The status of marine resources and coral reefs of Nauru

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Introduction

Nauru is a single island country situated in the middle of the vast Pacific ocean, about 60 km south of the equator, at latitude 0°31'S and longitude 166° 55'E (Figure 1). Its nearest neighbour is Banaba also known as Ocean Island in the Republic of Kiribati, about 300 km to the east. Sydney is about 4000 km to the south, Tokyo, some 4800 km to the north west and Honolulu about 4200 km to the north east.

Nauru is an ancient submerged volcano with a karstified limestone cap of coral origin about 550m thick (Hill and Jacobson 1989), measuring 6 km long by 4 km wide with a circumference of 18 km and a total land area of 21 km^2. The central plateau forms about 80% of the island with the highest point to 70 m above sea level. The remaining land area is composed of a flat coastal terrace measuring 300-1000 m wide and with a mean elevation of about 3m above sea level. The shallow intertidal fringing reef measures 110-320 m in width, and sloping 45° angle to the ocean floor to a 4000 m depth. Dalzell & Debao (1994) estimated that the total intertidal reef area down to the 200 m isobath measures 7.4 km^2.

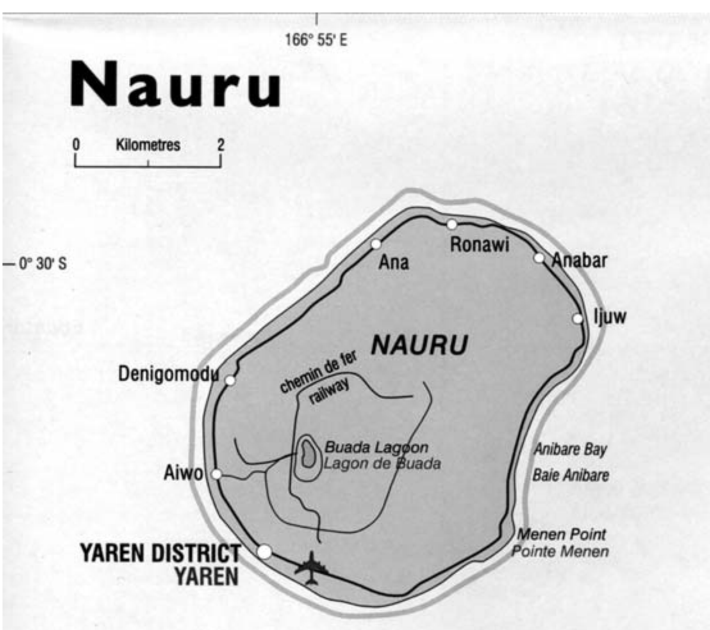

Figure 1
Map of Nauru.

The climate is tropical and humid with temperatures ranging from 24-34° Celsius, however, it is kept cool by the south east trade winds from April to October and by the westerly from November to March. While the trade winds are associated with periods of dry spells and calm seas, the westerly season on the other hand are associated with periods of heavy rainfall and stormy seas.

The population of Nauru at the last official census undertaken in 1992 was 9919 (Pitcher 1993). Estimates for this year is 12 460 based on the 1992 population growth rate. The population density is 593 km^2, which is the highest in the Pacific island countries.

Extensive phosphate deposits found on the plateau led to its mining in 1906. This resulted in the plateau's appearance being drastically altered, largely due to the open-cast mining method that removed vegetation, soil and rocks. Phosphate income, until recently, provided Nauruans with a comfortable lifestyle with most food requirements imported from overseas. The exploitation of the living marine resources was undertaken primarily on an artisanal level, on a moderate basis (Dalzell 1993). Its contribution to the nutritional requirements of the Nauruans is very important. Over the past three years the financial contribution of the fisheries sector has gained significance, particularly in terms of license fees received from distant water fishing nations. The revenue from fisheries now accounts for around 30% of the gross domestic product.

Coral reef biodiversity

The coral reef fauna and flora are among the richest ecosystems in the world containing a great diversity of species. The marine fauna and flora of Nauru are poorly documented. The earliest known information regarding the marine fauna was documented by North *et al.* (1903) and by Whitley & Colefax (1938). Petit-Skinner (1995) provided information on the common finfishes of Nauru. The benthic marine algae were documented by South and Yen (1992), while the coastal fisheries resources and a scientific checklist on finfish species are discussed by Dalzell and Debao (1994).

The lack of information is attributed to a range of factors including the orientation of the Nauru economy on phosphate mining and the smallness of the island. Previous research on coral reefs and marine resources of Nauru had been undertaken by overseas scientists, including a documentary film made by the Cousteau Society in 1992. Their results have not been made available to Nauruans.

