Sub-global Working Group

State of the Assessment Report

Papua New Guinea

Sub-Global Assessment of Coastal, Small Island and Coral Reef Ecosystems in Papua New Guinea

Summary National Assessment

Coordinating Lead Author: Colin Filer

Lead Authors: Simon Foale, Jean Kennedy, Christin Kocher Schmid, Len Mackenzie, Marcus Sheaves, Marjorie Sullivan

Contributing Authors: Bryant Allen, Michael Bourke, Alfred Hartemink, John McAlpine, Nadia Sirianni

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1 Introduction

1.1 The Assessment Process in PNG

In September 2000, the Millennium Ecosystem Assessment (MA) issued a call for proposals to undertake 'sub-global' assessments at local, national, and regional scales. The Call for Proposals was circulated amongst a group of social scientists who had previously had some connection to PNG's Biodiversity Conservation and Resource Management Program – an initiative which had been funded by the Global Environment Facility from 1993 to 1998. This program had sought to evaluate the actual and potential effectiveness of 'integrated conservation and development projects' in forested areas of PNG where high biodiversity values are associated with low population densities. One of the key lessons of the program had been that local communities in these areas are far more interested in 'development' than in 'conservation', because they can reasonably say that they have been conserving their ecosystems for thousands of years, but are now lagging in their access to modern health and education services because of their small and scattered populations (McCallum and Sekhran 1997; van Helden 1998, 2001; Filer 2004b). If the Government cannot afford to provide these services to remote and thinly populated areas, then local people tend to dream of the day when a logging company or mining company will deliver them from their state of backwardness.

In some coastal areas, by contrast, high *marine* biodiversity values are associated with very high population densities, and local communities are keenly aware of the limited capacity of their *terrestrial* ecosystems to supply the services required by continuing population growth. The MA's Call for Proposals happened to coincide with a spate of letters and reports from a number of small island communities which indicated the extent of this awareness (see Box 1). It therefore appeared that an assessment of small island ecosystems would best fit the MA's selection criteria for a sub-global assessment, because these specified that an assessment should be undertaken 'where it matters most', 'where people want it', and 'where there is a good chance of success'.

After some consultation amongst relevant stakeholders in the national capital, Port Moresby, an abstract of a 'pre-proposal' was submitted to the Millennium Assessment at the end of October 2000. In this document, a 'small island under pressure' (SMIP) was defined as an island which has a surface area of less than 100 km^2 and a crude population density in excess of 100/km^2, without rights of access to terrestrial subsistence resources on other islands which are sufficient to moderate this level of population pressure. A 'very small island under pressure' was defined as an island which has a surface area of less than 10 km^2, as well as these other properties.

Since data from the 2000 National Census was not yet available, an estimate was made of the number and distribution of such islands by projecting population growth rates from a previous census. This suggested that there were roughly 90,000 people living on 140 'small islands under pressure', and out of this total, about 35,000 were living on 120 'very small islands'. This appeared to confirm the general rule in Melanesia, which says that the density of population on small islands is inversely related to the size of the island, provided that the island is large enough to support a viable human community.

Box 1: PNG's 'singing islanders' unite to save their home.

'AUCKLAND: A small singing civilisation of Polynesians is being told by their own people that their homes will "one day vanish under the sea". Four hundred people on Papua New Guinea's Takuu may have up to five years before their atoll goes, or it could happen within months thanks to a deadly combination of plate tectonics and global sea-level rise. Their vulnerability has been dramatically highlighted in the last week by the weekend's massive earthquakes centred around Rabaul, 520 kilometres to the west. Their unique culture, in which every adult and many of the children have over 1,000 songs they can sing from memory, is to learn their grim fate from their own expatriate children scattered around PNG.

'Those living at Lihir, the rich gold mining island 520 kilometres north-east of Takuu, also known as the Mortlock Islands, have held a meeting addressed by Apeo Teata, who called for a voyage home to make a detailed study of what was happening. "The group of technical people to visit the island should also be given the task of educating the people at home about global warming and its effects," the Lihir minutes note. "The people should be told that Mortlock Island would one day vanish under the sea."

'The scattered islanders met after an AFP story in October quoted University of Auckland ethnomusicologist Richard Moyle warning of disaster. "I cannot see any way of stopping it with human intervention. If you want to say doomed, I guess in a literal sense they are," Mr Moyle said. For the people their fate is beyond comprehension. "I asked a few people, will you go, will you stay? The older people said they wanted to stay and I asked them what would happen when the island was underwater. They said 'I will die'."

'Mortlock Islanders met in East New Britain on Nov 5. "The group was informed that according to scientific information circulated, the sinking of Takuu is attributed to subduction/tectonic movement or greenhouse effect," the meeting's minutes record islander Lauatu Tautea saying. "Many present told of their observations which clearly indicated that the island is going underwater."

'Faiva Sione has just returned from Takuu and noted that gardens were being exposed and affected by seawater. Even the winds have changed and the sand dunes are being swept away. "The group was of the view that the islands were sinking basing this on their individual experiences and agreed that this was the most important agenda or issue confronting us", the minutes read. "It was agreed that the most important objective now was to seek land to relocate Takuu." They hold out some hope for a sea-wall and land reclamation – but admitted those were temporary fixes.

'Takuu is near war-torn Bougainville, a Melanesian island. Islanders have met with the Bougainville rebel[s] and were given support for resettlement. Mr Sione said they should push urgently for land at a time when there was no pressure for land in Bougainville. – AFP'

Source: *The National*, 20 November 2000 (article written by Michael Field).

In November 2000, a meeting of national stakeholders was convened to discuss the further development of the proposal. This meeting was attended by representatives of three national government agencies, three research institutions, two international conservation organisations, and two donor agencies. The meeting agreed that the University of PNG and the Australian National University would enter into a partnership to develop a more detailed proposal.

Further work on the proposal came to a halt when the MA Board decided to cluster the sub-global assessments in four 'focal regions', none of which would include PNG. The work was revived in May 2001, when the two universities were asked to recast the proposal as a study of 'small islands in peril' in Milne Bay Province. This was now to be a component of the Milne Bay Community-Based Coastal and Marine Conservation Project (MBCP), which had been conceived as a reincarnation of the earlier Biodiversity Conservation and Resource Management Program in a coastal and marine setting (van Helden 2004). The new project, like its predecessor, would be funded by the Global Environment Facility and implemented by the UNDP, but would have a provincial rather than a national focus, and would be executed by Conservation International in association with the Milne Bay Provincial Government.

It made sense to include an assessment of small island ecosystems in this program because Milne Bay, aside from being a marine biodiversity 'hotspot', has a higher concentration of densely populated small islands than any other province in PNG (see Table 1).

Table 1: Small islands in peril in Milne Bay Province and the rest of PNG.

LOCATION	Islands with area of 1-10 km^2		Islands with area of 10-100 km^2	
	No. of islands	Est. 2000 pop'n	No. of islands	Est. 2000 pop'n
Milne Bay Province	44	11,468	1	7,200
Rest of PNG	75	23,030	19	48,603
TOTAL PNG	119	34,498	20	55,803

A proposal for the Milne Bay SMIP Program was initially drafted in September 2001, and a revised version was included in final design documents for the MBCP submitted to the GEF in January 2002. The UNDP agreed to fund the project over a three-year period as part of the co-financing requirement of the GEF grant. Within the context of the MBCP, the SMIP Project was seen primarily as a capacity-building project for the Milne Bay Provincial Government and local communities within the Province. Conservation International had already established a process of user engagement for the MBCP during its three-year design phase, so the SMIP Program would simply add to this process by engaging small island communities outside of the zone in which a network of marine protected areas was to be established.

Since the conceptual framework and methodology of the Milne Bay SMIP Program were still aligned with those of the Millennium Assessment, the MA Board approved the 'PNG Local' assessment as a sub-global assessment at the end of 2001. The SMIP Program itself would have two scales of assessment – the provincial scale and the community scale – and this appeared to justify its designation as a 'local' assessment. However, the proponents were still interested in the possibility of gaining financial and political support for a broader national or regional assessment of *coastal* ecosystems, for which the Milne Bay SMIP Program could be treated as a sort of pilot project.

In May 2002, a workshop was convened in Darwin (Australia) to explore this possibility. The cost of this meeting was borne jointly by the Millennium Assessment and the Australian National University. The regional focus of the workshop was defined as 'Tropical Australasia' – a term which was held to cover northern Australia, Melanesia, eastern Indonesia, and East Timor. Sixty individuals from different countries and organisations within the region attended this meeting, and identified a number of local sites where an ecosystem assessment would be warranted. The choice of sites was motivated by three criteria: the distinctive nature of the drivers of ecosystem change; the availability of substantial amounts of data on ecosystem conditions and trends; and the presence of organisations with a long-term stake in the conservation or sustainable management of coastal ecosystems. Where a site met all three of these criteria, it was apparently reasonable to assume that local communities would also have an interest in the process of ecosystem assessment.

A number of national and regional initiatives have been developed on the basis of this meeting, but none has so far been developed to the point of being approved as a sub-global assessment within the current timeframe of the Millennium Assessment, except for the revised version of the 'PNG Local' assessment, which has now been modified to include a preliminary *national* assessment of costal ecosystems. The reason for this change of focus is the delayed inception of the Milne Bay Community-Based Coastal and Marine Conservation Program. Although the MBCP was formally approved by the GEF Board in May 2002, implementation was effectively delayed until the second half of 2004. The MA Board approved the change of focus in February 2003, and provided some additional funding for short periods of fieldwork and data collection in several local sites in PNG, most of which had been nominated as sites of special interest at the Darwin workshop (see Figure 1).

Figure 1: Local assessment sites in Papua New Guinea. [INSERT]

Given the financial and temporal constraints on the conduct of this national assessment of coastal ecosystems, the process of user engagement at the local and community scales has been designed around the interest of those organisations which have already been working with local communities on issues related to the management of coastal ecosystems, or around the existence of separately funded initiatives to identify and respond to local community needs. At the national scale, the users of this assessment are still identified as the organisations which originally endorsed the idea of conducting an assessment of 'small islands under pressure'. Their needs are identified primarily in terms of the sectoral resource management regimes in which they play an active role. For example, the Department of Environment and Conservation has a need for information which ought to be incorporated into the National Biodiversity Strategy and Action Plan which it has not yet been able to produce, despite the fact that PNG was one of the first countries to ratify the Convention on Biological Diversity. Likewise, the National Fisheries Authority has a need for information pertaining to the refinement and implementation of its coastal fisheries policy.

In the second (3-year) phase of the assessment, the needs of users within Milne Bay Province will take priority, and greater attention will be paid to the needs of local communities, because it will be possible to engage with those needs for a longer period of time without raising unrealistic expectations about the benefits of scientific research. However, it is expected that users of the preliminary national assessment will also gain additional information and benefit from the findings of the provincial assessment, because the latter is partly designed to test the application of approaches which should have wider relevance to the management of coastal ecosystems in other provinces.

1.2 Presentation of Summary Assessment

This is a preliminary assessment, as much as a summary assessment, because it presents the findings of work that is still in progress and will not be completed until the middle of 2005.

Sections 2, 3, 4 and 5 are primarily concerned to comment and elaborate on the application of the MA Conceptual Framework (MA 2003) to the assessment of coastal ecosystems in PNG, rather than to present the findings of the assessment itself. That is because some of the authors of this report are still engaged in a separate study to refine the analysis of existing data on the poverty-environment relationship in PNG as a whole, which has been commissioned by the Worldwide Fund for Nature, and which is due for completion in April 2005. The findings of this study will have particular relevance to our assessment of the relationship between coastal communities and *terrestrial* ecosystems, because the terrestrial ecosystems of PNG have already been subject to far more systematic analysis than the marine ecosystems.

Our assessment of the current conditions of specific ecosystems presented in Section 6 is exclusively concerned with coastal *marine* ecosystems because our assessment of these ecosystems is unlikely to be affected in any significant way by the findings of the work in progress. The problem of integrating an assessment of coastal terrestrial and marine ecosystems at a national scale is one that has yet to be addressed, and may need to be addressed by means of local assessments before it can be addressed at a national scale.

Section 7 presents a framework for the assessment of policy responses to a variety of 'environmental issues' whose significance is generally recognised by decision-makers operating at the national level, but then focuses on the analysis of responses to only one of these issues by way of illustrating the environmental policy process in PNG.

Section 8, on the other hand, contains a general discussion of scenarios for coastal ecosystems in PNG which may need to be revised when other parts of the national assessment have been finalised.

2 Definition and Classification of Coastal Ecosystems

2.1 The MA Conceptual Framework

The MA Conceptual Framework treats 'coastal' ecosystems as one of ten broad categories of ecosystem, but allows that any particular 'place on Earth' may belong to more than one of these classes (MA 2003: 54). The other nine categories include 'island', 'forest', 'cultivated' and 'urban' ecosystems. For the purpose of mapping ecosystems at a global scale, 'coastal' systems are assumed to occupy a space which extends '50 metres below mean sea level and 50 metres above the high tide level or … 100 kilometres from shore'. This broad 'coastal zone' is understood to include 'coral reefs, intertidal zones, estuaries, coastal aquaculture, and seagrass communities' (ibid.). Within this space, one finds most, if not all, of the land allocated to 'islands' (as defined by the Alliance of Small Island States), as well as some of the land allocated to 'forest', 'cultivated' and 'urban' ecosystems. So it is clear that the ten broad categories are not mutually exclusive.

However, this classification also reveals an ambiguity in the way that ecosystems are defined for mapping and reporting purposes. The boundaries of the coastal zone (like the size of an island or the extent of a river basin) in any one part of the world will remain fixed in the absence of a change in the mean sea level or a major tectonic event. But the boundaries which separate 'forest', 'cultivated' and 'urban' ecosystems are continually modified by human activity in a manner that is not mediated by the long-term impact of climate change.

The implication of defining an ecosystem as a space or a place on earth is that one ecosystem cannot be transformed into another ecosystem. If a patch of native forest is cut down and replaced by an oil palm plantation or an open-cut copper mine, it is only the qualities or characteristics of the ecosystem which have been transformed. But if an ecosystem is defined primarily as a type of biological community, then its boundaries are more flexible, and one ecosystem can be converted into another ecosystem within a given area.

Article 2 of the UN Convention on Biological Diversity attempts to combine biological and geophysical criteria in its definition of an ecosystem as ‘a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit’. The MA Conceptual Framework emphasises the criterion of interaction when it says that ‘a well-defined system has key feedbacks included in it and weak, slow, constant, or unidirectional interactions across the boundaries’ (MA 2003: 125). However, the possibility remains, at any given scale, that the boundaries of ecosystems defined primarily by reference to *geophysical* criteria may fail to coincide with those whose boundaries are defined primarily by reference to *biological* criteria.

While the MA Conceptual Framework recognises that human populations are themselves to be treated as an integral component of ecosystems (MA 2003: 50), it also treats ‘human systems’ or ‘social systems’ as if these were spatially bounded entities which can be ‘overlaid’ on those of ecosystems (ibid: 125). We take a slightly different approach, by allowing that the human beings who manage ecosystems or consume ecosystem services within a specific society, jurisdiction, or ‘level of social organization’ (ibid: 108) have their own ways of defining ecosystem boundaries which may not coincide with those postulated by natural scientists. We deal with this possibility by proposing a distinction between *scientific* (or *naturalistic*) and *political* (or *sociocentric*) perspectives on the definition of ecosystems. This cuts across the distinction already made between geophysical and biological perspectives.

2.2 The Coastal Zone and Coastal Ecosystems in PNG

For the purpose of this assessment, we shall define PNG’s *coastal zone* as the space which extends 10 kilometres inland from a shoreline up to a maximum height of 600 metres above sea level, or 10 metres below mean sea level but within 10 kilometres of a shoreline. This is a narrower definition than the one adopted in the MA Conceptual Framework, partly because of the scale at which this assessment is conducted, and partly because it reflects the normal limits of resource use by coastal communities.[1] PNG’s coastal ecosystems are thus defined as the ecosystems which lie wholly or partly within this coastal zone. These may either be terrestrial or marine ecosystems, or they maybe ecosystems which have both terrestrial and marine components.

At a mapping scale of 1:100,000, the length of the PNG coastline is approximately 17,100 kms, and the terrestrial component of the coastal zone covers roughly 10% of the country’s landmass. Approximately one third of PNG’s total population (estimated at 5.6 million in 2003) is currently resident in this coastal zone, which means that the average population density for the terrestrial component is about 40 persons per square kilometre.

[1] The 10-metre depth limit also reflects the extent to which marine ecosystems are normally visible from above the surface of the sea.

If ecosystems are defined as ‘places on earth’, with boundaries which are relatively fixed, then small islands (or very small islands) can be defined as ecosystems in their own right, with or without parts of the surrounding seas. But how should the coastal zone around the mainland or the larger islands of PNG be cut up into smaller local parts? If we follow the distinctions made in the previous section, there are four ways of answering this question, as shown in Table 2. We shall now consider each of these four answers in more detail.

Table 2: Alternative definitions of local ecosystems in Papua New Guinea.

	Geophysical Perspective	*Biological Perspective*
Scientific Perspective	RESOURCE MAPPING UNITS	BIOLOGICAL COMMUNITIES
Political Perspective	TERRITORIAL DOMAINS	LANDSCAPE ELEMENTS

2.2.1 Ecosystems defined as Resource Mapping Units

If we adopt a *scientific and geophysical* perspective, the terrestrial component of the coastal zone can be divided into the Resource Mapping Units (RMUs) distinguished by the PNG Resource Information System (PNGRIS) (see Bellamy and McAlpine 1995; Hammermaster and Saunders 1995).

PNGRIS was developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) as a method of determining the potential for sustainable smallholder agriculture in PNG, using the 1:500,000 scale Tactical Pilotage Chart as a base map. Each RMU is a unique configuration of the following variables: (a) landform, (b) rock type, (c) altitude, (d) relief, (e) inundation, (f) mean annual rainfall, and (g) province. (The inclusion of this last variable adds one political feature to the geophysical perspective.) A total of 4,849 unique RMUs have been identified for the whole of PNG, but if we combine those which are identical except for the fact of being split by a provincial boundary, the number comes down to 4,566, which means that the average area is just over 100km^2. From the original total of 4,849, 155 (or 3.2%) include some portion of the coastal zone, but more than half of these (86) are located in one of PNG’s 19 provinces – Milne Bay (see Figure 2). Nine of the 155 fall within Altitude Class 2 (600-1200m), which means that they are located in areas where the mountains descend very steeply to the sea, and it could be argued that these should not be counted as ‘coastal’ ecosystems.

Figure 2: Resource Mapping Units on Cape Vogel, Milne Bay Province. [INSERT]

The advantages of adopting this definition of coastal ecosystems are:

- PNGRIS has been established as the standard GIS database for use by national government agencies, and many government officials have been trained to use it.

- A variety of additional information on human and biological communities has been mapped into RMUs, even though these variables do not enter into their definition.

- The variables used to define RMUs should predict native vegetation cover in the absence of anthropogenic disturbance.

The disadvantages of adopting this definition are:

- RMUs are purely terrestrial entities – they have no marine component or equivalent.
- It is difficult to group RMUs into larger spatial clusters or divide them into smaller spatial units except by reference to specific variables.
- There is little or no data concerning the movements of people or flows of anything across RMU boundaries, which means that their boundary conditions are largely unknown.
- RMU boundaries have little or no significance for local ecosystem managers or local consumers of ecosystem services.

2.2.2 Ecosystems defined as territorial domains

If we adopt a *political and geophysical* perspective, we can define local ecosystems as the territorial domains of human social groups or communities.

In pre-colonial times, Papua New Guineans were members of sovereign political communities which rarely had less than 100 or more than 1000 members. There were perhaps 10,000 of these 'tribal' groups in what is now the State of PNG. These traditional communities normally retain a distinctive political identity (as census units or council wards) within the modern institutional framework of the State.

Approximately 98% of PNG's surface area is still held under customary tenure, and is thus divided between the territorial domains of these traditional groups. The other 2% has been alienated to form 'modern enclaves' which are occupied by urban or industrial communities, although some areas of customary land have been temporarily allocated to logging or mining companies (by agreement with the customary owners) for the purpose of extracting specific resources. The proportion of alienated land is higher within the coastal zone than it is in the hinterland, because colonial plantations and towns were concentrated in this zone, but it would still not account for more than 10% of its terrestrial component.

Most Papua New Guineans, including those resident in modern enclaves, still see themselves as members of traditional communities, and expect to be buried in their traditional domains. Even those areas of land which have been alienated for the creation of modern enclaves are still typically seen to belong to the original domains of traditional communities which still exist and still have some claim over them. And even within the boundaries of the larger towns, areas of alienated land are typically interspersed with areas of customary land.

The territorial domains of traditional communities are normally divided between the domains of smaller social groups, commonly known as 'clans' or 'lineages'. Nowadays, Papua New Guineans also tend to identify with larger territorial groupings of traditional political communities, such as those united by a common language or culture. We shall call these *'neo-traditional'* communities, but allow the definition of 'traditional domains' to include the territories jointly occupied by neo-traditional communities.

The advantages of adopting this definition of coastal ecosystems as territorial domains are:

- The territorial domains of coastal communities can include marine as well as terrestrial components, because customary ownership of inshore marine resources is recognised in law and asserted in practice.
- The members of traditional communities (which means the vast majority of Papua New Guineans) certainly see themselves as 'an integral component' of their own ecosystems.
- Traditional domains (and even modern enclaves) can be defined at several different scales, all of which make sense to members of the groups identified at each scale.
- Since the boundaries of community domains tend to coincide with those of political and administrative units defined at the local scale, there are some measures of the 'boundary conditions' of ecosystems defined in this way.

Yet there is one major disadvantage in adopting this definition. While the boundaries of modern enclaves have been thoroughly surveyed, those of most traditional domains are only known to members of the social groups which own or occupy them, or to their immediate neighbours.

