the existing wetland resources
- An investigation of wetland status and trends within American Samoa
- Identification of site specific opportunities for wetland restoration, rehabilitation and creation actions

- An assessment of the economic importance of wetlands
- A survey of public agency involvement and village sentiment for wetlands management
- Development and discussion of an array of management options and tools, and
- Formulation of a recommended approach for wetlands management.

Educating for Wetlands Management

To effectively provide residents with the information needed to help them appreciate and protect their wetlands as a productive resource, ASCMP continues in the development of a Environmental Awareness Education Plan to include all water resources. This strategy is dynamic, as it is culturally sensitive and will have a unique approach to each audience. To be effective, the program will need significant input from primary residents, including village councils and residents.

The focus of the educational strategy is to provide information to those who are responsible for a) protecting or maintaining wetland areas, b) making decisions regarding the use of wetland areas, c) eradicating or degrading the wetlands, or d) establishing and maintaining local sanctions and rules. Target audiences include:

- Village Councils
- Pulenu'u for those villages
- Landowners adjacent to the wetlands
- Users (primarily farmers and those harvesting fish or plants from the wetlands)
- Elders of the villages concerned with preserving the traditional ways and cultural pride
- Residents, children, and the general public
- Church groups, youth groups and religious leaders

Monitoring Wetlands

Three types of monitoring are necessary to sustain the management plan and to measure its success. These include monitoring of wetland status and trend, wetland functions, and mitigation. Monitoring wetland status and trends involves tracking changes in the amount and type of existing wetlands. Monitoring surveys should be conducted every 2 to 5 years to maintain zoning measures and other planning tools in the wetlands management plan. These monitoring surveys will contribute to future decisions regarding changes in enforcement, zoning, permitting, or other planning measures.

Changes in the function of wetlands are just as important as the changes in the amount of wetlands. Wetland functions should be monitored to record changes and to increase the knowledge about wetland ecology and function in American Samoa. Wetland functions

involve plant and animal diversity, species composition and structure, productivity, water quality, and hydrology.

Although wetlands vegetation has been surveyed (Biosystems's current wetlands vegetation survey, Whistler 1976, Cole 1988), neither wetlands water quality or hydrology has been studied. The management plan recommends placing wells to monitor water table fluctuations, testing water quality, and surveying for species abundance and diversity. This information on functions or values not previously known may then be useful in planning.

The advantages of monitoring within the wetlands program will allow us to track the success and challenges within our program. How will we know if we don't monitor? Monitoring will also help enforce mitigation measures, assess the success of restoration and creation projects and indicates the need for changes in methods or even a change in mitigation policy. Information relating to the progress of the wetland management plan will be helpful to the scientific community and other agencies Disadvantages are that monitoring can be expensive.

Community Based Wetlands Management Process: American Samoa Coastal Management Experience

"Tautua or Service" is the American Samoa Coastal Management Program's guiding philosophy. In the program's initial development stage, the purpose was to answer the following question; *"How can our actions best serve the people and natural resources we have been mandated to protect? "* The strategy was then determined to construct a Territory wide resource management system that would be compatible with traditional land use practices.

Traditional Authority vs. Government Authority

One of the main concerns ASCMP had to deal with in developing the Wetlands Plan was the conflict between traditional authority and government authority. All wetland areas within American Samoa exist within villages and, traditionally, these villages have authority over the use and management of these areas. ASCMP was concerned that the government's attempt to establish a management plan could be misinterpreted by the village wetland communities as an attempt to undermine the traditional authority by moving resource management decisions from the village council to regulatory government agencies.

Community Partnership Approach: Steps for Plan Development

1. Building an Alliance within ASG agencies
   Meetings with ASG agencies responsible for setting land use policies to address the protection, regulations and management of wetlands in A.S. (i.e. ASEPA, D, DPR, etc.) were held.

2. Village Involvement - Plan Development
   a. Village meetings - held to identify/prioritize village concerns regarding wetlands.
   b. Incorporation of Village input into the Plan.
   c. Final Draft Plan Review and Endorsement
      - Public Meetings

- Village council Meetings

Procedures and Outcomes

Village meetings were held to solicit views on values and functions of wetlands, a community perspective and issues were gathered for plan development. Problems were outlined by the village participants. Wetland areas were mapped and a draft plan for management of wetlands was developed in consultation with wetland area village leaders.

The review and endorsement of the Draft Wetlands Plan consisted of two approaches, 1) Conventional public meetings for comment on the draft plan and 2) The contemporary approach of village partnering. The purpose of the public meetings was to invite comments from consulted villages and from the general public. The turnout was low and the views of those not living within wetland villages were gathered which made implementation and ownership of the wetlands plan difficult.

The contemporary approach consisted of a series of meetings with Village Councils to present the plan and invite comments. Building an Appreciation for Wetlands Management through public awareness was created through pulenu'u and village council workshops and meetings, the commitment to establish a Community Wetlands Task Force, and select Wetlands Village liaisons and facilitators. Outcomes from this approach were well received by the community. An educational workshop and pulenu'u and village council meetings were effective in that the Matais were instrumental in getting village councils to agree to assist ASCMP in their efforts to protect wetlands resources within their respective villages. These leaders generated greater support and public interest for protection and lectured at their respective villages on the importance of wetlands within the specific villages. Pulenu'u and Faifeau workshops were well attended by the clergy, pulenu'u, and talking chief. The workshops emphasized the importance of wetlands with an emphasis on the theological role of nature and human interaction as caretakers of the earth.

The purpose of the Community Wetlands Task Force was to have a group that would act as a liaison between the community and the government on ongoing issues concerning wetland management. Specifically, the task force would serve as an advisory board to ASCMP in designing and implementing individual village plans, consistent with the recommendations stipulated in the Wetland Management Plan (Biosystems 1992) for the islands of Tutuila, Aunu'u, and Manu'a. Village councils and the ASCW selected members of the task force.

The Wetlands Community Task Force recommended ASCMP hire village liaisons and facilitators for the two largest mangrove wetland villages, Leone and Nuuuli (both Special Management areas). The objectives of this program:

- Obtain wetland protection/preservation village resolutions
- Obtain wetland ordinances designed to uphold resolutions enforceable by village law
- Obtain village support to conduct wetland delineation, allowing village residents to indicate where they determine the boundary line should be in their village
- Determine one boundary line following negotiations with the village

- Monument one line for future reference and wetlands management

Conclusions of the Community Based Wetlands Management Plan

The outcome of the Village Partnership approach was effective overall in generating support for wetland protection but was not without challenges. Some advantages include a village ownership of the plan (not a government plan), the ability to convince fellow villagers, and the familiarity of neighbors generated comfort and willingness to participate in resource management. Disadvantages of the approach included that it required a lot of resources and supervision. Finding participants that were committed for the long term was difficult and consistency in implementing the wetlands management plan over time proved challenging.

In conclusion, ASCMP's Community Based Approach recognized the hierarchical structure of the Traditional Samoan System and utilized the decision-making powers of the village council. There is an ongoing process on informing the public on the biological functions and values of wetlands while appreciating that each island (and ecosystem) is different and each strategy would be different as well.

Public Participation

The on going mission of the Community Based Wetlands Management Plan is to involve residents, including the village councils or pulenu'u in wetlands management and protection efforts. The focus of the program remains to encourage active participation in wetland management. Meetings that involve permitting and enforcement are always open for public participation and comment on a bi-monthly basis. The CZM program is always available to hold environmental lectures and presentations on an appointment basis. Public participation in wetland management and protection is necessary for the following reasons:

- To remind residents that wetlands are a public resource belonging to all residents, not just those residents living adjacent to the wetlands.
- To help the public understand why wetlands must be protected.
- To involve those residents who do not live adjacent to wetlands but who depend on them for subsistence.
- To encourage the matai's stewardship of the land.
- To encourage consensus building for ASG wetlands policy and implementation.
- To enable residents to understand the technical and other reasons for individual permit and enforcement decisions.

Current Situation

Presently awareness of the importance of wetlands, their ecological functions and protection are not fully understood by the community. There is still much work to be done in this area. Decision making at the village level is crucial to wetland protection. Traditionally, land use and resource utilization decisions are made in villages or at the aiga level and confirmed by the village council. Also American Samoa's traditional communal ownership of land and natural resources is defined at the village level.

Encouraging participation to protect wetlands is an ongoing process within the ASCW program. While village level participation is crucial, interest and awareness in wetlands management and protection should not be limited to residents of affected villages. A broader perspective must be obtained from residents who recognize that wetlands are a resource for all Samoans, not just those living on the edges of a wetland.

Due to population pressures much activity has revolved around permitting through the Land Use Permit Process and enforcement activities and attempting to regulate and in some cases, prevent and discourage wetland filling activities. This filling usually occurs on the edge of mangrove wetlands with the intent to create more land for personal use. More work is needed in the area of mitigation to compensate for some wetland loss.

Current Public Awareness on Wetlands

ASCMP continues to promote the ecological and cultural importance of wetlands preservation to the public through a variety of mechanisms. May is wetlands month and each year ASCMP offers a variety of outreach activities, such as wetland walks and educational activities to create wetlands appreciation. Some of these activities involve creating songs, skits, dances, trivia contests, school lectures, TV spots and videos. Other mechanisms include Coastweeks, which is a two-week event filled with activities, field trips and presentations aimed towards promoting environmental awareness and conservation. A Religious Consciousness Project has been developed to target the religious leaders of the community on recognizing and preserving American Samoa's environment and understanding how land use practices and population will affect these resources in the future. ASCMP's yearly Art and Tide calendar has been a tremendous success with much participation from schools on submitting environmental artwork along with traditional Samoan proverbs. A village of the year award encourages villages to participate in environmental protection and awareness.

TONGA COUNTRY REPORT

Compiled -by Netatua Prescott - Department of Environment

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)

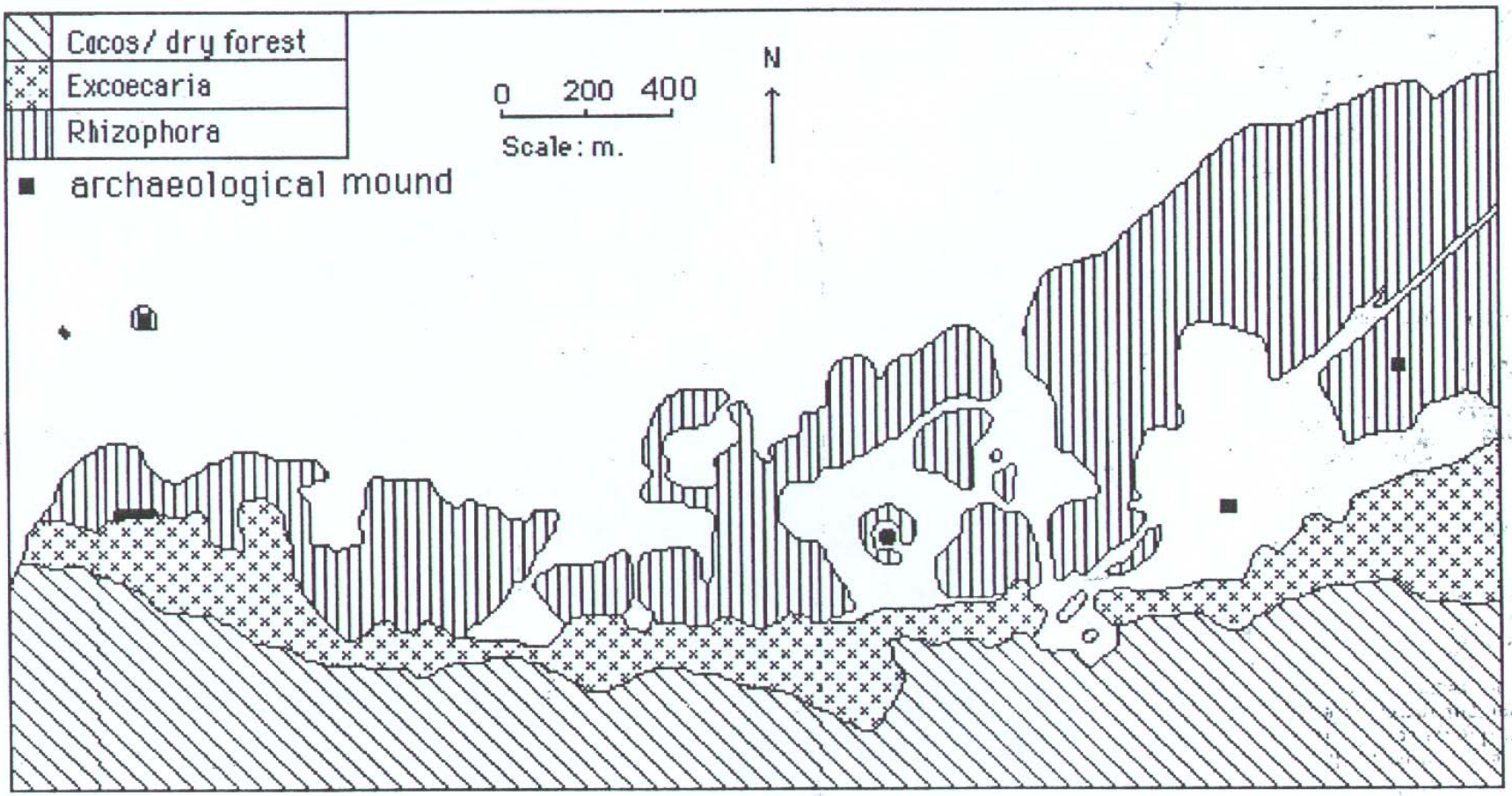


Figure 2. Mangrove zonation at Fatai, Tongatapu.

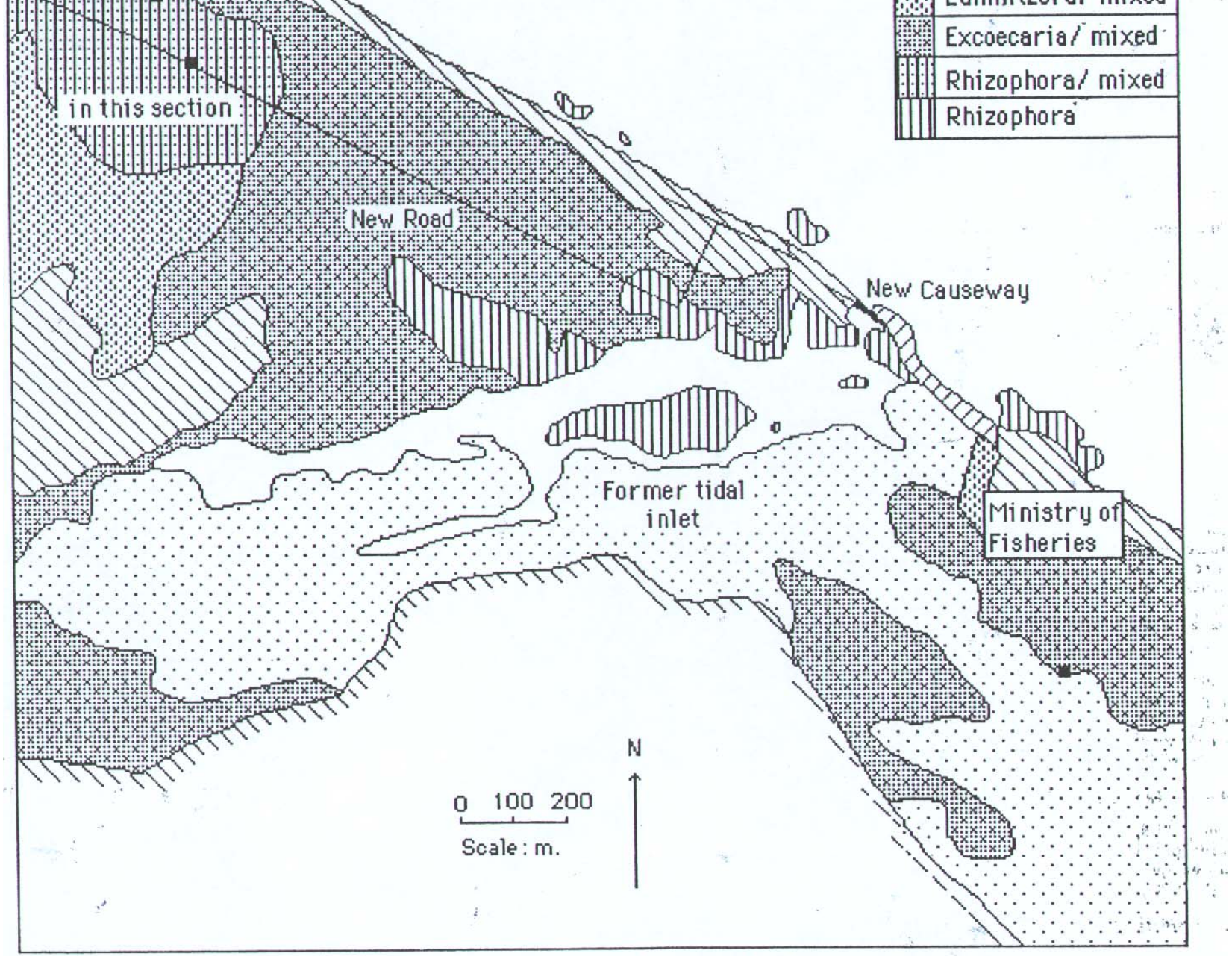


Figure 3. Mangrove zonation at Sopu/ Muifonua, Tongatapu.