Fauna

Finfish

Finfishes are the most commonly documented marine organisms on Nauru. The earliest accounts of finfish species were recorded by North *et al.* (1903), and by Whitley & Colefax (1938). Their lists were brief and only covered a few species. The most recent scientific checklist is compiled by Dalzell and Debao (1994), updating previous reports. The most fished species are pelagic fishes including tunas (*Katsuwonus pelamis* and *Thunnus albacares*) and rainbow runners (*Elagatis bipinnulata*). These species are abundant all year round accounting for 80% of landed catches. They are caught by trolling and through mid-water hand-lining often associated with fish aggregation devices (FADs) or in the open sea within sight of the island. Fish Aggregating Devices were first deployed in the early 1900s. Although they were initially deployed as mooring buoys for phosphate cargo ships, they soon became aggregators for tuna and rainbow runners. Cusack (1987) discussed the significant fishery that was borne from the deployment of these buoys. The identification of the finfishes and other fish species associated with the coral reefs of Nauru can be in taxonomic publications of notable authors such as Collette and Nauen (1983), Kobayashi (1994), Allen and Steene (1996) and Randall *et al.* (1997).

Corals

Corals are among the least understood and poorly documented marine organisms on Nauru, although identification of the different species of corals can be easily undertaken from taxonomic publications provided by authors such as Carpenter and Niem (1998) and Veron (1986). Dalzell and Debao (1994) stated that the hermatypic zone of the reef slope descends to between 15 m and 30 m, beyond which there is a transition zone with coral outcrops that descends to about 60 m.

Results undertaken from a snorkelling dive and manta towing survey in March 2000 covering about 50 % of the reefs, by the author and a Fisheries Officer (David Uera) showed that coral diversity was impoverished. The dominant coral species covering around 80% of growth belong to the genera *Pocillopora*, *Monitipora* and *Acropora*. Healthy coral growth on the western side was patchy with algae growing in places devoid of corals. Estimates of coral densities within a 2 metre quadrat varies from 20-60 %, with species diversity estimated at less than seven. Coral growth on the northern side of the island was greater with densities (in 2 metre quadrat) ranging from 60-80% and diversity of less than four. The north-east side, which is subject to heavy waves, was assessed and found to be limited in coral growth. Coral fragments and rubble were the main substratum. The density assessed from a 2 metre quadrat was less than five percent.

Invertebrates

There are no known publications describing the invertebrates of Nauru, however, species can be identified from taxonomic works by authors such as Allen and Steene (1996), Ryan (1994) and Wright and Hill (1993). The most harvested invertebrates are turban shells (*Turbo setosus* and *Turbo argyrostomus*), lobsters and variety of crabs.

Flora

The marine flora has been studied by Thaman *et al.* (1981) and South and Yen. The flora is impoverished with no seagrasses and only one mangrove species is known (Thaman *et al.*, 1981). The vascular plants, including littoral species, have been documented by Thaman *et al.* (1981). The benthic marine algae have been documented by South and Yen (1992). Forty species were found with *Valonia aegagropila* and *Padina tenuis* being the dominant algae in the intertidal area. *Jania adhaerens* was found to be the dominant algae on the reef flat. The diversity of Nauru's flora is small compared to other equatorial islands of the central Pacific. This is possibly attributed to reduce habitats and the great distance from the Indo-Pacific centre of marine biodiversity (Thaman pers comm.).

Endemic, rare or endangered species

The smallness of the coastal area means that resources are susceptible to over-exploitation, especially intertidal benthic organisms such as turban shells and octopi, which are easily gleaned during low tides. According to Dalzell *et al.* (1992), anecdotal information suggests that certain reef fish species are becoming scarce. Furthermore, the average size of fishes caught are decreasing. Jimwereiy (1999) observed that the finfish species that are becoming rare include mullets (Mugilidae), Topsail Drummer (*Kyphosus cinerascens*), Coral Cod (*Cephalopholis miniata*) and the Humpheaded Maori Wrasse (*Cheilinus undulatus*).

The spiny lobsters (Palinuridae) are rare, while giant clams (Tridacnidae) are most probably extirpated from Nauru. Today, giant clam shells are only seen outside peoples homes, although they were once commonly used in traditional customs (Petit-Skinner (1995). North *et al.* (1903) documented the existence of *Tridacna maxima* (as *Tridacna elongata*).

There are no known endemic species from Nauru, however, Alefaio (1999) mentioned that a new echinoderm species was discovered by an American scientist in 1998. It is important that surveys of neighbouring islands must be carried out to verify the endemism of this echinoderm from Nauru.

Threats to coral reef biodiversity

Anthropogenic factors

Threats to the coral reef biodiversity are largely of anthropogenic origin. These include overfishing, pollution and environmental degradation.