2.2.3 Ecosystems defined as biological communities or landscape elements

If we adopt a *scientific and biological* perspective, we can define coastal ecosystems as a combination of terrestrial and marine biological communities, each of which clearly provides a different set of ecosystem services to human consumers. However, we cannot assume that the local consumers of these services will perceive the boundaries of such biological communities, or the nature of the services which they provide, in the same way as a biologist. So we also allow for the existence of a *political* and biological perspective, in which coastal ecosystems are defined as distinctive elements of the 'landscape' (including the seascape) contained within the boundaries of a traditional or modern territorial domain.

Table 3 shows the eight major categories of biological community recognised in this assessment. The broad classification of terrestrial communities reveals some of the points at which local or indigenous perceptions of the landscape may diverge from those of the natural scientist. For example, the MA Conceptual Framework defines the boundaries of 'forest ecosystems' by reference to the minimum percentage of canopy cover produced by 'woody plants taller than 5 metres', but excludes 'orchards and agroforests where the main products are food crops' (MA 2003: 54). The boundaries of 'cultivated ecosystems' are then defined by reference to the minimum percentage of the landscape which comes under cultivation in any particular year (ibid: 55). The scientific perspective which generates this kind of distinction is aiming for mutually exclusive categories which can be mapped on the basis of aerial photography or satellite imagery. However, in PNG, where shifting cultivation is the dominant form of agricultural activity, and fallow periods vary according to soil fertility and population pressure, the eye in the sky may see a landscape which looks quite different to the indigenous farmer.

Table 3: General classification of coastal biological communities in PNG.

TERRESTRIAL COMMUNITIES
'Uncultivated' forest (including sago groves)
Cultivated land (including bush fallows and orchards)
Other 'natural' communities (e.g. grasslands, wetlands)
Towns, villages and other 'built environments'

MARINE COMMUNITIES
Mangrove swamps
Coral reefs
Seagrass beds
Unvegetated soft bottoms

One of the architects of the PNG Resource Information System has used aerial photographs from the late colonial period (mostly taken in 1973) to produce a baseline map, at a scale of 1 to a million, of 'Agricultural Land Use' in PNG (Saunders 1993a). This map shows all the areas of 'cultivated land' and some distinctive types of 'uncultivated land'. 'Cultivated land' is defined as 'all land where there is evidence of a relatively recent cultivation history as indicated by the presence of anthropogenous vegetation'. Different types of cultivated land are distinguished only by reference to degrees of 'land use intensity', except that a distinction is made within the 'very high intensity' class between land dominated by tree crops (coffee, cocoa, coconut or oil palm) and land planted primarily with food crops (such as sweet potato or taro). Within the general category of uncultivated land, the map designates specific areas as grassland, sago groves, savanna woodland, or 'larger urban centres'. The empty spaces on this map are all covered by forest.

The same data were used to produce a related baseline map of the 'Forest Resources' of PNG (Saunders 1993b) which divides areas of forested land into ten major categories. Mangroves (or 'estuarine communities') are mapped as a single forest type. Six other types of forest are shown to occur within the coastal zone, while the other three types are restricted to the hinterland. Sago groves are not recognised as a distinctive forest type, but some of the areas allocated to sago groves on the map of Agricultural Land Use are allocated to another forest type on the map of Forest Resources. Likewise, some of the areas shown as 'cultivated land' on the map of Agricultural Land Use are classified as forested land on the map of Forest Resources because they are areas of significant secondary regrowth following cultivation.

To limit the extent of spatial overlap between the eight main types of biological community distinguished in this assessment, we shall maintain a distinction between 'uncultivated forest' and 'cultivated land' (including forest fallow). However, we do not assume that the general category of 'uncultivated forest' is free of any human disturbance. On the contrary, mapping or analysis at smaller scales reveals complex patterns of indigenous forest management, as well as periodic incursions by commercial logging companies (Kennedy and Clark 2004).

In order to improve the management of commercial logging operations, consultants to the PNG Forest Authority have developed a 'Forest Inventory Mapping System' (FIMS) which maps PNG's forest resources and other vegetation, at a scale of 1:100,000, for the years 1975 and 1996. From the 1975 data, the whole country has been divided into a very large number of Forest Mapping Units (FMUs), each of which has then been allocated to one of 59 vegetation types, of which 36 are classified as forest types. From this database it is possible to establish changes in the extent and composition of forest cover in each FMU between 1975 and 1996.

2.3 Food-Cropping Systems Defined as Agro-ecosystems

From 1990 to 1996, the PNG Land Management Group at the Australian National University organised a thorough field survey of all areas previously designated as ‘cultivated land’ (Saunders 1993a) as part of the ‘Mapping Agricultural Systems Project’ (MASP) (see Bourke et al. 1998). For the purpose of this assessment, the local or indigenous ‘agricultural systems’ distinguished by means of this survey are designated as ‘food cropping systems’ rather than ‘agricultural systems’ in order to distinguish them from agro-industrial enclaves such as oil palm estates. Coastal food cropping systems are then defined as the systems which occupy some part of the coastal zone, even if they also occupy some part of the hinterland as well (see Figure 3). These food-cropping systems may be counted as distinctive ‘agro-ecosystems’ within the generic biological community of cultivated land.

Figure 3: Food-cropping systems on Cape Vogel, Milne Bay Province. [INSERT]

Food-cropping systems are defined in the MASP database as unique combinations of six variables related to the measurement of ‘agricultural intensity’:

- fallow vegetation type cleared from garden sites at beginning of planting;
- number of times land is planted before being fallowed;
- period of time the land is fallowed;
- most important crops;
- techniques used to maintain soil fertility (other than fallowing); and
- segregation of crops within or between garden sites.

The mapping of these systems has been carried out on the same map base and 1:500,000 scale as was used for the PNGRIS database. A total of 287 food-cropping systems have been identified for PNG, of which 138 (or 48.1%) occupy land within the coastal zone, and may therefore be counted as coastal agro-ecosystems. This implies that ‘coastal’ food-cropping systems are far more diverse than ‘coastal’ Resource Mapping Units when compared with those of the hinterland or interior of the country.

As in the case of PNGRIS, the MASP database contains a wide variety of additional information (102 attributes in all) which have been mapped into the food-cropping systems without being used to define their boundaries. These include estimated cash earnings from agricultural activities and measures of accessibility from the nearest service or market centre (Hanson et al. 2001). No attempt has been made to match the boundaries of food-cropping systems to those of the Resource Mapping Units distinguished by PNGRIS because that would have begged the question of whether food-cropping practices are determined by environmental conditions. Or to put the same point in another way, it would assume a questionable coincidence between the boundaries of local ecosystems defined by geophysical and biological criteria.

The role of traditional communities and groups in the development, management and understanding of these food-cropping systems means that the MASP database provides the best available source for a systematic survey of local ecosystems defined by a combination of *political and biological* criteria, as a set of *landscape elements* rather than a set of biological communities. On the other hand, the database also provides a set of scientific, rather than political, criteria for grouping traditional communities together on the basis of their ‘culture of cultivation’. Although there are some hinterland communities whose members practice more than one food-cropping system because of the altitudinal range covered by their territorial domains, it is reasonable to assume that each traditional community in the coastal zone is engaged in only one food cropping system.

3 Environmental Governance and Resource Management Regimes

3.1 Levels of Action, Management and Administration

The MA Conceptual Framework proposes to restrict the use of the word ‘scale’ to phenomena whose physical dimensions can be measured in units of space or time, or to the observations made of these phenomena (MA 2003: 108). This means that a ‘level’ of social or political organisation can only be said to have a scale if it occupies a specific area (or if it lasts for a specific period of time). The distinction between ‘scales’ and ‘levels’ reflects the distinction already made between ‘scientific’ and ‘political’ perspectives on the definition of ecosystems (Table 2).

In one respect, this choice of terminology is unduly restrictive. For example, the scale of a mining operation is normally measured by the volume of its throughput or output, rather than the physical extent of the area which is being mined, and the scale of an economic enterprise is often measured by the number of people which it employs rather than the floor space in its offices or factories. However, the scale of an ecosystem assessment is understood to refer to the spatial extent of the ecosystems which are being assessed.

In this assessment, the *national* scale is identified with the territorial extent of PNG’s national jurisdiction, and is therefore the scale at which the whole of PNG’s coastal zone is distinguished from the hinterland and the remainder of the country’s territorial waters. The *local* scale of the assessment is defined as the scale at which local-level governments (LLGs) are distinguished from each other *or* the scale at which local food-cropping systems (or agro-ecosystems) are distinguished from each other. The *community* scale is the scale at which the territorial domains of traditional and modern communities are distinguished from each other, which means that it is also the scale at which specific ecosystems are distinguished from each other from a political and geophysical perspective.

The number of LLGs in PNG is roughly equivalent to the number of food-cropping systems, although there is no correspondence between their respective boundaries. The practitioners of a single food-cropping system have no sense of political identity, nor any form of social organisation, which is based on their common practice. In this assessment, we treat food-cropping systems as the primary *mapping unit*, and LLG jurisdictions as the primary *reporting unit*, at the local scale.

There are two tiers or levels of political representation and government administration between the national and local levels. PNG has 19 provinces and a National Capital

District, each of which elects one member of the National Parliament. The 19 provinces are divided into 86 districts or 'open electorates', each of which is also represented by one MP, while the NCD is divided into three open electorates. Under the *Organic Law on Provincial Governments and Local-level Governments*, all national MPs are members of their respective Provincial Assemblies, as are the Presidents of all rural LLGs within the boundaries of each province. The MP representing the provincial electorate becomes the Provincial Governor unless he is appointed as a Minister of the National Government or holds a designated parliamentary office, in which case the Assembly elects another of its members to be the Governor. The MPs who represent the open electorates are able to wield substantial influence over public spending within their electorates through their control over the Joint District Planning and Budget Priority Committees and their access to District Development Funds allocated through the national budget.

The Organic Law says that provincial governments can pass laws on a variety of subjects, including: urban and rural development; agriculture, forestry and agroforestry; fishing and fisheries; and parks, reserves, gardens, scenic and scientific centres. However, these laws must be consistent with the National Constitution and prior national legislation. Furthermore, provincial governments are not allowed to make laws about mining, petroleum, forestry, fishing or marine resource ventures which the National Government defines as 'large-scale' ventures, nor can they make laws about the volumes of natural resources which can be harvested, the prices at which such resources are to be sold, or the revenues to be collected from those sales. These subjects are all deemed to be the exclusive preserve of national legislation.

The Organic Law says that local-level governments can also pass laws on a variety of subjects, including: the local environment; the protection of traditional sacred sites; human settlements; domestic animals, flora and fauna; hygiene and sanitation; provision of water supplies and electricity; and cottage industries. These powers are limited in the same way as those of provincial governments.

In practice, provincial and local-level governments have not made much use of the law-making powers granted to them under the Organic Law. Many of the decisions made about the management of local ecosystems are either made informally, by members of local groups and communities, or else by the executives or representatives of 'civil society' organisations, such as church groups, business groups, landowner companies or landowner associations.

3.2 Sectoral and Indigenous Resource Management Regimes

For the purpose of this assessment, a *resource management regime* is defined as the set of values, policies, institutions and practices which are applied to the human consumption, management, conservation or exploitation of specific natural resources, landscapes or ecosystems. A general distinction is drawn here between *sectoral* and *indigenous* regimes, but they are not mutually exclusive.

A sectoral resource management regime is defined by reference to a national government agency which is responsible for one or more policies which are themselves potential drivers of ecosystem change. However, the national government agency does not have a monopoly over the design or implementation of the policies which belong to this regime, let alone the values, institutions or practices which are associated with them. It only functions as a point of reference because other actors or stakeholders recognise the power of a national government to establish general rules about the consumption, management, conservation or exploitation of specific natural resources, landscapes or ecosystems – even if these rules are often broken in practice.

A sectoral regime engages multiple actors, stakeholders or decision-makers, each of whom may operate at several different scales. For example, the *environmental protection* regime, which is the notional responsibility of the PNG Department of Environment and Conservation, may involve officers of that department in global debate about the application of the Convention on Biological Diversity, or in purely local debate about the establishment of a 'Wildlife Management Area' under PNG's *Fauna (Protection and Control) Act* (see Section 7.2). Other actors in this regime would include the World Bank, in its capacity as the manager of a grant from the Global Environment Facility, or the villagers who apply to establish a Wildlife Management Area, or staff of the WWF South Pacific Program who encourage them to do so. Each sectoral regime therefore has institutional components at different levels of management or administration, and covers a variety of cross-scale linkages between institutional systems which affect the consumption, management, conservation or exploitation of coastal ecosystems.

Even the definition and classification of ecosystems within a specific national context may be seen as a function of specific sectoral regimes. For example, the scientific and geophysical equation of ecosystems with Resource Mapping Units is a function of the country's *agricultural* regime, because the Australian scientists who invented RMUs were not attempting to produce a definition of ecosystems, but to determine the potential for sustainable smallholder agriculture in PNG. Likewise, the fact that members of traditional communities know and control the boundaries of their traditional domains, while the Government has never contrived to map these 'ecosystem' boundaries in any systematic way, is a feature of the country's *landed property* regime.

An indigenous resource management regime is understood to operate only at a local scale or community scale, but the number of indigenous regimes greatly exceeds the number of sectoral regimes. That is because we assume a one-to-one correspondence between these indigenous regimes and the *food-cropping systems* defined by the PNG Land Management Group. In other words, each indigenous regime consists of a food-cropping system and a number of other practices, such as hunting, fishing, forest management, animal husbandry, or smallholder cash cropping practices, as well as the values, institutions and 'policies' which are associated with them.

To say that each food-cropping system is the central component of a single indigenous resource management regime is not to imply that each form of indigenous agricultural practice is accompanied by an equally distinctive form of indigenous fishing, hunting or forest management practice. Indigenous fishing, hunting or forest management practices cannot be mapped as spatially discrete 'systems' in the same way as indigenous food-cropping practices, so it does not make sense to ask whether the boundaries of 'hunting systems' coincide with those of food-cropping systems. This is not just because of the absence of any systematic nationwide survey of hunting practices, but also because contemporary hunting practices retain much less of their traditional technical content (and knowledge) than contemporary food-cropping practices. The same goes for fishing and forest management practices. We therefore treat food-cropping systems as the most significant element of continuity in the development of indigenous resource management regimes, and in this respect, it would be true to say that PNG is essentially a 'nation of gardeners'.

Management decisions attributed to indigenous resource management regimes are 'endogenous' to those regimes, and are only taken at the community scale, although they make be taken by individuals or smaller groups within each community. Management decisions attributed to sectoral regimes can be taken at several different scales, and may therefore seem to be endogenous to actors operating at one scale, while they seem to be exogenous to actors operating at another scale.

3.3 The Role of Local and Indigenous Knowledge

This assessment does not assume the existence of a single body of traditional ecological knowledge in PNG which is opposed to 'Western' or 'scientific' forms of ecology. Generic statements about 'traditional/indigenous ecological knowledge' in Melanesia may be the subject of *policy* (normative statements about what ought to be true or what people ought to do) or *ideology* (normative statements disguised as statements about what really is true or what people actually do). But they are not very enlightening when taken out of a specific local context and placed in the national or international domain.

In this assessment, *traditional or indigenous* ecological knowledge is treated as a feature of indigenous resource management regimes, while *local* ecological knowledge (along with other forms of knowledge) is treated as a feature of *sectoral*, rather than indigenous, regimes. Both types of knowledge yield 'political' perspectives on the definition and classification of ecosystems, but there are other political perspectives to be found in sectoral resource management regimes.

Each of the 287 food-cropping systems defined by 'Western science' contains a body of practical agricultural knowledge which is *also* ecological knowledge *and* indigenous knowledge *and* local knowledge. Each one therefore represents a point of intersection between traditional ecological knowledge and local agricultural knowledge. However, this does not mean that there are 287 discrete 'systems' of local or traditional agricultural knowledge, or 287 local or traditional ecologies.

We do not isolate 'knowledge' as a major component of indigenous (or even sectoral) resource management regimes (along with values, policies, institutions and practices), because we want to stress the potential gap between *practical knowledge* and *landscape values*. In other words, we want to question the link between local practices and the 'cultural services' which ecosystems provide to local consumers, and to question the role of traditional ecological knowledge in the *management* of traditional community domains or landscape elements.

Traditionally, specific forms of technical or magical knowledge were commonly regarded as the property of clans or individual experts within each community, and their practical effectiveness was not justified by reference to any collective vision or theory of landscapes or ecosystems. The people who knew garden magic, hunting magic, or fishing magic knew it because they had a *right to perform it*, not because they knew (or could say) *how it worked*. There is a very long tradition of debate about the relationship between Melanesian magic and Western science, but the relevance of this debate to the valuation and management of ecosystems by traditional communities has long been overlaid by a huge variety of Christian cosmologies.

The secrecy of traditional technical knowledge, as well as traditional magical knowledge, means that all forms of traditional knowledge are at risk of extinction when experts do not make them public, and do not therefore make them part of the policy component of indigenous resource management regimes. The role of the *expert* and the *manager* therefore seem to be separated, and either or both of these roles may not even seem to be occupied in some traditional communities. There is no reason to assume that traditional or indigenous knowledge of any kind can save local communities from the degradation or loss of ecosystem services within their traditional domains. Nor does it even seem likely that such knowledge can survive as a practical component of indigenous resource management regimes unless it also becomes a form of *local* knowledge within a *sectoral* regime which is connected to institutions (and other forms of knowledge) at higher levels of social organisation.

4 Ecosystem Services and Human Well-Being

4.1 Classification and Measurement of Coastal Ecosystem Services

Table 4 shows the modified terminology which is used in this assessment to distinguish between the four main types of ecosystem services distinguished in the MA Conceptual Framework. These are defined as follows:

- *Material benefits* (or 'provisioning services)' are 'goods produced or provided by ecosystems', such as food, water, and various other raw materials;
- *Landscape values* (or 'cultural services') are 'non-material' (e.g. spiritual or aesthetic) benefits obtained from ecosystems;
- *Control functions* (or 'regulating services') are 'benefits obtained from regulation of ecosystem processes', such as flood or disease control; and
- *Support services* are those which 'maintain the conditions for life on earth', such as soil formation or pollination, but do not provide any direct or immediate benefit for human consumers (MA 2003: 57).

Table 4: Basic classification of ecosystem services.

MA CONCEPTUAL FRAMEWORK	PNG NATIONAL ASSESSMENT
Provisioning services	Material benefits
Cultural services	Landscape values
Regulating services	Control functions
Supporting services	Support services

The PNG national assessment is primarily concerned with 'material benefits' and 'control functions', because:

- It is unlikely that a *national* assessment of 'landscape values' can make any useful observation about the way that different types of landscape value contribute to human well-being in PNG, except as part of a broader discussion of the relationship between *scientific, local and indigenous knowledge.*
- The distinction between control functions and support services is to some extent a distinction between direct services, which resident consumers can readily appreciate, and indirect services, whose contribution to human well-

being can best be understood as part of a discussion of *ecosystem conditions and trends* (see Section 6).

Although it is theoretically possible to list the services which each type of coastal biological community provides to resident consumers, the ranking or measurement of these services at a national scale is all but impossible, because the biological communities in each category are as diverse as the human communities that depend upon them. For example, it is safe enough to say that orchards provide material benefits such as fruit and nuts, building materials, or firewood, but some or all of these benefits are also derived from other terrestrial ecosystems, and even if there were a commonly agreed method of mapping their respective boundaries at a national scale, this alone would not enable us to determine the relative significance of different biological communities as providers of such benefits.

But the same point can be made in a different way by considering the inter-dependence of the services provided by different types of biological community within a single 'national' landscape. For example, most of the terrestrial biological communities, from food gardens to so-called 'primary forest', function as crop gene banks which support the overall genetic diversity among the landraces of PNG's subsistence food crops. This genetic diversity is generally very high, even by the standards of other regions where subsistence production is important, and is characteristic of crops introduced within the last few centuries, such as sweet potato, and well as 'indigenous' crops, such as sugar cane, sago, taro, banana, breadfruit. High crop diversity is maintained by a number of poorly understood mechanisms, which include:

- the interest of many PNG farmers in recognising, collecting and maintaining multiple varieties of particular crops, and
- continued interaction between actively cultivated crops and their passively maintained wider gene pools, held outside the active zone of farming in plant communities such as fallows, forests or grasslands.

In combination, these mechanisms encourage the retention and spread of new cultivars, and the range of choices available to individual farmers (Yen 1991; Kennedy and Clarke 2004).

The standard way of dealing with this issue is to shift from the ecosystem to the species as the unit of analysis, to list the different 'traditional' uses of the different parts of particular plant species, and then to assess the extent of such uses in different parts of the country (see Table 5). However, this approach tends to overlook those ecosystem services which do not count as material benefits, and there is still no way of assessing the relative importance of the material benefits derived from a particular species at a national scale, nor the degree to which these have been substituted by the use of imported commodities.

Table 5: Material benefits derived from miscellaneous planted tree species.

SCIENTIFIC NAME	PARTS USED	USES
Areca catechu [betel]	fruit	intoxicant
	timber	canoe parts, arrows and spears
	leaf sheath	temporary container
[Other arecoid palms ('limbum')]	timber	implements, bows and arrows, canoe parts
	leaf sheath	container, working surface
	timber, bark	flooring
	growing point	food (palm cabbage)
Artocarpus spp.	seed and whole fruit	food
	young leaves	food
	latex, leaves	medicinal
	latex	glue, bird lime
	inner bark	cloth
	trunk	canoe hull
Atuna racemosa	seed	caulking putty, tool hafts, containers
Broussonetia papyrifera	inner bark	string, cloth
Burckella obovata	fruit	food, dye/paint
Calophyllum spp.	trunk	canoe hull
	timber	canoe parts, carvings (implements), posts
	leaves	medicinal
	fruit latex	glue
Canarium spp.	fruit, seed	food
	trunk	canoe hull
Caryota rumphiana	timber	implements, flooring, bows
	broken up pole	substrate for insect larvae
	pith	inferior sago starch
Erythrina spp.	leaves	food, medicinal
	trunk	canoe hull
	timber	floats
	seeds	decoration, medicinal
Ficus spp.	fruit	food
	leaves	food, food wrapper, abrasive
	leaves, latex	medicinal
	latex	glue, bird lime
	inner bark	string, cloth, nets
	timber	construction
	trunk	canoe hull
Gnetum gnemon	leaves	food, food wrapper, insect repellent
	seeds	food
	inner bark	string, netbags
Hibiscus tiliaceus	inner bark	string, net, cloth
	bark	medicinal (emetic)
	timber	floats, canoe parts, posts
	sap	medicinal
	leaves	medicinal
Inocarpus edulis	seed	food
	bark	medicinal
Mangifera spp.	fruit	food
	timber	canoe parts
Morinda citrifolia	fruit	food
	leaves	food
	bark, leaves, sap	medicinal
	root	dye

Table 5 (continued).