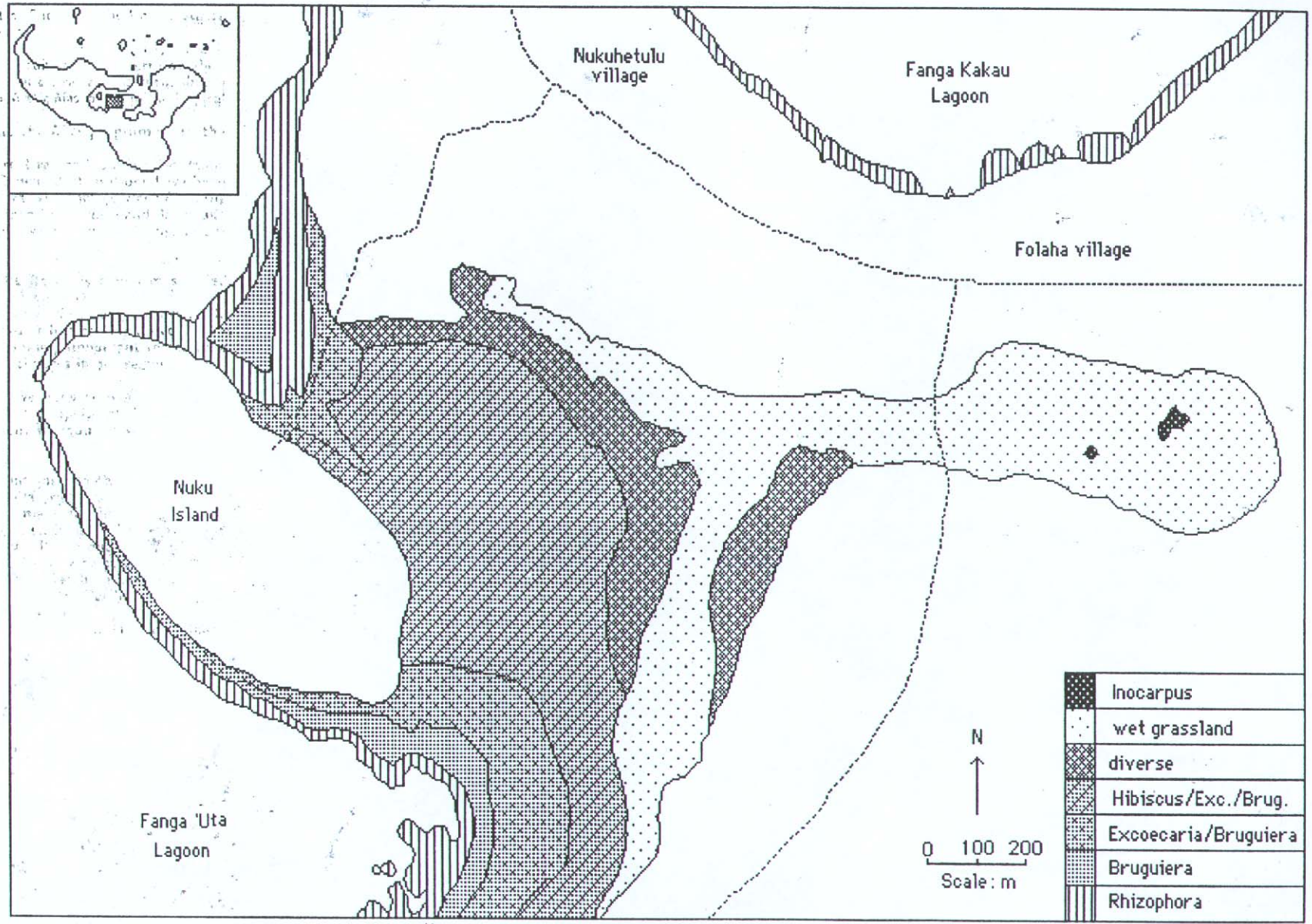


Figure 4 Mangrove zonation at Nukuhetulu, Tongatapu.

References

Bacon, P. R., Deane, C. A. and Putney, A. D., (1988) A *Workbook of Practical Exercises in Coastal Zone management for Tropical Islands.* London: Commonwealth Science Council, 30Opp.

Banus M.D. & Kolchmainen S.E. (1975) Floating, rooting and growth of red mangrove (Rhizophora mangle L.) seedlings: Effect on expansion of mangroves in southwestern Puerto Rico. *Proc. Int. Symp. on Biology and Management of Mangroves,* Walsh G.E., Snedaker S.C. & Teas H.J.. eds., Vol. 1, Univ. Florida (Gainesville), p. 370-374.

Bohorquez, C., (1996). Restoration of mangroves in Colombia: a case study of Rosario's Coral Reef National Park. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Mangrove Ecosystems, Okinawa, Japan, pp. 189196.

Chan, H. T., (1996). Mangrove reforestation in Peninsular Malaysia: a case study of Matang. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Mangrove Ecosystems, Okinawa, Japan, pp. 64-75.

Devoe, N. N. (1992). Mangrove assessments on Yap, Kosrae and Pohnpei, Federated States of Micronesia. In *Coastal resources and systems of the Pacific Basin: investigation and steps toward protective management.* UNEP Regional Seas Reports and Studies No 147, 1-20.

Duke, N. C. (1992). Mangrove flonistics and biogeography. InTropical *Mangrove Ecosystems,* Eds. A. 1. Robertson and D. M. Alongi, 63-100. Washington DC, American Geophysical Union.

Ellison, J. C. (1998). *First report on development of a mangrove environmental management plan for Tongatapu.* Tonga - Australia Environmental Planning and Management Strengthening Project (TEMPP), Working Paper No. 5. Hassall and Associates in association with AMSAT.

Ellison, J. C. and Oxley, W. (1998). *Mangrove Survey Workshop.* Tonga - Australia Environmental Planning and Management Strengthening Project (TEMPP), February, 1998,

"FAO. (1994).- Mangrove forest management guidelines. FAO Forestry Paper 117, FAO: Rome, 319p

Field, D.,' (1996a). Rationale for restoration of mangrove ecosystems. In L D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Mangrove Ecosystems,. Okinawa, Japan, 1 pp. 28-37.

Field, C. D., (1996b). General guidelines for the restoration of mangrove ecosystems. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Magrove Ecosystems, Okinawa, Japan, pp. 233-250.

Hamilton, L. S. and Snedaker, S. C., Eds. (1984). *Handbook for mangrove area management.* Honolulu: East-West Center, lUCN and UNESCO, 123pp.

Hong, P. N. (1996) Restoration of mangrove ecsystems in Vietnam: a case study of Can Gio District, Ho Chi Minh City. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Mangrove Ecosystems, Okinawa, Japan, pp. 76-96.

Idechong, N., Ellison, J. and Jaensch, R., (1996). *A Draft Regional Wetlands Action Plan for the Pacific Islands.* International Coral Reef Initiative Pacific Regional Workshop Report (Suva, Fiji, 27 Nov-1 Dec 1995), p. 116-134. South Pacific Regional Environment Programme, Apia.

Kaly, U. L. (1998). Second Report of Scientific Monitoring Adviser Baseline Monitoring of Fanga 'Uta- Fangakakati Lagoon System. TEMPP Working Paper 16.

Kogo, M. and Tsurunda, K. (1996). Species selection for mangrove planting: a case study of Ras al Khafil, Saudi Arabia. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Magrove Ecosystems, Okinawa, Japan, pp. 197208.

Metz, W. D., (1996). *The Polmpei Mangrove Management Plan.* Division of Resource Management, Office of Agriculture and Forestry, Pohnpei, Federated States of Micronesia.

Prescott, F. (1989). *The management of mangrove resources in Tonga.* M.Se. Thesis, University of Sydney.

Prescott, N. 1992a, Tonga Country Report. In *Proceedings seminar and Workshop on integrated research on mangrove ecosystems in Pacific Islands,* ed T. Nakamura, 79-89. Tokyo: Japan International Association for Mangroves'.

Prescott, N. 1992b, Country Report on mangrove ecosystems in the Kingdom of Tonga. In *Proceedings seminar and Workshop on integrated research on mangrove ecosystems in Pacific Region 11,* ed T..Nakamura, 79-89. Tokyo: Japan International Association for Mangroves.

P'rescott, N. (2001). State of the, Environment of Tonga. Unpublished DoE Report.

Siddiqi N. A, Islam, M. R.,Khan; M. A. S. and Shahidullah, M., (1993). *Mangrove Nurseries in Bangladesh.* ISME Mangrove Ecosystems Occasional Papers 1, Okinawa.

Soemodihardjo, S., Wiroatmodjo, P. Mulla, F. and Harahap, M. K., (1996). Restoration of mangroves in Indonesia: a case st . udy of Tembilahan, Sumatra. In C. D. Field (Editor) *Restoration of Mangrove Ecosystems.* International Society for Magrove Ecosystems, Okinawa, Japan, pp.

Thistlethwaite, R., Sheppard, D. and Prescott, N.;(1993). *The Kingdom of Tonga: Action Strategyfor Managing the Environment.* Apia, SPREP, 112pp.

Tupou, S. M., (1991) national Report of the Kingdom of Tonga to the United Nations Conference on Environment and Development. Nulcu'alofa: Ministry of Lands Surveys and natural Resources, 54pp.

Yuncker T.G., (1959). Plants of Tonga. *Bernice P. Bishop Mus. Bull. 220, 283pp.*

SAMOA COUNTRY REPORT

By Etuati T. Ropeti[1] and Tumutalie Foliga[2]

Introduction

The value of mangroves to social and economic development have been increasingly recognised nationwide, however there is still limited effort to directly conserve or regenerate the remaining mangrove areas in Samoa. There are several conservation strategies being promoted in the country which either indirectly include or specifically target some considerations for the protection and sustainable use of mangrove areas.

The Department of Lands, Surveys & Environment in partnership with the IUCN (World Conservation Union) is working with the Districts of Safata (9 villages) and Aleipata (11 villages) to establish two multi-use community based marine protected areas. Its objective is to empower the local communities of these districts to effectively protect and manage coastal marine biodiversity and help them achieve sustainable use of marine resources.

About 64 village-based Fisheries Reserves have been established in Samoa so far within a Fisheries Division programme supported by AUSAID. This programme focuses on promoting village or community involvement in the management of these fisheries reserve in an effort to conserve the fishery resources to enable it to replenish and recover to a more sustainable state. A similar approach is currently being promoted around the Pacific regions through the South Pacific Biodiversity Conservation Programme (SP13CP) of SPREP, and there are two areas established under this programme, the Uafato Conservation Area and the Saanapu - Sataoa Conservation Area. This approach tries to create a balance between nature and the need to provide for the daily livelihoods of people. Conservation and the sustainable use of mangrove areas is also reflected in the overall vision of the Samoa's National Biodiversity Strategy & Action Plan 2001-2005.

There was no detail survey undertaken for mangrove wetlands in Samoa but it has been estimated to be about 1,270 hectares or less than one percent of the land area of Samoa (Zann 1991). Two mangrove communities can be distinguished in Samoa, mangrove scrub and mangrove forest. Both are dominated by salt-tolerant trees with specialized breathing roots. Mangrove scrub is dominated.by *Rhizophora mahgle,* a tree that rarely reaches a large size.. Mangrove forest is dominated by *BOguiera emnorrhiza,* large trees of which form closed canopy forests in estuaries and. bays, especially on the south coast of Upolu.

Mangrove is scattered in distribution, and is typical of bays and estuaries on most of Upolu except the northern portion, and on the eastern part of Savaii (See Map 1). The best remaining example of mangrove forests in Samoa is at Saanapu/Sataoa on the South coast of Upolu. Another good site of mangrove forests is at Mulivai Safata and Lefaga Bay; which was seriously hit by the 1990 and 1991 cyclones. The best example of a remaining mangrove scrub is at Vaie'e/Tafitoala, Moataa and Vaiusu bay on either side of Apia, which was identified during the Survey for the Conservation of Biological Diversity in the Coastal Lowlands of Samoa 1992.

[1] **Fisheries Division, Apia, Samoa**

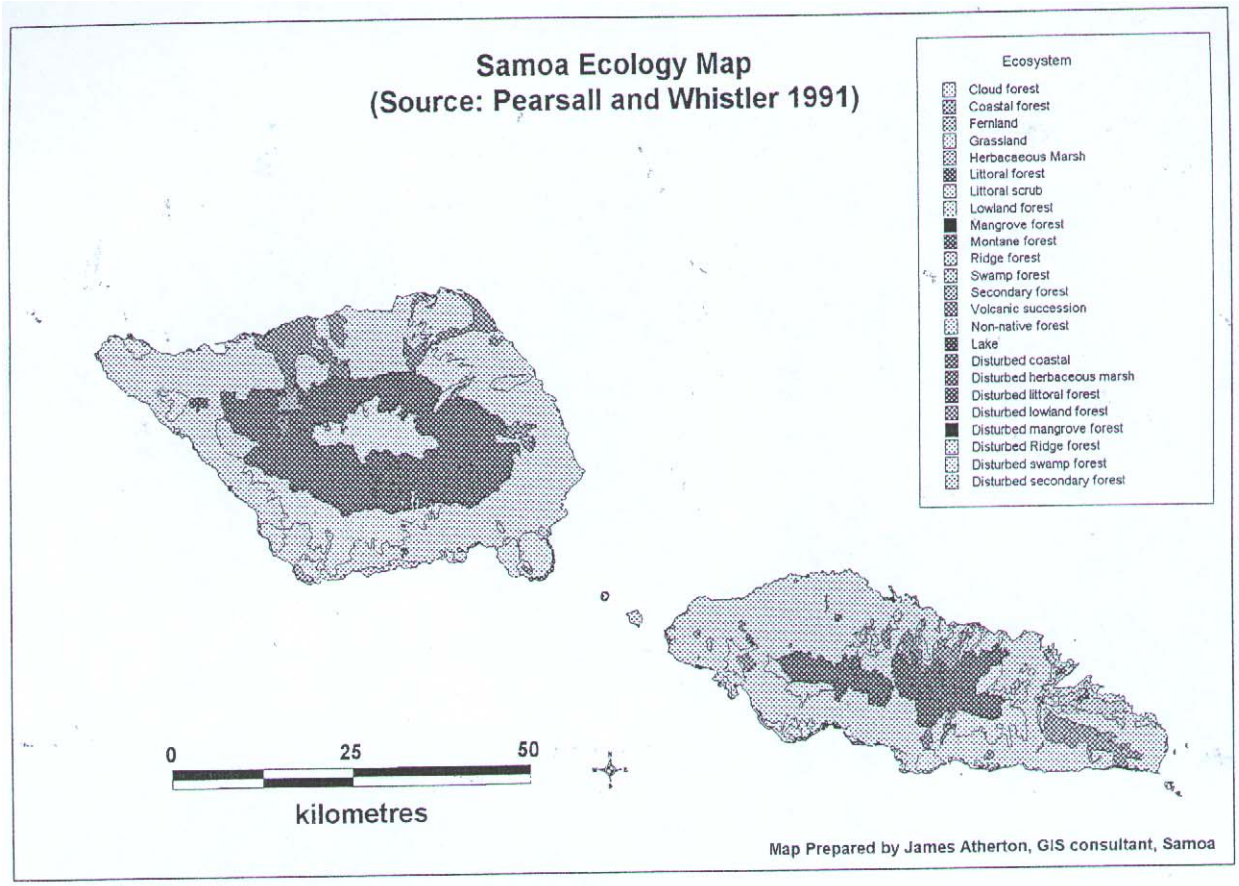
[2] **Division of Environment and Conservation, Apia, Samoa**

A small unique mangrove forest dominated by *XylocaTus moluccensis is* found on the south coast of Savaii just east of Salailua village. The Xylocarpus mangrove is unique to Samoa, perhaps the Pacific. Although small in extent, and not in immediate danger, it is worthy of protection.