Fishing

Overfishing has been blamed for the decline in the number of demersal finfish species. As mentioned earlier, anecdotal information showed that some species are becoming scarce. The old generation remembered the days when fish was available in abundance. Currently, there is no regulation on fishing equipment. The fishing gears currently used are very efficient at catching fishes. Many seine and cast nets used on the intertidal zone and on the reef front have small mesh size which prevents smaller fishes to escape. The availability of self contained underwater breathing apparatus (SCUBA) equipment, enables spear fishers to probe deeper habitats for snappers (Lutjanidae), groupers (Serranidae) and squirrel fish (Holocentridae). A fishing apparatus developed by the Nauruans around the 1930s, which was described as a ‘Christmas tree’ by Dalzell and Debao (1993), and ‘Enape Fishing Apparatus’ by Whitley and Colefax (1938) is efficient to catch snappers at 50-150 m depths. The device is a T-shaped or cruciform wire frame attached to which are between 18-50 hooks. A reel with a length of mono-filament is used to lower and bring up the gear. It was estimated that at around three hours of fishing using this gear can land at least 60-70 kg of snappers.

Pollution

Pollution of the marine environment is mainly from sewage discharge. This is considered minimal and will be rectified in the near future when the waste is recycled to provide soil and agriculture manure as part of the rehabilitation plan of Nauru. Other pollutants include small oil spills in the boat harbour from barges. Pollution from ballast water is not known although, the introduction of dangerous and non-indigenous organisms without predators to control them could create a big problem for the marine ecosystem. Investigation into this area needs to be undertaken in the future.

Human pollution by way of disposing rubbish on the beaches is a very serious problem that needs to be addressed, holistically involving all stakeholders such as the government, NGOs and the people. It is common to find disposable diapers, plastics, corrugated iron, cans, shoes, pieces of clothing *inter alia*, on the intertidal reef flat and the reef slope.

Reef blasting

The lack of deep lagoons and natural passage hinder boat movements in Nauru. This has resulted in reef being blasted to create artificial boat passages and channels. There are currently three blasted reefs: the boat harbour and two small channels one located on the west, and the other on the eastern side of the island. The channels permit the launching and retrieval of 4-5 metre aluminium boats. The eastern channel has recently been upgraded into a second boat harbour. The upgrading project, which involves reef blasting, drilling, excavation, erecting concrete retaining walls, and reclamation have resulted in massive disturbances to the reef area. Some materials used have been scattered by wave actions. The project, which is expected to be completed by May 2000 is a major environmental concern since it is located in a pristine area. This site is perhaps the most suitable site for a marine protected area.

Sedimentation

Sedimentation is not a problem on Nauru due to the absence of rivers and creeks. The soil is highly porous therefore rainwater is drained directly into the ground water table.

Tourism

Nauru is not developed as a tourist destination. The impact of tourism related developments is considered minimal.

Mining

Nauru is best known for its phosphate mine which commenced operation in 1906. Primary mining is expected to last another year with secondary mining currently being discussed and trials undertaken in the past. The mining operation, which is an open-cast method, has resulted in the removal of trees and other plants leaving behind limestone pinnacles all over the plateau rendering the place unsuitable for human habitation.

Loss of traditional environmental knowledge

Loss of traditional environmental knowledge (TEK) is a major problem with regard to traditional resource management in Nauru. Connel (1983) stated that Nauruans have occupied their land for a period of around 3500 years. Weeramantry (1992) added that Nauruans once had a customary law governing the use of the land and the marine tenure. Thaman (1992) stressed that TEK is very important in the sustainable management of natural resources on islands. The loss of TEK occurred with the advent of the mining industry and it resulted in the loss of the traditional marine tenure system. As a result the coastal area became a free for all, resulting in over-harvesting.

Environmental factors

Information and reports on non-anthropogenic environmental causes on Nauru is not available. Nauru plays a major role in regional environmental issues and is an active member of the South Pacific

Regional Environment Programme (SPREP). The Department of Island Development and Industry takes a lead role on environmental matters on Nauru.

The United States National Oceanic and Atmospheric Administration (NOAA) has set up a weather monitoring station on Nauru. It is a ten year project that commenced in 1998 with its primary role to study the El Niño Southern Oscillation (ENSO) event. Nauru is chosen because the island is located on the eastern edge of the warm water pool, which is a region that is very significant in terms of generating weather patterns that affect the whole world.

Climate Change

There is no known report available on the impacts of climate change on Nauru, however, micro climatic changes seem to be taking place on the island. Nauru has not experienced any significant rainfall over the past two years. Past ENSO events greatly affected the climate on the island. For instance, during an ENSO event, very heavy rainfalls were experienced (>3000 mm per annum) while droughts occur during La Niña periods. According to data received from the Nauru Phosphate Corporation laboratory, rainfall for 1999 was only 359 mm. This is the second lowest rainfall since 1915, when data were first recorded.