SCIENTIFIC NAME	PARTS USED	USES
Pandanus spp.	fruit	food, lure
	oil of fruit	food, medicinal, paint
	prop roots	tongs, fibre for fishing lines
	bark	fibre
	leaves	basket, sails, rain caps, sleeping mats
	leaves	walls, food wrapper, ornament
	timber	flooring, construction
Pangium edule	seed	food, poison, medicinal
	leaves	food
	fruit shell	rattle, bead for necklace
	bark	fish poison
Pometia pinnata	fruit	food
	seed	food
	timber	implements, construction
	leaves	mulch
Spondias spp.	fruit	food
	leaves and leaf shoots	medicinal
Syzygium spp.	fruit	food
	bark, leaves	medicinal
	bark	lashing
	timber	implements
	trunk	slit-gong
Terminalia spp.	seed	food
	leaves	medicinal
	bark	medicinal
	timber	implements

Sources: Powell 1976; Futscher 1959; Walter and Sam 2002; Kennedy and Clarke 2004.

4.2 Classification and Measurement of Ecosystem Boundary Conditions

The MA Conceptual Framework defines the general condition of an ecosystem in terms of its capacity to provide specific services to human consumers. To some extent, we can assess the condition of a local ecosystem by looking at the ‘things’ which it contains within its boundaries. However, insofar as an ecosystem has spatial boundaries, the assessment of that ecosystem has to take account of the ‘things’ which cross those boundaries in any given period of time. These may be called the spatial boundary conditions of an ecosystem.

While the MA Conceptual Framework says that ecosystem boundaries can partly be determined by the presence of ‘weak, slow, constant, or unidirectional interactions across the boundaries’ (MA 2003: 125), this certainly does not mean that such interactions are irrelevant to an understanding of ecosystem dynamics. We cannot simply assume, for example, that a food-cropping system is delivering more services to resident consumers just because the resident population has grown faster than the area of cultivated land. The resident population might have been swelled by large numbers of immigrants attracted by the income earned from a rapid increase in the value of marine or mineral commodities exported from the territorial domain in which that food-cropping system is located.

4.2.1 Transactions and interactions

Some of the things which cross ecosystem boundaries are the subjects of conscious or deliberate *transactions* between human agents or consumers who are 'inside' the system and those who are 'outside' it at any given moment or in any given period. *External* transactions are thus defined as transactions between internal or resident agents and external or non-resident agents, while *internal* transactions are defined as transactions between agents who are all 'inside' the system, and therefore count as internal or resident consumers of the services which it provides.

Transactions between human agents are distinguished from those *interactions* between ecosystems or their component parts which take place without the intervention of any human agency. External interactions constitute the second major type of spatial boundary condition. We can say that external interactions consist of a mixture of 'inflows' and 'outflows', while external transactions consist of a mixture of 'imports' and 'exports'.

However, we shall not assume that external transactions constitute a simple 'balance of trade' between commodities which are either bartered or sold across ecosystem boundaries, nor shall we assume that they constitute relationships between local 'socio-economic systems' whose boundaries coincide with those of local ecosystems. An import might consist of a new cultivar which an outsider gives to an insider because of a personal relationship (or a form of property) which binds these two individuals to the same social network (or socio-economic system). The insider may then introduce the imported cultivar to the local food-cropping system. But if that cultivar turns out to be the means by which a new variety of insect pest is accidentally introduced into the same food-cropping system, then the pest itself is counted as an inflow rather than an import.

For the purpose of this assessment, we assume that everything which crosses an ecosystem boundary by means of an external transaction or interaction is either an ecosystem *service* or a *driver* of ecosystem change. In the example just given, the invasive species of insect pest would not count as a service to internal or resident consumers if it has a negative impact on the ecosystem, but would count instead as a direct driver of change in that system. Likewise, if a mining operation in the hinterland discharges waste material into a river, this could be a driver of change in the coastal ecosystem which surrounds the mouth of the river, but if a coastal community then threatens to block the mine's supply route, and the company responds by reducing or eliminating the discharge, this would count as a service to the community, as well as a modification of the driver. From this example, it should be evident that the same boundary condition may count as both a service (to resident consumers) and a driver (of ecosystem change).

The only official statistics relating to the volume and value of transactions across the boundaries of coastal ecosystems are those which cover the country's overall balance of trade. The Bank of PNG reports the total volume and value of the country's major exports on a regular basis, and since all of these are the products of primary industry, they could all be said to constitute an export of services derived from local ecosystems. It is also possible to make a reasonable estimate of the proportion of these commodities which are derived from the coastal zone or from coastal ecosystems (see Table 6), although these estimates are somewhat complicated in the case of smallholder agricultural production and 'marine products'. Two of PNG's main export commodities – petroleum and coffee – are not included in this account because they are derived entirely from the hinterland.

Table 6: Volume and value (in millions of kina) of material commodities exported overseas from PNG's coastal zone, 2002.

COMMODITY CLASS	Volume of total PNG exports 2002	Value of total PNG exports 2002	Estimated % from coastal zone
Agricultural products			
Palm oil (K tonnes)	323.9	389.9	80-90
Cocoa (K tonnes)	34.9	226.3	80-90
Copra (K tonnes)	15.8	10.7	100
Copra oil (K tonnes)	28.2	33.3	100
Rubber (K tonnes)	3.8	8.8	10-20
Non-agricultural products			
Logs (K cubic metres)	1,834.0	365.5	10-20
Gold (tonnes)	56.1	2,294.8	50-60
Marine products (K tonnes)	15.6	94.1	20-30

Source: Bank of Papua New Guinea.

It is far more difficult to estimate the percentage of imported commodities which are consumed within the coastal zone, because that would entail a separate estimate of the proportion consumed in urban, as opposed to rural, areas. In the absence of any official statistics, it is also difficult to estimate the value of material benefits derived from local ecosystems which figure in the 'balance of trade' between the coast and the hinterland. We do have some survey data on the domestic market in primary commodities which indicate the direction and relative significance of the trade in specific items, but these relate primarily to the national market through which rural communities supply primary products to urban consumers, rather than the local markets through which traditional rural communities exchange products derived from their respective territorial domains. No attempt is made to analyse this data in our summary national assessment.

If the measurement of external transactions at the national scale is problematic for the reasons just described, the measurement of external interactions at any scale is even more difficult, and no attempt has yet been made to analyse what little information is available for this kind of boundary condition.

4.2.2 Human migration and circulation

The *migration and circulation of human beings* across ecosystem boundaries is treated as a third type of spatial boundary condition, distinct from both transactions and interactions, which may also function as a driver of ecosystem change. Of course, migrants and visitors are often the bearers of imports and exports, and may even be the unwitting carriers of inflows and outflows, but the movement of human agents is not to be confused with transactions between them. Migrants are defined as people who change their normal place of residence, while visitors simply leave their normal place of residence for short periods of time. This distinction is not always an easy one to make in a country like PNG, where fairly high rates of geographical mobility are associated with very low rates of formal employment. In this assessment, 'rural migration' means migration from one rural area to another, while 'urban migration' means migration from rural to urban areas, and 'circular migration' means migration from rural to urban areas and back again. It is assumed that net migration from one urban area to another is not significant for the assessment of coastal ecosystems.

For the purpose of this assessment, the population counted in the national census of 1980 and 2000 has been divided between the coastal zone and the hinterland, as well as between urban and rural areas within each of these zones. This enables us to gain a general impression of the net movement of population between these four quadrants over the intercensal period. However, there are still some problems with the interpretation of this data.

The latest national census of PNG in 2000 adopted a distinction between ‘urban’ and ‘rural’ areas that did not exactly match the distinction drawn in the first nationwide census in 1980. Some of the places labelled as ‘urban areas’ in 1980 were assigned to the rural sector in 2000, but a lot more of the places labelled as ‘urban areas’ in 2000 had been assigned to the rural sector in 1980. A direct comparison of the relative size of the ‘urban population’ in 1980 and 2000 would therefore tend to overstate the extent of urbanisation during the intercensal period. To limit the extent of this exaggeration, all government service centres and industrial settlements which had a population of less than 1000 in *both* years have been assigned to the rural sector, and Table 7 therefore counts only those ‘urban areas’ which had a population of more than 1000 in one of the two census years.

Table 7: Changes in spatial distribution of the PNG population, 1980-2000.

LOCATION	1980 POP.	% TOTAL	2000 POP.	% TOTAL	% CHANGE
Rural coastal	723,753	24.0	1,269,574	24.5	75.4
Urban coastal	299,590	10.0	533,274	10.3	78.0
Rural hinterland	1,905,831	63.3	3,271,849	63.0	71.7
Urban hinterland	78,809	2.6	116,089	2.2	47.3
Rural total	**2,629,584**	**87.3**	**4,541,423**	**87.5**	**72.7**
Urban total	**378,399**	**12.6**	**649,363**	**12.5**	**71.6**
Coastal total	**1,023,343**	**34.0**	**1,802,848**	**34.7**	**76.2**
Hinterland total	**1,987,384**	**66.0**	**3,387,938**	**65.3**	**70.5**
PNG TOTAL	**3,010,727**	**100.0**	**5,190,786**	**100.0**	**72.4**

Source: national census data.

This table suggests that population movement from the hinterland to the coast has been more significant than population movement from rural to urban areas over the last 20 years. Indeed, while the coastal towns seem to have grown at the expense of the hinterland towns, these aggregate figures suggest that the relative distribution of the population between urban and rural areas has been relatively static over this period.

However, there are two reasons to doubt whether this table reflects the real rate of urbanisation, especially within the coastal zone. First, there were two provinces which lost a very substantial proportion of their urban population over this period as a result of civil conflict or natural disaster. Bougainville lost more than 80% of its urban population as a result of the secessionist rebellion which forced the closure of the island’s massive copper mine in 1989, while East New Britain lost more than 50% of its urban population as a result of the volcanic eruption which destroyed most of the provincial capital in 1994. If these two provinces are removed from the calculation, then it seems that population movement from rural to urban areas is actually more significant than population movement from the hinterland to the coast (see Table 8). On the other hand, the number of former town-dwellers who were actually killed in the course of the Bougainville rebellion was smaller than the number of rural villagers who suffered this fate, and there were no urban casualties as a direct result of the volcanic eruption in East New Britain. The apparent decline of the urban population in these two provinces may therefore be attributed to the fact that many of the former town-dwellers simply migrated to urban areas in other provinces.

Table 8: Changes in spatial distribution of the PNG population in all provinces except East New Britain and Bougainville, 1980-2000.

LOCATION	1980 POP.	% TOTAL	2000 POP.	% TOTAL	% CHANGE
Rural coastal	567,429	20.6	994,276	20.7	**75.2**
Urban coastal	263,952	9.6	520,732	10.9	**97.3**
Rural hinterland	1,839,308	66.9	3,164,396	66.0	**72.0**
Urban hinterland	75,303	2.7	116,089	2.4	**54.2**
Rural total	2,406,737	**87.6**	4,158,672	**86.7**	**72.8**
Urban total	339,255	**12.3**	636,821	**13.3**	**87.7**
Coastal total	831,381	**30.2**	1,515,008	**31.6**	**82.2**
Hinterland total	1,917,355	**69.8**	3,280,485	**68.4**	**71.1**
TOTAL	2,748,736	**100.0**	4,795,493	**100.0**	**74.5**

Source: national census data.

There is a second, and more important, reason for doubting the extent to which Table 8 reflects the real rate of urbanisation over the period from 1980 to 2000. The very limited amount of land which has been made available for the development of new settlements within the official boundaries of most ‘urban areas’ means that rural villagers who wish to gain permanent access to urban services are normally obliged to set up their new homes in peri-urban settlements which are officially classified as ‘rural areas’. The process of urbanisation, especially within the coastal zone, has therefore been disguised as a form of migration within the rural sector. The extent of this kind of population movement therefore requires a more detailed analysis of the latest census data.

4.3 Biological Diversity and the Cultural Significance of Species

Biological diversity is not treated as a type of ecosystem service in the MA Conceptual Framework, although it obviously does count as a property, condition or ‘structural feature’ of ecosystems which is related to the category of ‘support services’ (MA 2003: 51).

If we focus on the services provided by an ecosystem defined as a biological *community*, this may obscure the role played by particular species in sustaining the rest of the biological community or in providing a special range of services to the human community which depends on that biological community.

Biologists distinguish between an ‘endemic’ species, which is unique to a certain type of ecosystem, and whose survival therefore depends on the survival of that ecosystem, and a ‘keystone’ species, which makes a unique contribution to the survival of a certain type of ecosystem, even if it is not endemic (Mills et al. 1993; Power et al. 1996). Generally speaking, keystone species are less significant for the maintenance of tropical ecosystems than they are for the maintenance of temperate ecosystems (Walker 1992). That is because there is a higher level of ‘redundancy’ in tropical ecosystems, which means that there are more species which have the same function, so the loss of any one species is less likely to affect the survival or resilience of the system as a whole.

A keystone species is not to be confused with a 'flagship' species, which is used to market the value of a biodiversity conservation project to its potential sponsors. Dugongs, turtles and birds of paradise may be recognised as flagship species without the existence of scientific evidence to show that they are also keystone species. A flagship species is one which has great intrinsic value to Western consumers, and thus provides them with a 'cultural service' which is related to the conservation of biodiversity. But indigenous communities have their own way of assigning cultural significance to individual species, and this may have very little to do with the conservation of biodiversity.

We can represent the difference between scientific and indigenous perspectives on the significance of particular plant or animal species by means of a four-cell matrix which resembles the one previously used to classify the alternative definitions of ecosystems (Table 2). In this case, we shall say that the indigenous equivalent of an endemic species is a *totemic* species, while the indigenous equivalent of a keystone species is a *keynote* species (Table 9). A keynote species is one whose services are essential to the survival of a specific form of traditional or indigenous culture, while a totemic species (at least in the Melanesian context) is one whose services are recognised in magic and mythology, and hence in the value which local people attribute to its reproduction.

Table 9: Alternative definitions of significant species within an ecosystem.

	Essential	*Important*
Scientific Perspective	KEYSTONE SPECIES	ENDEMIC SPECIES
Indigenous Perspective	KEYNOTE SPECIES	TOTEMIC SPECIES

The coconut counts as a keynote species for most, if not all, of the traditional coastal communities of Melanesia. Table 10 shows the variety of material benefits which one coastal community derives from this one species, and even the long list of uses shown in this table is not meant to be exhaustive. Coconuts can be found in 'plantations', 'smallholdings' or 'orchards', inside and outside the perimeters of human settlements, depending upon the social and economic context in which they are planted, so this is a species which can be counted as a member of different biological communities, and might better be regarded (from a political perspective) as a landscape element in its own right. But once we think of the coconut as an ecosystem, rather than a plant species, we would need to add other species, such as the much-prized coconut crab, to the list of services which it provides to human consumers.

Table 10: Material benefits derived from coconut palms in the Mortlock Islands, Bougainville Province.

Part of plant	Uses
Embryo of sprouting nut	Eaten raw or cooked (boiled, roasted, baked), especially as a snack food (raw), by elderly people and by infants 1–6 months old.
Young nut	A coconut type with a soft husk. Entire young nut is eaten raw or baked or boiled. Eaten by women after giving birth.
Immature nut	Liquid drunk. Significant amount consumed daily.
Flesh of immature nut	Eaten raw or boiled and eaten as a meal.
Flesh of mature nut	Coconut cream used to prepare most meals. Significant amount eaten.
Liquid from the flower stalk	Fermented for about three days to form a mild alcoholic beverage. Drunk at celebrations and regularly by most men and many women. Tapped and then boiled to condense sugar and form a sweet dark liquid. This is used to sweeten cooked rice, the embryo of sprouting nuts, pancakes, scones and bread. Tapped and used without fermentation or condensation. Used to sweeten rice, pancakes, scones and bread.
All woody parts	Trunk, shells, husk, fronds, fruit stalk, spathe used as firewood.
Bast	Used to filter grated coconut flesh to prepare 'coconut milk' for cooking.
Fronds	Woven to form house walls, fans and baskets. Mulch for swamp taro plots. Covers for canoes during storage. Raw material for brooms. Burnt for light, especially when fishing at night.
Husk	Personal hygiene after defecating.
Husk of young nuts	To make cord. The husk is soaked in seawater for 3–4 months till it is soft; the non-fibrous parts removed; sun dried; rolled and pleated to form cord. Used to construct houses; lash canoe parts together; as part of bride price payment; clothes lines; canoe anchor ropes; and other domestic purposes.
Mid-rib of leaves	To weave pandanus leaves for house roofs.
Oil	Prepared by boiling 'coconut cream'. Used for cooking, including making flour-based products such as pancakes and donuts. Also used as a disinfectant for sores.
Shell, entire	Cooking food such as rice in a stone oven. Storage of small items.
Shell, half	Container for carrying water. Transportation of embers for fire making.
Trunk	House construction (posts and beams). To build sea walls to reclaim land. Sticks made which are used to dehusk dry coconut. Sticks made which are used as garden tools, including harvesting swamp taro (men) and weeding (women).

Source: Bourke and Betitis 2003: 56-57.

In some coastal areas, the sago palm has a similar multiplicity of uses, and may even outrank the coconut as a keynote species. A number of other tree crops certainly count as totemic plant species in most areas, as do the two main types of root crop (yams and taro) which are traditionally planted in coastal food-cropping systems. In some areas, people have very elaborate traditional beliefs about the behaviour of yams, which include the belief that they can wander around at night in response to magical forces. Beliefs such as these could be taken as a sign that one or both of the two main species of yam would count as a keynote species, and not just a totemic species.

If the coconut does count as the most ubiquitous keynote species in the plant kingdom of Melanesia, its counterpart in the animal kingdom is the pig. The various parts of this animal provide a greater range of material benefits to human consumers than those of any other animal species. In most areas, people and pigs traditionally lived in a symbiotic relationship which is sometimes described as partial domestication, and this relationship survives to the present day (Hide 2003). A few island communities tried to remove all wild and domesticated pigs from their traditional domains when they embraced the teachings of the Seventh Day Adventist church, but in most cases, their action only resulted in a multiplication of the wild population. This endeavour only served to underline the status of the pig as a keynote species, because it was understood, by the converts themselves, as an act of wholesale cultural transformation. It was also an act of ecological transformation, because large pig populations have a major impact on local ecosystems.

4.4 Ecosystem Services and Human Well-Being

4.4.1 Poverty, diversity and productivity

The MA Conceptual Framework follows the World Bank (2001) in defining poverty as 'the pronounced deprivation of well-being'. But human well-being, or the quality of human life, has many different dimensions, so poverty can be defined as a deficiency in each or any of these dimensions. The trouble is that many aspects of human well-being are very difficult to measure, so economists and statisticians opt for indicators which are supported by datasets of known reliability that can be used to compare the status of different populations at multiple scales. That is why the World Bank has chosen to use the 'dollar-a-day' measure to define a globally significant poverty line. If this measure is applied to the population of PNG, we find that more than a third of the population falls below the poverty line *unless* we can impute a monetary value to the various ecosystem services consumed in the subsistence sector, but that is a notoriously difficult thing to do (Gibson 2001). The alternative is to use one or more of the human development indicators espoused by the United Nations, and in that case, we might choose to stress a demographic indicator, like female life expectancy, because it is consistently measured in each successive national census (PNGONP 1999).

If we aim to relate human poverty or well-being to the quality of the natural environment, we must look for environmental indicators which are supported by datasets of known reliability that can be used to compare the status of different ecosystems at multiple scales within PNG. Because PNG is famous for its biological diversity, we may be tempted to assume that the quality of ecosystems is a function of their biological diversity. But biodiversity is not necessarily a good thing for the people who have to live with it. An environment which is good for human beings may be bad for other species (and vice versa). This means that we need to make a distinction between the diversity and productivity of ecosystems, but it also means that we need to distinguish their *biological* productivity from their *social or economic* productivity.

From a biological point of view, the productivity of an ecosystem is measured in terms of biomass, not human well-being. A comparison of oil palm plantations in PNG with Australian desert ecosystems is sufficient to show that there is no linear relationship between biological productivity and biological diversity. However, measures of biomass are not necessarily any better than measures of biodiversity in predicting the volume of goods and services which a human population is able to extract from an ecosystem. This becomes evident when vegetation of any kind is cleared to make way for an open-cut gold mine – even if the people who make a profit from the mine can only do so for a limited period of time. From the human point of view, an unproductive ecosystem is one which does not produce enough services of the right types for people to maintain an acceptable quality of life under a specific resource management regime.

The *social* productivity of an ecosystem can be measured in terms of its overall contribution to human well-being, while its *economic* productivity can be measured in terms of the cash income derived from the sale of ecosystem services. In some circumstances, the social or economic productivity of an ecosystem may indeed be a function of its biological diversity or productivity, but this is not always the case. At the same time, from a human point of view, no ecosystem or environment can be said to be productive *in its own right*; it is only productive in its relationship to the specific practices which belong to a human resource management regime. For example, the huge amounts of rain which fall in some parts of PNG could be very productive for hydroelectricity schemes, yet have a negative impact on the soils in which local people plant their garden crops. Insofar as food-cropping systems are the main component of indigenous resource management regimes in Melanesia, the productivity of local ecosystems needs to be measured accordingly, and we should expect to find a close relationship between biological and social productivity. However, other forms of economic activity could make these ecosystems more productive, from a human point of view, by substituting new ecosystem services for current environmental constraints.