Mangrove have largely featured (especially in village communities with mangrove areas) as important fishing grounds for a variety of fish and shell fish, and sites for collecting plant material for medicines, handicraft, building and firewood supplies in the livelihood of traditional village communities from the past up to now.

With spreading modern developments around the country, mangroves have been made mainly out of ignorance into common sites for waste disposal and most of the country's land reclamation for building purposes. The best example of this is the continuing reclamation and the disposal of waste towards the remaining mangrove areas in and close to the capital of Apia. Inspite of a significant decision by the Government to relocate its urban dumpsite that was established since the middle of the last century at the largest mangrove area in the country-termed "Vaiusu Bay" located west of Apia to an inland site termed " Lafi Tafaigata" in the last decade.

Another crucial example of declining in mangrove habitats is happening and will be continuing to happen at Moataa mangrove scrub. The 1954 aerial photo has been compared with 1999 photo of the same area shows a decrease from 62 hectares to 28 hectares. Threats mainly caused by reclamation and over-harvesting of mangrove for fuelwood and as building material.



Map 1: Mangrove Areas of Samoa 1991

Legislation

There are no specific legislation on the protection of mangrove wetlands in Samoa mainly due to the fact that is not seen as a high priority need. The Lands and Environment Act 1989 covers the management areas deemed by the Government to be important for conservation. Other legislation, such as the Forestry Act 1967, Fisheries Act 1988 and the Water Management Regulations 1992 also assists in the management of wetlands and assessment of wetland importance.

Policies

Policies relating to the management and conservation of Mangrove wetlands in Samoa are generally lacking. The fourth and fifth National Development Plans (DP4 & 5) specified policies setting guidelines for land-use, water resource conservation and environment conservation. The protection of the Environment and conservation of natural resources are included in the objectives and strategies of the DP5. The primary goal of the DP5 is however increased production in the Agricultural sector.

The Tourism Master Plan (1983-1984) and the Samoa Tourism Development Plan (1992-2001) give important consideration to the conservation of Samoa's archaeological and historic sites, cultural patterns and natural environment although cultural and historic attractions are special consideration in view of their importance to the tourist industry.

The National Forest Policy approved by the government in 1994 aims at restoring the balanced multi-use functions for forestry, strengthening forestry administration and encouraging customary owners to become more committed to the protection of the remaining indigenous forests and reforestation activity. Ideally the Land Use, Waste Management, Population and Water Management Draft Policies have been drafted by an inter-agency task team as part of the National Environment and Development Management Strategies (NEMS) are mend to include conservation and sustainable use components. They are currently awaiting cabinet endorsement.

Administration

The management and conservation of Mangrove wetland ecosystems have been the responsibility of the Ministry of Agriculture, Forests, Fisheries and Meteorology. However, the Lands and Environment Act 1989 provides the protection of the natural resource and the environment of the country including the prevention and conservation of its foreshore and coastal areas from pollution.

Fauna

Birdlife
1991 survey in the Saanapu-Sataoa region recorded 14 bird species. They included the Samoan broadbill, crimson crowned fruit dove and the Samoan Whistler, species normally only common in large forest areas. Herons, waders and grey ducks were reported an the rare and elusive sooty and white browned rails also found. There is apparently a white-rumped swiftler population in at least one important lava tube cave and it is suspected that other caves have populations of the sheath-tailed bat, a species is in danger of extinction and whose status is of concern.

Non Fishery Marine
The lagoon of Saanapu and Sataoa are frequented by the hawksbill turtle which is a threatened species in the Pacific region.

Flora

Because mangrove communities are dominated by a single species, most o the species diversity is in the epiphytes, which are most common on *Bruguiera* trees. Some of the sites had 26 epiphytic species. One species of note is an epiphytic *Trichomanes* fern which does not match any other *Trichomanes* found in Samoa or apparently in Fiji. Other species associated with mangrove include species *Inorcarpus fagifer, Hbiscus* tiliaceaus, *Pandanus turitus* and *Acrostichum* coastal mash vegetation.

Tenure Ownership of Mangrove Wetlands

Traditionally, village's bordering lagoon or shallow water was a special preserve in which the village maintained rights of use and access in much the same way as it controlled its lands. The lagoon, inshore areas (as for as the reef) were considered to be the property of those near whose village it was situated (Bell 1985). Ownership of lagoons, reefs and their surrounding resources is traditionally vested with the *matais* of each village.

Presently, Article 104 of the constitution of the Independent State of Samoa provides that all land lying below the line of high-water mark is public land and that all citizens have a right to fish, harvest or use any of the resources there in. However, this public right must be exercise reasonably and so as not to damage the fishery or any of the resources.

As far as the ownership of mangrove wetlands is concerned, three systems seem to exist.

(a) The state by law owns the land below the high water mark giving all citizens the right to the resources.

(b) Freehold lands along the coast since the colonization era where the low-water mark was recognized considered the mangrove wetlands as part of these lands.

(c) The village or family which has adjacent mangrove areas claim ownership over such.

Other Sectors Involvement

The Fisheries Division

The Fisheries Division of the Ministry of Agriculture, Forests' Fisheries and Meteorology serves to promote the sustainable management and development of fisheries in Samoa. Its role centers on the scope of the Fisheries Act 1988 outlining the following purposes as its mandate,

- Promote the conservation, management and development of fisheries of Samoa
- Promote the exploration of the living resources of fishery waters
- Promote scientific research
- Promote the protection and preservation of the marine environment.

The Division of Environment and Conservation (DEC)

The DEC of the Department of Lands, Survey and Environment's functions as identified under the Lands and Environment Act 1989 are as follows:

- Advise government on all environmental management and conservation matters
- Ensure and promote the conservation and protection of Samoa's natural resources and environment.
- Assist in ways of preventing, controlling and correcting pollution of the air, sea and land, Promote public awareness as to the importance of the environment and its conservation.

The DEC is also responsible for the management of national parks such as the Palolo Deep Marine Reserve and the Sataoa/Saanapu Mangrove Conservation area.

Le Sisosiomaga Society

The society is a non-governmental organisation that promotes public awareness, education and information 0dissemination on environmental issues.

Faasao Savaii Samoa Society

Another non-governmental organisation that promotes public awareness on environmental issues.

Regional Organisations

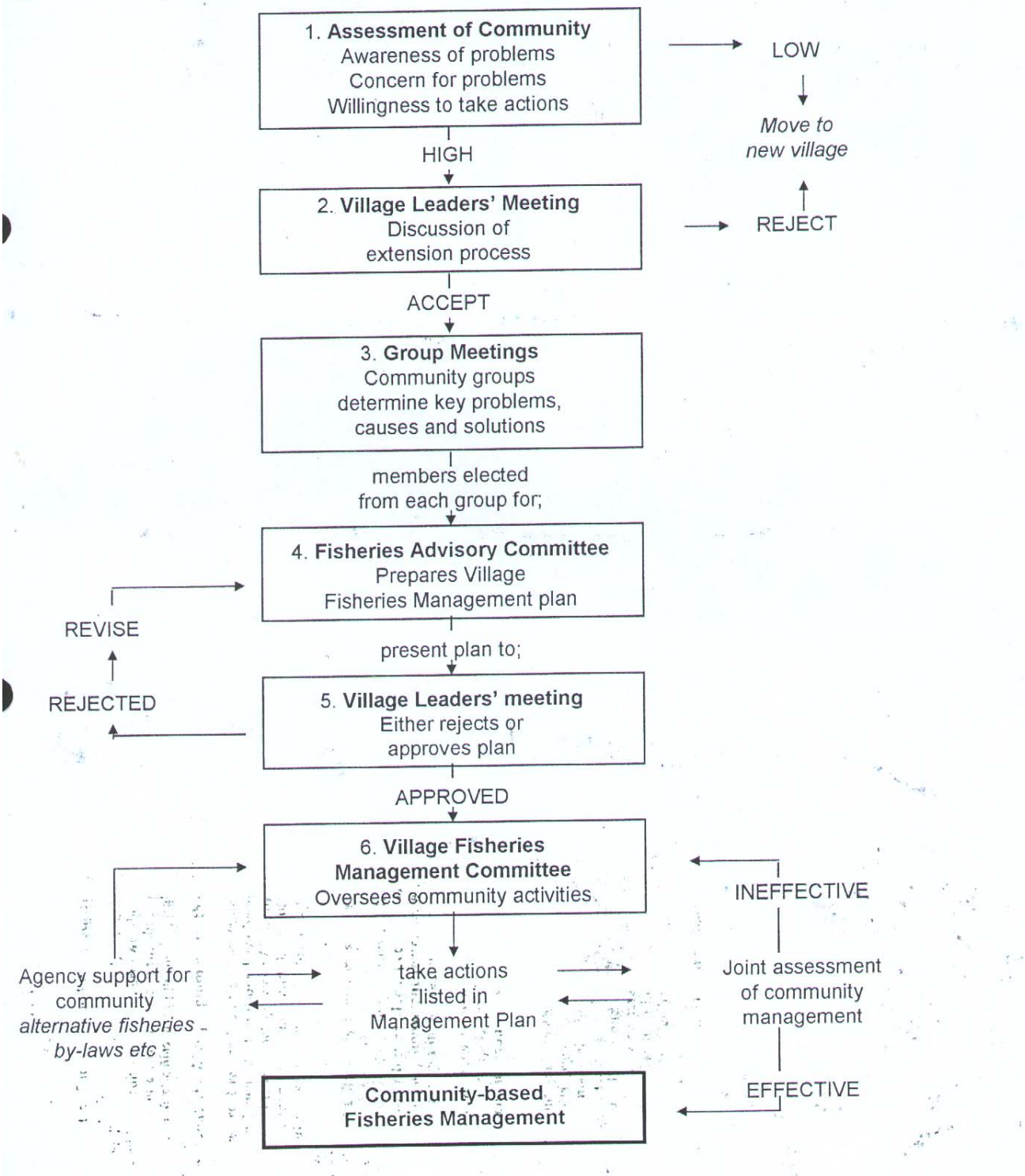
South Pacific Regional Environment Program (SPREP). SPREP functions to promote the conservation of the environment on a regional scale. It has funded several projects concerning marine conservation management and also provides technical assistance to the Pacific region on environmental conservation matters.

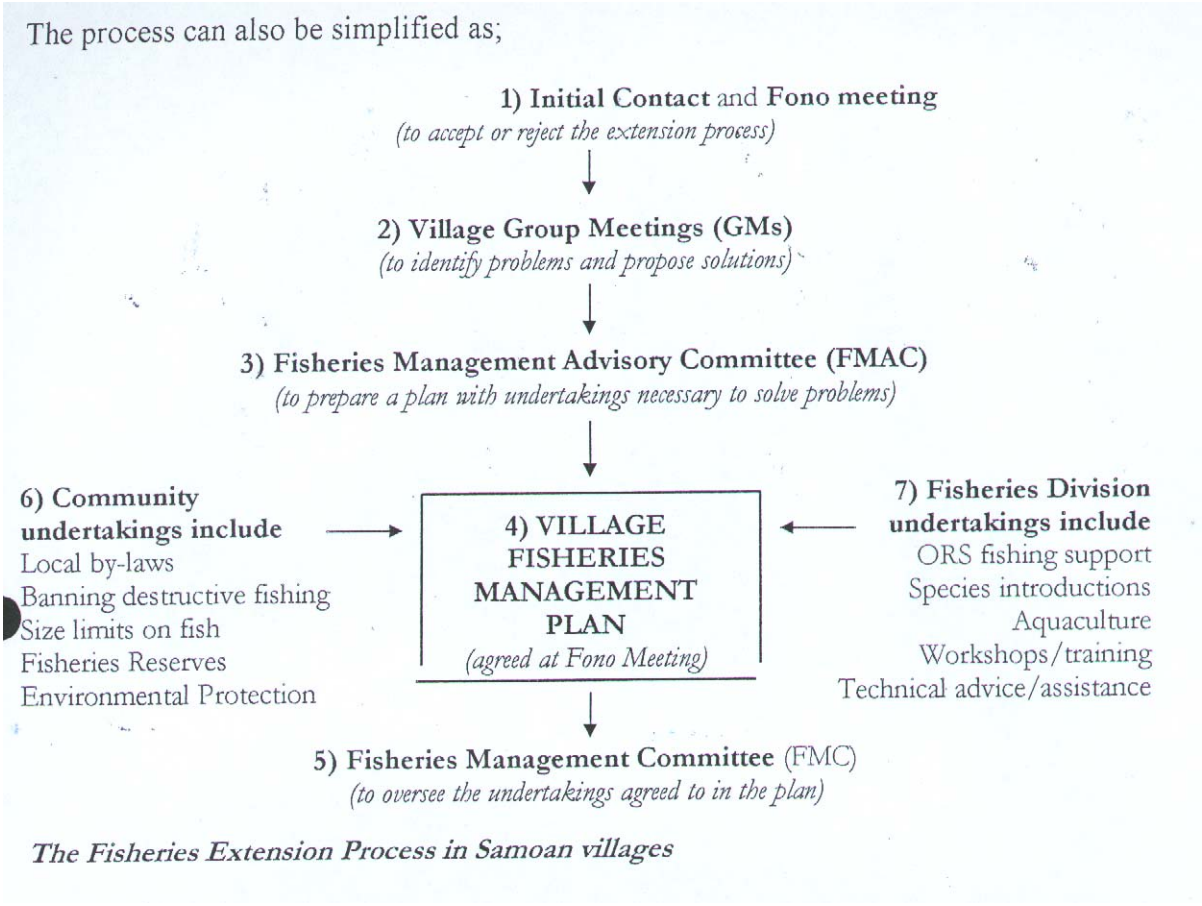
Food and Agriculture Organisation of the United Nations - Sub Regional Office for the Pacific Islands (FAO-SAPA). FAO-SAPA provides technical assistance on marine conservation management issues.

IX. Community Involvement

The AusAID funded Fisheries Extension and Training Project in its second phase continued to support the community/village-based fisheries management program. This program was established in 1995 and invented the process of community/village-based fisheries management in Samoa. The underlying philosophy of the project is to promote ***bottom-up*** planning and to create a lasting village infrastructure that will have the confidence, ability and motivation to tackle its problems. The stages are described briefly below and in more detail in the following diagram.

The Community Extension Process.





The Fisheries Extension Process in Samoan villages

The strategy used in the program is based on the belief that the primary responsibility for the marine environment lies with the village itself. The overall objective of the process is to promote the participation of village communities in the management of their marine environment and fishery resources. The medium term goal of the project is to prevent a further decline in village near-shore fisheries resources. Reasons for this decline include, overexploitation, the use of destructive fishing methods, and environmental disturbances.

The process of community involvement in the management of fisheries resources is achieved when:

- People of such community is aware of the problems with the marine environment and fisheries resources,
- There is a concern for these problems and their effects on the community
- There is a desire and willingness to take actions to address these problems
- There is an assumed control over adjacent fishing areas and,
- The community should have the power to make and enforce their own rules and regulations.

The village extension process employed is simply known as the '*bottom-up*' approach. This approach is designed in a way where the various groups of the community voiced the problems, possible solutions to the problems, what should be done to reduce or eliminate the problems and, who should be responsible for these actions.