The La Niña period from 1998 to 2000 aggravated the current drought conditions on the island. Exposed pinnacle rocks were heated up and heat radiation or the up-draft of hot air have been observed to disperse clouds over the island. As a result, as much as 40% of the ubiquitous coconut tree may have died with many other plants either dead or dying. The conditions of the flora on the island are in a very poor and dying state.

Sea level rise

No information on sea level rise is available. About 20 per cent of Nauru is low lying, therefore sea level rise will inundate these areas. Relocation to higher ground will be necessary, however, there is a need to rehabilitate the mined fields if it is to be used for human occupation. The sea level rise will also affect the salinity levels in brackish water wells, as well as the coastal plants distribution.

Coral bleaching

There are no information available on coral bleaching occurrences in Nauru. It is not known whether the 1997-98 bleaching occurrence affected Nauru. The survey that was carried in March 2000 by the author, showed no evidence of coral bleaching.

Conservation and monitoring programmes

Conservation and marine protected areas

No conservation or marine protected area (MPA) has been established. The most environmentally appealing area is the Anibare Bay area located on the eastern part of the island. Thaman and Hassall (1996) called for the establishment of a conservation area at Anibare, which is also supported by the locals.

Monitoring programmes

The monitoring programmes currently in place, are undertaken by the Nauru Fisheries and Marine Resources Authority. These cover finfish creel census, ciguatera outbreaks, and occasionally seawater salinity levels. Future plans call for the monitoring of the reef through the establishment of quadrats and other monitoring methods useful to compare changes over time.

Legislation

Nauru's fisheries legislation underwent reviews within the last few years and relevant provisions of regional and international laws and conventions were incorporated. The *Nauru Fisheries and Marine Resources Authority Act 1997*, calls for the Authority to manage and sustainably utilise the fisheries and marine resources of Nauru. The *Nauru Fisheries Act 1997* calls for the management, development, protection and conservation of the fisheries and marine resources of Nauru. The two legislation did mention the requirements for management and conservation of the marine resources but are not adequate to address conservation programmes in more detail. It has been proposed that a marine conservation bill be tabled in parliament. A draft bill has been documented but widespread consultation with stakeholders needs to be undertaken first before it becomes law.

Conclusion

The coral reefs and marine resources of Nauru are poorly documented and understood. The marine fauna and flora appear to be impoverished in terms of species diversity, due to the smallness of the island and its remoteness from the Indo-Pacific centre of marine biodiversity. Nauru is an island that has experienced great disturbances to its terrestrial and marine environments with mining being the greatest environmental impact on the marine biota. Other human induced changes also play role in the disturbance of the environment, with rubbish disposal on beaches being a serious environmental concern. This poses significant impacts to marine organisms. Non-anthropogenic induced changes, such as coral bleaching, have a major impact on the integrity of the marine ecosystem. Although these are beyond the capability of Nauruans to control, there are other changes that can be managed, such as the utilisation of certain fishing gear. The declaration of conservation areas or marine protected areas do have their merits and this may be the next approach in the management of the marine resources of Nauru. This will ensure that the integrity of the marine ecosystem is maintained, which will allow for Nauru's future generations to have access to a pristine marine environment.

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New Caledonia country report

Pascale Joannot
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The state of New Caledonia's coral reefs was surveyed in 1998 by the Ministère de l'aménagement du territoire et de l'environnement (ministry of physical planning and the environment) and the Secrétariat d'Etat à l'outre-mer (secretariat of state for overseas territories). The following paper produced by the local committee of the "French Coral Reef Initiative" is an updated version of the report from that survey.

An introduction to New Caledonia

New Caledonia has a land area of 18 585 km^2 (1500 km. from east to west and 1000 km. from north to south; the EEZ has been estimated to cover 1 450 000 km^2) with an unevenly distributed population of approximately 210 000, a majority of whom live in Nouméa or the 'greater Nouméa' area. The population density is 60 people per km^2 in Nouméa, while for the rest of New Caledonia it is 4.4 per km^2.

The total lagoon area of New Caledonia and Dependencies is 40 000 km^2.

With a barrier reef totalling 1600 km in length, New Caledonia therefore has the second longest barrier reef after Australia.

Various different types of reef occur there: barrier reefs divided up by passages, fringing reefs, islet reefs, atolls and coral banks.

Mangrove zones occupy a total area of 200 km^2, while the extent of seagrass bed areas is not yet known with accuracy.

The economy

New Caledonia possesses more than 20% of the world's nickel deposits, which naturally gives this mineral special importance.

Nickel therefore has a direct influence on land use on the island, population trends and more generally relations between communities, which gives it a highly political dimension over and above economic considerations.

Mining and ore-processing activities account for most exports (over 90%).

The tertiary sector (commerce and services) is preponderant (over 50% of GDP), especially non-market services, including public administration.

On account of the geomorphology of New Caledonia, the available arable land represents only 10% of the total land area.