If we cannot identify a single standard of environmental quality to match a single standard of human poverty, we should not take this to mean that we are unable to describe the relationship between these two things. What it does mean is that we need to think about the possibility that there is not *one* relationship, but a *number* of relationships, between human poverty and environmental quality, and instead of setting a single standard for each side of the equation, we should ask whether each equation has its own calculus.

4.4.2 Four types of poverty-environment relationship

To understand variations in the relationship between human poverty and the natural environment, we must first recognise that poverty may either be a *driver* or an *effect* of environmental change. This enables us to posit the existence of four basic forms of poverty in terms of their relationship to the environment:

- *Destructive* poverty is *both the driver and the effect* of environmental change. People living in destructive poverty are driven to degrade the services which an ecosystem provides, either to themselves or to other poor people, by consuming them at an unsustainable rate or in an unsustainable way. This means that poor people sink further into poverty because their poverty drives them to participate in unsustainable resource management regimes. This kind of poverty trap tends to dominate the aid industry's conception of the poverty-environment relationship in developing countries.

- *Creative* poverty is a *driver but not an effect* of environmental change. This means that the experience or threat of poverty makes people change their resource management regimes in such a way as to raise their own standard of living *without* degrading the services which an ecosystem provides to themselves or to other poor people. Although this type of poverty lies at the heart of Esther Boserup's classic (1965) study of the 'conditions of agricultural growth', it does not receive much attention in the literature dealing with the poverty-environment relationship. This might be due to the fact that poor people do not need 'aid' when they can solve their problems by themselves.

- *Derivative* poverty is an *effect but not a driver* of environmental change. In this case, people are impoverished, not as a result of their own actions, but because the ecosystem services which sustain them are degraded by natural events or by the actions of other people who are *not poor*. This is the type of poverty which counts as an 'external social cost' of resource management regimes from which the victims are excluded. It is also the type of poverty-environment relationship which appeals to people who blame the social and environmental problems of developing countries on the consumption patterns of the world's affluent elite.

- *Conservative* poverty is *neither an effect nor a driver* of environmental change. This type of poverty afflicts people who live in an unproductive environment, or depend on the services of an unproductive ecosystem, without the technical capacity or economic opportunity to either damage or improve its productivity. Even if other people are responsible for changes to this type of ecosystem, it is not these changes which are responsible for this type of poverty. People living in conservative poverty may participate in a resource management regime which is stable, sustainable, and resilient, but none of these qualities serves to lift them out of poverty.

Part of the original motivation for conducting an assessment of coastal ecosystems in PNG was the anecdotal evidence of destructive poverty on 'small islands under pressure' (see Section 1.1). However, there is no reason to assume that this is the only form of destructive poverty found within the coastal zone, nor to assume that any of the four types of poverty-environment relationship is restricted either to the coastal zone or to the hinterland. The critical problem for this assessment is to connect measures of environmental quality with measures of human poverty or well-being in such a way as to describe the spatial distribution of each type of relationship.

4.4.3 Measuring and mapping the relationships

Most of the datasets which are relevant to the analysis of human well-being and poverty cannot be disaggregated below the provincial, or at best the district, level without reanalysing the national census data, and the construction of time series for district-level data is problematic because of the change in the delineation of district boundaries between 1990 and 2000.

The PNG Land Management Group at the Australian National University has extended and modified its database on indigenous food-cropping systems to produce a ‘Rural Development Handbook’ (Hanson et al. 2001) which maps the spatial distribution of people who are ‘disadvantaged’ by one or more of four indicators, each of which is treated as an attribute of one of the country’s 287 food-cropping systems:

- *Access to services* is defined as the time taken to travel by foot, vehicle or boat from a ‘service centre’ to the furthest point of settlement in a food-cropping system. People with ‘poor access’ are defined as those who take 4-8 hours to reach a ‘minor service centre’, while people with ‘very poor access’ are those who take more than a day to reach any kind of service centre.

- *Income from agriculture* is inferred from the observed presence and relative significance of 21 marketed commodities as products of each food-cropping system during the period 1990-95. The 21 commodities include such things as firewood, fish and crocodile skins, so are not restricted to the products agricultural activity in the narrow sense of the term. The estimates for cocoa and coffee were validated by reference to provincial production figures (Allen et al. 2001). People with ‘low income’ are defined as those who make 21-40 kina per person per year, while those with ‘very low income’ are those who make 20 kina or less.

- *Land potential* is defined as a set of environmental factors (such as soil type, rainfall and temperature) which affect the growth of sweet potato, because this is the dominant staple crop in many parts of the country. People living in a ‘poor environment’ are then defined as those whose (agricultural) land has a low or very low potential for sweet potato cultivation. This means that most of the people whose dominant staple crop is sago are assumed to be living in a ‘poor environment’.

- *Agricultural pressure* is defined as the extent to which the intensity of a food-cropping system exceeds the land potential as previously defined. Agricultural intensity is defined by the relative length of cropping and fallow periods in each food-cropping system. People who experience ‘strong’ or ‘very strong pressure’ are those whose food-cropping systems exhibit very high agricultural intensity with low or very low land potential.

If human poverty is defined as the combination of low cash incomes and poor access to services, or defined by either of these indicators alone, we might infer that conservative poverty is likely to be found in ‘poor environments’ where there is no evidence of ‘agricultural pressure’, while destructive poverty is associated with ‘strong agricultural pressure’ *as well as* a ‘poor environment’.

In that case, the Rural Development Handbook indicates that the conservative poverty syndrome is mainly found in the lowland interior and highland fringe, while the destructive poverty syndrome is mainly found in the central highlands and the coastal zone – especially on small islands. The two notable exceptions to this rule are the people living along the south coast of New Britain and some of the communities at the western end of the central highland zone (in Enga and West Sepik provinces), whose very low levels of income are associated with an environment impoverished by very high levels of rainfall or cloud cover.

The authors of the Rural Development Handbook concede that this dataset has a number of limitations as a tool for understanding the dynamics of the poverty-environment relationship:

- The factors which are used to measure the quality (or relative 'poverty') of the environment are defined by reference to one ecosystem service, which is the most common staple food crop in PNG. The actual significance of sweet potato as a food source varies enormously between food-cropping systems and indigenous resource management regimes. Those people who are able to derive significant quantities of protein from hunting or fishing activities tend to live in areas which are short of good gardening land.

- The scale at which food-cropping systems are distinguished from each other conceals local variations in both human well-being and environmental productivity within each system. Different communities with the same food-cropping system may have very different degrees of 'access to services', and hence access to markets for the sale of their agricultural products. They may also have differential access to services derived from ecosystems that are not recognised in the land use map which is used to define their food-cropping system.

- The emphasis placed on agricultural commodity sales in the estimation of rural incomes obscures the possible significance of incomes derived from extractive industry or from urban relatives in mediating the relationship between poverty and environment. It may be true that these other sources of income are relatively unimportant in most parts of the country, but we still need to consider the ways in which their variation in space and time relates to specific forms of poverty, especially where local people have very limited access to agricultural markets.

- Since this is a *rural* development handbook, it tells us nothing about the environmental context or impact of urban and peri-urban forms of poverty, despite the fact that many poor people in urban areas supplement their meagre cash incomes with a variety of subsistence practices, some of which are derived from the food-cropping systems or indigenous resource management regimes practiced in their rural areas of origin. Information on this aspect of urban poverty is rather hard to come by.

- The relative vulnerability of different food-cropping systems to natural disasters or environmental shocks (especially drought and frost) has not been used as one of the measures of relative disadvantage, although there is quite a lot of information on this subject (Allen and Bourke 2001; Hide 2001). Indicators of social or environmental resilience might prove to be another useful device for distinguishing different forms of human or environmental poverty.

Our national assessment of coastal ecosystems aims to supplement the information available in the Rural Development Handbook by producing a separate classification of 'environments' based on the PNG Resource Information System, and then linking this classification to those nationwide measures of 'human development' which have been based on point sample data whose sampling frame has already been informed by PNGRIS. The most important of these additional sources of data is the National Nutrition Survey conducted in 1982-3 (Heywood et al. 1988; Heywood and Jenkins 1992; Mueller et al. 2001, 2002), but it may also be possible to incorporate data from other surveys undertaken (with smaller samples) since that time.

5 Drivers of Ecosystem Change

The MA Conceptual Framework defines a driver as 'any natural or human-induced factor that directly or indirectly causes a change in an ecosystem' (MA 2003: 87). A 'direct' driver is distinguished from an 'indirect' driver by the observable and measurable nature of its impact on a specific ecosystem, while an 'endogenous' driver is distinguished from an 'exogenous' driver by virtue of the fact that it is under the control of decision-makers operating at a certain level of social or political organisation.

In this assessment, we shall replace the distinction between 'endogenous' and 'exogenous' drivers with a parallel distinction between *internal* and *external* drivers. That is because we propose to link such drivers to resource management regimes, including those which are *indigenous.* If we talk about drivers which are 'endogenous' to indigenous regimes, this is only likely to cause confusion, because most Papua New Guineans (and most Australians for that matter) do not understand the different meanings of the words 'indigenous' and 'endogenous'.

The distinction between direct and indirect drivers is made from the point of view of the scientist, while the distinction between internal and external drivers is made from the point of view of the manager or decision-maker. The classification of drivers therefore includes the distinction between scientific and political perspectives which has already been encountered in our alternative definitions of an 'ecosystem' (Table 11) and in the distinction drawn between the 'scale' of a physical phenomenon and a 'level' of social or political organisation (Section 3.1). The political perspective is the one that enables us to link drivers to responses, because the responses that we analyse in this assessment are essentially those of decision-makers at specific levels of social or political organisation.

Insofar as the two distinctions overlap or correspond with each other, we may say that direct and internal drivers (at a given scale or level) are both 'obvious', while indirect and external drivers are both 'mysterious', either to the scientist or to the decision-maker (see Table 11). However, this does not mean that we rule out the existence of drivers which are both direct and external, or both indirect and internal, at any given scale or level.

Table 11: Classification of drivers of ecosystem change.

	'Obvious' Drivers	*'Mysterious' Drivers*
Scientific Perspective	DIRECT DRIVERS	INDIRECT DRIVERS
Political Perspective	INTERNAL DRIVERS	EXTERNAL DRIVERS

The MA Conceptual Framework assumes that key decisions are made at one of three levels – the 'local' (or community) level, the 'regional' (provincial or national) level, and the 'global' level (MA 2003: 90). In this assessment, we focus on decisions taken at the level of the nation and the level of the community, because these are more significant than decisions taken at any intermediate level of social organisation. However, for the purpose of our national assessment, we attribute the management decisions taken at the community level to indigenous or urban resource management regimes which are distinguished from each other at the local scale (see Section 3.1). Variations in the drivers of ecosystem change between the communities which have the same food-cropping system (and hence by implication the same resource management regime) will only be considered in our local and community assessments.

Tables 12 and 13 show the key drivers of ecosystem change at each of these two scales or levels. All external drivers of change at the national level could also be listed as external drivers of change at the community level, but we suggest that they take a more specific form at the community level. For example, world market prices for exports and imports become the prices of specific exports and imports which are significant for coastal communities. In some cases, we allocate a specific driver to the scale and level at which it has the most significant impact. For example, we identify tectonic disturbances as local drivers because recent examples have all had a restricted local impact, but if there were to be a volcanic eruption on the scale of Krakatoa, this would obviously have a national impact on coastal ecosystems (and human well-being).

While it seems fairly obvious that a driver which is internal at the national level is likely to appear as an external driver at the community level, it is not so obvious (though nevertheless true) that the reverse may also be the case. For example, the national policy component of a sectoral resource management regime (like the fisheries regime) will appear as an external imposition or constraint to members of a coastal community; but resource management decisions taken by members of traditional communities within their own domains are barely subject to any control by national government agencies, so become an external constraint on their own decisions. That is primarily because the country's landed property regime grants so much power to customary landowners to do what they want with their own resources (even though it gives them little opportunity to use their land as security for bank loans).

Finally, it is not always clear whether or to what extent a specific driver is under the control of decision-makers operating at a given level of social or political organisation. For example, the devaluation of local custom and customary leadership would seem to be a driver which is not under the control of traditional leaders, but other members of traditional communities might also say that there is nothing anyone can do about it either. Likewise, bureaucrats could blame the general decline in the quantity and quality of government services on revenue shortfalls over which they have no control, or else attribute the maintenance of these services in some local areas to foreign aid projects over which they also have little or no control.

Table 12: Key drivers of coastal ecosystem change in PNG at the national scale or level.

INTERNAL AND DIRECT	EXTERNAL AND DIRECT
• Discharge of waste material by resident industrial organisations • Industrial exploitation of inshore marine resources	• Global warming and periodic droughts • Accidental introduction or invasion of exotic species • Land use or resource management decisions by members of traditional communities within their own territorial domains
INTERNAL AND INDIRECT	**EXTERNAL AND INDIRECT**
• Macro-economic policies and economic development strategies • National policy component of sectoral resource management regimes • General decline in quantity and quality of government services to rural areas • Industrial exploitation of PNG's natural resources in areas outside the coastal zone.	• Global policy component of sectoral resource management regimes • World market prices for exports and imports • Technical innovations in agriculture, energy and water supply • Natural population increase (excess of fertility over mortality)

Table 13: Key drivers of coastal ecosystem change in PNG at the local scale or community level.

INTERNAL AND DIRECT	EXTERNAL AND DIRECT
• Intensification of food-cropping systems or hunting, fishing and gathering practices • Clearance of uncultivated forest for expansion of food-cropping systems • Industrial exploitation of inshore marine resources held or claimed under customary tenure • Discharge of domestic waste material by local households • Deliberate introduction of exotic species or varieties of flora and fauna	• Tectonic disturbances (volcanic eruptions, earthquakes and tsunamis) • Freak weather events with localised impacts
INTERNAL AND INDIRECT	**EXTERNAL AND INDIRECT**
• Volume of human migration and social transactions across boundaries of traditional community domains • Change in value or policy component of indigenous resource management regimes • Devaluation of local custom and customary leadership	• National policy component of sectoral resource management regimes • Price of commodity exports, imported food and imported fuel • Scientific and technical innovations in agriculture, energy and water supply

In this summary assessment, we make no attempt to rank drivers in terms of the extent of their relative impact on different coastal ecosystems because our assessment of coastal ecosystems is still incomplete. However, any ranking of drivers should probably ignore the distinction between internal and external drivers which has already been drawn, because this is simply a way of distinguishing between the decision-making capacities of actors operating at different levels of social and political organisation. The ranking of drivers should instead make another distinction between periodic and cumulative drivers, because of the inherent difficulty of comparing the relative impact of a periodic driver, such as periodic drought, with that of a cumulative driver, such as population growth.

6 Assessment of Coastal Marine Ecosystems

6.1 Coral Reefs

6.1.1 Current conditions

Dalzell and Wright (1986) estimated that PNG has approximately 40,000km^2 of coral reefs to 30m depth, including coastal fringing reefs and offshore atolls, though Munday (2000) believes this to be a considerable underestimate. The vast majority of these reef systems appear to be in good to pristine condition. This is mainly because of PNG's relatively low human population density (average 11/km^2), even in the coastal zone (average 40/km^2), when compared with Java (800/km^2), Bali (500/km^2), Sulawesi (100-130/km^2), the Philippines (257/km^2), Jamaica (236/km^2), and Barbados (626/km^2).

The most recent research on the condition of coral reefs in PNG has been commissioned by Conservation International (CI) (G. Allen et al. 2003), the Wildlife Conservation Society (WCS) (Cinner et al. 2002a,b,c; Marnane et al. 2002a,b,c), and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Brewer et al. 2001). The Global Coral Reef Monitoring Network has also published a comprehensive review of the status of reefs in PNG (Munday 2000).

The work commissioned by CI has been associated with design of the Milne Bay Community-Based Coastal and Marine Conservation Project (see Section 1.1), and is therefore focused on the condition of coral reef ecosystems in Milne Bay Province. The work commissioned by WCS has consisted of local-level surveys in a number of different provinces, while the CSIRO team was engaged to assess the impact of the Lihir gold mine on local reef systems. The MA team undertook some reef-crest coral cover surveys and Underwater Visual Census (UVC) fish surveys at the local assessment sites in Cape Vogel and Buka Western Islands in March 2003 (see Figure 1).

The results of the RAP surveys in Milne Bay Province (G. Allen et al. 2003) include a 'Reef Condition Index' (RCI) which is generated by a number of parameters, including coral cover and diversity, as well as fish densities and diversity. With a maximum possible rating of 300, the mean RCI for the surveyed sites was 199.16, which compares favourably with the Togean-Banggai Islands of Indonesia, with a mean RCI of 179.87 (ibid.). Percentage coral cover ranged from 13 to 85%, with averages between 30 and 50%. The data from the WCS and CSIRO surveys, along with another local-level survey in the Lak area of southern New Ireland (Hair 1996), also show reefs in relatively good condition in most locations.

There have been no major longitudinal studies of the condition of coral reefs and associated fisheries in PNG that can give us any idea of significant trends since 1975. We therefore need to approach the identification of trends through the concept of resilience, by asking how much disturbance PNG's coral reefs can cope with before their capacity to provide the ecosystem services they are currently providing is compromised, and what are likely to be the most significant sources of disturbance.

Based on recent experience, the kinds of disturbances we would expect to impact on PNG's reefs include fishing (including blast-fishing), pollution (including sedimentation), storms, coral bleaching, *Acanthaster planci* (or Crown of Thorns Starfish: COTS) predation, and coral diseases – not necessarily in that order. A number of studies have now been published describing global declines in the condition of coral reefs (Goreau 1992; Roberts 1993; Roberts and Hawkins 1999; Pandolfi et al. 2003), while at the same time recent surveys around PNG have found the vast majority of reefs to be in good to excellent condition (Cinner et al. 2002a,b,c; Marnane et al. 2002a,b,c; G. Allen et al. 2003). There have been very few comprehensive studies quantifying the magnitude of any of the threats that currently exist or could be expected within the next 50 years. The few relatively detailed quantitative studies of the above mentioned stressors appear to be limited to studies of sedimentation around mining operations (Barnes and Lough 1999; Rotmann 2001; Fallon et al. 2002; Thomas et al. 2003). Studies of coral bleaching and sea temperature patterns are few (Davies et al. 1997; Quinn 2002), as are reports of COTS infestations (Quinn and Kojis 1987).

6.1.2 Cyclones and storms

In their review of a number of different stressors of coral reefs, Jones and Syms (1998) cite a number of studies that show that cyclones do not necessarily impact negatively on fish populations. Hughes and Connell (1999) present data showing that coral recovery from cyclone damage is often rapid, except where it is compounded by other sources of mortality, particularly overgrowth by macro-algae, in which case recovery might never occur. The southeastern parts of PNG experience occasional cyclones (Huber and Opu 2000), but most of these areas are likely to be free from other key stressors, particularly heavy over-fishing of grazing fish. The scale of damage to corals created by cyclones depends very much on the past experience of a given reef to rough weather – reefs that regularly experience high impact waves tend to be dominated by low-relief corals and coralline algae which afford resilience (e.g. Cheal et al. 2002). Assessing the likely threats from storms in PNG will depend on an understanding of the likely changes in storm trajectories, intensities and frequencies caused by climate change.

6.1.3 Fishing pressure

Some destructive fishing, mainly in the form of 'dynamite' or blast fishing, along with the use of traditional fish poisons (*Derris* spp.), are routinely reported anecdotally for a number of sites around PNG, e.g. Buka Western Islands (Bougainville), Kavieng (New Ireland), parts of the Hiri Coast in Central Province (Hair 1996), and Hansa Bay on the north coast (Jenkins and Kula 2000). Fishing with explosives ('dynamite') produces high yields but shatters coral skeletons and transforms coral reefs into rubble zones (Pet-Soede and Erdman 1998; Fox and Erdmann 2000). Regeneration of hard coral cover is inhibited by the difficulty coral recruits have surviving on rubble fragments, due to their instability. Fox et al. (2003) monitored dynamite-generated rubble zones in Komodo and Bunaken National Parks in Indonesia from 1998 and found little regeneration of reef-building scleractinian corals at any of the sites. However, they did observe an important 'phase shift' of soft-coral colonisation at many of the sites monitored. Such an ecological switch is akin to the phase shifts in which drastic depletion of grazing herbivores, sometimes in conjunction with increases in nutrient levels (through coastal erosion or fertilizer runoff from farming) give rise to reefs that are dominated by macro-algae (Knowlton 1992; McCook 1999; Hughes and Connell 1999). There is some fishing with dynamite in PNG, but Huber and Opu (2000) comment that while the method is much remarked on and worried about due to its reputation for destruction, it is not being used in sufficient quantities in PNG to create observable reef damage on a scale sufficient to qualify as a significant stressor.

Some minor damage from nets and anchors was reported by the WCS team in peri-urban locations near the port of Kavieng and in Madang Lagoon. PNG shows no evidence of the impacts of heavy fishing pressure in its own right, on the scale that has caused phase shifts (to algal dominated systems) in places like the Caribbean and East Africa (McCook 1999; McClanahan et al. 2002a,b,c). Over-harvesting of grazing fish has been commonly found to cause ecological phase shifts in Caribbean and East African reef systems (McManus et al. 2000; Kaiser and Jennings 2002; McClanaghan et al. 2002a). In these situations, macro-algae proliferate and dominate as a consequence of the decrease in grazing pressure, but in many cases sea-urchins, which are also grazers, can proliferate and prevent any recovery of grazer populations. While a great deal has been written about these dynamics, they do not yet appear to be a feature of Indo-Pacific reefs, and as such need not be given detailed attention here. However, a recent study in Fiji by Dulvy et al. (2004) found a significant correlation between over-fishing of predatory reef fish and outbreaks of COTS – a dynamic previously hypothesised by Bradbury and Seymour (1997) – which constitutes something of a phase shift, though quite different in nature to the grazer-algal shift already mentioned. There are small populations of urchins (*Diadema* spp.) clustered around disturbed sites such as wharves, and near small overpopulated islands where fishing pressure (on both predators and grazers) may be linked to their abundance, but these are not large or widespread.

