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Acronyms

ADB	Asian Development Bank
AIMS	Australian Institute of Marine Sciences
CPUE	catch per unit effort
DBH	diameter at breast height
DEC	Department of Environment and Conservation
IUCN	International Union of Nature Conservation
IWP PNG	International Waters Programme Papua New Guinea
MMP	mangrove management plan
MPA	marine protected area
NFA	National Fisheries Authority
NGO	non-government organisation

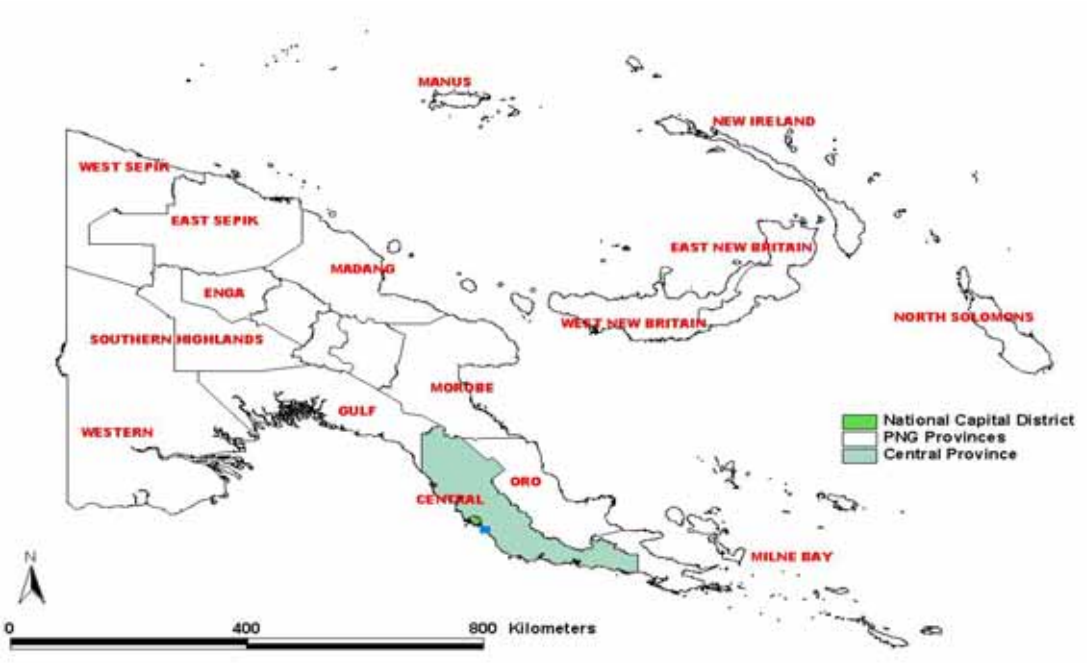

Figure 1: Map of Papua New Guinea

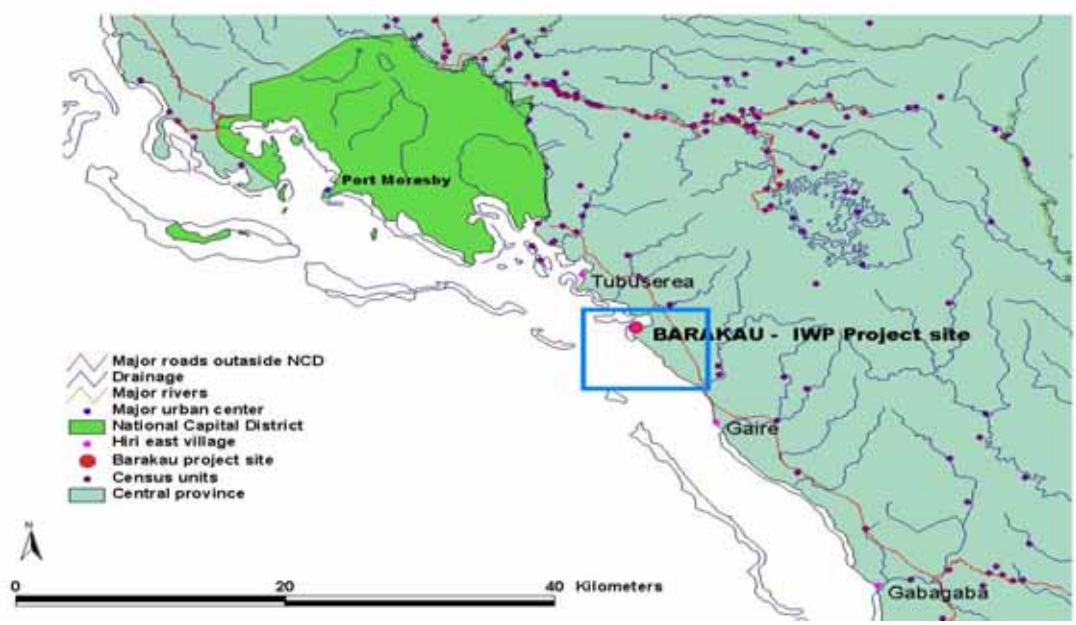

Figure 2: Location of Barakau Village relative to the National Capital District

1 Introduction

International Waters is one of four focal areas of the Global Environment Facility (GEF), which was created in 1994 to fund programmes aimed at achieving global environment benefits in four focal areas: biodiversity, climate change, international waters and ozone layer depletion.

International Waters include oceans, large marine ecosystems, enclosed or semi-enclosed seas and estuaries as well as rivers, lakes, groundwater systems, and wetlands with trans-boundary drainage basins or common borders involving two or more countries. The ecosystems and habitats associated with these waters are essential parts of the system.

The Pacific region International Waters Project is a seven-year project involving 14 participating island countries (Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea (PNG), Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu).

IWP has two main components. The oceanic component focuses on the management and conservation of tuna stocks in the western central Pacific. The focus of the coastal component is on integrated coastal watershed management. It involves the implementation of 14 pilot projects addressing sustainable resource management and conservation issues in the coastal zone. The vision for the whole programme is sustainably managed and effectively conserved coastal and marine resources and habitats in the Pacific islands region.

The primary objective of the coastal component is to "address root causes of the degradation of international waters in coastal regions through a programme focused on improved integrated coastal and watershed management". It requires action at the community level to address priority environmental concerns relating to: marine protected areas, sustainable coastal fisheries projects, protection of freshwater resources and community-based waste reduction.