The process culminates in each community producing its own Village Fisheries Management Plan including the resource management and conservation undertakings of the community, and the support undertakings of the Fisheries Division.

Village Management Plans

The plans contain a range of community undertakings designed to conserve and rebuild fish stocks and to protect the marine environment. Undertakings have differed from village and the most common are summarized below:

- Banning the use of dynamite and poisons to kill fish
- Banning smashing of corals to catch sheltering fish
- Minimum size limits on fish
- Banning underwater torches for spearfishing at night
- Collecting crown of Thorns starfish
- Banning removal of beach sand and dumping of rubbish
- Establishment of fish reserves
- Production of village By-Laws
- Preserve the mangrove wetlands.

Conclusion and Recommendations

The loss of Samoa's limited mangrove wetlands and resources due to human activities such as land reclamation, garbage disposal and harvesting for firewood and construction materials should be controlled and be given high priority by the government and agencies responsible for their management.

The management of mangrove wetlands in Samoa seems to be the responsible of a few government departments that has provisions for such areas in their Acts, Regulations and Policies. However, no one particular department takes it as their mandate.

The involvement of communities in the decision-making process should be encouraged to ensure the successful implementation of managing mangrove wetlands and/or any inshore fisheries resources.

References

Bell L. (1985) *Coastal Zone Management in Samoa, A Case Study in the Third South Pacific National Parks & Reserves Conference.* Conference Report Volume 2, SPREP. Samoa.

Bell L. (1989) *Environmental Problems in Samoa.* Fisheries Division, Apia, Samoa.

King M, Faasili U & Ropeti E. (1995) *Management Strategies for Inshore Fisheries in Tropical Pacific Islands.* SPC/Inshore Fisheries Management/BP 65, Noumea.

Mulipola A, Ropeti E & Iosefa S. (1995) *Fisheries Management Policies, Laws, Regulations, Constraints and Recommendations in Samoa.* SPC/Inshore Fisheries Management/BP CP 17, Noumea.

Trevor A. (1999) *Marine and Coastal Environment Conservation in Samoa.* Fisheries Lib. Apia. Samoa.

Fisheries Extension Manual.

WORKSHOP PROGRAM

South Pacific Regional Environment Programme

Regional Workshop – Mangrove Wetland Protection & Sustainable Use
12 – 16 June 2001, Suva, Fiji

Agenda

TUESDAY 12 JUNE

5:00 – 6:00 PM **Workshop Registration – Peninsula Hotel, Suva**

6:30 – 8:00 PM **Welcome Reception – Peninsula Hotel, Suva**

WEDNESDAY 13 JUNE

Marine Studies Centre, USP

8:30 - 9:30 AM Introductions, Workshop Overview, General Arrangements
Mary Power, SPREP

Session I: **Overview of Mangrove Wetlands in the Region**

9:00 - 9:30 AM **Global and Asia-Pacific Regional Status**
Aaron Jenkins, Wetlands International

9:30 – 12:00 PM **Country Reports I–** Status Report for each country (10-15 min each)

Fiji	Manasa Sovaki
Palau	Theofanes Isamu & Alma Ridep-Morris
FSM	Asher Edwards & Andreas Poll

10:30 - 10:45 AM **MORNING TEA**

Tonga	Netatua Prescott & Feauini Vi
Solomon Islands	Nathaniel deWheya
New Caledonia	Francois Devinck

12:30 - 1:30 PM **LUNCH**

1:30 - 3:30 PM **Perspectives: The Value of Mangrove Ecosystems**

Ecosystem Services & Functions	Joanna Ellison, Univ. of Tasmania
Cultural and Ethnobiology	Dr R Thaman & B. Thaman, USP
Fisheries	Anne Clark, Queensland Fisheries
Forestry	Aru Mathias, FAO Apia

3:30 - 3:45 PM **AFTERNOON TEA**

3:45 - 5:00 PM **Country Reports II**

Vanuatu	William Naviti & Trinison Tari
Samoa	Etuati Ropeti & Talia Foliga
Marshall Islands	Maity Bungitak
American Samoa	Mary Midkff & Peniamina Siatunu'u

THURSDAY 14 JUNE

Session II: Technical Addresses

9:00 - 9:20 AM **Linking Mangroves and Fisheries**: towards a trophic model of a mangrove community in Darwin Harbour, northern Australia. (MW_16) - Julie Martin NTU Darwin.

9:20 - 9:40 AM **Economic Evaluation**: the effects of ecological characteristic in economic evaluation of development projects (MW_17) - Dr Padma Lal , ANU

9:40 – 10:00 AM **EIA for Mangrove Protection:** what to look for (MW_18) - Anne Clarke

10:00 - 10:15 **MORNING TEA**

Session III: Mangrove Wetland Management

10:15 - 11:30 AM **Management Plans – Case Studies**

Tonga Lagoon Management Plan	Netatua Prescott
American Samoa Wetland Management Plan	Mary Midkiff
Challenges of Involving Local Communities	Joeli Veitayaki, USP

11:30 - 12:30 PM **Regional Wetland Action Plan**

Review of Recommended Actions - Mary Power, SPREP

Prioritisation of National and Regional Issues for New Initiatives (Survey Questionnaire)

12:30 - 6:00 PM **SITE VISIT - to proposed RAMSAR Site Nasoata Island**. **Batiri and Randy Thaman (USP)**

FRIDAY JUNE 15

8:30 – 10:30 AM **Working Group Session**

Monitoring and Assessment Methodologies - Joanna Ellison

10:30 - 10:45 **MORNING TEA**

10:45 - 11:00 AM **Prioritisation of National and Regional Actions in the RWAP** Report Back - Mary Power

11:00 - 12:00 PM **Mangrove Monitoring and Management Network for the Pacific Islands**: a potential approach for New Initiatives- Eric Gilman, Audubon Society.

12:00 – 1:00 **LUNCH**

1:30 - 3:00 PM **Group Discussions (groups led by speakers)**

Criteria for site selection for management intervention at the community level.

Proposed site(s) in each country based on criteria identified that would be a potential candidate for development of Community Based Management Plan

Discussion on the pros and cons of establishing a monitoring and management network as a regional approach to mangrove wetland management

3:00 - 3:15 PM **AFTERNOON TEA**

3:15 - 4:30 PM **Groups Report Back**

4:30 - 5:00 PM **Summations & Conclusions –** Mary Power

FIELDTRIP HANDOUTS

20 April 2001 Visit to Tonasoata Mangrove islet, Rewa Delta, Viti Leve, Fiji Islands

Organised by: Randy Thaman[10] and Batiri Thaman[11]

Dick Watling, Environmental Consultants (Fiji) Ltd.
Suva, Fiji Islands, 22 April 2001

BACKGROUND

A reconnaissance visit to Nasoata Island was made by members of the Ramsar Working Group on 20th April 2001. The purpose was to make an initial assessment as to the potential for Nasoata to be Fiji's Ramsar nomination site. The party arrived at the island at about 0930 and left at 1515. Low tide was at 1027. This note records wildlife observations and impressions on the mangrove habitat.

WILDLIFE – TERRESTRIAL VERTEBRATES

Mammals

Manupusi – Mongoose (*Herpestes auropunctatus*). Common – several individuals seen and tracks observed throughout the mangrove.

Kalavo – Rats (*Rattus* spp.). No sign noted but may well occur.

Reptiles

Skinks

Moko sari - Blue-tailed Copper Skinks (*Emoia cyanura/impar*) Common

Moth Skink (*Lipinia noctua*). Recorded.

Neither the Snake-eyed Skink (*Cryptoblepharus eximius*) or the Green Tree Skink (*Emoia concolor*) were observed, but may well occur.

Geckos

Oceanic Gecko (*Gehyra oceanica*). Recorded

Mourning Gecko (*Lepidodactylus lugubris*). Recorded

Birds

Land & Freshwater Birds

Belō - Reef Heron (*Egretta sacra*)

Visakō - Mangrove Heron (*Butorides striatus*)(observed by Randy)

Gā ni Viti - Pacific Black Duck (*Anas superciliosa*). Several flocks feeding or resting on mudflats. 60 in three flocks counted from one spot during our lunch break. The largest number I have ever seen at one time in Fiji.

Sōsō - Collared Kingfisher (*Todiramphus chloris*). Observed and heard several times.

Kikau - Wattled Honeyeater (*Foulehaio carunculata*). Very common and noisy.

Matayalo, solesole waqa, tina ni uto -Vanikoro Broadbill (*Myiagra vanikorensis*). At least 2 pairs calling.

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[10] Professor of Pacific Islands Biogeography, The University of the South Pacific, Suva, Fiji Islands.

[11] Scientific Officer, Institute of Applied Science, The University of the South Pacific, Suva, Fiji Islands.

Mainā - Jungle Mynah (*Acridotheres fuscus*). 6 individuals seen in the mangroves – a rather surpising observation of this introduced bird.

Sea and Shore Birds

Kasaga - Lesser Frigatebird (*Fregata ariel*). A single individual flying overhead

Icō **-** Crested Tern (*Sterna bergii*). Approximately 50 observed resting on flats adjacent to the island**.**

Turī - Whimbrel (*Numenius phaeopus*). 30 observed on the mudflats off the southern beach. This is a large flock of this uncommon and shy migrant, by Fijian standards.

Dilio - Pacific Golden Plover (*Pluvialis fulva*). A few individuals mixed in with the Wandering Tattlers (see below).

Batibalavu, teitei kai dawa - Bar-tailed Godwit (*Limosa lapponica*). 8 noted (but see note below).

Dilio seasea - Turnstone (*Arenaria interpres*). A few individuals mixed in with the Wandering Tattlers.

Juli - Wandering Tattlers (*Heteroscelus incanus*). A flock of over 200 on the mudflats off the southern beach.

Points of Interest – Wildlife

As to be expected, nothing of great interest or unexpected in the mangroves or the small dry-land area. However, the mudflats adjoining the island are extensive and of major interest in respect of Nasoata's possible selection for Ramsar nomination. Over 300 waders were observed on these mudflats, the majority of which were Wandering Tattlers which are our last waders to leave on their northern migration (they leave in late April or early May). Fiji's other commoner waders, the Golden Plovers, Bar-tailed Godwits and Turnstones have already left on their northern migration which accounts for their low numbers during our visit. If these waders occur around Nasoata in the same proportion as they do at Suva point, where the numbers are monitored, then peak numbers in February, March at Nasoata would be approximately 900-1000, a very impressive number by Fijian standards, and a major attribute for Nasoata's possible selection, provided the adjacent mudflats are part of the selected site. Two of these mudflats are quite elevated, i.e., they concentrate the waders as the tide rises and allow them to rest and feed when much of the surrounding flat is submerged.

Mangroves

The visit confirmed the observations made in 1985 that Nasoata Island has an outstanding stand of **Dogo** (*Bruguiera gymnorhiza*), as impressive as any I have seen anywhere in Fiji. The small area of **Dabi** (*Xylocarpus granatum*) dominated mangrove is also very impressive. Overall the mangroves look almost completely untouched, whereas many similar areas on the `mainland' have had some felling – Nasoata was never included in Forestry's coup plan for the exploitation of timber and firewood in the Rewa mangroves.

Conclusions

In my opinion, Nasoata has the following attributes for Ramsar nomination –

Positive:

- A very good example of `classical' Rewa mangrove with fringing **Tiri** (*Rhozophora* spp.) and very impressive stand of **Dogo** (*Bruguiera gymnorrhiza*) inside;
- Impressive **Dabi** (*Xylocarpus granatum*) stand;
- A nationally important wader habitat surrounding the island;
- Minimal disturbance to the mangrove, existing use appears to be non-destructive;

Negative

There is no easy access for visitors – this, however, may be interpreted as beneficial, since access could then be controlled to the advantage of landowners and fishing rights owners.

There are four places along the west coast of the island that have been infested with trailing daisy or wedelia (*Wedelia trilobata*) which has invaded mangroves, river courses and coastlines on mainland Fiji and other areas in the Pacific Islands. This could become one of the most invasive weeds in the Pacific Islands (e.g., it is already a major pest in Pohnpei and Fiji), and could lead to serious ecological disturbance, particularly on small offshore islands and in mangrove ecosystems

In some areas there has been some cutting of mangroves in the interior part of the island.

VASCULAR PLANTS OF NASOATA ISLAND, REWA DELTA, REWA PROVINCE, VITI LEVU, FIJI

R. R. Thaman[12], Alifereti Naikatini[13], Batiri Thaman[14], Timoci Gaunavinaka[15], Nemani Bolaqace[16] and Manasa Masere[17]

PTERIDOPHYTA (Ferns and Fern Allies)

ASPLENIACEAE (Spleenwort Fern Family)

Asplenium nidus L. bird's-nest fern

Fijian: vale ni gata?, beluve, butubutu, dovidovi, taqala

Indigenous. Paleotropical. Rare. Single plant seen near the ground growing on an old *Entada phasioloides* vine trunk on the margin of inner swamp inland from the former Hedstrom settlement area on the southeast corner of the island.

BLECHNACEAE (Water Fern Family)

Stenochlaena palustris (Burm.) Beddome

Fijian: wamidri, sinasina, vulavula

Indigenous. Northern India to Polynesia and northern Australia. Uncommon. Climber on large **uto ni bulumakau** (*Annona glabra*) and some other trees on the margins of the backswamp area inland from the former Hedstrom settlement area on the southeast corner of the island. Stems used to bind *Miscanthus flloridulus* stems together to make fish fences; young fronds also edible and cooked as a vegetable (**ba ni ika, ba ni ilava**) (1).

DAVALLIACEAE (Hare's- Foot Fern Family)

?Davallia fejeensis Hooker Fiji hare's-foot fern

Fijian: wavulovulo, auvutimerakula, vuluvululevu, vativatimatalalai

Endemic to Fiji. Found on Viti Levu, Vanua Levu, Ovalau and Taveuni. Common. Found both living and dead trees in both mangroves and in inner coastal forest. Used medicinally in many areas of Fiji. Leaves crushed and used to treat and bandage wounds; juice of the leaves used to aid the healing of fractured bones; plants reportedly used to treat stomachache

?Davallia solida (Forst. f.) Swartz hare's-foot fern

Fijian: mokomokoni ivi?, wavulovulo, auvutimerakula, vaulavualilevu

Indigenous. Malesia to Eastern Australia and Polynesia. Occasional. Found both living and dead trees in both mangroves and in inner coastal forest.

NEPHROLEPIDACEAE (Sword Fern Family)

?Nephrolepis biserrata (Sw.) Schott fishtail fern
Fijian: digi

Recent introduction. East Asia, Africa, Brazil, Florida. Occasional. Found as an epiphytic ferns on older trees on the margins or in slightly raised areas of the mangrove and uncommonly in inner coastal forest. Reportedly used medicinally in some parts of Fiji to aid child delivery.

?Nephrolepis hirsutula (Forst.) Presl. sword fern, fishtail fern
Fijian: digi

Indigenous. Tropical Asia to Polynesia and Micronesia.. Occasional. Found in isolated clusters on the margins of mangrove as an epiphyte. This fern could in fact be *Nephrolepis biserrata* (Sw.) Schott. Used medicinally to treat diarrhoea in some areas of Fiji.

POLYPODIACEAE (Common Fern Family or Polypody Fern Family)

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[12] Professor of Pacific Islands Biogeography, The University of the South Pacific, Suva, Fiji Islands.
[13] Technician, South Pacific Regional Herbarium, The University of the South Pacific, Suva, Fiji Islands.
[14] Scientific Officer, Institute of Applied Science, The University of the South Pacific, Suva, Fiji Islands.
[15] Research Officer, Department of Environment, Fiji Government, Suva, Fiji Islands.
[16] Community Consultant, Nakorovou Village, Rewa Delta, Rewa Province, Viti Levu, Fiji Islands.
[17] Community Consultant, Drakena Village, Rewa Delta, Rewa Province, Viti Levu, Fiji Islands.

Drynaria rigidula (Sw.) Bedd. basket fern
Syns. *Polypodium rigidulum* Sw.
Fijian: vale ni gata, koukou yalewa

Indigenous. Sumatra and Malaysia to Australia to Polynesia. Uncommon. Epiphytic fern with seen growing on a **dogo** (*Bruguiera gymnorrhiza)* in the central Bolavou Swamp on the eastcentral part of the island.