The impact of non-destructive fishing on reef fish community structure and coral reef ecosystem function is a field of research still dominated by considerable uncertainty. In highly speciose systems such as in PNG, this uncertainty is likely to remain a feature of such enquiries. In the Seychelles (Jennings et al. 1995) and Fiji (Jennings and Polunin 1997), there was no impact (either increase or decrease) on prey species of removal of large proportions of predatory reef fish by fishing. At smaller scales (m^2 as opposed to km^2), some measurable impact on prey species has been measured (Kaiser and Jennings 2002).

Pet-Soede et al. (2001) attempted to compare the relative influence of fishing intensity and habitat parameters (‘Live Substrate Cover’) on fish density, size and total biomass, for a wide range of fishing pressures and fish species, at Komodo and South Sulawesi in Indonesia. They predictably found reduced sizes and numbers of ‘commercial’ species, and indeed the complete absence of certain highly prized species, in the heavily fished areas, and were able to detect some correlation between % Live Substrate Cover and fish length and biomass *within* one particular fishing pressure category (but not others). However, they also found significant differences in fish community structure between the two major sites that could not be confidently linked to fishing pressure. They concur with previous observations (e.g. Jennings and Kaiser 1998) that studies attempting to compare impacts of fishing through spatial comparisons face major obstacles due to significant ecological dissimilarities (including abiotic features such as currents, upwellings, topography, terrestrial influences etc) between sites.

6.1.4 Coral bleaching

Coral bleaching is a consequence of elevated sea temperatures caused by global warming. The biology and ecology of coral bleaching has been comprehensively reviewed by Brown (1997a) and Hoegh-Guldberg (1999). Impacts of coral bleaching on fish community structure and abundance, including on reefs where the majority of corals died, appear so far to be limited to reductions in a small number of highly coral-dependent species such as chaetodontids and pomacentrids, and increases in some grazers (Lindahl et al. 2001; Booth and Beretta 2002; McClanahan et al. 2002b; Sheppard et al. 2002; Spalding and Jarvis 2002). There have also been no significant impacts on fishery yields reported so far (Grandcourt and Cesar 2003). However, the time scale over which bleaching is likely to manifest significant structural impacts on coral reefs and their associated fish fauna is clearly larger than 3-5 years (but perhaps not that much larger), and major impacts on both corals and fish communities within the next 50 years cannot be ruled out. Recent findings that corals exude as much as 50% of the primary production of their zooxanthellae as mucus (Wild et al. 2004) indicate that the importance of corals in the trophic networks of reef ecosystems may have been under-recognised in the past. This considerably magnifies the ecological implications of increasing mortality from bleaching. Substantial bioerosion and topographic simplification of heavily bleached reefs was reported from Chagos in the central Indian Ocean following the 1998 bleaching event (Sheppard et al. 2002), which suggests potential dramatic changes in reef fish community structure over the medium to long term.

PNG's coral reefs also show little evidence of bleaching to date, when compared with sites in the central and eastern Pacific, and the central and western Indian Ocean (Wilkinson 1999). Although the reports available (Davies et al. 1997; Srinivasan 2000) suggest that bleaching has not been as severe in PNG as in other countries, the thinness of the available data adds to the already significant difficulties in making predictions about potential impacts over the next 50 years. The fact that most corals are likely to be experiencing annual temperature maxima within a degree of their bleaching thresholds (Quinn 2002; Hughes et al. 2003), suggests that massive bleaching could easily be a regular reality in PNG within this time frame.

Bleaching has been reported for several of the sites covered by the RAP surveys in Milne Bay Province in May and June 2000 (M. Allen et al. 2003). The worst affected areas were Collingwood Bay, Goodenough Bay, the D'Entrecasteaux Islands and East Cape, where Sea Surface Temperatures (SSTs) were higher than in the more southerly and easterly parts of the province (ibid.). It is assumed that this bleaching was caused by SST maxima in early 2000. Davies et al. (1997) report earlier bleaching episodes for sites around East Cape (on the tip of the PNG mainland). An unpublished consultancy report by Sea Rotmann (2001a) details coral bleaching on Lihir Island caused by SST maxima in early 2001, but many of the bleached corals at Lihir later recovered. Bleaching was also reported from a number of sites on the Lak coast by Hair (1996), though no links to elevated SSTs or other possible causes could be demonstrated. The extent to which elevated SSTs will cause bleaching over the next 10 to 50 years in PNG is very difficult to predict. However, the fact that most corals and their zooxanthellae symbionts in PNG are adapted to annual SST maxima that are likely to be only one degree or so less than their bleaching threshold (see Hughes et al. 2003) means that severe bleaching events in the near future cannot be ruled out.

6.1.5 Crown of Thorns Starfish.

There is relatively little information about damage from COTS (*Acanthaster planci*) infestations in PNG, but the small number of outbreaks reported (Quinn and Kojis 1987; Huber and Opu 2000) suggest that it is nowhere near as significant a stressor of coral reefs in PNG as it is in other locations such as the Great Barrier Reef (Moran 1986; Moran and Davies 1989; Seymour and Bradbury 1999; Lourey et al. 2000). Small numbers of COTS, and associated coral damage (mostly limited to one colony or part of one colony), were consistently observed at Buka Western Islands in March 2003 by the MA field team, but fewer than five individual starfish were observed in the RAP survey of Milne Bay Province in 2000 (Allen et al. [eds] 2003). The most significant recorded infestations appear to be some isolated outbreaks in Milne Bay in the 1970s (Quinn and Kojis 1987, 2000).

Bradbury and Seymour (1997) suggest that the majority of field and modelling studies support the hypothesis that depletion of a guild of lethrinid-like fish predators may be linked to outbreaks of COTS populations, and a similar link has been postulated by Jennings (1998) for Fiji. As mentioned above, recent work by Dulvy et al. (2004) in Fiji provides convincing empirical support for this idea.

6.1.6 Sedimentation and pollution

By contrast with the Great Barrier Reef (Fabricius and Wolanski 2000; McCulloch et al. 2003), there is scant evidence of damage to PNG reefs from sediments or nutrients (Huber and Opu 2000). Anthropogenic sources of sedimentation are likely to be restricted to mining operations (Barnes and Lough 1999; Rotmann 2001b; Fallon et al. 2002; Thomas et al. 2003), logging operations, and plantation agriculture (notably oil palm). It is possible that sedimentation will constitute a threat to reef resilience for a small number of reefs in PNG within the next 50 years around centres where human populations are increasing at a higher rate than the national average, and possibly at point sources where poorly managed logging or plantation operations are taking place.

The localised impact of sediments from barge dumping and mine-site runoff on the coral reef ecosystems at Lihir has been documented by Rotmann (2001b), Brewer et al. (2003), and Thomas et al. (2003). Barnes and Lough (1999) have measured the effects of sediments on corals of the *Porites* genus at various sites around the mine at Misima in Milne Bay Province, and a similar scale of impact was found as for Lihir. However, it is worth noting that coral species in this genus tend to be more tolerant to sedimentation than most others (Brown 1997b).

Very little hard data is presently available on the volumes of sediment, nutrient and pesticide runoff from oil palm plantations, nor on their effects on coral and fish community structure. Similarly, we are aware of no studies to date that have measured impacts of sediment runoff from logging operations on fringing or offshore reefs anywhere in PNG (see also Munday 2000).

The construction of a tuna cannery in Madang has prompted concern about the possible impacts of pollutants from the cannery on coral reef health. The only detailed water quality work done to date (Benet n.d.) has not shown any elevation in heavy metals, sediments, nutrients, Biological Oxygen Demand (BOD), or other water quality parameter that could be linked to effluent from the factory and would cause coral mortality.

Sediments and nutrients from subsistence gardening probably count as the most important and widespread drivers of change in PNG's coral reef ecosystems in PNG, since they have undoubtedly been influencing reef ecology for a long time. But these impacts are also very difficult to quantify. Several sites in Milne Bay appear to be affected by sediment runoff from gardening (G. Allen et al. 2003, supported by observations of the MA team in March 2003). Discriminating new sources of sedimentation from older ones is likely to be a challenge in many areas. For example, rapidly eroding coastlines, such as the steep, fire-prone, grassy hills of Goodenough and Collingwood bays, are probably mostly responsible for the creation of relatively turbid, sediment-dominated marine habitats, which grade into the clear-water, coral-dominated habitats at the eastern end of Cape Vogel . Detailed longitudinal monitoring (of both land clearing and reef condition) in areas experiencing expansion of swidden agriculture will be necessary to determine any impacts and trends.

Suspended sediments not only impact on the survival and health of adult coral colonies, but also on fertilisation success and on larval survival and settlement (Gilmour 1999). For this reason, sustained high levels of sedimentation are likely to prevent recovery of reefs that have lost coral cover. If high levels of fishing pressure contemporaneously deplete grazing species of fish, a phase shift to an algal dominated system may ensue (McCook 1999). Unfortunately, Gilmour (1999) did not measure larval mortality or settlement success in sediment loads less than 50mg/litre, so likely recovery trends at lower sediment levels are yet to be determined.

6.1.7 Summary of current trends

At the present time, it is unlikely that any ecosystem services provided by coral reefs have been significantly compromised by either overfishing or other impacts in most parts of PNG's coastal zone, with the probable exception of some of the reefs around Port Moresby, and some of the other larger urban centres (Munday 2000), though reports of these impacts remain anecdotal as far as we are aware at this stage.

The current population growth rate in PNG is around 2.2% per annum. Even at this rate, the average density in 50 years will be around 32/km^2, which is still nowhere near as high as the current figure for most of Southeast Asia and the Caribbean. However, even if we assume no further migration from the hinterland to the coastal zone, the population of the coastal zone alone will be roughly equivalent to the current population of the whole country, and the average density in this zone will be roughly 113/ km^2.

In the medium term, the major threats to PNG's reefs are likely to come from coral bleaching, localised destructive fishing around urban centers and on overcrowded small islands, and possibly sedimentation and eutrophication near urban centers, logging and mining operations, and possibly some plantations. The relative importance of these various drivers is impossible to predict from current knowledge. Many of these reefs (e.g. in Milne Bay) are likely to demonstrate increased resilience due to the proximity of large areas of relatively undisturbed reefs (Bellwood and Hughes 2001).

6.2 Seagrass Beds and Soft Bottoms

6.2.1 Current conditions

Seagrass meadows are an important marine habitat of Papua New Guinea coastlines. Seagrasses are a functional grouping referring to vascular flowering plants which grow fully submerged and rooted in soft bottom estuarine and marine environments.

In the last few decades, seagrass meadows have received greater attention with the recognition of their importance in stabilising coastal sediments, providing food and shelter for diverse organisms, as a nursery ground for fish and invertebrates of commercial and artisanal fisheries importance, as carbon dioxide sinks and oxygen producers, and for nutrient trapping and recycling. Seagrass are rated the 3rd most valuable ecosystem globally (on a per hectare basis) and the average global value for their nutrient cycling services and the raw product they provide has been estimated at ^{1994}US$19,004 ha^{-1} yr^{-1} (Costanza et al. 1997). This value would be significantly greater if the habitat/refugia and food production services of seagrasses were included.

Seagrasses are also food for the endangered green sea turtle (*Chelonia mydas*) and dugong (*Dugong dugon*) (Lanyon et al. 1989), which are found throughout the PNG region, and used by traditional PNG communities for food and ceremonial use. Tropical seagrasses are also important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities. Seagrasses slow water movement, causing suspended sediment to fall out, and thereby benefiting corals by reducing sediment loads in the water (Ogden 1988; Kitheka 1997).

Nutrient availability is one of the major factors determining seagrass presence across PNG. Seagrasses frequently grow on intertidal reef platforms and mud flats influenced by pulses of sediment laden, nutrient rich freshwater, resulting from high volume seasonal summer rainfall (Carruthers et al. 2002). Cyclones and severe storms or wind waves also influence seagrass distribution to varying degrees. On reef platforms and in lagoons the presence of water pooling at low tide prevents drying out and enables seagrass to survive tropical summer temperatures. Often, the sediments are unstable and their depth on the reef platforms can be very shallow, restricting growth and distribution. Most PNG species are found in water less than 10m deep and meadows may be monospecific or consist of multispecies communities, with up to 10 species present at a single location.

The earliest records of seagrasses in the PNG region come from Salamaua in the Huon Gulf in 1890 (den Hartog 1970). However, apart from these early collections, the majority of studies on seagrasses in PNG did not occur until after the mid-1970s. It is generally agreed that there are 13 seagrass species present in PNG (Short et al. 2002). Seagrass species diversity is highest in the southern part of the country (adjacent to Torres Strait) and declines towards the east. The highest number of species reported is 13 from Daru (Johnstone 1979), followed by Motupore Island (Bootless Inlet) and the Fly Islands, each with 10 species (Johnstone 1978a,b; Brouns and Heijs 1985). No species are considered endemic to PNG, and none are listed as threatened or endangered.

Seagrass communities in PNG grow on fringing reefs, in protected bays and on the protected side of barrier reefs and islands. Major seagrass meadows occur around Manus Island, in the coastal bays surrounding Wewak and Port Moresby, on the island reef complexes of Milne Bay Province, and on the reef platforms surrounding the Tigak Islands and Kavieng. Seagrass meadows are also a significant feature at several other localities (e.g. Rabaul, Kimbe) and scattered areas of seagrasses line much of the coastline of the New Guinea mainland (e.g. Madang, Morobe and Western provinces) and the offshore islands (including Lihir and Mussau). Areas of the coast where seagrasses do not exist are either steep slopes exposed to oceanic swells or along the 500km of gulf coast east of Daru, a possible consequence of high silt loads and large volumes of fresh water in the runoff from the Fly and Purari Rivers (Johnstone 1979).

Seagrass zonation appears fairly similar across PNG (Johnstone 1982) and seems to be determined by comparable biotic and abiotic parameters. From intertidal to subtidal, the zonation pattern of seagrasses generally begins with a zone of one or two species (mostly *Halodule uninervis, Halodule pinifolia* or *Halophila minor*[2]). Subsequently, in the lower eulittoral zone, other seagrass species join in a mixed seagrass meadow generally dominated by *Cymodocea rotundata*, *Halodule uninervis* and *Thalassia hemprichii*, with isolated patches of *Halophila ovalis*. In the upper sublittoral zone, the mixed seagrass meadow is dominated by *T. hemprichii* and *Enhalus acoroides*, with isolated patches of *Syringodium isoetifolium*, *C. serrulata* and *Halodule uninervis*. This zone is generally the most abundant, and usually constitutes the bulk of the meadows throughout PNG. The lower edge of the meadow consists of a combination or 2-4 species when a reef plateau is present or monospecific *Halophila decipiens* or *Halophila spinulosa* at the deepest depths on the sublittoral sandy slopes. The remaining species are less common and not widely distributed. Monospecific patches of *Thalassodendron ciliatum* have been reported to occur on coral rubble banks in 6-8m depth on the deeper edges of the reef slopes on Manus, Kavieng and the Fly Islands. *Zostera capricorni* has only been reported from Daru (Johnstone 1982) and is one of the most northern locations for the species in the western Pacific.

Local conditions may often determine which seagrass species are present. Extensive mixed seagrass meadows are the dominant community type in the bays, harbours and sheltered capes along the coasts of the New Guinea mainland and the islands of New Britain and New Ireland (den Hartog 1970, Johnstone 1982, Brouns and Heijs 1985, Heijs and Brouns 1986). These extensive seagrass meadows are dominated by *Thallassia hemprichii* and/or *Enhalus acoroides*, with up to another 10 species present to varying degrees. *Halophila decipiens* meadows sometimes occur in the deeper areas and meadows of *E. acoroides* border the gentle sloping mangrove fringes in the more protected bays and the shallow lagoons surrounding Kavieng.

Throughout the rest of the PNG archipelago, most seagrass occurs in shallow lagoons adjacent to large islands, or on the reef platforms and leeward shores of small vegetated cays orislands of the Solomon and Bismarck seas. A survey in 2001 of seagrasses in Milne Bay Province found that seagrass mainly occurred on the tops of the reefs and shoals with reef flats, and cover was generally low in regions without large islands (e.g. Louisiade and Bwanabwana regions) (T. Skewes, CSIRO, pers. comm.). Some of the most abundant seagrass meadows in the Bismarck Sea occur on the reef plateaus on the eastern and northern coastlines of Seeadler Harbour (Manus Island) (Heijs and Brouns 1986). These communities are dominated by colonizing and intermediate species, such as

[2] *Halophila minor* was originally reported as *H. ovata*, but taxonomists now regard *H ovata* in the Indo-western Pacific as only present in the South China Sea and Micronesia (Kuo 2000).

Thallassia hemprichii, *Cymodocea rotundata* and *Halodule uninervis*, which can survive a moderate level of disturbance. *Enhalus acoroides* occurs in protected small bays or behind the reef crest on the sublittoral reef flat, as it has low resistance to perturbation (Walker et al. 1999).

Smaller islands are generally characterised by relatively small fringing reef platforms, such as Niolam Island (Lihir group) where the mean extent of inter-tidal habitat is approximately 81m from shore to reef crest (D. Dennis, CSIRO, pers. comm.). Seagrass communities in these cases are restricted to locations with shallow fringing reef-flat with lagoons (0-2 m depth). Most inter-tidal seagrass communities are dominated by *Cymodoceum rotundata* and *Thallassia hemprichii;* with small quantities of *Halophila ovalis* (D. Dennis, CSIRO, pers. comm.). *Enhalus acoroides* dominates the intertidal reef flats on the protected sides of islands (e.g. Duke of York, Nanuk and Talele Islands) and in the bays and harbours protected from oceanic swells (e.g. Luise Harbour, Malie Harbour, Lakakot Bay, Londolovit Bay) (D. Dennis, CSIRO, pers. comm.; S. Foale, ANU, pers. comm.).

The total area of seagrasses worldwide is estimated to be at least 177,000 sq km (Spalding et al. 2003). However, the total area of seagrass meadows in PNG is unknown, as no broad scale mapping exercise has been conducted (Coles et al. 2003). This is because mapping in tropical systems is generally from field observations as remotely sensed data (satellite and aerial imagery) is generally ineffective for detecting tropical seagrasses of low biomass and/or in turbid water (McKenzie et al. 2002). Some estimation could be possible using a simple modelling approach, based on the high likelihood that between 4-5% of almost all shallow water areas of reef and continental slope within the depth range of most seagrasses (less than 10 metres below MSL) would have at least a sparse seagrass cover. This however, has not been attempted. The closest attempt so far is a new dataset prepared by the United Nations Environment Programme World Conservation Monitoring Centre (http://stort.unep-wcmc.org/maps). These maps, however, should be interpreted with caution as they have been migrated to GIS based on literature review and outreach to expert knowledge. Much of the information is from only a few localities and is generally historic (e.g. Wewak, Manus, Kavieng, Rabaul, Port Moresby).

There are also many anecdotal reports of extensive unmapped seagrass meadows covering the reef flats and shallow lagoons around the Fullerborne region, Cape Gloucester, Stettin Bay (Kimbe Bay), Mussau Island, Heina - Ninigo Islands, and along the perimeter of the sea corridor between Buka and Bougainville. Recent mapping initiatives in Milne Bay province (Skewes et al. 2003) and the Lihir group (D. Dennis, CSIRO, pers. comm.) are a major step forward. In 2001, a survey by CSIRO and CI estimated 11,717 ha of seagrass in the Milne Bay area (J. Kinch, CI, pers. comm.). Such efforts will serve as important baselines against which future changes can be assessed.

6.2.2 Current trends

Tropical seagrass meadows are known to fluctuate seasonally and between years (Mellors et al. 1993; McKenzie 1994; McKenzie et al. 1996), but losses have been reported from most parts of the world, sometimes from natural causes such as cyclones and floods (Poiner et al. 1989; Preen et al. 1995). More commonly, loss has resulted from human activities such as dredging, land reclamation, industrial runoff, oil spills or changes in land use and agricultural runoff (Short and Wyllie-Echeverria 1996).

The major changes in PNG seagrass meadows would have occurred since World War Two and are related to coastal development, agricultural land use, or population growth. In general, there is insufficient information and no long-term studies from which to draw direct conclusions on historic trends. Munro (1999) does report that 2000 year old mollusc shell middens in PNG have basically the same composition as present day harvests, suggesting indirectly that the habitats, including seagrass habitats and their faunal communities, are stable, and any changes occurring are either short term or the result of localised impacts.

These localised impacts are likely to be from soil erosion related to coastal agriculture (palm oil plantations), land clearing (logging and mining), bush fires, and from the discharge of mine tailings. For example, there are unconfirmed reports of losses due to mining operations in Luise Harbour (Lihir), where the seagrass has declined significantly compared to before the mine (M. Macintyre, University of Melbourne, pers. comm.). Other effects include sewage discharge, industrial pollution and overfishing (N. Wangunu, WWF, pers. comm.). Most of these impacts can be managed with appropriate environmental guidelines, but climate change and associated increase in storm activity, water temperature and/or sea level rise has the potential to damage seagrasses in the region or to influence their distribution. Sea level rise and increased storm activity could lead to large seagrasses losses.