Located within the Department of Environment and Conservation (DEC), IWP PNG is concerned with the implementation of the coastal component. At the conclusion of the assessment of the priority environmental concerns of PNG (see Nicholls 2004), IWP focal areas were ranked in terms of severity as follows: 1) waste management, 2) protection of freshwater quality and 3) sustainable coastal fisheries.

Due to funding constraints it was decided that the pilot project would be located in the Central Province. When invitations were requested for expressions of interest to host the pilot project, the public in the Central Province was advised that those intending to apply should ensure the environmental issues in their respective villages are relevant to the focal areas and preferably in the same order of importance. Barakau was among the sixty villages that responded. In the final selection it was chosen as the host site for a number of reasons. These were: (i) relatively easy accessibility from Port Moresby, (ii) manageable population size, (iii) environmental issues relevant to IWP focal areas and (iv) degree of understanding of these environmental concerns by the people and their apparent preparedness to address them.

Barakau is a coastal Motuan village situated about 40 km southeast of Port Moresby. It is accessible by road (driving time at an average speed of 70 to 80 km per hour is about half an hour). It has a population of 1500 people. About 40 % of the houses are built over the sea. This is a traditional Motuan practice which in the modern era has serious negative waste management implications (see Figs. 1 and 2).

Consistent with the priority environmental concerns assessment of the country, IWP PNG has been concentrating its activities on waste management and sustainable coastal fisheries at the local and national level.

While most of the resources will be directed towards improving waste management, every effort will be made to ensure the marine ecosystems around Barakau village are protected and

the fish and other resources are extracted in a sustainable manner. Appropriate actions are also planned at the national level to support and reinforce the strategies undertaken in Barakau village and subsequently in other parts of PNG.

Fishing and gardening are common village activities practiced by both men and women. Most of the male youth and men who are unable to find work elsewhere go fishing for their household needs and sell the surplus at the village market or in town. Women collect shellfish on the tidal flats and mangrove areas. Any surplus shells are sold in the village market.

Table 1: Population distribution by age and sex for each section of Barakau village

SECTION	No. of HH	No. of Occupants										Total
		Adults		Children								
				0-5yrs		6-12yrs		13-18yrs		>19yrs		
		M	F	M	F	M	F	M	F	M	F	
Bagava (BA)	**36**	78	72	34	26	34	29	7	16	28	18	
Derehua (DH)	**24**	53	52	16	14	21	14	15	14	9	19	
Middle East (ME)	**17**	35	35	11	9	13	13	10	10	5	5	
Kida (KD)	**21**	73	61	13	9	23	25	14	18	14	8	
Bay Entry (BE)	**22**	63	56	13	14	30	14	18	8	9	3	
Bay Side (BS)	**39**	81	64	16	13	30	19	13	13	11	6	
Total	**159**	**383**	**340**	**103**	**85**	**151**	**114**	**77**	**79**	**76**	**59**	**1467**

HH = households

In order to determine the current status of Barakau's marine environment and the biodiversity it supports, baseline surveys were undertaken on the reefs and mangrove areas. Sections 2 and 3 of this report address the results, observations, threats and remedial measures associated with the reef, while Sections 4 and 5 do the same for the mangrove areas.

2 Reef surveys

2.1 Methodology

The surveys were undertaken by three scientists; one from IWP PNG and two from DEC. Three local fishermen also participated in the survey as resource persons. Most of the survey effort concentrated on Vanaga and Nahua reefs. Figure 3 shows the locations of the areas surveyed. During the surveys, the variety and conditions of the corals, fishes, sea grasses and invertebrates were examined. The survey methods used were manta tows and intercept transects. Intercept transects seem to be the most cost effective method developed by AIMS and is used extensively throughout the Oceania region. Trial fishing surveys were not conducted due to time and resource constraints. Nevertheless, the required information was obtained through interviews of fishermen on aspects such as fishing locations, catch rates and gear used. Food reef fish resources were surveyed using the Underwater Visual Census method where each of the three divers did a spot count, recording presence and densities of the main food fishes on the three dive sites. In addition, threats posed on the reefs were investigated and possible solutions were evaluated.