State of the coral reefs

The state of health of the country's coral reefs, mangroves and seagrass beds has not been quantified and is not accurately known. Outside the reef zones receiving outflow from catchments in mining areas, and apart from some reefs in the Nouméa area, most of the coral reefs are thought to be in good condition.

Figure 1
Barrier reef (P. A. Pantz).

A survey of the available knowledge on marine biodiversity in New Caledonia points to the existence of 15 000 species (IRD), but many areas remain unexplored, suggesting that the real level of biodiversity is considerably higher. The mean endemicity rate is in the 5% range. Of endangered species, special mention should be made of the coconut crab, whose habitat is being destroyed.

The pressures

Natural pressures

Cyclones

In addition to the direct impact of destruction due to the force of cyclone-induced swells, cyclones also contribute to high levels of sedimentation in lagoon areas at river mouths.

Coral bleaching

Following a positive seawater temperature anomaly in 1995, a major bleaching event affected corals and certain Alcyonaria from January to March 1996. This was the first time that such an event had been observed in New Caledonia.

Crown-of-thorns starfish

In 1980, some reefs were affected by the crown-of-thorns starfish (*Acanthaster planci*), but with apparently limited effects. A new development was observed in 1998, at a location in the Ilot Maître reserve. It intensified in 2000 and we will be monitoring the situation.

Human pressures

Mining and terrigenous sedimentation

Problems of erosion and natural sedimentation are heavily accentuated by bush fires, but especially by mining activities. Natural erosion causes problems, especially when the mangrove, which retains sediment, disappears and no longer plays its protective role. When very heavy rain creates flood situations in rivers, these problems represent the worst source of deterioration for the coastal zone, the fringing reefs and the lagoon.

The history of mining in New Caledonia shows that more than 500 mining sites have so far been operated, the majority before 1976 (over 160 million tonnes of ore extracted). This date is important as regards the obligation to rehabilitate these sites; it has been acknowledged in New Caledonia that operators who ceased activities before 1976 were released from their obligation to rehabilitate such sites. On the other hand, the sites recognised as operating after that date must ultimately be rehabilitated.

Although mining operators took no heed of the impact on the environment from the outset and until 1976, today, despite the absence of regulations, it can be noted that there is, generally speaking, no longer any uncontrolled activity in the mining sector.

Coastal zone management, landfill/reclamation and dredging

The development of the coastal strip in the Nouméa urban area and the construction of certain coastal roads over the sea on reclaimed land and causeways have led to the destruction of very large areas of mangrove and fringing reef in many parts of the urban area. The mangrove has been extensively degraded in the Nouméa area, where 30% of the mangrove has disappeared since 1960.

Industrial and domestic pollution

Economic growth and increased domestic consumption by households in New Caledonia are generating more household refuse. In New Caledonia, this is estimated at some 400 kg per inhabitant per year in the urban area and some 200 kg per person per year in rural settings. These figures seem overall to be lower than those observed on the French mainland (over 500 kg per person per year for household-type waste and bulky rubbish).

Unfortunately, even if 100% of the urban population enjoys a household waste collection service, there are still uncontrolled tips and dumps to be eliminated. Sanitation is in an embryonic state in New Caledonia, except in Nouméa, where the municipal council has been funding a sanitation master plan for some ten years now (mains sewage and not individual sanitation systems).

Industrial pollution is only significant in the Nouméa urban area with the Doniambo nickel ore smelter and the Ducos industrial area.

Resource exploitation

The artisanal fisheries sector includes relatively few professionals (350 boats) recreational fishers and subsistence fishing, which is the major activity. Total lagoon production is some 4500 t, more than 70% of which comes from subsistence and recreational fishing. Fish are top of the list of lagoon products (50%), with sea cucumber (bêche-de-mer) and trochus shells, both for export.

The exploitation of lagoon resources raises no major difficulties. The main fishing pressure occurs in the southern portion of the lagoon, where artisanal fisheries, mostly for subsistence purposes, are active and where their impact is amplified by leisure fishing and spear-fishing (114 t per year). Pressure is also being put on Northern Province populations around Koné and Népoui. With yield levels falling sharply in recent years, bêche-de-mer stocks (some 111 t per year dry weight) and trochas (250 t exported in 1996) are said to be overexploited.

Collection of marine organisms

This activity exists but has not been quantified.

Exploitation of coral

After a stock survey, professional exploitation of madrepores for ornamental or medicinal purposes has been developed to a limited degree. Current regulations only allow such harvesting on Tetembia Reef. Further consultation is in progress between the departments concerned for the purpose of coming up with new and stricter regulations. Coral production for medical purposes does not exceed 2 t.

Tourism and leisure activities

The tourism industry is still depressed and the impact of tourism on the environment is not yet very marked. However, disturbances are to be feared due to fish-feeding, which upsets the trophic chains, and destruction of the most popular reef flats by trampling.