To provide an early warning of change, scientific (SeagrassNet) and community-based (Seagrass-Watch) long-term monitoring sites have been established as part of the Global Seagrass Monitoring Network (www.SeagrassNet.org) (McKenzie et al. 2001; Short et al. 2002). Sites are monitored quarterly in Kavieng, the Tigak Islands and Madang, and the program hopes to expand to include other regions of PNG. By working with both scientists and local communities, it is hoped that many anthropogenic impacts on seagrass meadows which are continuing to destroy or degrade these coastal ecosystems and decrease their yield of natural resources can be avoided.

6.3 Mangroves

PNG has approximately 200,000 hectares of mangroves, representing about 1.4% of the world's total (Ellison 1999). Situated at the core of the Indo-Malay centre of diversity, PNG's mangrove systems contain at least 33 true mangrove species (Ellison 1995), as well as a number of species also found in other habitats. This represents the greatest diversity of mangroves in the Pacific island region, and one of the greatest diversities in the world. The high diversity of mangrove flora is matched by a rich and abundant fauna, including endemic species such as the Papuan Black Bass, *Lutjanus gouldii*. The high species richness of mangrove systems parallels the situation in other marine habitats around PNG. Extreme variation in the nature and structure of mangrove systems is due to their occurrence in a wide variety of locations, from coastal deltas to forests on coral atolls, under a variety of sedimentary regimes, and in areas of both increasing and decreasing relative sea level (Womersley and Teas 1984). Major mangrove areas occur in the Fly, Purari and Sepik rivers deltas, but there are several other significant locations, and scattered areas of coastal mangroves line much of the coastline of the New Guinea mainland and the offshore islands.

The health of PNG's mangrove ecosystems is of global importance because they are highly productive ecosystems (Leach and Burgin 1985; Robertson et al. 1991), vital as sinks for atmospheric CO_2 (Borges et al. 2003), and crucial in the cycling and exchange of nutrients (Alongi et al. 1993; Gattuso et al.1998). For example, the Fly and other rivers draining into the Gulf of Papua play a major role in river-shelf carbon exchange (Alongi 1991; Robertson and Alongi 1995).

Mangrove ecosystems are generally close to population centres, which makes them vulnerable to major damage from various types of development and prone to chronic, low-level impacts from local traditional utilisation. In addition, their position at the interface between land and sea places them in the direct path of off-site impacts flowing from activities such as mining, forestry and large-scale agriculture. Despite this vulnerability, and the well-recognised importance of the ecosystem services provided by mangroves systems from ecological, subsistence and commercial points of view, there are no sound longitudinal studies of PNG's mangrove ecosystems and no definitive base-line studies against which to judge ecosystem change. Such studies are crucial given the need to detect the effects of population pressure, agricultural and industrial development and human induced global warming, against a background of natural sea-level change, global climatic forcing, extreme weather events, and tectonic disturbances.

Less is known about PNG's mangroves than those of Australia, Southeast Asia, and North America (Ellison 1999), and this even extends to a paucity of information on changes in mangrove area (Unua 1992). However, what information is available suggests that mangrove systems in PNG are substantially intact, at least in terms of their areal extent.

PNG's mangroves undergo the same natural changes as those in other parts of the world. Past sea level change has led to both increases (Vanderkaars 1991; Chappell 1993) and decreases (Barham 1999) in the extent of mangrove forests. Natural change also occurs over shorter time scales, with many events in the lives of mangroves showing strong seasonality. For example, leaf-fall for all species peaks in the wet season (Leach and Burgin 1985). At a much smaller scale, leaf and propagule loss and damage due to herbivory is common (Johnstone 1981), and wood breakdown by organisms such as teredos is ubiquitous and vital to recycling of mangrove timber (Cragg 1993).

There is little commercial exploitation of mangroves in PNG. However, there are small- to medium-scale commercial mangrove forestry operations in Bintuni Bay in Irian Jaya, which were worth about $20 million a year in the early 1990s (Ruitenbeek 1994). This suggests that there could be pressure for similar forms of development in PNG, although these are presently ruled out by government policy. Where careful management maintains ecosystem integrity, this can render such enterprises sustainable, allowing logged areas to regenerate. However, because the dynamics of tropical mangrove food webs are poorly quantified, we do not know the long-term effects on mangrove systems of the removal of organic carbon, nutrients and energy that would normally be recycled.

There are no long-term studies that would allow evaluation of even large-scale change to PNG's mangrove systems over time. Little more information exists about the effects of specific impacts on mangrove health. It is known that mangrove areas adjacent to population centres are heavily exploited (Unua 1992), often with extensive local clearing, such as that around the town of Daru in Western Province , and on some small overpopulated islands (Bourke and Betitis 2003). Mangroves are traditionally used to supply building materials (both wood and palm thatch), fuelwood, and raw materials for the production of fish traps and other artifacts (Percival and Womersley 1975; Eley 1988; Hamilton and Murphy 1988; Unua 1992). Additionally, a range of mangrove components are used for a variety of purposes in different areas. Leaves of *Avicennia* are used as contraceptives, *Bruguiera* fruit to treat malaria and diarrhea (Percival and Womersley 1975), mangrove propagules as food (Harris 1977), and mangrove tanins as a fungicidal treatment on nets and fish traps (Ellison 1999). Pigs range through mangrove areas but the damage they do to the mangrove forests has been reported to be 'insignificant' (Gray 1960). Whether insignificant or not, all of these activities impose obvious and direct impacts on mangrove systems.

While our understanding of mangroves themselves is poor, our understanding of mangrove ecosystems, their component flora and fauna, and their functioning is even worse (Ellison 1999). This is despite the well-recognised role of mangroves as nursery grounds for fish and crustaceans (Robertson and Duke 1997; Mumby et al. 2004), and the importance of PNG's mangrove areas as overwintering sites for shorebirds from Eurasia (Diamond and Bishop 1999). In fact, the information on mangroves systems is so sparse that no reasonable assessment of the health of mangrove ecosystems in PNG is possible, and any evaluation must be limited primarily to speculation.

Mangrove systems, mangrove flora and mangrove fauna in PNG are used for the same activities as in other parts of the world: fishing, the hunting of crocodiles (Barlow 1985), monitor lizards and birds, and the gathering of crabs, clams and other molluscs. These traditional uses may have deleterious impacts, especially since mangrove swamps tend to be situated in vulnerable locations along coasts and in estuaries, where they are often readily accessible to growing human populations. For instance, it has been suggested that the paucity of some bivalve and gastropod species at particular locations may reflect human collecting activities (Poraituk 1986). The use of traditional fish poisons (*Derris* spp.) has been reported anecdotally for a number of sites such as Buka, Kavieng, and parts of the Hiri Coast in Central Province (Hair 1996).

The 'traditional' uses of mangrove ecosystems have increasingly been supplemented by the impact of commercial and recreational fishing. For instance, there are small-scale, estuary-based commercial banana prawn, mud crab, oyster and sport fisheries (Frusher 1983, as well as some large-scale commercial prawn trawling (Dalzell et al. 1996). There is also a considerable potential for impact from the developing aquaculture industry, because the flushing of materials such as shrimp pond effluent is often slow in mangrove-fringed tidal creeks (Wolanski et al. 2000). Similarly, although there is a history of low-level pollution from village activities (washing clothes, household cleaning, sewage, etc.), there is a steady increase in pollution derived from urban centres (Opnai 1980), and from large-scale development in the agricultural, mining and forestry sectors.

7 Responses to Ecosystem Change

7.1 Identification and Classification of Issues, Actors and Responses

The MA Conceptual Framework defines responses as 'human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems' (MA 2003: 214). Responses may be classified as legal, technical, institutional, economic or behavioural in nature, but they can also be distinguished by reference to the identity of the actor, or by reference to the issue or relationship which they seek to address.

In this section, we identify a number of issues related to the present and future condition of coastal ecosystems in PNG, and establish a process for considering who has done what to address each of these issues over the course of the past decade, and for evaluating the impact and effectiveness of each of these responses. For this purpose, our aim is to locate the actors and their responses within the context of specific indigenous and sectoral resource management regimes.

A recent report for the PNG Department of Environment and Conservation identified ten 'principal environmental problems' for PNG as a whole, namely: increasing land degradation; hazardous waste management practices; declining water quality in rivers and coastal waters; disturbed or unpredictable hydrological regimes; loss of critical habitats and biodiversity; declining coastal and marine resources; inadequate or unsatisfactory water supplies; declining air quality in some urban areas; noise pollution; and climate change (Nicholls 2003: 68).

A recent review of national compliance with multilateral environment agreements identified four 'clusters of inter-linked issues' in the 'environmental governance process':

- 'Physically related environmental issue areas such as waste management and persistent organic pollutants, or the various water related conventions;
- 'Governance functions, such as strategic planning, consultation and coordination, information management, the development of legal frameworks, capacity building, awareness raising, or financing;
- 'Linked environmental impacts, such as deforestation, land degradation, drought, etc.;
- 'The production of goods and services derived from the environment, such as, agricultural products, forestry, fisheries, mining, and industrial outputs' (Piest and Velazquez 2003: 10).

The seven issues proposed for analysis in the complete version of this assessment are as follows:

- Population pressure on scarce subsistence resources
- Loss of biological diversity and ecosystem support services
- Commercial exploitation of inshore marine resources
- Industrial and domestic waste management
- Periodic droughts and famines associated with El Niño
- Tectonic disturbances and freak weather events with localised impacts
- Impact of invasive species on ecosystem integrity and human health

This selection of issues is closely related to our previous identification of the key drivers of ecosystem change (Section 5). The sample is also meant to include the full range of actors who have recently been responding to all forms of ecosystem change, and to encompass all the main types of response which they have adopted.

We divide the actors and their responses into three categories:

- *Community* responses are responses by members of traditional political communities or (more rarely) by members of urban or industrial communities operating within the limits of their respective enclaves. These responses therefore belong to the communal level of organisation or local scale of adaptation, even if they have common features in different local contexts. Most of these responses can be attributed to indigenous resource management regimes.

- *Government* responses are responses by government agencies at any level of administration which take their cue from national or (more rarely) from international policy regimes and legal frameworks. These include responses which are engineered or sponsored by foreign aid agencies operating with PNG government agencies as their national counterparts.

- *Civil society* responses are responses by all other organisations or institutions which cannot be construed as community responses (although community responses could themselves be classified as a type of civil society response). These include the responses by private companies, as well as by 'civil society organisations' in the narrower sense favoured by some foreign aid agencies.

Within each group of actors, we may be able to distinguish several different responses to the same issue. We do not assume that these are part of a mutually consistent package of responses, because the actors or stakeholders in each group (even in the 'government' group) may be acting quite independently of each other, with no common sense of purpose or policy. Nor do we assume that a response entails an acceptance of responsibility for managing the issue. For example, one response to the pollution or damage caused by the discharge of industrial or domestic waste may simply be to 'pass the buck' to another actor or group of actors, and this response might even be common to all the actors dealing with the issue.

For each of the responses made by a group of actors to a given issue, we shall run through the following list of questions to see which questions can usefully be applied to that response, and then to briefly answer them:

- Why did the actors choose to make this response?

- Has it achieved the intended effect (and how do we know that it has done so)?

- What factors explain its success or failure?

- What (if any) have been the unintended consequences?

- What has been the net impact on human well-being?

- What has been the net impact on social and institutional capacity to deal with the issue?

In this summary assessment, we shall only consider responses to one of the seven issues identified for consideration in the complete version of the assessment, which is 'loss of biological diversity and ecosystem support services'. This issue has been chosen because it is the one which has been the subject of most intense and extensive debate in recent years.

7.2 Loss of Biological Diversity and Ecosystem Support Services

The standard government response to the loss of biological diversity is to strengthen or expand a national network of protected areas which may originally have been established for somewhat different purposes. In PNG, the feasibility and effectiveness of this response has been seriously constrained by the fact that customary landowners retain legal ownership and substantial control over most of the terrestrial and marine habitats that might be included in such a network. When left to their own devices, government agencies have therefore been inclined to focus their attention on the regulation of those commercial activities which pose a distinctive threat to the maintenance of biological diversity, in the hope that local communities will maintain those 'traditional' institutions which underwrite their own subsistence. However, international responses to this problem still tend to assume that government or non-government organisations should be willing and able to establish a maintain a set of protected areas through negotiations and partnerships with local communities.

There are three national laws relating to the establishment of protected areas – the *Fauna (Protection and Control Act* 1966, the *Conservation Areas Act* 1978, and the *National Parks Act* 1982. The *National Parks Act* is descended from a piece of colonial legislation which made allowance for several different types of protected area, depending on their purpose, but required that all such areas be alienated from customary ownership. The combined extent of 13 terrestrial reserves established under this act is less than 10,000 hectares, and the five that fall within the coastal zone cover only 215 hectares between them, while a single marine park covers 396 hectares of coral reef (King and Hughes 1998). The *Conservation Areas Act* was apparently meant to facilitate PNG's compliance with the World Heritage Convention, and could in theory be applied to the protection of areas currently under customary ownership, but the Department of Environment and Conservation has not so far had the human or financial resources that would be required to bring the act into effect (Kwa 2004). This means that the *Fauna (Protection and Control) Act* is the only effective legal mechanism for the conservation of biodiversity values under customary ownership and control. This act, as its name implies, was originally introduced by the colonial administration because some species of fauna, most notably birds of paradise, were thought to be at risk of local extinction once the 'natives' were allowed to own shotguns. The law allows the members of a traditional community to have a portion of their territory gazetted by the government as a 'wildlife management area' (WMA), and then requires them to establish a management committee that will make and enforce its own rules to regulate the exploitation of wildlife within the protected area. By 2000, 31 separate areas, with a combined extent of more than 1.5 million hectares, were officially protected through this mechanism. Nineteen of these areas, with a combined extent of more than 1 million hectares, included some portion of the coastal zone, and most these areas were protected by a set of rules which make specific reference to coral reefs, mangroves or marine fauna.

All of these WMAs have been established in the period since Independence, and the number has grown steadily throughout that period. It might therefore seem that this has been the most effective legal and institutional response to the problem of biodiversity conservation. Although it might be the only feasible response to the problem of protecting areas under customary ownership (Eaton 1997), its effectiveness may still be questioned on several grounds:

- The *Fauna (Protection and Control) Act* was not designed for the protection of entire habitats or ecosystems, and does not even allow for the imposition of any substantial penalty for the breach of rules established by a local wildlife management committee (Whimp 1995).
- Only four of the WMAs which have so far been gazetted cover an area of more than 100,000 hectares, and thus approximate the size criterion that is normally regarded as a fundamental condition for effective conservation of biological diversity (Hedemark and Sekhran 1994).
- Local interest in the establishment of a WMA is often based on a desire to register and defend a territorial claim against some external threat, rather than any specific desire to limit the exploitation of wildlife within the 'protected area' (van Helden 2001; Filer 2004b).
- There is nothing in policy or legislation to prevent government or private agencies from negotiating with local landowners to include a WMA within an area allocated for 'resource development', and local landowners will commonly take this development option because it enables them to establish another kind of legal claim to customary ownership of their resources, as well as to secure a share of the resource rent generated by the development process (Filer 1998).
- Local communities have generally be unwilling or unable to maintain an effective management system without the continued presence and support of external agencies, especially when the 'protected area' is of a size that demands collaboration between a number of neighbouring communities.
- The national government has had a limited and diminishing capacity to assume this management role, or even to process applications for the establishment of WMAs, so the only areas in which any kind of effective management activity now takes place are those for which an NGO has secured foreign funding for the purpose of biodiversity conservation (Hedemark and Sekhran 1994; Whimp 1995).
- In 1995, the national government devolved its own responsibility for the management of protected areas to provincial and local-level governments, but 'forgot' to supply them with the funds required to exercise this responsibility.

The fact that landowning communities are still being engaged in the production of responses to the loss of biological diversity and ecosystem support services is primarily due to the amount of foreign funding that has been dedicated to this issue since the PNG government ratified the Convention on Biological Diversity and the Ramsar (Wetlands) Convention in 1993. By that time, the World Bank had already orchestrated the development of a National Forestry and Conservation Action Program supported by a number of bilateral and multilateral aid agencies. In 1989, the PNG government had asked the Bank to help design an institutional response to the problems revealed by a judicial investigation of corrupt practices in the forestry sector (Barnett 1989, 1992;

World Bank 1989), but national engagement with preparations for the Rio Earth Summit gave increasing weight to questions of conservation as distinct from those relating to 'sustainable management' of the forest industry (Unisearch PNG 1992; Gladman et al. 1996). The Global Environment Facility was thus persuaded to provide US$5 million worth of technical assistance for a Biodiversity Conservation and Resource Management Program (BCRMP) to be executed by a Conservation Resource Centre within the PNG Department of Environment and Conservation (Kula and Jefferies 1995).

The central feature of the BCRMP was a process of experimentation with two integrated conservation and development projects, and the elaboration of an institutional, legal, financial and policy framework for the expansion of the country's protected area system on the basis of lessons learned from these experiments. The subject of the first experiment was a group of coastal communities in New Ireland Province whose forests were already being logged by a Malaysian company. This experiment failed because the conservationists were unable to persuade a majority of local landowners that their project offered a better deal than the one on offer from the logging company (McCallum and Sekhran 1997). The second experiment was conducted in a sparsely populated part of the forested interior of the main island of New Guinea, where some local landowners were apparently convinced of the value of conservation, but the conservationists were not obliged to compete with any foreign logging companies (Ellis 1997; van Helden 1998, 2001; Filer 2004b). BCRMP staff also established a dialogue between government officials and members of the NGO community whose own conservation projects were funded from other foreign sources (James 1996; Saulei and Ellis 1998).

Although these other projects engaged a mixture of coastal and hinterland communities, they were all primarily concerned with the establishment and maintenance of 'wildlife management areas' to conserve the biodiversity values of forest ecosystems, or the development of 'ecoforestry' projects as an alternative to large-scale commercial logging operations. One important obstacle to these endeavours has been the fact that many rural communities make little use of those 'primary' forests which do not count as forest fallows in their food-cropping systems, and in that case, it is hard to persuade local landowners of the need to protect these ecosystems against the possible encroachments of extractive industry. Since the two experiments funded under the BCRMP had shown that forest conservation projects were only likely to work in areas where the forest would most likely survive without them, the GEF was averse to the prospect of funding more projects of this kind. So when the BCRMP came to an end in 1998, its last act was to start the design of the Milne Bay Community-Based Coastal and Marine Conservation Project. International and national NGOs have also found that an increasing proportion of the funds available for conservation projects in PNG are dedicated to the protection of coral reefs and other coastal ecosystems. This is no doubt partly due to a change in global priorities, but can also be justified in the national context by the volume of services which these ecosystems provide to their customary owners, and by the threat posed to the maintenance of these services by the high population densities and rapid rates of population growth in many coastal communities (Kinch 2001a; van Helden 2004).

Given the significance of customary resource ownership as an obstacle to any form of central land use planning in PNG, it is interesting to note that much of the international funding which has recently been dedicated to the cause of biodiversity conservation has been concentrated on the improvement of formal planning and management institutions rather than any systematic investigation of what customary resource owners actually think and do about their own property. This issue was raised at two workshops that sought to establish national conservation priorities in the early 1990s (Alcorn and Beehler 1993; Sekhran and Miller 1994), but donor-funded efforts to strengthen the Department of Environment and Conservation were still based on the assumption that such priorities should be based on scientific assessments of the spatial distribution of biodiversity values. The most notable example was the Biodiversity Rapid Assessment Project funded by the World Bank and the Australian government, which used complex spatial modelling tools to establish a flexible scheme of 'trade-offs' between the spatial distribution of biodiversity values, the temporal change in patterns of land use, and the policy choice of which areas to conserve in order to maximise the conservation of biodiversity values within a fixed proportion of the country's total surface area (Nix et al. 2000; Faith et al. 2001). Some international NGOs have also begun to apply geographical information systems to the problem of biodiversity conservation in PNG, and therefore have reason to support the national government's own attempts to do so, but it is not yet clear how these activities will produce better outcomes 'on the ground'.

The central planners might draw some consolation from the fact that conservation projects established in response to local community initiatives may still run into trouble when external agencies fail to meet local expectations (Martin 1999). But it is hard to see how the planning of protected areas can go much further when a decade of donor support has not yet enabled the Department of Environment and Conservation to formulate a National Biodiversity Strategy and Action Plan or to rationalise and consolidate the legal framework for this planning exercise (Kwa 2004).

Now it could be argued that all such governmental 'responses' are not really responses to any specific local problem, but responses to the availability of international funding for something to be done about the conservation of one of the world's 'last great places'. If the main beneficiaries of this funding are government and non-government organisations in the conservation industry, rather than local landowning communities, there is little reason to suppose that it will make much impact on local people's attitudes and behaviour (PAFNN 2003). The question then is whether local community responses to the problem would be more or less effective in the absence of this industry.

The scientific literature is generally skeptical about the existence of a 'traditional conservation ethic' in Melanesia (Bulmer 1982, Allen 1986, Dwyer 1994), although some indigenous environmentalists are more enthusiastic on this score (Morauta et al. 1982; Lalley 1998). Some scholars have lauded the effect of indigenous marine management regimes in the Pacific region (Johannes 1978), but traditional marine tenure systems in Melanesia seem to have arisen as a result of competition for resources rather than any indigenous interest in conservation (Polunin 1984; Carrier 1987; Otto 1997, 1998). A similar argument can be made about terrestrial resource management regimes, including the institutions of customary land tenure (Ward and Kingdon 1995; Filer 1997). Given that biological and cultural diversity was generally maintained under these indigenous regimes, the question of intent is only relevant when we come to ask whether 'traditional ecological knowledge' can form the basis for local community responses to current drivers of ecosystem change. Since most coastal communities in PNG have been exposed to Christian teachings and Western schooling for several generations, it is just as pertinent to ask whether these form a stronger basis for such responses (Juvik 1993; Filer 1994).