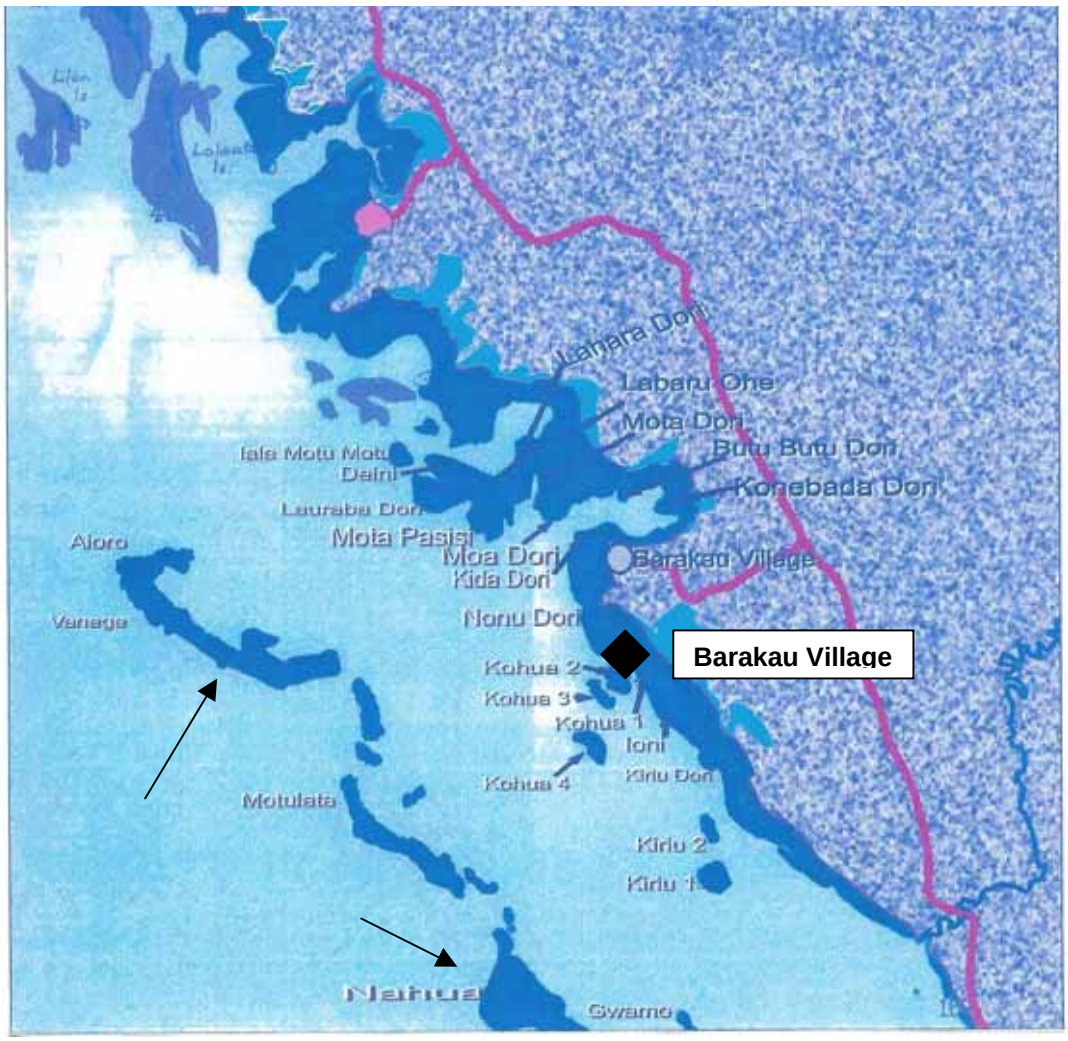

Figure 3: Hiri East coastline showing the reefs off Barakau village

2.2 Observations and discussions

2.2.1 Reef benthos

The reefs consist of the following types and genera of corals: massive (*Porite*, *Diploastrea*); foliaceous (*Montipora*); plating (*Oxypora*); branching (*Seriatopora*, *Acropora*); solitary (*Fungia*); flabellate (*Euphyllia*); meandroid (*Lobophylla*); and plocoid (*Favia*).

Evidence of dynamite blasting was obvious on both Nahua and Vanaga reefs where sections of important coral communities were completely devastated. The extent of damage on Nahua is estimated at 15% and about 10% in Vanaga. Some sporadic coral bleaching was also observed. The cause of the bleaching could not be established. The only invasive species observed on the reefs is the crown of thorn starfish, *Acanthaster planci*, but the degree of impact on the reef is yet to be assessed. Regrowth in the devastated areas is rather slow. Fishermen attributed this to strong wave action and sedimentation carried by overland runoff.

2.2.2 Coral reef and associated fishes

During the brief survey, a total of 95 different species of reef fishes were observed. These observations were checked with the village fishermen and the following profile compiled: groupers appeared to be the most common fish with 15 species, followed by 10 species of cods, 10 of emperors, 7 each of parrot fish and surgeon fish, and 5 species each of trout and snappers. Four pelagic species were also observed. These included the Spanish mackerel, rainbow runner, chevron barracuda and giant trevally.

2.2.3 Underwater visual census of food reef fishes

The main groups observed included the groupers, surgeonfish, parrotfish, snappers, emperors, sweetlips, goatfish, rabbitfish and unicornfish.

It was noted that the smaller species of squirrelfish (*Sargocentrom* sp.) and two species of surgeon fish preferred the devastated areas while butterfly fishes preferred the undisturbed habitats. The yellow-tailed fusiller aggregated in rather large groups on the inner edges and around the patches.

A detailed study should be undertaken to provide a more accurate checklist of fish and sedentary resources in all reefs and patches of the Barakau marine environment.

2.2.4 Pelagic and deep sea fishes

The pelagic fishes observed in the study area included chevron barracuda (*Sphyraena genie*), rainbow runner (*Elagatis bipunnulata*), trevally (*Caranx* sp.) and Spanish mackerel (*Scomberomorus commersoni*).

The fishermen pointed out that when trolling, they catch bonito (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), giant barracuda (*Sphyraena barracuda*) giant trevally (*Caranx ignobilis*) and rainbow runner (*Elagatis bipunnulata*). Deep sea catches include long-nosed emperor (*Lethrinus elongatus*), red emperor (*Lutjanus sebae*), red snapper (*Lutjanus* sp.) and coronation trout (*Variola louti*). The pelagic and deep sea fish resources are practically untapped mainly due to fishing gear preference by the Barakau fishermen and the fact that trolling is time consuming and expensive.

2.2.5 Commercial invertebrates

As in other coastal villages throughout Papua New Guinea, invertebrate marine resources provide an important source of food and cash for the Barakau community.

During the survey, a total of nine holothurians, seven nacreous shell species and the tropical spring lobster were observed. Octopus, squid and cuttlefish of the class Cephalopoda were also observed, but rather uncommon. In general, holothurians were in low numbers in the three sites studied. At the time of this survey National Fisheries Authority was in the process of notifying the public of the seasonal closure of bêche-de-mer harvest in the Central Province. Table 2 indicates the current status of Nacreous shell species found in the surveyed sites.

Although both trochus (*T. noliticus*) and blacklip pearl oyster (*Pinctada margaritifera*) were observed on the two reefs Nahua and Vanaga, their numbers were relatively low. Of the five *T. noliticus* sighted, none was of harvestable size.

The giant clam species observed in the study sites include boring clam (*Tridacna crocea*), rugose giant clam (*T. maxima*), smooth giant clam (*T. derasa*) and horseshoe clam (*Hippopus hippopus*). Except for *T. crocea*, the other three were in very low numbers. This may be attributed to rather intensive harvesting of all sizes, disturbance of preferred habitats or changes in water quality and temperature. The numbers were too low to support a subsistence fishery. Table 3 indicates the status of the giant clams observed in the study sites.

2.2.6 Marine turtles and mammals

Two species of marine turtles observed during the survey (green turtle, *Chelonia mydas*, and hawksbill turtle, *Eretmochelys imbricata*); both are listed in the as endangered in the IUCN Red Data Book. Only one individual *C. mydas* was sighted on Nahua while one individual *E..imbricata* was sighted on Nahua and another on Vanaga.