Recreational boating and sea fishing are major activities, with around 12 000 boats, over 60% of which are based in or near Nouméa. Despite the regulations and low individual catches on average (10 to 13 kg. per boat and per trip), pleasure boating applies substantial pressure to fish stocks.

The major increase in the pleasure boat fleet in recent years, and the increase in these boats’ range, may have caused some degradation by anchor dropping around the most popular lagoon moorings, and some pollution by waste water release at those same moorings.

Sea traffic in the lagoon and pollution risks

Nickel ore is carried by sea in the lagoon. 25.000 tonne ore-carriers serve the various mining centres in New Caledonia and the Doniambo smelter in Nouméa; the total unloading rate in Nouméa may reach approx. 1.88 t per hour.

These operations, loading in particular, are pollution risks for the lagoon. The risks also concern accidental spills of hydrocarbons and chemicals transported by sea in the lagoon. A small oil spill occurred in 1996 in the south-west lagoon, destroying several hundred meters of mangrove.

Aquaculture and water eutrophication

In 1999, prawn production rose to 1800 t per year from 450 ha of aquaculture facilities. The waste water from the prawn farms is pumped out into the lagoon, providing an input of nutrients, causing hyper-sedimentation and some water eutrophication. At present, the problem is limited to very localised silting in the outflow zones. An impact study is in progress (IRD-IFREMER).

Regulations

New Caledonia is a French overseas community. Its institutional organisation results from the Nouméa Accord (5 May 1998), promulgated in law by the Organic Law No 99-209 relating to New Caledonia.

French Government

In environmental matters in New Caledonia, the French State is responsible for:

monitoring and application of international agreements, such as the Washington Convention;

Introduction and if necessary implementation of the POLMAR plan.

New Caledonia

New Caledonia has jurisdiction over animal and plant quarantine (Article 22, para. 10 of the Organic Law).

The Provinces

Since the signing of the Matignon Accords, environment responsibility has been devolved to the three (Figure 2) provinces that cover:

- general regulation of activities such as hunting and fishing;
- regulation of protected areas (Resolution No 108 dated 9 May 1980).

Under the Organic Law, the provinces are responsible for the maritime zone and manage exploration, exploitation, management and conservation rights over the natural living and non-living resources of the inland waters. The provinces take the necessary measures, after obtaining the opinion of the Customary Senate.

There is no legal framework or general law (obligatory impact study, environmental code) to guide environmental action. Most current sectoral regulations are out of date or unsuited to today's context. Regulations are inadequately enforced chiefly because of the lack of policing resources.

Article 213 of the Organic Law provides for the establishment of a consultative council on the environment, which should be set up as a body for making proposals and consultation.

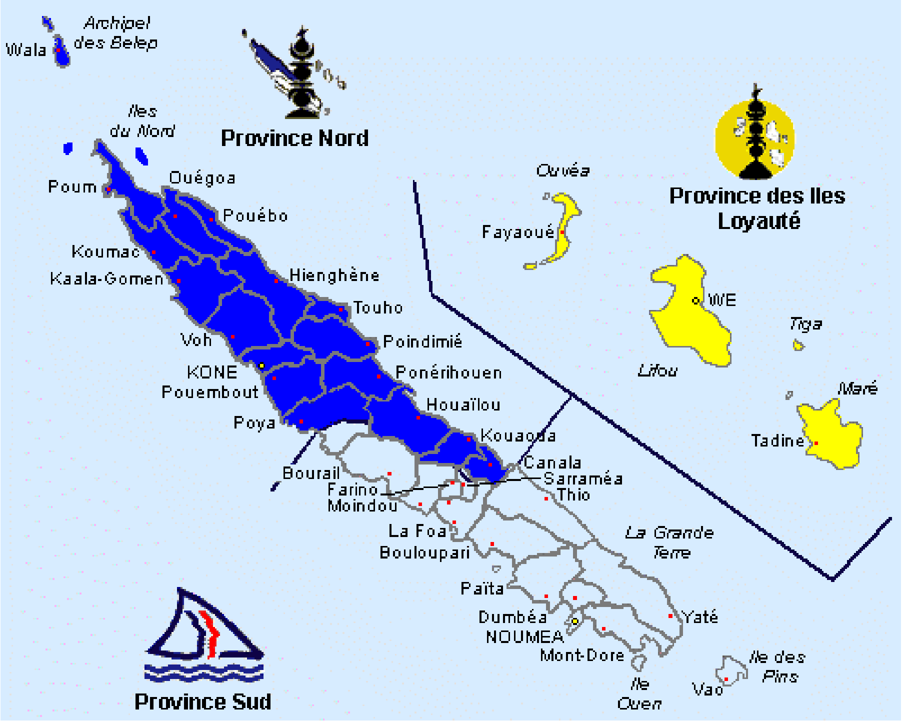

Figure 2
Presentation of the 3 Provinces.