Phymatosorus grossus (Langsd. & Fisch.) Brownlie scented fern
Syns. *Microsorum grossum* (Langsd. & Fisch.) S.B. Andrews; *Polypodium grossum* Langsd. & Fisch.
Misapplied names: Phymatosorus scolopendria (Burm.f.) Pichi-Serm.; Polypodium scolopendria Burm.f.; Phymatodes scolopendria (Burm.) Ching; Microsorium scolopendria (Burm.) Copel.; Polypodium phymotodes L.

Fijian: vativati, kadakada

Indigenous. Paleotropical. Uncommon. Terrestrial and epiphytic fern under coconut plantations, on the bases of coconut trunks, and in the coastal strand vegetation on the southeastern part of the island. Very important medicinal plant throughout Fiji; juice of leaves used to treat stomach ache and boils, as a purge, and for swollen breasts during breast feeding; juice from leaves and slimy rhizome used to assist breathing; an infusion of the pounded stem is used to treat fish poisoning; an infusion of the plant used in medicines to strengthen mothers after childbirth and to assist postnatal discharge.

Pyrrosia lanceolata (L.) Farwell lanceolate felt fern
Syn. *Pyrrosia adnascens* (Sw.) Ching
Fijian: mokomoko, mokomoko ni ivi

Indigenous. India and South China to Polynesia. Common. Found as a small epiphytic fern on the trunks of trees in the inner part of the mangrove and on trees inland from the coastal strip. Used medicinally in many areas of Fiji; leaves crushed and used to treat and cover fresh wounds; stems used to treat urinary infections; plant also reportedly used to treat fevers.

PTERIDACEAE (Bracken or Brake Fern Family)

Acrosticum aureum L. swamp fern, mangrove fern
Fijian: borete, burete, caca, drababasavuga, babasaga

Indigenous. Pantropical. Abundant. Found growing as an understory species backswamps of *Bruguiera gymnorrhiza*, *Xylocarpus granatum* and a side range of mangrove associates, in the central mangrove swamps of Bolavou, and behind the main mangroves. Young fronds edible when cooked. Important medicinal plant in many parts of Fiji where fronds reportedly used to treat constipation; chewed roots and leaves used as a remedy for fever, sore throat and lungs, chest pains and sinus troubles; fronds used during pregnancy and the plant is also said to be used to treat elephantiasis.

VITTARIACEAE (Tape Fern Family)

Vaginularia angustissima (Brack.) Mett**.** grass fern
Syns. *Monogramma paradoxa* (Fee) Bedd.; *Vaginularia paradoxa* Fee
Fijian: mokomoko ni ivi

Indigenous. Fiji and possibly Vanuatu. Rare. Seen on the base of a small **dabi** (*Xylocarpus granatum*) tree in a slightly raised area in Bolavou Swamp in the east-central part of the island. Used medicinally with **vativati** (*Phymatosorus scolopendria*) as a medicine for babies and young children.

Vittaria elongata Swartz tape fern
Fijian: kumi ni tuwawa
Old World tropics from Africa through Asia to Polynesia. Uncommon. Found in a number of sites on trees in slightly raised areas in Bolavou Swamp in the east-central part of the island and near the coast on the outer margin of the central mangrove swamp on the southeastern part of the island.

ANGIOSPERMAE (Angiosperms)
MONOCOTYLEDONAE (Monocotyledons)

AGAVACEAE (Century Plant Family)

Cordyline fruticosa (L.) A Chev. cordyline, ti-plant (Hawaii)
Syns. **C. terminalis** (L.) Kunth; **Taetsia fruticosa** (L.) Merr.
Fijian: vasili, qai, masawe, qolo

Recent introduction. Tropical Asia. Uncommon. Seen growing wild in area inland from, and in the areas of the Hedstrom settlement on the southeast part of the island. Planted as an ornamental in villages and occasionally naturalised in garden and fallow areas and open forest throughout Fiji. A number of different cultivated varieties recognized. Leaves used in traditional dancing costumes and to wrap food for cooking in the earthen oven (**lovo**), especially to wrap Fijian bread (**madrai ni Viti**) which is normally made out of cassava (**tavioka**) starch. Also widely used medicinally throughout Fiji. The tuber of the green-leaved variety was formerly cooked in an earthen oven for over a week to yield a sugar like desert.

ARECACEAE or **PALMAE** (Palm Family)

Cocos nucifera L. coconut palm
Fijian: niu

Native and aboriginal introduction. Southern Asia, Indian Ocean and Pacific Islands. Abundant. Common on the inner margins or mangroves and on the beaches along the southeast and south coast of the island. Large plantations still exist inland from the coast of the southeast and southern parts of the islands, where there are countless seedling and palm in all stages of regrowth. The Pacific Islands's tree of life. Formerly

processed into copra for sale on the island.

COMMELINACEAE (Dayflower or Spiderwort Family)

Commelina diffusa Burm. f. day flower
Fijian: airogorogo, airorogi, drano, cobulabula, matabulabula, wa cabocola

Recent introduction. Southern Asia. Rare. Single plant seen growing in the area of the former Hedstrom settlement on the southeastern side of the island. Used as a medicinal plant throughout Fiji.

CYPERACEAE (Sedge Family

Mariscus javanicus (Houtt.) Merr. sedge, marsh sedge
Syn. *Cyperus javanicus* Houtt.
Fijian: dava i raduna, benici selesele, benici

Indigenous. Paleotropical from Africa through tropical Asia into the Pacific Islands to Micronesia and Polynesia. Uncommon. Seen in a couple of sites on the inner margins of the coastal forest and mangroves on the northeast of the island and in the inner beach forest on the south coast of the island.

Scirpodendron ghaeri (Gaertn.) Merr.
Syns. *Chionanthus ghaeri* Gaertn.; *Hypolytrum costatum* Thw.; *Scirpodendron costatum* Kurz.
Fijian: vulu, misimisi

Indigenous. Sri Lanka thorough Malesia and northern Australia to Fiji, Samoa and Micronesia. Occasional. In swampy, but better-drained areas on the margins of central mangrove basin in the southeastern part of the island. Leaves used for thatching houses.

Scleria polycarpa Boeck.
Fijian: tavatava i raduna, benici selesele

Indigenous. Ranges from northeastern Australia through Melanesia to Samoa and Tonga and to the Marianas and Caroline Islands in Micronesia. Uncommon in moist sites inland from the coastal forest on the northeast side of island and in areas bordering the old Hedstrom settlement on the southeast side of the island.

ORCHIDACEAE (Orchid Family)

?Bulbophyllum longiscapum Rolfe
Fijian: vadra, voivoi

Indigenous. Solomon Islands to Fiji, Tonga, Uvea, Samoa and Niue. Rare. Identification unsure; seen on a large *Xylocarpus granatum* in the centre of Bolavou Swamp.

PANDANACEAE (Pandanus Family)

Pandanus tectorius Warb. pandanus, screw pine
Syns. *Pandanus pyriformis* Gaud.; *Pandanus carolinianus* Martelli; *Pandanus odoratissimus* L. f. var. *novaguineensis* (Martelli) St. John; *Pandanus pulposus* (Warb.) Martelli; *P. odoratissimus* L.f. var. *pyriformis* Mart.; *P. fragrans* Gaud.
Fijian: vadra, voivoi

Indigenous and probably an aboriginal introduction or locally horticulturally developed in the case of the particularly useful cultivars. Pacific Islands. Common. Adult trees scattered throughout the inner parts of the mangrove; seedling numerous in backswamp areas; occasional in strand forests along beaches on the southern and southeastern parts of the island; one small tree, about 1.5 m high seen growing on a large branch of an **ivi** (*Inocarpus fagifer*) tree inland from the former Hedstrom settlement on the southeast coast of the island.

POACEAE OR GRAMINAE (Grass Family)

Arundo donax L. giant reed
Fijian: gasau ni vavalagi, sina ni vavalagi

Recent introduction. Tropical Asia and the Mediterranean area. Rare. A couple of plants seen just inland from the beach on the southeast corner of the island about 400 m to the west of the Hedstrom settlement. Could become weedy if allowed to persist on the island.

Brachiaria mutica (Forsk.) Stapf Para grass, Mauritius grass
Syn. *Panicum muticum* Forsk.
Fijian: para, parakarasi

Recent introduction. Northern Africa, but probably established in South America in the early days of trading; now a widespread fodder grass. Introduced into Fiji in 1877 as a pasture grass. Uncommon. Locally common on the inner, upper beach ridge on the southeast part of the island about 400 m east of the former Hedstrom settlement; also present with **lawere** (*Ipomoea pes-caprae*) on beach on the southwest tip of the island facing Nukui Village.

?Centotheca lappacea (L.) Desv.
Fijian: luna, bitubitu

Probably an aboriginal introduction. Tropical Africa through Asia and Malesia to the western Pacific Uncommon. Found along paths and in moist shady places inland from the southeast coast of the island.

Ischaemum indicum (Houtt.) Merr. Batiki blue grass
Fijian: luna

Recent introduction. India, Southeast Asia and parts of Malesia. Uncommon. One extensive area covering the entire open area of the former Hedstrom Residence site.

Lepturus repens (G. Forst.) R. Brown beach bunch grass
Fijian: vutika

Indigenous. Sri Lanka through Malesia and northern Australia to Polynesia and Micronesia. Occasional. Occurring in clusters among strand vegetation on sandy beaches and around bases of coconut palms that have been eroded away from the original coastline. Plant has a well developed root system with runners that make it a good sand binder.

Oplismenus compositus (L.) Beauv. basket grass
Syn. **Panicum compositum** L.
Fijian: luna?

Recent introduction. Ceylon. Rare. Seen in only one site inland from the southeast corner of the island.

Miscanthus floridulus (Labill.) Warb. sword grass
Fijian: gasau, sina

Indigenous. Indian Ocean through Malesia to the Society Islands. Rare. One single clump found growing about 70 m from the sea in the open grassy area of the former Hedstrom settlement. Bamboo-like stems used for walling and the leaves for thatching for the roofs of Fijian houses (**bure**); stems also used for making fish traps and as trellising in yam gardens.

Paspalum vaginatum Sw. knot grass, salt grass, knotweed, swamp couch grass
Syns. *Paspalum distichum* L. (some authors); *P. littorale* R. Br.
Fijian: kabuta, kabuta nawanawa

Indigenous. Tropical America, but now pantropical. Common. Found forming dense patches on some beaches on the southeast and south coasts of the island, and seen occasionally in open areas in the mangroves elsewhere on the island Found in brackish marshy areas and bordering mangrove areas in many areas of Fiji.

??Sporobolus diander (Retz.) Beauv.? Indian dropseed
Syn. **Agrostis diander** Retz.
Fijian: ?

Recent introduction. Southern Asia. Rare. One plant seen near the back of the former Hedstrom settlement.

Stenotaphrum micranthum (Desv.) Hubb.
Syns. **Ophiurinella micrantha** Desv.; **Stenotaphrum subulatum** Trin.
Fijian: ?

Indigenous. Mascarene Islands in the Indian Ocean through Malesia to eastern Polynesia and the Marshall Islands in Micronesia. Rare. Possibly seen at one site on the inland margin of the beach on the southeast corner of the island.

Thuarea involuta (Forst. f.) R. Br. ex R. & S.
Syn. **T. sarmentosa** Pers.
Fijian: co seni ni wei taci (Y)

Indigenous. Madagascar to Eastern Polynesia and Micronesia. Rare. Possibly seen at one site on the inland margin of the beach on the southeast corner of the island. (Need to confirm, as this is either *Thuarea* of *Stenotaphrum*).

TACCACEAE (Polynesian Arrowroot Family)

Tacca leontopetaloides (L.) O. Kuntze Polynesian arrowroot
Syn. **Tacca pinnatifida** J.R. and G. Forster
Fijian: yabia, abia

Possibly indigenous, but probably and aboriginal introduction. India and Sri Lanka through Malesia to Melanesia. Uncommon. Seen in undergrowth of coconut plantations and in the inner margin of coastal littoral forest on the southeastern part of the island. Potato-like tubers used in the past to make starch for Fijian pudding (**madrai ni Viti**) and to be used as and glue or paste for tapa cloth in other areas of Fiji.

ZINGIBERACEAE (Ginger Family)

Zingiber zerumbet (L.) Sm. wild ginger
Fijian: ulaula i rabici, cagolaya, layalaya, drove, beta, lailai

Aboriginal introduction. Tropical Asia. Occasional. Found in drier inland areas as an understory plant in disturbed forest and thickets on the southeastern part of the island.

DICOTYLEDONAE (Dicotyledons)

ANACARDIACEAE (Cashew or Rhus Family)

Mangifera indica L. mango
Fijian:maqo

Recent introduction. Indo-Burma. Uncommon. One mature tree seen in the former Hedstrom settlement and a young tree seen inland in a tree grove, probably an old garden site in the southeast of the island.

ANNONNACEAE (Custard Apple Family)

Annona glabra L. pond apple
Fijian: uto ni bulumakau, seremaia

Recent introduction. Tropical and subtropical America. Abundant. Found in the backswamp areas on the inner parts of the mangroves and occasionally in the middle parts; a stand of very large trees, some with dbh of over 40 cm inland from the southeastern part of the island. A serious invasive species in mangroves in many parts of Fiji.

APOCYNACEAE (Dog-bane Family)

Cerbera manghas L. cerbera
Fijian: vasa, rewa

Indigenous. Tropical Asia to the Pacific. Occasional. A number of medium-sized trees and a number of seedlings found in the inner parts of the coastal strand forest and the inner edges of the mangroves in the southeastern and southern parts of the island.

Plumeria rubra L. frangipani, plumeria
Syns. **P. acuminata** Ait. f.; **P. acutifolia** Poir.
Fijian: bua, bua ni vavalagi

Recent introduction. Tropical America. Rare. A single tree about 3 m high seen in the back end of the former hedstrom residence site.

ASCLEPIADACEAE (Milkweed Family)

Hoya australis R. Br. ex Traill wax vine
Fijian: wa bibi, bitibiti, bitabita, bitubitu, wa bi, drau bibi

Indigenous. Northeastern Australia to Tonga and Samoa. Rare. Seen growing a vesi (Intsia bijuga) trees just inland from the Hedstrom settlement. Leaves used medicinally throughout Fiji and elsewhere in the Pacific Islands.

ASTERACEAE or **COMPOSITAE** (Aster, Sunflower or Composite Family)

Wedelia trilobata (L.) Hitchc. wedelia, trailing daisy
Fijian:

Recent introduction. Tropical America. Uncommon. Three small, but spreading populations seen on the southeastern cost of the island just inland from the beach. The first just to the east side of the frontage of the Hedstrom settlement, and the other two about 400 and 500 m to the west of the settlement. Planted ornamental groundcover; shown to be a serious weed that can out-compete native coastal plants and plants bordering mangroves. The eradication of this plant from Nasoata should be seen as a priority, as it could replace many useful indigenous plants and spread into and cover the entire central part of the island.

BARRINGTONIACEAE (Barringtonia Family)

Barringtonia asiatica (L.) Kurz. fish-poison tree, barringtonia
Fijian: vutu, vutu rakaraka

Indigenous. Madagascar to southeastern Polynesia and Micronesia. Common. Common on the inner margins of the mangroves, in the drier inland sites on the southeast of the island and occasional in the coastal beach forest on the southeast and south coast of the island; seedling numerous. Seeds formerly used to poison fish and the buoyant seeds as fishnet floats.

Barringtonia racemosa (L.) Spreng.
Fijian: vutusiriwai, vutu wai, vutuvala, vutu ni wai, vutuvutu

Indigenous. Eastern and southern Africa including Madagascar to Indian the Ryukyu Islands eastward through Micronesia to Queensland into the Pacific as far east as Samoa. Occasional. A number of seedling, saplings and some small trees seen along the inner margins of the mangroves and backswamps where the water is less saline.

BORAGINACEAE (Heliotrope or Borage Family)

Tournefortia argentea L. f. beach heliotrope
Syn. **Messerschmidia argentea** (L.f.) M. Johnst.
Fijian: roro ni bebe?, kau ni yalewa, evo

Indigenous. Indian Ocean to Southeast Polynesia. Rare. One single small tree seen in the coastal beach forest on the southwest coast of the island. Used medicinally to treat high blood pressure (**tubu ni dra**); elsewhere in Fiji and other Pacific Island the plant is considered one of the most important plants for women's medicine. Also a favoured species by butterflies.