Table 2: Invertebrates observed on Barakau Reefs

Group	Common Name	Scientific Name	Motu Name	Abundance*		
				C	NC	R
Nacreous Shells	Trochus	*Trochus niloticus*	Laia		✓	
	Spider Shellfish		Ragaraga		✓	
	Blacklip	*Pinctada margaritiferaa*	Mairi		✓	
Holothurians	Pinkfish	*Holothuria edulis*	Kava/korema			
	Greenfish	*Stichopus chloronotus*	Kava/korema		✓	
	Black Teatfish	*Holothuria nobilis*	Kava/korema		✓	
	Lollyfish	*H.atra*	Kava/korema		✓	
	Elephant Trunkfish	*H.fuscopunctata*	Kava/korema		✓	
	Curryfish	*Stichopus variegatus*	Kava/korema		✓	
	Surf Redfish	*Actinopyga mauritiana*	Kava/korema		✓	
	Amberfish	*T.anax*	Kava/korema		✓	
	Stonefish	*Actinopyga lecanora*	Kava/korema			
Crusteaceans	Painted lobster	*Panulirus versicolor*	Hura		✓	

*(C=common, NC=not common, R=rare)

Table 3: Giant Clams observed on Barakau Reefs

Common Name	Scientific Name	Motu Name	Abundance		
			Common	Not Common	Rare
Boring Giant Clam	*Tridacna crocea*	Kunukunu	✓		
Rugose Giant Clam	*T.maxima*	Laba			✓
Fluted Giant Clam	*T.squamosa*	Laba			✓
Horseshoe Clam	*Hippopus hippopus*	Butubutu		✓	

Barakau beaches once served as popular nesting sites for at least four species of marine turtles, but fishermen indicated that over the last ten years no nesting sites have been seen. *C. mydas* is harvested for its meat, while *E. imbricata* is harvested for the shell, from which necklaces and earrings are produced, both locally and overseas. Due to lack of effective awareness programmes, local people are not aware of international and national regulations banning the sale of marine turtles, turtle parts and derivatives for monetary gain.

The only marine mammal observed in the area was the bottle-nosed dolphin, *Tursiops truncatus*. This mammal was sighted in large groups following schools of mullets and yellow-tail into the lagoon area. They are not affected by any hunting pressure because they are not taken for meat or cash.

Both DEC and the National Fisheries Authority (NFA) must be pressured to undertake appropriate awareness programmes for the protection of the endangered turtle species found on the reefs of Barakau. The numbers observed during the survey definitely indicates that numbers of these species are declining; if positive action is not taken, these animals could be totally eliminated from the area studied.

3 Threats to reefs and possible remedial measures

The reefs are currently threatened by direct disposal of household and human waste into the sea, sedimentation (worsened by increasing land clearance near the coast), use of dynamite fishing, and anchoring. The fishermen explained that a large proportion of previously damaged areas appear to be recovering, but at a very slow rate. This underscores the importance of establishing management systems to minimise further damage.

Table 4 outlines the current fishing practices in Barakau, the main targeted fish groups and the effectiveness of the methods.

Table 4: Current Fishing Practices in Barakau Village

Method and net size (inches) and line weight (pounds)		Target fish group(s)	Effectiveness*		
			H	M	L
Nets (cast)	.5–1.5 in.	baitfish, garfish, pike	✓		
	2–3.5 in.	mullet, big eye trevally, mackerel (young)		✓	
	4–6 in	trevally, mackerel, queenfish, surgeonfish, unicornfish, bonito,		✓	
Spear(day)		baitfish, pilchards, sardines, garfish, squids, octopus		✓	
Spear (with spotlight)		long tom, mullets	✓		
		trevally		✓	
Spear gun (with torch)		unicornfish, surgeonfish, parrotfish, sweetlips, triggerfish, emperor	✓		
Spear gun (day)		surgeonfish, batfish, mackerel, unicornfish, barracuda, trevally, trout, cod		✓	
Trolling		tuna, mackerel, trevally		✓	
		trout			✓
Bottom line (reef)	20–50 lbs	emperors	✓		
		sweetlips		✓	
		wrasses			✓
		snappers, cod/groupers	✓		
Bottom line (deep sea)	50–120 lbs	red emperor, red snapper, grouper		✓	
		long nose emperor, giant trevally		✓	

***** H=high, M=medium, L=low

Fishing nets appear to be the most common and effective method of fishing followed by spear gun fishing at night. Bottom line fishing is not as common and the catch per unit effort (CPUE) tends to be lower. According to the NFA, deep water fisheries in the area are underutilised, and

the Asian Development Bank-(ADB) funded coastal fisheries project[1] has been designed to establish artesian fishing ventures through which the fish can be caught and sold to markets in Port Moresby on a sustainable basis.

In order to relieve pressure on the reefs, new improved and pelagic fishing techniques should be introduced, along with complementary additional facilities (e.g. ice-making machines, transportation and marketing outlets). Such assistance may be provided under the ADB-funded project.

4 Introduction to mangrove ecosystems

4.1 Background

Mangrove ecosystems are an integral and important part of tropical marine environments. In addition to minimizing shoreline erosion and serving as a filtration facility and silt trap for overland runoff, mangroves constitute a critical breeding site for fish, crabs and shellfish, and help maintain productivity of these organisms. Mangroves are important habitat for a number of species eaten by people, and provide wood for fuel and various construction purposes.

Barakau is fortunate to have sizeable mangrove forests on both sides of the village. This report presents the results of a survey carried out to determine the extent of the mangrove forest area, its species composition, the various uses and threats and the need for a resource management plan.

4.2 Biophysical and ecological importance of mangrove ecosystems

Mangroves protect local communities by reducing coastal erosion, flooding, and storm surges. Erosion control can lead to shoreline accretion, which is another function attributable to mangroves. The quality of the adjacent coastal waters is regulated by mangroves, which act as silt traps, with the numerous and extensive root systems helping to settle out particulate matter, thus reducing the flow of silt-laden rivers and streams. Mangroves also act as pollution "sinks" for agricultural runoff and other municipal pollutants including chemicals, pesticides, fertilizer residues, plastics and old tyres.

The other well known ecological functions of mangrove ecosystems include providing spawning grounds and nurseries for many commercially important fish such as shrimps, emperors, crabs, oysters, mullets, and rabbit fish. Mangroves also act as a "clearing house" for the export of nutrients and other organic detritus, and form the basis of a complex food web supporting coastal, estuarine and pelagic fisheries.