There is evidence to suggest that most adult members of coastal communities still fail to recognise the loss of biodiversity as a problem in its own right, simply because they have not been introduced to the basic principles of evolutionary biology, and may even subscribe to a form of Christianity which is actively opposed to these principles (Foale 2001). However, this does not prevent them from recognising and responding to the loss of specific ecosystem services. Anecdotal evidence indicates considerable variation between local communities in the capacity to formulate and implement collective responses to such problems (Bourke and Betitis 2003). The effectiveness of such responses appears to depend in large part on the authority of individual community leaders, which may or may not be based on 'traditional' values. But for this very reason, it is hard to sustain such responses over long periods of time or to make them effective beyond the local scale at which such leadership is exercised. The scale constraint is especially problematic for community management of marine ecosystems whose services cannot be sustained by small groups of people acting alone.

The absence of a traditional or local 'conservation ethic' does not necessarily mean that indigenous resource management regimes are inherently unsustainable; it may only mean that the local component of sectoral resource management regimes is unable to resist the damage caused by extractive industry (Filer 2004b). Donor-funded conservation projects may themselves be ineffective because they are unable, for political reasons, to mitigate such damage, and are thus obliged to make the false assumption that community attitudes and behaviour are the 'problem' which needs to be addressed. For example, the Milne Bay Community-Based Coastal and Marine Conservation Project has no mandate to restrict the activities of foreign fishing vessels within the area earmarked for the establishment of marine protected areas because it is a 'community-based' conservation project (van Helden 2004).

If the degradation of coastal ecosystems is primarily the result of large-scale commercial exploitation of specific resources, rather than pressures exerted by indigenous resource management regimes, then the government could in theory respond to the problem by limiting commercial access to these resources under existing legislation, without needing to enter into negotiations and partnerships with local communities (Filer 1998). But this response is unlikely to be effective if government institutions are corruptible or if local people are willing to entertain the exploitation of their resources in the name of 'development', even if that development is unsustainable.

The strategy adopted by some environmental NGOs – most notably Greenpeace – is to advocate for measures to be taken by the donor community to force or persuade the PNG government to clamp down on the activities of foreign logging and fishing companies (Greenpeace n.d.). This strategy is based on the argument that many politicians, bureaucrats and self-styled 'community leaders' have already been corrupted by the managers of these companies, and some members of the NGO community believe that this is the main reason why 'community-based' conservation projects are doomed to failure (PAFNN 2003). The World Bank appears to sympathise with this point of view, because PNG is one of the few countries in which it has attached environmental governance conditions to structural adjustment loans, and in PNG's case, it has done this twice, first in 1995 and then again in 1999 (Filer 2000). On the second occasion, the main loan was conditional on the government's acceptance of a separate US$17 million loan for a Forestry and Conservation Project which included a matching GEF grant to a Conservation Trust Fund. However, at the time of writing, the government has still failed to meet the conditions attached to the subsidiary loan, so the project has yet to be implemented (Filer 2004c). This appears to reinforce the argument that loan conditionality is a fairly blunt policy instrument which may occasionally be justified, but is unlikely to achieve any lasting results in its own right (Lele et al. 2000). It has also caused a good deal of unhappiness among members of the national conservation community, because the GEF grant funds have been frozen while the bank argues with the government.

Those members of the national conservation community who still believe in the potential value of localised conservation projects now tend to agree that is that these should be based on a scientific process of assessment to determine the broad areas in which biodiversity values need protection, followed by a process of social engagement that seeks to identify specific local communities whose members are willing and able to do something about the problem (van Helden 1998). There is also general agreement that local resource owners will not buy into the conservation of biodiversity for its own sake simply because they have been made aware of the problem (van Helden 2004). This means that there has to be some positive financial or material incentive for them to do so. The question then is how these incentives can be constructed and made to last.

During the 1990s, the Biodiversity Conservation Network provided ‘implementation grants’ to a total of 20 conservation projects in the Asia-Pacific region, including three projects in PNG in order to evaluate the effectiveness of what were described as ‘enterprise-oriented approaches to community-based conservation of biodiversity’ (BCN 1999). The European Union and several other donor agencies have funded ecoforestry projects in various parts of the country, including parts of the coastal zone, and the ‘walkabout sawmills’ which feature as the central component of these projects have also sometimes featured as the ‘development’ component of integrated conservation and development projects (Chatterton et al. 2000). Various attempts have also been made to market non-timber forest products (such as butterflies) and to develop an ecotourist industry. In the absence of donor support, most of these business ventures prove to be unsustainable because of high transport and transaction costs, quality control problems, and a lack of marketing expertise in the conservation community (Martin 1997; Hunt 2002). The operators of diveboats and diving resorts are perhaps the most notable exception to these rules (Benjamin 1996), but coastal communities have not so far received much in the way of financial benefit from these operations (Kinch 2001b).

There is growing recognition, in PNG as elsewhere, of the fact that partnerships between conservation organisations and local communities are unlikely to have positive and sustainable outcomes so long as conservation projects are dependent on unpredictable and time-limited grants from foreign funding agencies. This is the main reason why the World Bank has supported the establishment of a Conservation Trust Fund. However, it is not possible to evaluate the success of this institution while its financing is blocked by the dispute between the bank and the government. The GEF already funds a small grant scheme in PNG which is implemented by the UN Development Programme, and experience with the operation of this scheme suggests that the main difficulty may arise in the evaluation of project proposals and outcomes.

The Convention on Biological Diversity has fostered another kind of ‘conservation industry’ in developing countries by means of institutions designed to protect indigenous intellectual property rights in biological and genetic resources. One of the last acts of the BCRMP, in 1998, was to establish a PNG Institute of Biodiversity (PINBio), modelled on its Costa Rican counterpart, as a network of national research and training institutions with a common interest in this issue. The secretariat of this body is located in the same branch of the Department of Environment and Conservation that is responsible for national compliance with the Convention on International Trade in Endangered Species and the relevant provisions of the UN Convention on the Law of the Sea. With PNG's accession to the World Trade Organisation, there has been much talk of the need to formulate 'access and benefit sharing agreements', of the kind envisaged by the CBD, in order to appropriate and distribute the revenues derived from a 'conservation based industry' that revolves around the activities of foreign 'bioprospectors' (Whimp and Busse 1998; Kwa 2004). However, it is still not clear whether an institution like PINBio, or its bureaucratic secretariat, is in the business of facilitating or hindering the conduct and/or commercialisation of scientific research, especially in light of the tendency to assume that all forms of scientific research have some hidden commercial potential. The obvious risk in the development of responses which emphasise intellectual property rights, whether at the national or local level, is that they will simply create a new domain for the kind of rent-seeking behaviour which is already evident in the realm of extractive industry (Filer 1998).

If there is no short-term prospect of developing any form of 'conservation based industry' that can match the revenues which extractive industry already provides for both the national government and local landowners, except in places where extractive industry has nothing to extract, an alternative response to the loss of biodiversity values would be the establishment of 'conservation concessions' through which the donor community would compensate national and local stakeholders for the opportunity cost of forsaking development options that have a negative impact on biodiversity values. This alternative has been canvassed by Greenpeace in respect of potential forestry concessions in Western Province, and Conservation International seems to have briefly contemplated its potential application to the creation of marine protected areas in Milne Bay Province. However, there are several reasons to doubt whether this response can be effective in PNG:

- Current legislation is not conducive to the formulation of binding conservation agreements between customary landowners and alien organisations, unless perhaps the latter would be prepared to sue the former for breach of contract (Brunton 1998).

- Government agencies and local landowners are both liable to overestimate the commercial value of unharvested resources under customary ownership in the absence of accurate scientific knowledge.

- The World Bank, other members of the donor community, and even some local NGOs are concerned that the prospect of 'conservation rents' may only add further fuel to the 'compensation culture' that is already associated with PNG's version of the 'resource curse' (van Helden 2004).

- Even if it were possible to establish credible trust funds to finance these concessions, there is no obvious way to demonstrate the future sustainability of institutions set up to manage them at a local level.

This last problem afflicts several of the other responses already discussed in this section. The production of new policies or passage of new laws cannot of itself create the institutions that can either manage conservation projects or manage the financial or other benefits which such projects may provide for local communities. Wildlife management committees may be granted legal recognition, but they are essentially rule-making bodies whose management functions are not supported by the government. Since 1995, local-level governments have been granted the power to make laws about the 'local environment', provided that these are consistent with national and provincial laws on the same subject. One international NGO (The Nature Conservancy) has recently negotiated that drafting of such laws with the local governments responsible for the two areas in which it has already established conservation projects, one of which covers part of the coastal zone in West New Britain Province. These laws entail a further process of negotiation with bodies representing separate groups of customary resource owners and set out a range of penalties for breaches of any mutual agreement to create a protected area. However, local governments in PNG are notoriously short-staffed and under-funded, so they could hardly be expected to take on the function of managing such areas, or helping local communities to do so, even if they were able to secure national government endorsement of their declarations under the *Conservation Areas Act* (Kwa 2004).

The *Local-level Governments Administration Act* 1997 does allow the national government to establish a 'special purposes authority' to perform such management functions in circumstances where a local government does not have the capacity to do so. This mechanism has so far been used primarily to manage revenues derived from major resource projects, but could in theory be applied to the management of revenues derived from a conservation trust fund (Filer 2004a). Unfortunately, the creation and maintenance of such bodies requires a substantial input from the national Department of Provincial and Local Government Affairs, and this agency is also short of capacity. If an NGO proposes to carry out these management functions, and also to persuade foreign funding agencies that this will be a sustainable arrangement, it may need to enter into a joint venture with legally incorporated groups of local landowners. This kind of arrangement is currently used to extend the commercial management of oil palm plantations on customary land (Oliver 2002), but has not so far been considered as a vehicle for protected area management, partly because the transaction costs are very high.

8 Scenarios for Coastal Ecosystems

8.1 Scenarios, Plans and Prophecies in PNG

The MA Conceptual Framework defines a scenario as 'a plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces … and relationships' (MA 2003: 214).

PNG has a history public engagement or participation in the policy process which dates back to the work of the Constitutional Planning Committee in the years leading up to Independence in 1975, but scenario construction has rarely been part of this process. Some of the major investors in the mining and petroleum sector are known to have commissioned country risk assessments and project closure strategies which include the analysis of alternative scenarios, but these have not been placed in the public domain. The PNG Department of National Planning and Rural Development is responsible for a Medium-Term Development Strategy which was presented in the 2003 Budget, but this is a conventional five-year plan which has nothing to say about alternative scenarios in a longer timeframe.

This does not mean that Papua New Guineans are averse to speculating about the future, whether it be the future of the nation as a whole or that of their own local community.

Indeed, the standard discourse of 'development' is one which revolves around the choice which has to be made between several different 'roads' or 'paths', such as 'business', 'law', 'religion', 'custom', and so forth (Carrier 1992; Foster 1995). Since PNG has a very free press, the local newspapers are also full of speculations, prophecies and warnings about the future, not only from political leaders with loud voices, but also from members of the public writing letters to the editors. The amount of noise already generated by this kind of public debate means that it is difficult for a group of scientists, or even a group of policy makers, to use scenario construction in ways that will engage different interest groups in the production of new insights or visions. Furthermore, PNG has a history of millenarian beliefs and movements – formerly associated with the road called 'cargo' (Lawrence 1964), but now associated with Christian fundamentalism – which can create its own surprises for those who would like to use scenarios as a tool for inserting 'science' into the policy process.

For the purpose of this assessment, no attempt has been made to engage any interest groups directly in a new process of scenario construction. The authors have not had the time or the resources that would be necessary to make this a useful and meaningful exercise for people at different levels or social and political organisation. The following discussion is therefore limited to a review of the way in which scenarios have so far figured in national and local debates about the relationship between people and ecosystems in PNG.

8.2 Climate Change Scenarios and Coastal Ecosystems

The drivers of climate change are external and direct. Greenhouse-induced global warming will affect ecosystems and nearshore processes. Periodic droughts in PNG are a result of the El Niño-Southern Oscillation (ENSO) phenomenon, controlled by coupled ocean and atmospheric systems.

The scenarios set out by the Intergovernmental Panel on Climate Change (IPCC) are treated here as part of a story about the impact of climate change which is common to all three of PNG's 'development scenarios' over the next 50 years. Future action taken by national stakeholders to mitigate the impact of climate change will have no appreciable effect on the rate of global warming in that period. If there were determined efforts to reduce greenhouse gases over this period, there would be an impact on reducing the trend after that period, but warming associated with emissions to date is in train for the next 50 years, and the emission trend is not yet lowering.

The third IPCC report (2001) concluded (amongst other things) that most of the observed global mean warming of the last 50 years (0.6^{o}C) is attributable to human activities, and will continue under current trends. Sea level which increased 100-200mm between 1900 and 2000 will continue to rise. Climates will tend towards a more constant 'El Niño' situation, with less pronounced periodic variability, but with a likelihood of more extreme events including cyclones and associated low pressure surges and intense rainfalls.

For the next 50 years, the most recent IPCC (2001) scientific working group projections, based on global climate models and coupled ocean-atmosphere models, are for a temperature rise of 0.9^{o}C to 1.3^{o}C, with an associated sea level rise of 230mm to 430mm, whether or not world emissions of greenhouse gases are stabilised or reduced. These values remain highly dependent on model assumptions, so scenarios (choosing arbitrary low and high value assumptions broadly consistent with contemporary scientific projections) are commonly applied to predict future situations under such conditions. The IPCC Working Group III used global climate models, relative sea level rise scenarios, and a range of global socioeconomic assumptions that include global population and average gross domestic product, to develop scenarios for the 21st Century, in a Special Report on Emissions Scenarios (Nakicenovic and Swart 2000). These SRES scenarios are for a temperature rise of 0.8 to 2.6 ^{o}C, with an associated sea level rise of 50 to 320mm by 2050 (Carter and La Rovere 2001: 177).

The direct impacts of global warming on PNG's coastal zone have been assessed in a report covering the whole of the South Pacific region (Pernetta and Hughes 1990), and may be summarised as follows:

- Temperature rise with no decrease in humidity will increase the relative strain index for coastal PNG, with a deterioration in human comfort, and increased stress and lower productivity for manual workers. There will be higher demand for building air-conditioning, increased energy use, and hence increased cost of work productivity.
- Water-borne vector diseases (malaria, dengue fever, filariasis) and skin fungal diseases may have prolonged seasonal virility in coastal areas.
- Limestone-based soils are likely to become less fertile as increased temperature changes sodium/calcium ratios.
- Ecosystems particularly vulnerable to global warming will be coastal forests, especially mangroves, seagrasses and coral reefs.

Despite current research on coral symbiotic algae (*zoozanthellae*) indicating that one subgroup of these organisms may adapt to rising water temperatures, the overall impact of warmer water appears likely to be algal expulsion, with consequent extensive coral reef bleaching and death. Re-establishment of hermatypic corals on dead reef structures may occur in the future if systems adapt to warmer water. Most Pacific corals are now growing in their optimal water temperature range, and most communities show extreme species loss at water temperatures above 28^{o}C, and reef growth is considered unlikely at water temperatures above 30^{o}C – well within the 50 year global warming scenario.

Indirect impacts, especially associated sea level rise, will have greater impact on PNG than direct temperature rise, but as PNG is made up mainly of 'high islands', the impact on the country will be relatively less than that expected on atoll and other low coral-based islands in the Pacific. Permanent coastal inundation is expected where the coastline is flat or gently sloping and coastal erosion will increase. There will be a significant impact on depositional coastal areas, and on areas subject to submergence/tectonic sinking (such as the Mortlock atolls or the coastline of Gulf and Western Provinces). Fertile agricultural areas and coastal infrastructure, especially roads, will be affected.

There will be an overall decrease in the extent of low-lying wetlands, with a corresponding decrease in freshwater species diversity and abundance for most catchments, except possibly the Fly and Sepik-Ramu systems where some new wetlands may become established further upstream.

Initial scenarios for the rate of warming and sea level rise that were applied to project impacts for the first IPCC report (in 1990) have been modified by subsequent IPCC findings, but for PNG these were the only attempted quantification of impacts, based on scenario conditions, not projected timeframes. Scenarios based on a 500mm rise in average sea level above the 1980 level are now likely to be realised early in the second half of this century, so form a useful basis for a 50 year projection.

Five landform types – deltaic floodplains, sand barrier and lagoon complexes, coral atolls and cays at sea level, raised coral islands and small high islands will all be impacted. At a mapping scale of 1:100,000 the length of the PNG coastline is approximately 17,100kms, of which 4,250kms (25%) is deltaic floodplains and barrier-lagoon complexes, and 4,180kms (24%) is islands and atolls. The impacts will be loss of economic land, loss of fresh water and traditional resources, damage to roads and other infrastructure, disruption of wastewater and sewerage outfalls, loss of protective functions of nearshore barriers, damage to villages and village agricultural areas. People most at socioeconomic risk are those living on low coral-based islands or on depositional landforms, especially deltaic floodplains on areas not backed by rising land.

Deltaic floodplains, mainly in the Gulf of Papua, will be affected most extensively. Watertables are already high, and a 50 to 500mm rise in sea level will cause extensive liquefaction of the sedimentary deposits, and consequent erosion. Watertables will become saline. Seawater incursion over the extensive southern coast deltaic plains will cause additional weighting adjustment, with likely increasing submergence, exacerbating the impacts of sea level rise. In the Gulf of Papua, flooding will be more extensive and of longer duration. There will be a reduction in availability (already limited) of land suitable for habitation and cultivation, and of potable water. Some agriculture may give way to aquaculture. A 1990 study in a 70 km zone of the coastline in the Kerema-Vailala area indicated a 500mm rise in sea level would destroy one third of the villages, affect another third, and disrupt the livelihoods of about half the area's population.

Sand barrier and lagoon complexes will retreat, with many lagoons filling.

Low islands – atolls and cays at sea level will suffer virtual destruction with sea level rises of 500mm. Land loss will be preceded by loss of freshwater lenses. For the low island groups in PNG (mainly in Milne Bay, Manus, and Bougainville provinces), there will be a rise in saline watertables. Sediments that make up both beaches and entire island deposits will 'liquefy' and be swept away by tidal action if/when sea level rises to their basal layers. If coral growth does not keep up with sea level rise (as seems likely under present projection scenarios) coral-based islands will become saline swamps before submergence and sediment dispersal. Living reef corals will continue grow upwards and outwards, but reef growth rates observed (0.5 to 2 m/100 years) suggest their growth will not keep pace with expected sea level rise over the next 50 years. Islands may not become re-established for many decades, and then in different locations from the present. More important than the rate of coral growth (initially considered to be the critical factor) is the recent knowledge of coral reef susceptibility to direct ocean warming, and any re-establishment of coral growth may not occur for many decades.

Populations of low islands or using low islands as resource areas will suffer from any rise in sea level, but will undergo total or significant loss of land resources and fresh water if sea level rises at the SRES high scenario or the IPCC projected maximum level (320-430mm) by 2050. For other coastal areas, the impacts of the low scenario sea level rises would be minor, with encroaching coastal erosion and loss of coastal ecosystems and land resources for coastal populations. Given the quality of available topographic data for PNG, projections based on a 500mm rise in sea level above the 1980 level, as used during the first IPCC study, remain appropriate for a projected maximum sea level rise by 2050. Thirteen coastal provinces in PNG contain over 1000 small islands with a maximum elevation of less than 40m above sea level, and most of them have an elevation of less than 10m above sea level. These islands support an estimated population of between 90,000 and 100,000, who are wholly or largely dependent on those resources for subsistence or (where there are plantations on the islands) cash income. Most of these islands (87%) have no permanent inhabitants – they are used as bases for fishing, food processing or the collection of land-based resources.

High islands will suffer land loss that relates directly to the nature of the land surface. Many volcanic islands will suffer loss of the low-lying, fertile depositional plainlands.

The extensive *mangroves and aquatic ecosystems* fringing the Gulf of Papua and near the mouth of the Sepik River will undergo substantial reductions in area, with the compression of existing zones. This will result in loss of coastal resources and probable social tensions. There will be a reduction in nursery areas of penaeid prawns with likely impacts on that commercial resource. Fisheries nursery habitats will be similarly reduced. Mixed mangrove communities, Nypa and sago swamps will all be reduced in extent. Perched lakes and coastal wetlands near the major river mouths will be inundated, with negative impacts on their grass, sedge and aquatic plant communities.

8.3 One Utopian Scenario for PNG's National Development Strategy

The most obvious case of public engagement in an 'official' process of scenario construction which deals (amongst other things) with the relationship between people and ecosystems is the one organised by a body known as the 'Planning the New Century Committee' (PNCC) in 1997. This body was established in 1996 at the instigation of the Minister for National Planning 'to offer a vision of how realistically, Papua New Guinea might choose to develop over the next 25 years'. The committee included representatives of both government and civil society, and its work was facilitated by a small group of expatriate consultants funded by the UN Development Program. After two years of deliberation and consultation, it produced a report called 'Kumul 2020' – the title of which refers (in Tok Pisin) to PNG's national symbol, the Bird of Paradise (PNG/PNCC 1998).

This report is built around the contrast between a 'Probable Future' scenario, which is a 'business-as-usual' scenario, and a 'Preferred Future' scenario, which is the alternative vision encapsulated in the title of the report. The Probable Future scenario consists of a set of familiar vicious circles or feedback loops which connect environmental degradation with growing poverty, inequality and social conflict. These are linked to the five forms of undesirable growth – jobless, ruthless, voiceless, rootless and futureless – which were listed in the UN Human Development Report for 1996. The Preferred Future scenario is presented in two ways: first as a set of recommendations for action by government and civil society over a period of five years; and then as a story told in the year 2020 about the way in which these recommendations were actually implemented. With the benefit of hindsight, it is possible to see that a few of them have actually been implemented, but most have not.

The actions recommended and taken in the Preferred Future scenario are presented as the best way to implement the goals and directive principles already contained in the National Constitution of 1975, including the fourth goal, which calls ‘for Papua New Guinea’s natural resources and environment to be conserved and used for the collective benefit of us all, and be replenished for the benefit of future generations’. Box 2 shows the actions taken to realise this goal in the storyline for this scenario. If the national government had acted (or were to act) on the committee’s recommendation to establish an independent Conservation and Biodiversity Commission and make it responsible for producing annual reports to Parliament on the ‘state’ and the ‘sustainable use’ of PNG’s natural environment, then this assessment might count as part of that process.