CAESALPINIACEAE (Senna Family)

Intsia bijuga (Colebr.) O. Ktze. ipil tree
Fijian Names: vesi, vehi

Indigenous. Madagascar to Polynesia. Occasional. A few trees on the south side of the central mangrove swamp and inland from the coastal strand forest in the southeast and southern parts of the island. Formerly there were more **vesi** trees on all of Fiji's islands, but overuse for house posts, canoes, and carving kava bowls and other items, plus indiscriminate burning have made it an endangered species. Wood highly valued for woodcarving, house posts and, in the past.

CLUSIACEAE OR GUTTIFERAE (Mangosteen Family)

Calophyllum inophyllum L. Portia tree, Alexandrian laurel, beach mahogany
Fijian: dilo

Indigenous. Tropical Africa to eastern. Polynesia and Micronesia. Occasional. A few medium trees and a number of smaller trees, saplings and seedlings seen on the inner margins of mangroves and in the beach forest on the southeast and south coasts of the island; occasionally found inland from the strand forest.

COMBRETACEAE (Terminalia Family)

Lumnitzera littorea (Jack) Voigt red-flowered black mangrove
Syn. *Lumnitzera coccinea* Wight & Arn.
Fijian: sagale

Indigenous. Tropical Asia through Malesia into Micronesia and Polynesia to the Marshall Islands, Kiribati and Tonga and Tuvalu in Polynesia. Rare. One single fallen, but still living tree seen on the inner margin of the beach on the southwest part of the island. Reportedly formerly common on the island, but extensively cut for houseposts.

Terminalia catappa L. beach almond, Indian almond, Malabar almond
Fijian: tavola vula?, tavola, tivi

Indigenous. Tropical Asia and Australia to W. Polynesia and Micronesia. Common. Occasional in coastal forest, on the margins of mangroves and freshwater swamps, and in drier inland sites, where large trees often dominate the landscape. Leaves used medicinally to treat sore throats and to treat **wai ni vu**? And thrush (**macake**) in both infants and adults; wood used in woodcarving, especially for making slitgongs (**lali**).

Terminalia littoralis Seem.
Syns. **T. littoralis** sensu auct. non Seem.; **T. saffordii** Merr.
Fijian: tavola damu, tavola, tavola ni waitui, tivi ava

Indigenous. Fiji and Tonga. Uncommon Small to medium-sized tree found in coastal strand forest on the south coast of the island. Leaves use medicinally to treat **vu**?

CONVOLVULACEAE (Morning-Glory Family)

Ipomoea littoralis Bl. Littoral morning-glory
Fijian: wa sovivi, sovivi, suani

Indigenous. Malaysia and the Pacific. Rare. Seen in a disturbed site and climbing in trees near the back of the Hedstrom settlement.

Ipomoea macrantha R. & S. wild moon flower; white morning glory
Syn. *Ipomoea tuba* (Schlecht.) G. Don
Fijian: wa damu, tobili, tobici, wa ika

Indigenous. Pantropical. Common. Common liana in coastal strand forest and on the inner margins of coastal mangroves.

Ipomoea pes-caprae (L.) Sweet ssp. **brasiliense** (L.) v. Ooststr. beach morning-glory
Syn. **I. brasiliense** (L.) Sweet
Fijian: lawere, lauwere, wa vulavula, yale, yaleyale,

Indigenous. Pantropical. Uncommon. A number of isolated plants seen in the coastal strand vegetation on the southeast and south coasts; one large population seen on the upper beach ridge on the widest part of the beach on the southeast corner of the island.. Used medicinally to prepare a drink for breastfeeding mothers?

EUPHORBIACEAE (Spurge Family)

Codiaeum variegatum (L.) Bl. croton
Fijian: sacasaca

Recent introduction. Malaysia to Melanesia. Rare. A single plant seen near the back of the former Hedstrom settlement in a grassy area. A common ornamental plant in houseyard garden throughout Fiji.

Excoecaria agallocha L. blinding tree, poison mangrove tree
Fijian: sinu, sinu gaga, hinu, toca, sota

Indigenous. India to Niue in Polynesia, and Yap and Chuuk (Truk) in the Caroline Islands of Micronesia. Abundant. A very common tree on the inner margins of coastal mangroves and on better drained sites in the central Bolavou Swamp; also common in coastal strand forest on the east and

south coasts of the island. Bark used medicinally, at one time to cure leprosy in other parts of Fiji. White sap or latex burns skin and can blind a person if it gets in the eyes.

Macaranga seemannii (Muell.- Arg.) Muell.- Arg. Macaranga
Fijian: gadoa, davo, mama, velutu

Indigenous. Fiji, Tonga and Niue. Rare. A single tree seen about 100 m from the coast in the southeastern part of the island on a upraised area between the inner mangrove swamp and the coast. Sap reportedly used as glue in the past.

FABACEAE (Pea Family)

Canavalia cathartica Thou. Mauna Loa bean (Hawaii)
Syns. **C. microcarpa** (DC.) Piper
Fijian: drau tolu, rau tolu

Indigenous. Pantropical. Occasional. A single plant seen in the coastal strand forest on the southeast corner of the island.. Reportedly used medicinally; stems used to bind house frames.

Dalbergia candenatensis (Dennst.) Prain
Syns. *Cassia candenatensis* Dennst.; *Dalbergia monosperma* Dalz.
Fijian: denimanā, wa denimanā

Indigenous. India to southern China eastward through Malesia to northern Australia and Tonga. Common. Climbing liana or sprawling shrub found on the inner margins of coastal mangroves and on well-drained sites throughout the central mangrove area, and occasional inland from beaches.

Derris trifoliata Lour. derris vine, derris root
Syn. **Derris ulignosa** Willd.
Fijian: wa duva, wa lai, duva, wa tuva, tuva, duva ni Viti, tuva ni Viti, duva gaga, raurau

Indigenous. Eastern Africa to tropical Asia eastward through Malesia to Tonga and Samoa in Polynesia and to Nauru and the Caroline Islands in Micronesia. Abundant. Found climbing trees and shrubs on the margins of the intertidal flat and in the backswamp area and in well0drained inland sites and in coastal strand forest. Crushed roots and stems used as a fish poison. Parts of plant used medicinally.

Desmodium heterophyllum (Willd.) DC. tropical trefoil
Fijian: seni vakacegu, wakutu

Recent introduction. Southeastern Asia to Malesia, and perhaps the Mariana Islands in Micronesia. Now naturalised on many Pacific Islands. Rare. Seen growing amongst Batiki blue grass (*Ischaemum indicum*) in the former Hedstrom settlement area.

Erythrina variegata var. **orientalis** (L.) Merr. coral tree, dadap
Fijian: drala, rara

Indigenous. Zanzibar and other Indian Ocean Islands north to India, China and the Ryukyu Islands, and eastward through Malesia into the Pacific to the Society Islands and the Marquesas and the Marshall Islands. Rare. A single tree, about 10 m high seen growing on the beach below the erosion scarp on the southwest corner of the island Used medicinally to throughout Fiji.

Inocarpus fagifer (Parkinson) Fosb. Polynesian chestnut, Tahitian chestnut
Syn. *Inocarpus edulis* J.R. and G. Forst.; *Inocarpus fagiferus* Fosberg ex Yuncker Parkinson
Fijian: ivi

Recent introduction; possibly an aboriginal introduction in the past. Reportedly native from Malesia into Micronesia as far as Kosrae and the Marshall Islands and as far west as French Polynesia. Common. A large number of small and medium-sized trees seen on better-drained soils on the southeast side of central Bolavou Mangrove Swamp; an number of large trees also seen inland from the coastal zone on the southeast portion of the island.

Pongamia pinnata (L.) Merr.
Syn. *Cytisus pinnatus* L.
Fijian: vesi wai?, tavesivesi, vesi ni wai, tosiga, `tohiga

Indigenous from the Indian Ocean to Fiji and Samoa and into the large islands of Micronesia. Occasional. Occasional. Found as scattered individuals on the southern drier margin of the central mangrove swamp, and occasionally in land from the coastal forest on the south coast. Wood used occasionally in construction; used medicinally to treat women's ailments.

Vigna marina (Burm.) Merr. beach pea, beach bean, vigna
Fijian: drautolu, toka tolu, wa vue

Indigenous. Pantropical. Common. Common on the sandy inner margins of the coastal strand vegetation, often climbing in coastal thickets on the southeast and south coasts of the island. Leaves used medicinally to treat body aches (**mosi ni yago**) and for treating women's ailments.

GOODENIACEAE (Naupaka Family)

Scaevola taccada (Gaertn.) Roxb. beach saltbush, half-flower
Syn. **Scaevola sericea** Vahl.
Fijian: vivevedu, vevedu, dredre

Indigenous. Tropical Asia to Hawaii. Uncommon. A few medium sized shubs found in the coastal strand forest in sandy sites on the southeast and south coast of the island. Fruit used medicinally to treat conjunctivitis (**sui ni cika**), the bark and stems mixed with other plant extracts to treat a

number of sicknesses throughout Fiji**.**

HERNANDIACEAE (Hernandia Family)

Hernandia nymphaeifolia (Presl.) Kubr. lantern tree, hernandia
Syns. *Hernandia sonora* L.; *Hernandia. peltata* Meisn
Fijian: evuevu, yevuyevu, buevu

Indigenous. Tropical Asia to the Pacific Islands. Occasional. Tree in the coastal forest along the sandy beaches on the southeast and south coasts of the island. Used medicinally to facilitate childbirth (**wai ni taratara**).

LAMIACEAE or **LABIATAE** (Mint Family)

Hyptis pectinata. (L.) Poit. mint weed, wild mint, purple top
Fijian: tomole, tamole ni vavalagi, wavuwavu, ben tulsia (Hindi)

Recent introduction. Tropical America. Uncommon. Seen in disturbed sites on the former Hedstrom settlement and in disturbed open well-drained sites in the southeast of the island. Common weed of waste places throughout Fiji.

LAURACEAE (Laurel Family)

Cassytha filiformis L. beach dodder, devil's twine
Fijian: wa urulagi, wa uruilagi, wa lutumailagi, wa verlagi, dredruma, fatai, bualawalawa

Indigenous. Pantropical. Common. Common on shrubs and in coastal thickets inland from coastal mangroves and in coastal strand forest. Plant used medicinally to treat stomach aches (**mosi ni kete**) and a **wai ni taratara** for women; leafless net-like stems used a fishing net for **daniva** (fourspot herring, gold-spot herring**, *Herklotsichthys quadrimaculatus***); twining stems also used as makeshift casual head garlands as an indication of having a good time on picnics.

MALVACEAE (Mallow Family)

Hibiscus tiliaceus L. beach hibiscus, hibiscus tree
Fijian: vau

Indigenous. Pantropical. Common. Occasional on the inner margins of coastal mangroves and common in thickets on drier sites and inland from the coastal forest on the southern part of the island. One of the Pacific Island's most useful plants. Inner bark or bast fibre used to make dance skits, material, to tie things together, and to strain kava (**yaqona**) and coconut cream. Leaves, particularly those of **vau leka** are used as an analgesic to wrap broken bones, torn ligaments and sprains. Light straight branches and stems or trunks occasionally used in house construction, in making connectives in boatbuilding and for specialized woodcarving of light items, such as spoons, etc. Also occasionally used as firewood.

Sida rhombifolia L. broomweed, broom plant, Cuba jute, Paddy's lucerne, coffee bush
Fijian: qawe ni lawe, qavi ni lawe, cavucidra, de ni me, de ni ose, de ni vuaka

Recent introduction. Pantropical. Rare. A single plant seen in an open site in the former Hedstrom settlement.

Thespesia populnea (L.) Sol. ex Correa Thespians tree, milo (Hawaii and Polynesia)
Fijian: mulomulo, wiriwiri

Indigenous. Paleotropics and the Pacific Islands. Common. Found on the inner margins of coastal mangroves and occasional in coastal strand forest on the southeast and south coast. Durable and attractive chocolate-brown wood favoured for woodcarving and used for outriggers, spears, knife handles and other carved islands. Bark used medicinally to treat stomach aches (**mosi ni kete**), as exlax (**sava ni kete**) and thrush (**macake**).

MELASTOMATACEAE (Melastoma Family)

Clidemia hirta (L.) Don Koster's curse
Fijian: dradrasiga, severo, mara na bulumakau

Recent introduction. Mexico, West Indies, Brazil. Rare. A couple of plants growing in and around the former Hedstrom settlement. A serious noxious weed of shady sites, shady trailsides and forest margins on the main islands.

MELIACEAE (Mahogany Family)

Dysoxylum richii (A. Gray) C. DC. stinkwood
Fijian: tarawau kei rakaka, tarawau kei coge, sasawira, sasauira, hauira

Indigenous to Fiji, Tonga and Niue. Rare. One single tree growing inland on the well-drained sites on the southeast corner of the island.

Xylocarpus granatum Koenig puzzle nut
Fijian: dabi, leqileqi, leqileqi alewa, lokoloko

Indigenous. India and Sri Lanka through Malesia to the Caroline Islands in Micronesia and Tonga in Polynesia. Abundant. Abundant in more well-drained areas of Bolavou Swamp in the interior of the islands, and common to occasional in the inner portions or coastal mangroves forests and in coastal strand forest. Very important Fijian medicinal plant; Bark used medicinally to treat stomach ailments, headaches (**kuita**) and **sasala ni yago**. Considered an excellent firewood.

Xylocarpus moluccensis (Lam.) M. Roemer puzzlenut
Fijian: dabi, leqileqi, leqileqi taqwane, bolavatu

Indigenous. Madagascar to India and eastward through Malesia to the Marianas Islands in Micronesia and to Tonga and Samoa in Polynesia. Rare. A couple of trees seen in the coastal strand forest on sandy sites on the southwest corner of the island. Considered an excellent firewood.

MIMOSACEAE (Mimosa Family)

Entada phaseoloides (L.) Merr. water vine, St. Thomas bean
Fijian: wa lai, **cibicibi**, wa tiqiri, wa taqiri

Indigenous. Tropical Asia, through Malesia east to Cook Islands. Common. Occasional n the inner margins of coastal mangroves and common in Bolavou Swamp and in forests in the centre of the island where there are some giant vines over 100 m long and over 30 cm in diameter. Drinking water obtained from the hanging loops of the large stems of mature plants; smaller stems used to bind timbers in house construction or for binding fences; seeds (**ai cibi**) used for dancing anklets, as large beads in handicrafts and in children's games in which they are skidded across pandanus mats. Parts of the plant reported to be used medicinally.

Leucaena leucocephala (Lam.) de Wit leucaena, lead tree, jumbie tree
Syn. *Leucaena. glauca* (L.) Benth.
Fijian: vaivai, vaivai dina, vaivai du, vaivai ni vavalagi, balori (hindi)

Recent introduction. Tropical America. Uncommon. Seen in a couple of drier sites inland from the southeast coast of the island and inland from the southwest coast. Considered an excellent firewood; seeds used in necklaces and other handicrafts; leaves fed to goats and cattle. A well-known nitrogen-fixing species.

Mimosa pudica L. sensitive plant, sensitive grass
Fijian: co gadrogadro, o gadrogadro, o moku

Recent introduction. Tropical America, but now pantropical. Rare. Seen in a couple of disturbed sites on the former Hedstrom settlement on the southeast of the island. Weed in cultivated areas, lawns, pastures, waste places; considered to be a troublesome weed in many areas.

MORACEAE (Mulberry Family)

Ficus barclayana (Miq.) Summerhayes Barclay's fig
Fijian: losilosi, loselose, masi, masimasi, vuaiatmona

Indigenous. Endemic to Fiji. Uncommon. A few plants seen on the southern edge of the central mangrove area and around the former Hedstrom settlement. Very important medicinal plant throughout Fiji.

Ficus vitiensis Seem. Fiji fig
Fijian: lolo, koba

Indigenous. Endemic to Fiji and frequent on many islands. Uncommon. A number of trees seen in inland tree stands on the more well-drained sites near the former Hedstrom settlement on the southeast part of the islands. Fruit and leaves edible.