The response of the actors

Until the provinces were set up, the response of the actors was limited to species regulation and protected areas. Since then, the provinces have selected the environment as one of the objectives of the development contracts, which has made it possible to deploy the first management tools.

Conservation

New scientific studies are being requested by the various administrations of existing scientific bodies (ZoNéCo, IRD, IFREMER, IAC, CNRS, UNC, etc.), to draft or update regulations and/or create new protected areas.

Some conservation activities are carried out with the support of the custom chiefs (coconut crab).

Management

Of the various international agreements, only Washington is applied in New Caledonia. The marine fauna of New Caledonia includes some rare and endangered species listed in Annex 1 of CITES, such as whales, dugong, turtles and others in Annex 2, such as Tridacna (giant clams) and corals.

The total area of marine reserves in New Caledonia (37 000 ha) represents 2.8% of the lagoon area.

The southern lagoon park has been the recipient of development work, accompanied by the human and material resources required for management purposes. The Southern Province's protected areas are managed by the Service de l'environnement. These areas are demarcated and some one hundred moorings making it possible to moor boats without damaging the coral have been put in. Island cleaning has been sub-contracted to a local company that also installs facilities and provides waste wood for barbecue areas. Reserve surveillance is carried out by 2 boats, but also by police officers (marine gendarmerie). The Nouméa courts have jurisdiction over offences and penalties (fines) can involve confiscation of equipment, including boats.

Other communes are gradually acquiring boats for surveillance purposes (Moindou, Bourail, Poya).

The Northern Province and the Islands Province are both planning their development and the acquisition of basic equipment; they are pursuing the development of lagoon resource exploitation, for which research has been requested in order to define the sustainable exploitation levels.

The Northern Province is addressing terrestrial pollution and degradation problems and the protection of marine areas.

A mining site rehabilitation policy was put in place in 1999; almost 130 million CFP has been allocated for the restoration of old mining sites.

Under SYSMIN (European funding) it is planned to survey degraded areas all over New Caledonia; this survey will be supplemented by a review of the situation today and a description of the work needed. Priorities may be established as a result of this major task, together with a costing for the work needed. The decision-makers will then have to decide whether or not to fund these projects.

Education

Conservation activities by schools and associations have been supported by the administrations, who also contributed to the establishment and operations of the Centre d'Initiation à l'Environnement (centre for initiation into the environment).

The production of educational materials (pamphlets, booklets, posters) and awareness campaign materials (fire, cleanliness, lagoon conservation) have been intensified.

In 1997, the Southern Province contracted a local consulting firm to review the state of the coral reefs near Nouméa. This initiative led to the creation of the Observatoire des récifs coralliens (ORC, coral reef observatory), operated by volunteer experienced divers, to carry out repeated surveys on predefined areas all around New Caledonia. The information is communicated to the Global Coral Reef Monitoring Network (GCRMN, Reef Check).

While the associations play a very active role in community awareness and education (Centre d'initiation à l'environnement, Association de sauvegarde de la nature, Action biosphère, Association symbiose) the media also have a vital role to play and usually cover all such activities.

An underwater path and an educational mangrove walk are being put in near Nouméa.

In October 1999, under the chairmanship of the French High Commissioner, a local committee of the French Coral Reef Initiative (IFRECOR) was set up, comprising many partners from four constituencies: political and administrative representatives, scientists, groups and socio-professionals; the secretariat is provided by the French Government Agriculture, Forestry, Fisheries and Environment Service.

This is a venue for meeting, discussing proposing and co-ordinating work for the protection and sustainable management of coral reefs.

This committee has drafted a local action plan listing the action required to protect the coral reefs which should be taken into account in New Caledonia's development plans as foreshadowed in the Organic Law, the purpose of which is to plan future work under the 'development contracts' between the French Government and the administrations of New Caledonia.

Conclusion

The management of coral reefs in New Caledonia is an issue related to the island condition that can be characterised as follows: a catchment issue. Any land-based activity has an impact lower down on the lagoons (erosion, sedimentation, sanitation, and pollution). The costs of anti-pollution work, such as treatment, recycling and rehabilitation are higher than elsewhere because of the small population (about 210 000) and the distance from established market systems (e.g. waste treatment and recycling).

Environmental problems linked to high population densities for the moment occur only in Nouméa and the surrounding area (greater Nouméa: some 60 people per km^2. and, for the rest of New Caledonia, 4 people per km^2). The southern lagoons around Nouméa are thus important protective barriers against damage and pollution coming from the residents and activities of this urban area. The impact of mining elsewhere in New Caledonia is sparse in some specific locations, but not negligible.