There are many complex ecological interactions between mangroves, adjacent coral reefs and sea grass beds. The health and productivity of these ecosystems is reflected in their ability to sustain a rich and diverse marine life. Like any natural ecosystem, mangroves are also delicate and vulnerable to abrupt changes that can alter their overall dynamics. It is important that people use mangrove resources in a responsible manner in order to safeguard their continued health and existence in any given location.

5 Mangrove survey

5.1 Study site

The mangroves near Barakau village extend about 3 km east along the coast (towards Gaire village) and approximately 20 km west (towards Tubuserea village). Figure 4 shows the

[1] Papua New Guinea Coastal Fisheries Management and Development Project; see www.fisheries.gov.pg/about_proj_cfmdp.htm

location and extent of the mangrove forest.

5.2 Methodology

The mangrove stands were investigated to determine species composition and zonation types. Surveyors walked from sea to land (low to high tide mark) through the mangrove forest at a set bearing. All species of mangroves located along each transect were examined and features such as height, diameter at breast height (DBH), phenology and substrate types were recorded. Appendix 5 shows the mangrove species recorded near Barakau.

Isolated patches of mangrove stands on pockets of rocky shores were also examined and species present recorded; all beach vegetation was also recorded. Appendix 6 shows the species recorded in the mangrove patches and other beach vegetation. For each site selected, transect lines were established from the seaward margin of the forest at right angles to the edges of the mangrove forest, ensuring that the edge of the forest margins did not confound the measurements. Within each transect line selective healthy mature trees were tagged at the DBH height, for future monitoring purposes and DBH measurements taken.

Figure 4: Mangrove forests (shaded light-green) near Barakau village

6 Observations and discussion

The mangrove vegetation near Barakau (from Gaire to Tubuserea) can be divided into four different forest types: mixed mangrove patches, young *Rhizophora-Bruiguiera* forest, mature *Bruigurea-Rhizophora* forest, and *Avicennia-Ceriops* forest.

6.1 Overview of mangroves in the Central Province

The overall extent of mangroves in the Central province has not been accurately measured. However, most mangrove associations in the Central Province occupy or occur as fringe vegetation and stretch from Yule Island in the west to Cloudy Bay in the East. Maragos (1991) estimates there are 75,685 ha of mangroves along the Central Province coastline (Table 5).

Table 5: Major mangrove areas in the Central Province

District	Locality	Estimated Mangrove Area (ha)
Bereina	Yule Island	8,712
West Hiri	Galley Reach	30,631
Aroma	Hood Bay	11,285
Kupiano	Cape Rodney	10,303
Abau	Cloudy Bay	13,700
East Hiri	Gabagaba	1,054
Total		**75,685**

6.2 Mixed mangrove vegetation

This vegetation type includes the small and isolated stands of mangroves commonly found as fringe vegetation stretching 2 km east of Barakau village towards Gaire. This vegetation type does not show the typical zonation pattern characteristic of mangroves, but instead the pattern is more or less determined by the locality and substrate composition. Thus is exposed locations with substrate consisting of coral debris or rocky shores, the predominant species encountered were *Aegialitis*, *Avicennia*, and *Sonneratia*. The landward fringe was usually made up of *Rhizophora stylosa*/*R.apiculata* association with isolated patches of *Ceriops*.

In other areas *Osbornia octodonta*, *Scyphiphora hydrophyllacea* and *Lumitzera racemosa* were to be present. Generally, the heights and DBH of the trees at these sites rarely exceed 10 m and 30 cm respectively.

In areas where sufficient accumulation of coral debris and gravel has occurred the usual strand vegetation prevails, and includes typical species (e.g. *Thespia populenea*, *Hibiscus tiliaceus*, *Scaevolla taccada*, *Cordia subcordata*, the creeper *Ipomoea pes-carpae*, and the succulent *Sesuvium portulacastrum*).

6.3 Young *Rhizophora-Bruguiera* forest

Young *Rhizophora-Bruguiera* forest was observed in the bay area west of Barakau village. Although the stretch of the forest was not extensive, it was definite enough to categorize the vegetation separately from the mature stands. The outermost fringe was dominated by *Rhizophora stylosa*. However, as one progresses landward it is replaced by *R.apiculata* and *Bruguiera gymnorrhiza*, which often comprise the dominant forms throughout the stand. Scattered stands of *Xylocarpus* and *Heritiera littoralis* may sometimes be encountered. At the spring tide level the stand is occupied by *Avicennia*, *Ceriops*, *Lumnitzera* and *Excoecaria*. The height of the trees in this type of forest rarely exceeds 20 m, while the diameter generally ranges between 10 to 20 cm.

6.4 Mature *Rhizophora-Bruguiera* forest

This type of forest covers approximately 10 km west of Barakau and crosses over the border into Tubuserea. It is characterized by a mature well-developed forest dominated by *Rhizophora-Bruguiera* association. The stand measures up to about 1 km in width, with the characteristics of mature mangrove stands (stand height to 30 m, and diameter ranging from 40 to 50 cm). The canopy cover is generally uniform; understory seedling density is generally low, except where gaps occur (mostly due to felling by humans) where prolific growth of *Rhizophora* and *Bruguiera* was noted.

The dominant canopy species observed are *Rhizophora apiculata* and *Bruiguiera gymnorrhiza*.

Scattered stands of *Xylocarpus granatum* and *Heritiera littoralis* were found among the *Rhizophora/Bruguiera* complex. *Rhizophora stylosa* tends to occupy the outermost seaward fringes while the landward stand is occupied by *Ceriops tagal*, which associates with *Avicennia, Lumnitzera* and *Excoecaria*, with isolated stands of *Xylocarpus australicus.*

6.5 *Avicennia* association

Avicennia was observed to occur as communities or as isolated patches along the coast of Barakau. In exposed rocky shores *Avicennia* occur as individual stands (usually as shrubs). In other sheltered areas (e.g. the Barakau Bay area) they tend to occur intermixed with *Rhizophora-Bruguiera* but as individual stands.

On sandy and well drained salt marshes, communities of *Avicennia* as the dominant vegetation is more common. Such communities are seen in the Bay area of Barakau. Isolated patches of *Ceriops*, *Lumnitzera*, and *Excoecaria* may also associate with the *Avicennia* dominated community. Tree heights and diameter was seen to be very variable. Strand vegetation (e.g. *Cordia, Scaevola*, and *Thespia*) was found to form distinct association with *Avicennia*.