PASSIFLORACEAE (Passion Flower Family)

Passiflora laurifolia L. bell apple, laurel-leaved passionfruit
Fijian: qaranidila, karadila

Tropical America. Occasional. High climbing vine naturalised on the margins of coastal mangrove forest, on the drier southern parts of the central mangrove forest, and in the disturbed tree groves on the southeast of the main island.

POLYGALACEAE (Polygala Family)

Polygala paniculata L.
Fijian Names: lole, tavitaviraki

Recent introduction. Tropical America. Rare. Seen as a weed in disturbed in a couple of sites around the former Hedstrom settlement.

RHAMNACEAE (Buckthorn Family)

Colubrina asiatica (L.) Brongn. soapbush, hoop withe
Syns. *Ceanothus asiaticus* L.; *Ceanothus capsularis* Forst. f.
Fijian: vuso levu, wa vuso, vere, verevere

Indigenous. Eastern Africa, Indian Ocean islands and southeastern Asia extending through Malesia to Australian and the Pacific Islands eastward to the Tuamotus. Occasional. Locally common on the inner margins and in coastal thickets on the southwest corner of the island. A traditional source of soap in Fiji and other Pacific islands.

?Smythea lanceata (Tul.) Summerhayes
Fijian: wa vuso?

Indigenous. Seychelles, Philippines, Malay Peninsula and Sumatra eastward to the Caroline Islands in Micronesia and to Fiji. Common. Found on the inner margins of coastal mangroves, in inner coastal forest and inland thickets. Needs to be confirmed.

?Ventilago vitiensis A. Gray ventilago
Fijian: vere, wawa?

Indigenous. Fiji, Tonga and the Cook Islands. Uncommon. Climber in disturbed sites along trailsides and in disturbed thickets.??

RHIZOPHORACEAE (Mangrove Family)

Bruguiera gymnorrhiza (L.) Lam. f. black mangrove, oriental mangrove, brown mangrove
Fijian: dogo, lailai

Indigenous. Indo-Pacific. Very abundant. Abundant on the inner margins of coastal mangrove forests and the dominant trees in the mangroves of Bolavou Swamp in the central portion of the island. A number of very large trees found in some central portions of the swamp; such areas of *Bruguiera*-dominant swamps are referred to locally as **veidogodogo**. A very important Fijian medicinal and firewood plant; the bark yields a dark black-brown dye used as a preservative (tannin) and dye for tapa cloth in many areas of Fiji. The *Bruguiera*-dominant ecosystem is one of the most important ecosystems for fishing for mangrove lobsters, **manā** (*Thallasa anomala*) and mangrove crabs, **kuka damu** (*Sesarma erythrodactyla*) and **kuka loa** (*Metopograpsus messor*).

Rhizophora samoensis (Hochr.) Salvoza mangrove
Syn. *Rhizophora mangle* var. *samoensis* Hochr.
Fijian: tiri wai, tiri dina, dogo

Indigenous. East Asia to Micronesia and Western. Polynesia. Very abundant. The dominant species in the outpost zone of coastal mangroves around the entire island and common on the margins of the in the inner part of the outpost zone and occasional in the backswamp area. Very important source of firewood and medicine. The *Rhizophora*-dominant ecosystem, including *Rhizophora stylosa* (**tiri solo**), is referred locally as **vei kaka**.

Rhizophora stylosa Griff. mangrove
Syn. *Rhizophora mucronata* A. Gray var. *stylosa* Schimper
Fijian: tiri solo, tiri, tiri wai, dogo

Indigenous. Formosa to Malesia and northern Australia and eastward to New Caledonia, Tonga and Tuvalu and to Kiribati in Micronesia. Abundant. Common species on the inner margins of mangroves, in more well-drained areas of the inner mangrove swamp and occasionally as stands on the southern, more sandy coast.

RUBIACEAE (Coffee Family)

Morinda citrifolia L. beach mulberry, Indian mulberry
Fijian: kura

Indigenous. Tropical Asia and Australia to Southeast Polynesia. Occasional. Found on the inner drier margins of coastal mangroves, in thickets and stands of trees in the southeast of the island and sometimes just behind the coastal strand forest on the south coast of the island. One of Fiji's and the Pacific Island's most important medicinal plants, the fruit of which is sold locally and exported to produce "noni" a multi-million dollar health product, elixer and naturopathic medicine.

??Unknown ?Spermacoce bartlingiana (DC) Fosb. or **Mitracarpus hirtus** (L.) DC.
Syn. *Spermacoce hirta* L; *Spermacoce villosa* Sw.; *Mitracarpus villosus* DC.

Recent introduction. Southern Asia/Tropical America. Rare. Weed in waste places in disturbed areas bordering the inner mangroves on the southeastern part of the island.

Tarenna sambucina (Forst. f.) Dur. ex Drake
Fijian: vakacaredavui, ai caradavui

Indigenous. New Caledonia to Southeast Polynesia and Micronesia. Rare. A single juvenile plant found in a well-drained area in a stand of trees in the southeast portion of the islands. Very important medicinal plant throughout Fiji and the Pacific Islands.

STERCULIACEAE (Cocoa Family)

Heritiera littoralis Ait. Looking-glass tree
Fijian: kedra ivi yalewa na kalou, kendra ivi na kuka, savara buludamu, iolomasima

Indigenous. Eastern Africa to India, north to Taiwan and through Malesia to Fiji, Tonga and Samoa. Common. Common on the inner margins of coastal mangroves, occasional in more well-drained areas of the central mangrove, and uncommon in the inner parts of coastal strand forest along the windward south coast of the island.

VERBENACEAE (Verbena Family)

Clerodendrum inerme L. beach privet
Fijian: verevere, aria

Indigenous. Indomalaysia, Australia and the Pacific Is. Common. Found on inner margins of coastal mangroves and in occasionally in thickets on the inner margins of coastal strand forest on the windward south coast. where it occurs as a scandent climbing shrub. Used medicinally in Fiji and throughout the Pacific.

Lantana camara L. var. **aculeata** (L.) Mold. lantana
Fijian: lanitana

Recent introduction. Tropical America. Uncommon. A few plants found around the former Hedstrom settlement in the southeast of the island.

Premna serratifolia L. premna
Syns. *Premna. obtusifolia* R. Br.; *Premna taitensis* Schauer
Fijian: yaro, araro

Indigenous. Indopacific. Occasional. Found as isolated individuals on the inner margins of mangroves and coastal littoral forest and in inland thickets on well-drained sites in the southeast of the island. Plant used medicinally.

Stachytarpheta urticaefolia Sims blue rat tail, false verbena
Fijian: se ni tieri, se karakarawa

Recent introduction. Tropical America. Rare. A single specimen found in an opening a higher portion of the inner mangrove in the southeast portion of the island.

Vitex trifolia L. var. **trifolia** blue vitex, beach vitex
Syn. **Vitex negundo**
Fijian: dralakaka, drala, drala tagwane, mulokaka, vulokaka

Indigenous. East Africa to Polynesia. Rare. A single mature tree about 3 m tall seen growing on the inner margin of the upper beach terrace on the widest part of the beach on the southeast part of the islands. Leaves used medicinally to body aches (**wai ni yago**) and as a vaporizers or steam bath to cure colds and lung problems? Planted as a manicured hedge, with reported mosquito-repellent properties in Majuro, Marshall Islands.

BIBLIOGRAPHY

Brownlie, G. 1977. *The Pteridophyte flora of Fiji*. J. Cramer, Vaduz.

Fosberg, F.R., Sachet, M.-H., and Oliver, R. 1979. A geographical list of the Micronesian dicotyledonae. *Micronesica* 15(1-2):41-295.

Fosberg, F.R., Sachet, M.-H., and Oliver, R. 1982. Geographical checklist of the Micronesian Pteridophyta and gymnosperms. *Micronesica* 18(1):23-82.

Fosberg, F.R., Sachet, M.-H., and Oliver, R. 1987. Geographical checklist of the Micronesian Monocotyledonae. *Micronesica* 20 (1-2):19-129.

Parham, J.W. 1972. *Plants of the Fiji Islands*. Government Printer, Suva.

Smith, A.C. 1979. *Flora Vitiensis nova: A new flora of Fiji (spermatophytes only)*. Vol. 1. Pacific Tropical Botanical Garden, Lawai, Kauai, Hawaii.

Smith, A.C. 1981. *Flora Vitiensis nova: A new flora of Fiji (spermatophytes only)*. Vol. 2. Pacific Tropical Botanical Garden, Lawai, Kauai, Hawaii.

Smith, A.C. 1985. *Flora Vitiensis nova: A new flora of Fiji (spermatophytes only)*. Vol. 3. Pacific Tropical Botanical Garden, Lawai, Kauai, Hawaii.

Smith, A.C. 1988. *Flora Vitiensis nova: A new flora of Fiji (spermatophytes only)*. Vol. 4. Pacific Tropical Botanical Garden, Lawai, Kauai, Hawaii.

Stemmermann, L. 1981. *A guide to Pacific wetland plants*. U. S. Army Corps of Engineers, Honolulu.

Whistler, A.W. 1980. *Coastal flowers of the tropical Pacific*. The Pacific Tropical Botanical Garden, Lawai, Kauai, Hawaii.

Whistler, W.A. 1995. *Wayside plants of the islands: A guide to the lowland flora of the Pacific Islands including Hawai'i, Samoa, Tonga, Tahiti, Fiji, Guam and Belau*. Isle Botanica, Honolulu.

Appendix: Field checklist of the flora of Nasoata Island, Rewa Delta, Rewa Province, Viti Levu, Fiji Islands.

PTERIDOPHYTA (Ferns and Fern Allies)

ASPLENIACEAE (Spleenwort Fern Family)
Asplenium nidus L. — bird's-nest fern
Fijian: vale ni gata?, beluve, butubutu, dovidovi, taqala

BLECHNACEAE (Water Fern Family)
Stenochlaena palustris (Burm.) Beddome
Fijian: wamidri, sinasina, vulavula

DAVALLIACEAE (Hare's- Foot Fern Family)
?Davallia fejeensis Hooker — Fiji hare's-foot fern
Fijian: wavulovulo, auvutimerakula, vuluvululevu, vativatimatalalai
?Davallia solida (Forst. f.) Swartz — hare's-foot fern
Fijian: mokomokoni ivi?, wavulovulo, auvutimerakula, vaulavualilevu

NEPHROLEPIDACEAE (Sword Fern Family)
?Nephrolepis biserrata (Sw.) Schott — fishtail fern
Fijian: digi
?Nephrolepis hirsutula (Forst.) Presl. — sword fern, fishtail fern
Fijian: digi

POLYPODIACEAE (Common Fern Family or Polypody Fern Family)
Drynaria rigidula (Sw.) Bedd. — basket fern
Fijian: vale ni gata, koukou yalewa
Phymatosorus grossus (Langsd. & Fisch.) Brownlie — scented fern
Fijian: vativati, kadakada
Pyrrosia lanceolata (L.) Farwell — lanceolate felt fern
Fijian: mokomoko, mokomoko ni ivi

PTERIDACEAE (Bracken or Brake Fern Family)
Acrosticum aureum L. — swamp fern, mangrove fern
Fijian: borete, burete, caca, drababasavuga, babasaga

VITTARIACEAE (Tape Fern Family)
Vaginularia angustissima **(Brack.) Mett.** — **grass fern**
Fijian: mokomoko ni ivi
Vittaria elongata Swartz — tape fern
Fijian: kumi ni tuwawa

ANGIOSPERMAE (Angiosperms)

MONOCOTYLEDONAE (Monocotyledons)

AGAVACEAE (Century Plant Family)
Cordyline fruticosa (L.) A Chev. — cordyline, ti-plant (Hawaii)
Fijian: vasili, qai, masawe, qolo

ARECACEAE or **PALMAE** (Palm Family)
Cocos nucifera L. — coconut palm
Fijian: niu

COMMELINACEAE (Dayflower or Spiderwort Family)
Commelina diffusa Burm. f. — day flower
Fijian: airogorogo, airorogi, drano, cobulabula, matabulabula, wa cabocola

CYPERACEAE (Sedge Family)
Mariscus javanicus (Houtt.) Merr. — sedge, marsh sedge
Fijian: dava i raduna, benici selesele, benici
Scirpodendron ghaeri (Gaertn.) Merr.
Fijian: vulu, misimisi
Scleria polycarpa Boeck.
Fijian: tavatava i raduna, benici selesele

ORCHIDACEAE (Orchid Family)
?Bulbophyllum longiscapum Rolfe
Fijian: vadra, voivoi

PANDANACEAE (Pandanus Family)
Pandanus tectorius Warb. — pandanus, screw pine
Fijian: vadra

POACEAE OR GRAMINAE (Grass Family)
Arundo donax L. — giant reed

Fijian: gasau ni vavalagi, sina ni vavalagi

Brachiaria mutica (Forsk.) Stapf — Para grass, Mauritius grass
Fijian: para, parakarasi

?Centotheca lappacea (L.) Desv.
Fijian: luna, bitubitu

Ischaemum indicum (Houtt.) Merr. — Batiki blue grass
Fijian: luna

Lepturus repens (G. Forst.) R. Brown — beach bunch grass
Fijian: vutika

Oplismenus compositus (L.) Beauv. — basket grass
Fijian: luna?

Miscanthus floridulus (Labill.) Warb. — sword grass
Fijian: gasau, sina

Paspalum vaginatum Sw. — knot grass, salt grass, knotweed, swamp couch grass
Fijian: kabuta, kabuta nawanawa

??Sporobolus diander (Retz.) Beauv.? — Indian dropseed
Fijian: ?

Stenotaphrum micranthum (Desv.) Hubb.

Thuarea involuta (Forst. f.) R. Br. ex R. & S.
Fijian: co seni ni wei taci (Y)

TACCACEAE (Polynesian Arrowroot Family)

Tacca leontopetaloides (L.) O. Kuntze — Polynesian arrowroot
Fijian: yabia, abia

ZINGIBERACEAE (Ginger Family)

Zingiber zerumbet (L.) Sm. — wild ginger
Fijian: ulaula i rabici, cagolaya, layalaya, drove, beta, lailai

DICOTYLEDONAE (Dicotyledons)

ANACARDIACEAE (Cashew or Rhus Family)

Mangifera indica L. — mango
Fijian:maqo

ANNONNACEAE (Custard Apple Family)

Annona glabra L. — pond apple
Fijian: uto ni bulumakau, seremaia

APOCYNACEAE (Dog-bane Family)

Cerbera manghas L. — cerbera
Fijian: vasa, rewa

Plumeria rubra L. — frangipani, plumeria
Fijian: bua, bua ni vavalagi

ASCLEPIADACEAE (Milkweed Family)

Hoya australis R. Br. ex Traill — wax vine
Fijian: wa bibi, bitibiti, bitabita, bitubitu, wa bi, drau bibi

ASTERACEAE or **COMPOSITAE** (Aster, Sunflower or Composite Family)

Wedelia trilobata (L.) Hitchc. — wedelia, trailing daisy
Fijian:

BARRINGTONIACEAE (Barringtonia Family)

Barringtonia asiatica (L.) Kurz. — fish-poison tree, barringtonia
Fijian: vutu, vutu rakaraka

Barringtonia racemosa (L.) Spreng.
Fijian: vutusiriwai, vutu wai, vutuvala, vutu ni wai, vutuvutu

BORAGINACEAE (Heliotrope or Borage Family)

Tournefortia argentea L. f. — beach heliotrope
Fijian: roro ni bebe?, kau ni yalewa, evo

CAESALPINIACEAE (Senna Family)

Intsia bijuga (Colebr.) O. Ktze. — ipil tree
Fijian Names: vesi, vehi

CLUSIACEAE OR GUTTIFERAE (Mangosteen Family)

Calophyllum inophyllum L. — Portia tree, Alexandrian laurel, beach mahogany
Fijian: dilo

COMBRETACEAE (Terminalia Family)

Lumnitzera littorea (Jack) Voigt — red-flowered black mangrove
Fijian: sagale

Terminalia catappa L. — beach almond, Indian almond, Malabar almond
Fijian: tavola vula?, tavola, tivi

Terminalia littoralis Seem.