Box 2: Some steps to sustainable development under the ‘Kumul 2020’ scenario.

The Department of Environment and Conservation is abolished, and replaced by an ‘Environment and Sustainable Development Division’ within the Department of National Planning, with a mandate to integrate environmental considerations into the country’s social and economic development strategies.

A ‘Conservation and Biodiversity Commission’ (CBC) is established as a statutory body to manage and monitor the sustainable development of the country’s biological resources. The CBC assumes legal responsibility for auditing the management of the country’s biological resources by line agencies such as the PNG Forest Authority and National Fisheries Authority, and uses foreign aid to contract national and international research institutions to undertake this kind of task.

The CBC orchestrates a series of joint ventures between national and foreign investors to develop an ecotourism and cultural tourism industry targeted at elite niche markets in the developed countries; it supports a bioprospecting program which attracts investment from foreign pharmaceutical companies, but also incorporates traditional medicine into the training of national health professionals; and it develops artificial coral reefs as carbon sinks in order to claim tradeable carbon emission credits.

An ‘Indigenous Agricultural Development Program’ is established by the National Agricultural Research Institute, with financial support from an Agricultural Venture Capital Fund, to develop new export markets for indigenous flora and fauna, adding economic value to the nation’s wealth of biodiversity through the supply of a unique set of material benefits to the rest of the world.

PNG becomes a world leader in the organic farming of conventional export crops (such as coffee) after the national government bans the use of organochlorines and strictly regulates the use of other chemicals in commercial agriculture.

The use of local and traditional materials in rural architecture and infrastructure becomes a key component of the government’s Rural Development program, and is regulated through a *Village Construction and Health Ordinance*.

An ‘Initiation Education Program’ is established to incorporate traditional forms of initiation into the formal education system, and this places particular emphasis on the role of traditional foods and other ecosystem services in the maintenance of human health and wellbeing.

Customary landowners are required to register their land, on either an individual or collective (clan) basis, and to demonstrate that it is either being used productively or being set aside for conservation purposes in order to avoid payment of a land tax.

Source: PNG/PNCC 1998.

Insofar as the Preferred Future scenario counted as a policy package, its basic justification was that PNG has come so late to the process of ‘development’ that it has a comparative advantage in the marketing of its own 'backwardness', which partly means its unique wealth of biological and cultural diversity. But since most of the actions described in this scenario are undertaken within the first 5 years of the storyline, the report reads more like a utopian 5-year plan than a reflection on alternative long-term futures. While globalisation is recognised as the generic context of any national development strategy, there is no consideration of alternative global scenarios and their implications for national (or local) policy choices. Nor is much attention paid to interactions or feedbacks between the drivers in the preferred story-line, even within the national policy domain, because the story is essentially one in which the good guys wake up to reality and do the right thing. The Department of National Planning and Rural Development also seems to have forgotten the plot.

8.4 Three Scenarios Which Make Most Sense for National Political Debate

Papua New Guineans tend to debate the changing balance of global political and economic forces in terms of the relative strength and merit of Western and Asian forms of control over their government and their economy. We can accommodate the terms of this debate by constructing three new scenarios which also take account of recent changes in the visions or policies of the World Bank and the Australian Government as key representatives of the 'Western' interest. Each of these scenarios has optimistic and pessimistic versions which reflect the views of their supporters and detractors, and the main point of difference between them is the capacity of the national economy to support a rapidly expanding population, but the difference can also be expressed in terms of the capacity of national ecosystems to support this population.

The GLOBALISATION scenario is one in which the 'donor community', currently led by the World Bank and the Australian Government, maintains and expands its control over the levers of PNG's national development strategy. This scenario stands midway between the 'resource dependency' and 'structural adjustment' scenarios, because the World Bank no longer believes that the growth of agricultural incomes and revenues can offset the precipitous decline of incomes and revenues from major mining and petroleum projects which is bound to continue if no new foreign investment is attracted to these two sectors (World Bank 1999; Baxter 2001). This scenario therefore envisages a convergence of interest between the donor community and multinational mining and petroleum companies which are domiciled in the developed countries.

The optimistic version of this Globalisation scenario is one in which the donor community helps the PNG government to maintain a mineral-dependent economy for many years to come, to manage its mineral revenues in such a way as to avoid the so-called 'resource curse', and hence to pave the way for greater economic diversification in the longer term. The pessimistic version is one in which this effort fails, and PNG's condition of 'resource dependency' is simply replaced by a growing dependency on foreign aid, which entails a further loss of national control over the national development strategy.

The ASIANISATION scenario is one in which the declining influence of the donor community creates the space for a substantial increase in the level of Asian investment in the exploitation of PNG's forest and marine resources, and more especially, for investment by ethnic Chinese capitalists catering to the demands of a rapidly expanding Chinese economy. This form of investment is presently constrained by the donor community's insistence on standards of 'good governance' and 'sustainable development', and the resulting conflict is best exemplified by the decade-long struggle between the World Bank and the Malaysian company, Rimbunan Hijau, which not only occupies a monopolistic position in the logging industry, but also owns one of the country's two national newspapers and has a major stake in the wholesale trading sector (Filer 2000).

Some politicians who support the process of Asianisation have invoked a 'Look North policy' which is based on their admiration for the Malaysian Prime Minister's readiness to thumb his nose at both the World Bank and the Australian Government. In their optimistic version of this scenario, PNG could also follow the Malaysian road to economic development and diversification if only it were freed from the shackles of the aid industry. In the pessimistic version preferred by their opponents, the Asian investment boom will only last as long as it takes to deplete and degrade the nation's natural capital, and the people of PNG will then be worse off than they were before it started.

The LOCALISATION scenario is one in which the indigenous people of PNG, and most especially the rural communities that own or control most of its natural capital, constitute an increasingly powerful obstacle to the designs of the donor community and all foreign investors, including the Asian variety. This scenario is also one which entails a substantial decline in the wealth and power of the PNG Government, because it assumes that state institutions are bound to be instruments of foreign domination in what was formerly a stateless society. The 'self-reliance' and 'collapsing state' scenarios may then be seen as the optimistic and pessimistic versions of this one scenario. The correspondence columns of the national newspapers in PNG suggest that the optimistic version of this scenario has widespread popular support.

The relationship between these three scenarios or 'roads' can then be expressed as a sequence or cycle of decisions taken at a number of different levels or scales. If the pursuit of one road leads to an undesirable outcome, which means that the pessimistic version of that scenario turns out to be the correct one, then supporters of at least one of the other two roads will have the means and the motivation to change the direction of history. But if supporters of the other two roads have equal amounts of power and influence, the change will not be very rapid.

These general rules seem to explain the recent history of the Solomon Islands, as well as that of PNG. In the former case, the Australian Government has acquired the means and motivation to deal with the collapse of state institutions because the indigenous population is prepared to accept a form of neo-colonial intervention and the Asian business community has no alternative to offer. In the latter case, a condition of stalemate and stagnation is likely to last for as long as it takes for the citizens of PNG to decide whether they subscribe to the optimistic or pessimistic version of the Globalisation scenario.

8.5 Relationship between National and Global Scenarios

The Millennium Ecosystem Assessment is itself an activity which belongs to what we call the Globalisation scenario. This means that an assessment of coastal (or any other) ecosystems in PNG is only likely to contribute to the policy process in PNG if the donor community maintains or expands its influence over that process. In the optimistic version of the Globalisation scenario, mining and petroleum companies with major production facilities in the coastal zone will be able to incorporate the findings of such an assessment in their own planning and management frameworks, and the national government's own policies might encourage them to do so. In both the optimistic and pessimistic versions, the donor community will continue to fund local projects which involve the conservation or management of local ecosystems.

Table 14: Four global scenarios in the Millennium Ecosystem Assessment.

	Interconnected World	*Disconnected World*
Reactive Management	GLOBAL ORCHESTRATION	ORDER FROM STRENGTH
Proactive Management	TECHNO-GARDEN	ADAPTING MOSAIC

The Globalisation scenario at the national scale (in PNG) appears to correspond to the 'Global Orchestration' scenario at the global scale, if we assume that the donor community is able to manipulate national government policy to ensure that major foreign investors (under the optimistic version) are willing and able to fix the damage which their activities cause to coastal ecosystems, or else (under the pessimistic version) that a portion of PNG's foreign aid is devoted to fixing the damage caused by its own citizens. The optimistic version of the Globalisation scenario also allows for the use of mineral revenues to maintain reasonable levels of formal employment in urban centres and in the public service (as well as in the mining and petroleum project enclaves), and thus to relieve some of the population pressure on scarce subsistence resources in rural coastal communities while adding to the localised environmental impact of coastal towns and cities. This trend is also a feature of the Global Orchestration scenario.

On the other hand, it is hard to imagine that PNG will experience the clarification of property rights or the concentration of agricultural production which are also envisaged in the first three decades of the Global Orchestration scenario, because the donor community will not have the resources or popular support to tackle the wholesale registration of customary land. In an increasingly specialised global economy, it is more likely that PNG will enlarge its comparative advantage as a haven of biological diversity, and donor-funded aid projects will apply new technologies to the protection of that diversity by mitigating the impact of invasive species (including new pathogens). This means that PNG will also be one of the last havens of social and ecological resilience.

The optimistic version of PNG's Globalisation scenario approximates the 'Kumul 2020' scenario that was generated by the Planning for the New Century Committee. In this instance, the global 'TechnoGarden' scenario allows for various types of 'eco-enterprise' to play a significant role in the process of economic diversification which lifts the 'curse' of mineral resource dependency. These could resemble some of the 'development' components which have figured (somewhat unsuccessfully) in the so-called 'integrated conservation and development projects' funded by the donor community over the past decade, but their future success would depend to some extent on a major upgrade of the country's research infrastructure and capacity, and this is unlikely to happen without substantial private investment by foreign companies. In the pessimistic version of the Globalisation scenario, where such investment is not forthcoming, the global TechnoGarden scenario simply entails a much 'greener' package of foreign aid, which might certainly include some provision for building national research capacity, but not to an extent that would transform the national economy. Although bioprospecting and scientific tourism have been touted as forms of 'green business' in which PNG could develop some comparative advantage in the global economy, it is more likely that PNG's small farmers and gardeners will reap most of the benefits from the TechnoGarden scenario (as its name seems to imply).

The global 'Adapting Mosaic' scenario is PNG's Localisation scenario writ large, in both its optimistic and pessimistic versions. If PNG's detachment from the global economy and international institutions is one aspect of a global process, PNG will have the comparative advantage of being made up of local communities which have never really lost ownership or control of their own territorial domains, and are still able to apply traditional techniques to the management of their environmental problems. The experience of the drought in 1997-98 (as well as the earlier civil war in Bougainville) suggests that most rural communities will be able to adjust to the projected impact of global warming without external support. Our 'small islands in peril' will have to find an outlet for their surplus populations, even if they do not lose ecosystem services to rising sea levels, and traditional forms of resettlement may be blocked if neighbouring communities are also under pressure.

The most problematic aspect of the Adapting Mosaic scenario is the loss of any common framework for the management of marine resources which lie beyond the effective control of local communities. On the other hand, very few communities, even in the coastal zone, are dependent on the supply of such resources for their own survival, so this 'tragedy of the commons' will be as much a global as a local issue. While people in other parts of the world may respond to this kind of problem by rebuilding regional institutions, PNG is likely to lag a long way behind in this process, because 'the state' will by then be seen as a brief interlude in the long-term evolution of a stateless Melanesian society in which local communities rarely find cause for collaboration. Nor will the further collapse of PNG's communications infrastructure provide much in the way of opportunity for this to occur.

The 'Order from Strength' scenario at the global scale is the one that envisages a major reduction in foreign aid to developing countries world, and therefore seems to be inconsistent with the Globalisation scenario in PNG. But if the alternative for PNG turns out to be the pessimistic version of either the Asianisation or the Localisation scenarios, the Australian Government is still likely to intervene in the management of national affairs (as it has done in the Solomon Islands) simply in order to protect its own interests and its international border. If the Order from Strength scenario is one in which 'resource-intensive' industries (and their environmental impacts) are increasingly concentrated in the developing countries, it would seem to be consistent with the maintenance or expansion of all forms of extractive industry in PNG, but those multinational mining and petroleum companies which are domiciled in developed countries are unlikely to make substantial new investments in PNG unless they are 'covered' by a degree of international control over national government policy, precisely because they will fear for the security of their investments under the Asianisation or Localisation scenarios.

Under the Asianisation scenario, Asian investment might be attracted to the mining and petroleum sectors, as well as the 'renewable' resource sectors, and in the pessimistic version of this scenario, it might also extend to such unsavoury activities as the dumping of hazardous waste materials, though there is no reason to suppose that this would have to be a monopoly of Asian business interests. There remains a big question mark over the ability of the PNG government or the 'political elite' to both support and control environmentally hazardous forms of foreign investment in the absence of institutions 'strengthened' by the donor community, given the country's very high level of cultural diversity or social fragmentation, and also the power which traditional communities still retain over the disposition of the country's natural resources. In this kind of disconnected world, the pessimistic version of the Asianisation scenario is likely to precipitate one version of the Localisation scenario even if it fails to prompt Australian political intervention.

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Figure 1: Local assessment sites in Papua New Guinea.

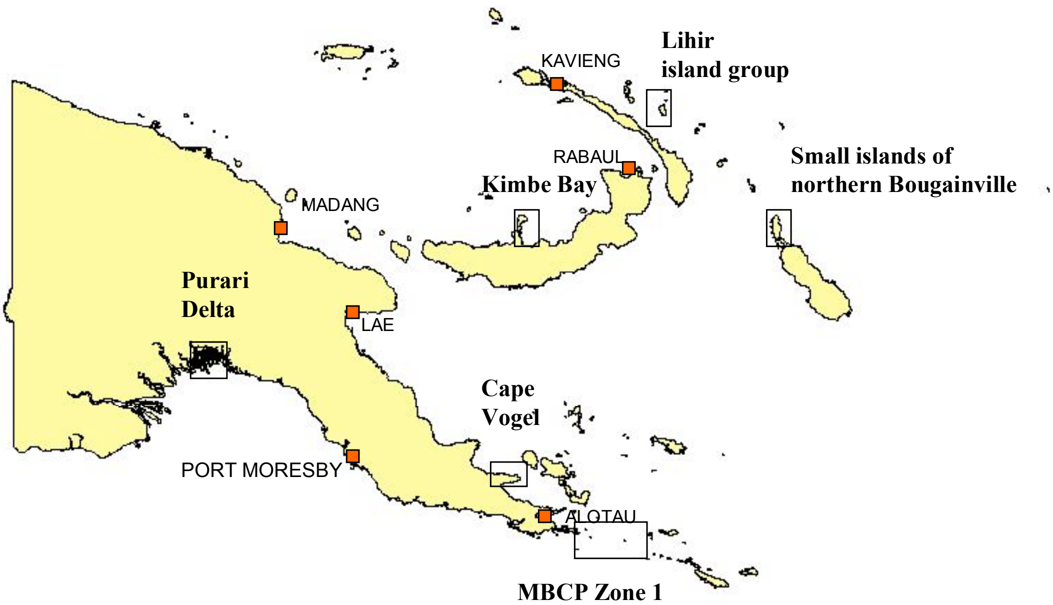
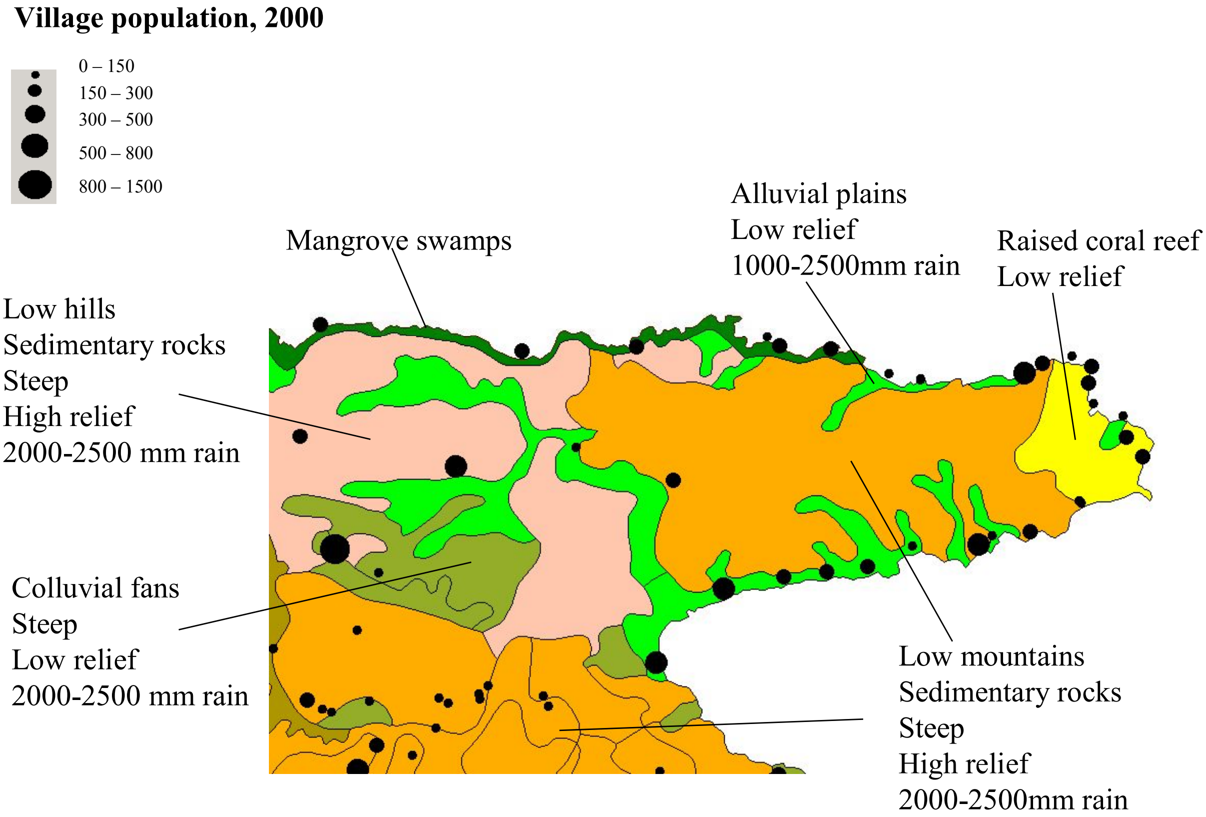
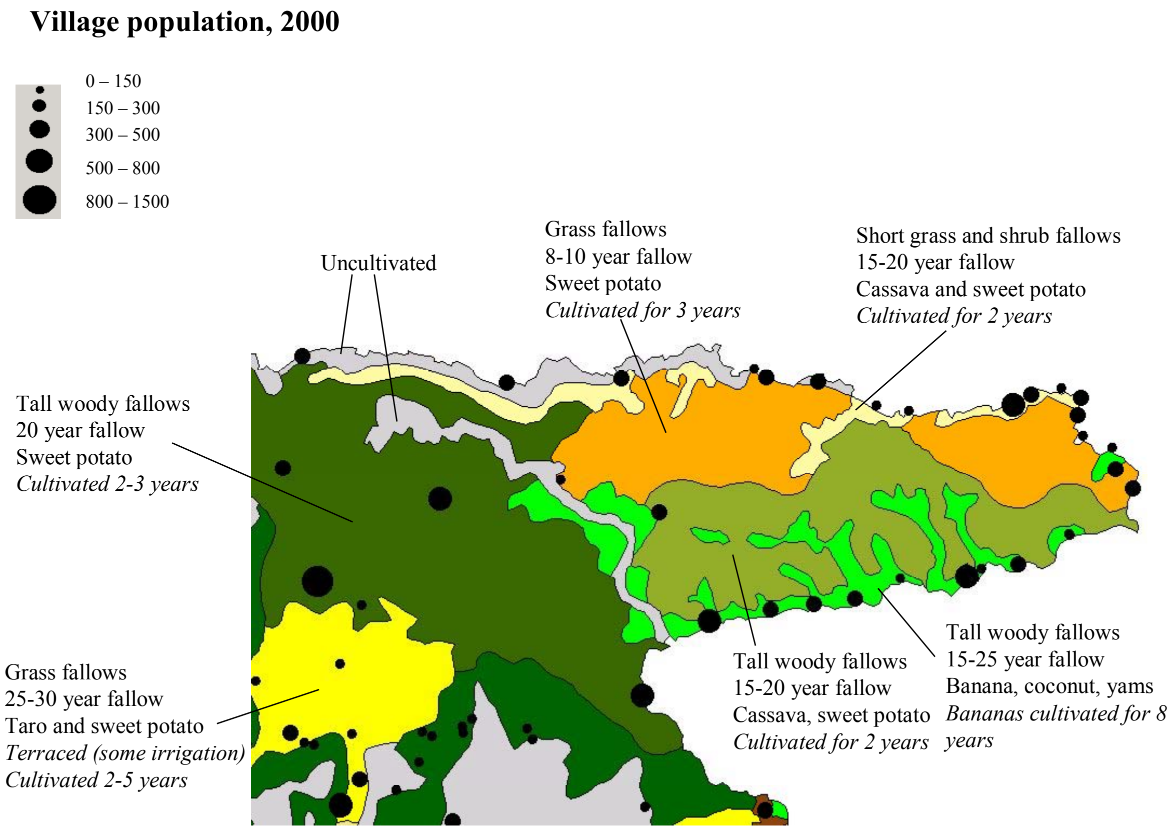


Figure 2: Resource Mapping Units on Cape Vogel, Milne Bay Province.



Source: PNG Resource Information System.

1 **Figure 3**: Food-cropping systems on Cape Vogel, Milne Bay Province.



2 **Source**: Hide et al. 1996.

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