6.6 Beach-associated vegetation

The strand vegetation forms the transitional zone between the shoreline and the mangrove forest. The typical strand vegetation consists of species such as *Cordia subcordata, Thespesia populnea*, *Hibiscus tiliaceus*, *Scaevola taccada*, and *Pongamia pinnata*, with associated creepers like *Ipomoea pes-caprae* and the succulent *Sesuvium portulacastrum.*

This transitional zone emerges initially into a *Ceriops* or *Avicennia* dominanted stand, than eventually into a mature *Rhizophora-Bruguiera* complex.

7 Barakau mangroves: uses and threats

In addition to being a source of wood for fuel and construction of houses, fences and pig pens for the people of Barakau, mangroves also provide food items such as shell fish, crabs and fish. A growing population, indiscriminate waste disposal and the forced transition into an increasingly cash dependant, semi-subsistence economy have accelerated the rate of resource extraction from the mangroves; if this trend continues unabated, the it may exceed the ability of the ecosystem to accommodate such stresses. Appendix 7 outlines the various uses of mangroves by the Barakau village people.

7.1 Cropping for firewood

A clearly noticeable impact on mangrove vegetation along the entire Central Province is the extensive forest clearing largely due to heavy cropping of mangroves for firewood and various construction purposes. The exploitation of mangroves for firewood has been carried out for generations and one can identify large tracts of coastline that are either completely devoid of mangroves or are occupied by regeneration species such as *Bruguiera parviflora* and *Avicennia marina*.

In most villages, the preferred genus of mangroves for firewood is *Ceriops*. These are either removed by direct felling, chopped into billets and dried or are initially ring-barked, left to partially dry out and felled. In most cases, trees are cropped when still "green" as they are much easier to spilt into billets. Heavy cropping is most common during feasts or bride price food preparation. Similar levels of cropping for firewood have been observed in other Central Province coastal areas. Just past the Tubusereia village towards Barakau, the vegetation consisted of a dense regenerating community of predominantly *B. parviflora* indicating recent heavy extraction of mangrove wood.

7.2 Construction materials

The common mangrove species used for poles are *Rhizophora apiculata*, *Bruguiera gymnorrhiza* and *Avicennia marina.* Most of the village houses are now permanent to semi-permanent, with many using mangrove timber as posts, columns, braces, wall beams, and roof frames. There is also extensive use of young straight mangrove poles for pig pens and garden fencing.

7.3 Crab collection

Mud crabs *(Scylla serrata*) are either consumed locally or sold to restaurants, hotels and the public. Mud crabs are also ecologically important in their role as detritus feeders but this is not understood by the villagers. It is imperative that villagers understand that over-exploitation can lead to depletion of natural stocks and reduction in ecosystem productivity.

In the past, women harvested crabs by using wooden sticks but nowadays implements such as sharpened metal bars are used to dig crabs out of their holes. The use of such items can damage mangrove roots and lead to the loss of trees through "dieback".

7.4 Waste disposal

Household wastes, including plastic bags, empty cans, old cars and other machinery, as well as human faeces, are disposed off either directly or indirectly into the mangrove forests on either side of the village. This foreign material adversely affects the normal functions of the mangrove ecosystem.

8 Development of a mangrove management plan

The people of Barakau appreciate the importance of the mangrove forests as a source of wood for fuel and building materials as well as a breeding site for crabs, shellfish and fish. Many have expressed serious concerns over the rate of extraction of the mangrove resources and the long-term negative consequences for the young and future generations.

In parallel with these concerns is the need to extract timber and food from the mangrove forests, either for household utilization or for sale. Additional stress is imposed on the mangrove forest by improper waste disposal and sedimentation carried by silt laden runoff and nearby watercourses.

It is important that everyone in Barakau understand that uncontrolled exploitation of the mangrove forests and irresponsible disposal of waste is destructive and unsustainable. There is clearly a need to enforce proper waste management practices and impose harvesting regulations that will allow the mangrove ecosystem to recuperate and maintain its productivity at a sustainable level. Regulations must be acceptable to villagers, and flexible enough to allow the people to continue to enjoy the subsistence and economic benefits provided by the mangroves. In addition, the regulations must be simple and enforceable by the community. Everyone should know what the rules are and be able to monitor them and ensure compliance.

The above harvesting regulations should be part of a mangrove management plan (MMP) that outlines how the resource should be managed to ensure the continued health of the mangrove ecosystem. The following steps should be followed in the formulation of the MMP:

(i) compile a thorough inventory of the Barakau mangrove areas;

(ii) identify all stakeholders;

(iii) ascertain uses, and frequency and level of resource extraction;

(iv) determine sources of waste and level of impact;

(v) conduct awareness raising and gauge community interest and willingness to

establish a MMP;

(vi) formulate a draft MMP and present to stakeholders;

(vii) discuss, evaluate and finalise the MMP.

A significant consideration in the rehabilitation and sustainable extraction of mangrove resources is the availability of alternative fuel and timber sources. If such alternatives are readily available, people can make a conscious decision to use them and in so doing reduce the pressure applied on mangroves.

9 Reef and mangrove recommendations

In order to prevent further degradation of the reefs around Barakau and ensure long term sustainability of the fishery, the following actions should be given priority.

(i) Intensive awareness and education should be provided to all sections of the community on the vulnerability of the reefs and the need to utilize them in a responsible manner.

(ii) The reefs should be included within a marine protected area (MPA) with a management plan developed in conjunction with all stakeholders.

(iii) As part of the MPA management plan local fishermen should be trained to carry out six-monthly and annual monitoring of the reefs.

(iv) The potential for mariculture activities such as giant clam, pearl and fish faming should be investigated to reduce harvesting pressure on reef resources.

The rate of deforestation of the mangrove forest near Barakau and the accumulation of waste materials in the area will result in severe loss of trees, inadequate regrowth and reduction in the amount of forested area. In order to prevent this, it is strongly recommended that the community develop an acceptable and enforceable resource management plan for these mangrove areas.