Fijian: tavola damu, tavola, tavola ni waitui, tivi ava

CONVOLVULACEAE (Morning-Glory Family)
Ipomoea littoralis Bl. Littoral morning-glory
Fijian: wa sovivi, sovivi, suani
Ipomoea macrantha R. & S. wild moon flower; white morning glory
Fijian: wa damu, tobili, tobici, wa ika
Ipomoea pes-caprae (L.) Sweet ssp. **brasiliense** (L.) v. Ooststr. beach morning-glory
Fijian: lawere, lauwere, wa vulavula, yale, yaleyale,

EUPHORBIACEAE (Spurge Family)
Codiaeum variegatum (L.) Bl. croton
Fijian: sacasaca
Excoecaria agallocha L. blinding tree, poison mangrove tree
Fijian: sinu, sinu gaga, hinu, toca, sota
Macaranga seemannii (Muell.- Arg.) Muell.- Arg. Macaranga
Fijian: gadoa, davo, mama, velutu

FABACEAE (Pea Family)
Canavalia cathartica Thou. Mauna Loa bean (Hawaii)
Fijian: drau tolu, rau tolu
Dalbergia candenatensis (Dennst.) Prain
Fijian: denimanā, wa denimanā
Derris trifoliata Lour. derris vine, derris root.
Fijian: wa duva, wa lai, duva, wa tuva, tuva, duva ni Viti, tuva ni Viti, duva gaga, raurau
Desmodium heterophyllum (Willd.) DC. tropical trefoil
Fijian: seni vakacegu, wakutu
Erythrina variegata var. **orientalis** (L.) Merr. coral tree, dadap
Fijian: drala, rara
Inocarpus fagifer (Parkinson) Fosb. Polynesian chestnut, Tahitian chestnut
Fijian: ivi
Pongamia pinnata (L.) Merr.
Fijian: vesi wai?, tavesivesi, vesi ni wai, tosiga, `tohiga
Vigna marina (Burm.) Merr. beach pea, beach bean, vigna
Fijian: drautolu, toka tolu, wa vue

GOODENIACEAE (Naupaka Family)
Scaevola taccada (Gaertn.) Roxb. beach saltbush, half-flower
Fijian: vivevedu, vevedu, dredre

HERNANDIACEAE (Hernandia Family)
Hernandia nymphaeifolia (Presl.) Kubr. lantern tree, hernandia
Fijian: evuevu, yevuyevu, buevu

LAMIACEAE or **LABIATAE** (Mint Family)
Hyptis pectinata. (L.) Poit. mint weed, wild mint, purple top
Fijian: tomole, tamole ni vavalagi, wavuwavu, ben tulsia (Hindi)

LAURACEAE (Laurel Family)
Cassytha filiformis L. beach dodder, devil's twine
Fijian: wa urulagi, wa uruilagi, wa lutumailagi, wa verlagi, dredruma, fatai, bualawalawa

MALVACEAE (Mallow Family)
Hibiscus tiliaceus L. beach hibiscus, hibiscus tree
Fijian: vau
Sida rhombifolia L. broomweed, broom plant, Cuba jute, Paddy's lucerne, coffee bush
Fijian: qawe ni lawe, qavi ni lawe, cavucidra, de ni me, de ni ose, de ni vuaka
Thespesia populnea (L.) Sol. ex Correa Thespians tree, milo (Hawaii and Polynesia)
Fijian: mulomulo, wiriwiri

MELASTOMATACEAE (Melastoma Family)
Clidemia hirta (L.) Don Koster's curse
Fijian: dradrasiga, severo, mara na bulumakau

MELIACEAE (Mahogany Family)
Dysoxylum richii (A. Gray) C. DC. stinkwood
Fijian: tarawau kei rakaka, tarawau kei coge, sasawira, sasauira, hauira
Xylocarpus granatum Koenig puzzle nut
Fijian: dabi, leqileqi, leqileqi alewa, lokoloko
Xylocarpus moluccensis (Lam.) M. Roemer puzzlenut
Fijian: dabi, leqileqi, leqileqi taqwane, bolavatu

MIMOSACEAE (Mimosa Family)
Entada phaseoloides (L.) Merr. water vine, St. Thomas bean
Fijian: wa lai, **cibicibi**, wa tiqiri, wa taqiri
Leucaena leucocephala (Lam.) de Wit leucaena, lead tree, jumbie tree
Fijian: vaivai, vaivai dina, vaivai du, vaivai ni vavalagi, balori (hindi)
Mimosa pudica L. sensitive plant, sensitive grass

Fijian: co gadrogadro, o gadrogadro, o moku

MORACEAE (Mulberry Family)
Ficus barclayana (Miq.) Summerhayes — Barclay's fig
Fijian: losilosi, loselose, masi, masimasi, vuaiatmona
Ficus vitiensis Seem. — Fiji fig
Fijian: lolo, koba

PASSIFLORACEAE (Passion Flower Family)
Passiflora laurifolia L. — bell apple, laurel-leaved passionfruit

POLYGALACEAE (Polygala Family)
Polygala paniculata L.
Fijian Names: lole, tavitaviraki

RHAMNACEAE (Buckthorn Family)
Colubrina asiatica (L.) Brongn. — soapbush, hoop withe
Fijian: vuso levu, wa vuso, vere, verevere
?Smythea lanceata (Tul.) Summerhayes
Fijian: wa vuso?
?Ventilago vitiensis A. Gray — ventilago
Fijian: vere, wawa?

RHIZOPHORACEAE (Mangrove Family)
Bruguiera gymnorrhiza (L.) Lam. f. — black mangrove, oriental mangrove, brown mangrove
Fijian: dogo, lailai
Rhizophora samoensis (Hochr.) Salvoza — mangrove
Fijian: tiri wai, tiri dina, dogo
Rhizophora stylosa Griff. — mangrove
Fijian: tiri solo, tiri, tiri wai, dogo

RUBIACEAE (Coffee Family)
Morinda citrifolia L. — beach mulberry, Indian mulberry
Fijian: kura
??Unknown ?Spermacoce bartlingiana (DC) Fosb. or **Mitracarpus hirtus** (L.) DC.
Syn. *Spermacoce hirta* L; *Spermacoce villosa* Sw.; *Mitracarpus villosus* DC.
Tarenna sambucina (Forst. f.) Dur. ex Drake
Fijian: vakacaredavui, ai caradavui

STERCULIACEAE (Cocoa Family)
Heritiera littoralis Ait. — Looking-glass tree
Fijian: kedra ivi yalewa na kalou, kendra ivi na kuka, savara buludamu, iolomasima

VERBENACEAE (Verbena Family)
Clerodendrum inerme L. — beach privet
Fijian: verevere, aria
Lantana camara L. var. **aculeata** (L.) Mold. — lantana
Fijian: lanitana
Premna serratifolia L. — premna
Fijian: yaro, araro
Stachytarpheta urticaefolia Sims — blue rat tail, false verbena
Fijian: se ni tieri, se karakarawa
Vitex trifolia L. var. **trifolia** — blue vitex, beach vitex
Fijian: dralakaka, drala, drala tagwane, mulokaka, vulokaka

List of Participants

South Pacific Regional Environment Programme

Regional Workshop – Mangrove Wetland Protection & Sustainable Use
12 – 16 June 2001, Suva, Fiji

American Samoa

Ms. Mary Midkiff
Water Quality Specialist
American Samoa Coastal Management Programme
Department of Commerce
Pago Pago
American Samoa
Phone : (684) 633 5155
Fax : (684) 633 4195
Email : taputimu@hotmail.com

Peniamina Siatunu'u
Wetlands Village Conservation Officer
American Samoa Coastal Management Program
Department of Commerce
Pago Pago
American Samoa
Phone : (684) 633 5155
Fax : (684) 633 4195
Email :

Federated States of Micronesia

Mr. Asher Edward
COM-FSM Sea Grant Agent
Pohnpei
FSM
Phone : (691) 320 2523 / 3231
Fax : (691) 320
Email : aedward@mail.fm

Mr. Andereas Poll
Assistant Manager – Awak Pah Marine Park
Pohnpei
FSM
Phone : (691) 320 2641 / 2613
Fax : (691) 320 2993
Email:

Fiji

Official Govt. Reps

Mr. Manasa Sovaki
Principal Environment Officer
Department of Environment
Suva
Fiji
Phone : (679) 311-699
Fax : (679) 312-879
Email : biodiversity@suva.is.com.fj

Mr. Aisake Batibasaga
A/Principal Fisheries Officer
Department of Fisheries
Suva
Fiji
Phone : (679) 361 122
Fax : (679) 361 184
Email: abatibasaga@fisheries.gov.fj

NGOs

Ms. Aivisake Ravuvu
SPACHEE
Suva, Fiji

Phone : (679) 312 371
Fax : (679) 303 053
Email: spachee@is.com.fj

Floyd Robinson
Conservation Officer
FSP,

Phone : (679) 662 535
Fax : (679) 663 414
Email: kanaproject@is.com.fj

Mr. Etika Rupeni
WWF Office
Suva
Fiji

Phone : (679) 315 533
Fax : (679) 315 410
Email: erupeni@wwfpacific.org.fj

Ms. Pauline Laqere
National Trust for Fiji
Suva
Fiji

Phone: (679) 301-807
Fax: (679) 305-092
Email: nationaltrust@is.com.fj

Gerald Billings
FSP, Box 14447
Suva, Fiji

Phone: (679 300 392
Fax: (679) 304 315
Email: fspsuva@is.com.fj

Sylvia Troost
FSPI Regional Secretariat
C/- FSP Fiji
Suva, Fiji

Phone: (679) 300 392
Fax: (679) 304 315
Email: sylviatroost@yahoo.com

University Participants

Ms. Aliti Vunisea
USP Suva
Fiji

Phone: (679) 212 589
Fax: (679) 301 487
Email: vunisea_a@usp.ac.fj

Mr. Alifereti Naikatini
USP Herbarium
Suva, Fiji

Phone: (679) 212245
Fax: (679)
Email: naikatini_a@usp.ac.fj

Others

Mr. Timoci Gaunavinaka
BSAP Project Assistant Database
Dept. of Environment
Suva, Fiji

Phone: (679) 311699
Fax: (679) 312 879
Email: biodiversity@suva.is.com.fj

Mr. Prem Chand
Forestry Officer
Department of Forestry
Nausori, Fiji

Phone: (679) 479 199
Fax:
Email:

Ms Asenaca Ravuvu
UNDP Focal Point
Suva

Filipe Rokovasa
OISCA
Box 495, Sigatoka, Fiji

Phone/Fax: (679) 520 348

Marshall Islands

Mr. Maity Bungitak
Monitoring Officer
Jaluit Atoll Conservation Project
Jaluit Atoll
Marshall Islands 96961

Phone : (692) 625 3035/5203
Fax : (692) 625 5202
Email : eparmi@ntamar.com

New Caledonia

Francois Devinck
Head of Environment
South Province
New Caledonia

Phone: 687 243255
Fax: 687 243 256
Email: devinck@drn.province.sud.nc

Palau

Mr. Theofanes Isamu
Chief, Division of Marine Resources
Bureau of Natural Resources & Development
PO Box 117
Koror
Palau 96940

Phone : (680) 488 3125
Fax : (680) 488 1475
Email : theodmr@palaunet.com

Ms. Alma Ridep-Morris
Conservation Area Support Officer (CASO)
Bureau of Natural Resources & Development
PO Bo 117
Koror
Palau 96940

Phone : (680) 488 5395
Fax : (680) 488 1475
Email : almarm@palaunet.com

Papua New Guinea

Mr Tunou Sabuin
Acting Divisional Manager
PNG Forest Authority
PO Box 5055
Boroko, National Capital District,
PNG

Phone: 327 7819/ 323 0696
Fax: 323 0315/ 325 4499

Samoa

Mr. Talie Foliga
Environment Officer
Division of Environment & Conservation
Private Bag
Apia, Samoa

Phone : (685) 23800
Fax : (685) 25856
Email : envdlse@samoa.ws

Mr. Etuati Ropeti
Senior Fisheries Officer
Fisheries Division
eropeti@hotmail.com/eropeti@fisheries.ws
PO Box 1874
Apia, Samoa

Phone : (685) 20369
Fax : (685) 24292
Email : eropeti@fisheries.ws

Solomon Islands

Nathaniel daWheya
Senior Conservation Officer
Department of Forests, Environment & Conservation
PO Box G24
Honiara, Solomon Islands

Phone : (677) 25 848/27084/24325
Fax : (677) 21245/25811
Email : dawheya@pacificbiodiv.org

Peter Chanel Ramohia
Senior Fisheries Officer, Research
Research and Resource Management Division
Ministry of Fisheries & Marine Resources
PO Box G13
Honiara, Solomon Islands

Phone: (677) 30564 / 30743 / 38484
Fax: (677) 38106
Email: livefish@solomon.com.sb

Tonga

Ms. Netatua Prescott
Senior Ecologist/Environmentalist
Department of Environment
Nukualofa
Tonga

Phone : (676) 25050
Fax : (676) 25051
Email : tempp@kalianet.to

Mr. Feauini Vi
Fisheries Assistant
Ministry of Fisheries
Nukualofa
Tonga

Phone : (676) 21399
Fax : (676) 23891
Email :

Vanuatu

Mr. William Naviti
Resource Manager
Fisheries Department
Port Vila, Vanuatu

Phone : (678) 23119
Fax : (678) 23641
Email : fishery@vanuatu.com.vu

Mr. Trinison Tari
Environment Education Officer
Environment Unit
PMB 063
Port Vila, Vanuatu

Phone : (678) 25302
Fax : (678) 23565
Email : environment@vanuatu.gov.vu

Wetlands International

Aaron Jenkins
Wetlands International
Suva

SPREP Secretariat

PO Box 240
Vailima
Apia
Samoa

Phone : (685) 21929
Fax : (685) 20231
Email : sprep@sprep.org.ws
Website : http//www.sprep.org.ws/

Ms. Mary Power
Coastal Management Officer
Email : MaryP@sprep.org.ws

Ms. Helen Ng Lam
Divisional Assistant – CNR
Email : HelenN@sprep.org.ws

Resource Persons / Presenters

Ms Batiri Thaman
Institute of Applied Sciences
USP, Suva, Fiji
Phone: (679) 212 653
Email: thaman_b@usp.ac.fj

Dr Randy Thaman
Depat. Of Geography
USP, Suva, Fiji
Phone: (679) 212 546
Email: thaman_r@usp.ac.fj

Mr Joeli Veitayaki
Marine Affairs
USP, Suva
Phone: (679) 212 092
Email: veitayaki_j@usp.ac.fj, Fiji

Mr Roger Jaensch
Wetlands International
Email: Roger.Jaensch@env.qld.gov.au

Dr. Eric Gilman
Audubon Society
2718 Napuaa Place
Honolulu, Hawaii 96822
USA
Phone: 808 988 1976
Fax: 808 988 1440
Email: egilman@lava.net

Ms. Julie Martin
Northern Territory University, Darwin
Australia
Phone : (618) 8924 4172
Fax : (618) 8981 3420
Email : Julie.Martin@nt.gov.au

Ms. Anne Clark
Manager, Habitats
Fisheries Resource Mangement
Dept of Primary Industries, Queensland
Northern Fisheries Cenre
38-40 Tingira St, Portsmith
PO Box 5396, Cairns Qld 4870
Australia
Phone:617 403501440
Fax: 617 403551401/ 61 7 40 355 4664
Email: ClarkeA@dpi.qld.gov.au

Ms Joanna Ellison
School of Geography and Environmental Studies,
University of Tasmania, Locked Bag 1-376,
Launceston, Tasmania 7250, Australia.
Phone: 613 6324 3834
Email: Joanna.Ellison@utas.edu.au

Dr. Padma Lal
Director, Graduate Studies in Environmental Law & Development
NCDS, ANU
Australia
Phone: 612 6125 0093
Fax: 612 6125 5570
Email: padma.lal@anu.edu.au

Mr Aru Mathias
Forest Resources Management Officer
FAO Sub-Regional Office, Apia Samoa
Email: Aru.Mathias@fao.org