10 Conclusion

Like all coastal villages, the marine environment is absolutely crucial to the people of Barakau because it provides fish and other resources for both domestic consumption and income production (through sales). Extraction pressure on these resources is increasing as a result of the growing population and entry of outsiders. The people are now aware that their targeted fish species and sedentary resources are declining and some of the fishing methods as well as improper waste disposal are contributing to the degradation of the marine environment.

The mangroves near Barakau are an important component of the coastal ecosystem and are important in maintaining the productivity of marine species; they also provide wood for fuel and construction, and provide habitat for many edible marine resources. Mangrives also serve an essential; function in protecting the shoreline from erosion and storm damage.

As a matter of urgency, appropriate actions should be taken to reverse the negative impacts on both reef and mangrove habitats. A marine resource management plan (that addresses both reefs and mangrove forests, either jointly or separately) should be developed with the participation of all stakeholders; it should be designed within the framework of a marine protected area . Additional assistance to achieve this should be sought from NFA, DEC, interested NGOs and donor agencies.

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Appendix 1: Main coral types observed on the reefs

a: **Massive Corals**

- Porites, Diploastrea

b: **Foliaceous Corals**

- Montipora

c: **Plating Corals**

- Oxypora

d: **Branching Corals**

- Seriatopora, Porites, Acropora

e: **Solitary Corals**

- Fungia

f: **Flabellate Corals**

- Euphyllia

g: **Meandroid Corals**

- Lobophyllia

h: **Plocoid Corals**

- Turbinaria, Favia

Appendix 2: Main food reef fishes observed on reefs

Group	Common Name	Scientific Name	Motu Name	Abundance		
				C	NC	R
Grouper	giant grouper	*Epinephelus lanceolatus*	Dono		✓	
	flowery cod	*E.fuscoguttatus*	Taguma	✓		
	white line rock cod	*Anyperodon leucogrammicus*		✓		
	barramundi cod	*Chromileptes altivelis*	Hododo			✓
	coral trout	5 sp.	Bogi	✓		
Parrot Fish	bumphead parrotfish	*Bolbometopon muricatum*	Bedo		✓	
	bicolor parrotfish	*Cetoscarus bicolour*	Derakaka	✓		
	steephead parrotfish	*Chlorurus microrhincus*	Karavani	✓		
	swarthy parrotfish	*Scarus niger*	Kukulado	✓		
	bullethead parrotfish	*Chlorurus sordidus*	Kukulado	✓		
	highfin parrotfish	*Scarus longipinnis*	Kukulado	✓		
	globehead parrotfish	*Scarus globicep*	Malakomu	✓		
Jack/Snapper Bass	red bass	*Lutjanus bohar*	Siaro		✓	
	midnight snapper	*Macolor macularis*	Guriamagani		✓	
	red emperor	*Lutjanus sebae*	Kokoroku	✓		
	paddletail snapper	*L.gibbus*	Tadiva	✓		
	mangrove jack	*L.argentimaculatus*	Hakala	✓		
Goatfish	dash-dot goatfish	*Parupeneus barberinus*	Sio	✓		
	black spot goatfish	*P.spilurus*	Sio	✓		
	goldsaddle	*P.cyclostomus*	Sio	✓		
Batfish	shaded batfish	*Platax pinnatus*	Bula		✓	
			Ahoio		✓	
Surgeonfish	elongate surgeonfish	*Acanthurus mata*	Ahuota	✓		
	pencilled surgeonfish	*Acanthurus dussumieri*	Ahuota	✓		
	mimic surgeonfish	*A.poryferus*	Vanaga	✓		
	sailfish surgeonfish	*Sibrasoma veliforam*	Vanaga	✓		
		Acanthurus nigricauda	Taiamava	✓		
		Acanthurus	Gaburu	✓		
	lined surgeonfish	*A.lineatus*	Vanaga	✓		
Sweet lips	dotted sweet lips	*Plectorhichus picus*	Kopi	✓		
	diagonal-banded	*P.lineatus*	Gareni	✓		
	striped sweet lips	*P.lessonii*	Gidare	✓		
	harlequin sweet lips	*P.chaetodoinides*	Omutu	✓		
Wrasses	tripletail maori wrasse	*Cheilinus trilobatus*	Mami	✓		

Group	Common Name	Scientific Name	Motu Name	Abundance		
				C	NC	R
	humphead maori wrasse	*Cheilinus undulates*	Mami		✓	
	slingjaw wrasse	*Epibulus insidiator*	Mami	✓		
	rockmover wrasse	*Novaculichthys taeniourus*	Mami	✓		
	six-barred wrasse	*Thalassoma hardwicke*	Mami	✓		
Triggerfish	titan triggerfish	*Balistoides viridescens*	Barubaru	✓		
	orange-line triggerfish	*Balistapus undulates*	Dumu	✓		
Eels	giant moray	*Gymnothorax javanicus*	Dagwala	✓		
	honeycomb moray	*Gymnothorax favagineus*	Dagwala	✓		
	yellowmouth moray	*G.nudivomer*	Dagwala	✓		
Unicorn Fish	orange spine unicornfish	*Naso lituratus*	Taranaria	✓		
	blue spine unicornfish	*Naso* sp.	Ialata	✓		
	spotted unicornfish	*Naso brevirostris*	Ikoko	✓		
		Naso sp.	Girini		✓	
		Naso sp.	Alana		✓	
Angelfish	six banded angelfish	*Pomacanthus extriatus*	Taureureu		✓	
	half circled angelfish	*P.semicirculatus*	Taureureu		✓	
	regal angelfish	*Pygoplites diacanthus*	Taureureu	✓		
	emperor angelfish	*Pomacanthus imperator*	Taureureu	✓		
	bluefaced angelfish	*P.xanthometopon*	Taureureu		✓	
Rabbitfish	happy morning	*Siganus* sp.	Beki	✓		
	barred rabbitfish	*Siganus doliatus*	Gani	✓		
	coral rabbitfish	*Siganus corallinus*	Beki	✓		
Pelagics	big eye tuna	*Thunnus obesus*	Bekebeke		✓	
	yellowfin tuna	*Thunnus albacares*	Kidukidu	✓		
	sail fish	*Istiophorus platypterus*	Varimoroe		✓	
	bonito	*Katsuwonus pelamis*	Inauga	✓		
	spanish mackerel	*Scomberomorus commerson*	Dae	✓		
	barracuda	*Sphyraena barracuda*	Balulu	✓		
	trevally	*Caranx* spp.	Matamata	✓		
	rainbow runner	*Elagatis bipunnulata*	Samani	✓		

(C=common, NC=not common, R=rare)

Appendix 3: Deep sea fishes caught by fishermen

Fish Family Name	Common English Name	Local Motu Name
Grouper	giant grouper	dono
	trout	bogi
	cod	haga/taguma/balala
Emperor	emperor	daragi/adia
	jobfish	kododoro
Mackerel	spanish mackerel	dae
	shark mackerel	dae
	tuna mackerel	dae
Trevally	giant trevally	matamata
Barracuda	great barracuda	balulu
	chevron barracuda	ono
Tuna	bonito	inauga
	yellowfin	vainavaina (kidukidu)
	big eye	bekebeke
	rainbow runner	samani
Snapper/ Bream	paddletail	tadiva
	red emperor	kokoroku
	red bream	siaro

Appendix 4: Major threats to critical habitats in Barakau

EVENT	CONTRIBUTING ACTIVITIES	HABITAT	IMPACT	REMEDIAL ACTION
Waste disposal	Disposal of solid waste Disposal of hazardous waste Disposal of animal waste Disposal of human waste	Mangroves Coral reefs Seagrass beds Ground water	Degradation Destruction Contamination	Public education & awareness Waste management plan Reef/mangrove management plan Waste management plan
Turbidity and sedimentation	Gardening Residential development	Mangroves Coral reefs Seagrass beds	Compromising assimilative capabilities of mangroves, corals and sea grasses Degradation of habitats	Develop management plans for gardening and village development/extension
Clearing of mangroves	Fuel wood Building material (posts, bearers; pig pens) Residential development	Mangrove forests	Destructing important nursery grounds Compromising assimilative capabilities of mangrove forests Leaving mangrove forest vulnerable to natural disasters	Develop policies to ban clearing of mangrove forest Introduce alternative fuel wood, building materials Establish mangrove nursery (reforestation and/or rehabilitation)
Communal harvest of edible items	Traditional tenure with neighbouring villages – tubusereia, gaire, dagoda and seme.	Mangroves Coral reefs Seagrass beds	Overfishing Over harvesting Disputes and arguments Poaching Encroachment	Establishment of marine protected area Identification of boundaries Formation of committee Gazettal of mpa & committee Formulation of rules/regulations Policing/enforcement of rules/regulations
Dynamite fishing	Fishing	Coral reefs Seagrass beds	Non-targeted species Extensive reef damage	Develop regulations for total ban Public awareness/education
Fishing with derris root	Fishing	Coral reefs	Non-targeted species	Develop regulations for total ban Public education/awareness
Small mesh nets	Fishing	Coral reefs seagrass beds	Non-targeted species	Public education/awareness Develop regulations Monitor activities
Vessel anchoring	Anchorage	Coral reefs	Coral damage Reef destruction	Public education/awareness Introducing appropriate alternatives

Appendix 5: Mangrove species recorded at Barakau

Species	Description of Location
Aegialites annulata	Rocky shoreline
Aegiceras corniculatum	High tide mark, flowering
Avicennia resinifera	Mud flats and mangroves edges
Avicennia alba	Outer edge of mangrove swamp
Avicennia marina	Inner mangrove swamp, fruiting
Baringtonia asiatica	Landward edge
Bruguiera cylindrica	Clay soil
Bruguiera exaristata	Back of mangrove swamp
Bruguiera gymnorrhiza	Dry well-aerated soil, fruiting
Ceriops decandra	Edge of mangrove swamp, rare
Ceriops tagal	Muddy soil, inner mangrove. End of Fruiting
Heritiera littoralis	Back swamp
Lumnitzera racemosa	Tidal mudflats
Osbornia octodonta	Sandy substrate, high tide mark
Pemphis acidula	Small bushy shrub on sandy soils
Rhizophora apiculata	Dark muddy soil, fruiting
Rhizophora stylosa	Sandy shores, fruiting
Rhizophora mucronata	Dark humus soil and also sandy areas
Scyphiphora hydrophyllacea	
Sonneratia alba	On muddy and sandy soil
Xylocarpus australasicus	High tide mark
Xylocarpus granatum	Back swamp, Start of Fruiting

Appendix 6: Mangrove associates and beach vegetation

Species	Description of Location
Acanthus ilicifolius	Under shrub in mangrove forest
Acassia aurifolius	On dry land after mangrove forest
Acrostichum speciosum	Landward edge of mangrove forest
Baringtonia asiatica	Found on beach close to mangroves
Baringtonia racemosa	Growing upstream close to creek
Brownlowia argentata	Shrub
Canavalia maritima	Creeper
Casuarina littoria	Mouth of river
Cocos nucifera	Planted
Cordia subcordata	Landward, beach shrub, at the back of mangrove forest
Crinum pedunculatum	Landward on high tide mark
Cypress sp. *(rotundus)*	Back of mangrove forest, on land
Eucalytus papuana	Dry land, close to mangrove forest
Fimbristylis sp.	Sedge,
Hibiscus tiliaceus	Along high tide mark at edge of mangroves
Imperata cylindrica	Abundant on beach ridge
Ipomoea pes-caprae	Creeper on the beach close to mangroves
Ischaemum muticum	Grass,
Magnifera indicus	Planted
Morinda citrifolia	Shrub
Pandanus tectorius	
Pemphis acidula	Dwarf shrub
Pongamia pinnata	
Remirea sp.	Sedge,
Scaevola taccada	Back of mangroves
Sesuvium portulacastrum	Creeper, on the beach behind mangroves
Terminalia catapa	
Themeda australis	Back of mangrove forest, on dry land
Thespesia populenea	
Wedelia biflora	

Appendix 7: Use of mangroves by Barakau villagers

Species	Local name	Uses
Ceriops tagal	ara ara	Firewood, construction and building material, spear handle, for husking coconuts
Ceriops sp.	ara ara rautari	Canoe pole
Bruguiera gymnorhiza	gavera	House post, jtty construction, canoe pole, building materials
Xylocarpus granatum	kou kou (kairu)	Fencing, construction and building materials
Avicennia marina	duahi	Houses, Fences
Rhizophora apiculata	totoho	Construction
Rhizophora stylosa		Fuelwood, Spear handle, and for husking coconuts