Overall, however, although the coral reefs of New Caledonia are in good condition, vigilance is necessary on account of the constant growth. The administrations are becoming increasingly aware of this and the introduction of IFRECOR, SAD and soon the 'advisory committee on the environment' are evidence of this.

Figure 3
Fringing reef isle of Pines (New Caledonia).

Rapport de la Nouvelle-Calédonie

Pascale Joannot
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L'état des récifs de Nouvelle-Calédonie, a été réalisé en 1998 par le ministère de l'aménagement du territoire et de l'environnement et par le secrétariat d'État à l'Outre-mer. La présentation qui en est faite ici dans le cadre du comité local de l'Initiative Française des Récifs Coralliens est une réactualisation.

Présentation de la Nouvelle-Calédonie

La Nouvelle-Calédonie a une superficie de 18 585 km² (1500 km d'est en ouest et 1000 km du nord au sud. La ZEE a été évaluée à 1 450 000 km²) avec une population d'environ 210 000 habitants inégalement répartie et dont la majorité vit à Nouméa ou grand Nouméa. La densité de population est de 60 h/km² à Nouméa alors que dans le reste de la Nouvelle-Calédonie elle est de 4,4 ha/km².

L'ensemble des lagons de Nouvelle-Calédonie et dépendances couvre une superficie totale d'environ 40 000 km².

Avec une barrière récifale de 1600 km, la Nouvelle-Calédonie est dons le second ensemble récifal de la planète après l'Australie.

On y trouve différents types de récifs : barrières entrecoupés de passes, récifs frangeants, récifs d'îlots, atolls et bancs coralliens.

Les mangroves occupent 200 km² et les superficies d'herbiers sont encore mal connues.

Économie

La Nouvelle-Calédonie possède plus de 20 % des réserves mondiales de nickel, ce qui assure naturellement à ce minerai une importance particulière.

Ainsi le nickel influence directement l'aménagement de l'île, la démographie et plus généralement les relations entre les Hommes, ce qui lui confère au delà des questions économiques, une dimension hautement politique.

Les activités minières et métallurgiques constituent l'essentiel des exportations (plus de 90 % des exportations).

Le secteur tertiaire (commerces et services) est prépondérant (plus de 50 % du PIB), notamment les services non marchands, dont ceux de l'administration publique.

Compte – tenu de la géomorphologie de la Nouvelle-Calédonie, la surface cultivable est de 10 %.

État des récifs coralliens

L'état de santé des récifs coralliens, des mangroves et des herbiers n'est pas quantifié et mal connu. En dehors des zones récifales en aval des bassins-versants miniers, et de certains récifs aux abords de la ville de Nouméa, la grande majorité des récifs serait en bonne condition.

Figure 1
Le récif barrière (P. A. Pantz).

Le bilan des connaissances sur la biodiversité marine en Nouvelle-Calédonie fait état d'environ 15 000 espèces (IRD), mais de nombreux secteurs demeurent encore inexplorés, ce qui laisse à penser que la biodiversité est bien plus élevée encore. L'endémisme moyen est de l'ordre de 5 %. Parmi les espèces menacées, citons le crabe de cocotiers menacé en raison de la destruction de son habitat.

Les pressions

Les pressions naturelles

Les cyclones

Outre l'impact direct de destruction du à la force des houles cycloniques, les cyclones favorisent une forte sédimentation en zone lagonaire au débouché des rivières.

Le blanchissement des coraux

Suite à une anomalie positive de température de l'eau de mer en 1995, un important phénomène de blanchissement a affecté les coraux ainsi que certains alcyonaires, de janvier à mars 1996. C'est la première fois qu'un tel phénomène a été observé en Nouvelle-Calédonie.

Acanthaster

En 1980, certains récifs ont été affectés par *Acanthaster planci*, mais il semblerait que les effets aient été limités. Des dégradations ponctuelles sont observées mais aucune évaluation scientifique n'en est faite. Un nouveau développement a été observé en 1998, depuis un foyer situé dans la réserve de l'îlot Maître. Il s'est intensifié en 2000 et un suivi du phénomène est prévu.

Les pressions anthropiques

Mine et sédimentation terrigène

Les problèmes d'érosion et de sédimentation naturels sont fortement accentués par les feux de brousse et surtout par l'exploitation minière. L'érosion naturelle pose des problèmes, notamment lorsque la mangrove, qui maintient les sédiments, disparaît et ne joue plus son rôle protecteur. Ces problèmes représentent, en période de crues cycloniques, la plus importante source de dégradation pour le littoral, les récifs frangeants et le lagon.

L'histoire de la mine en Nouvelle-Calédonie montre que plus de 500 sites miniers ont été jusqu'alors exploités dont la majorité d'entre elles avant 1976, (plus de 160 millions de tonnes de minerai ont été extraits). Cette date est importante en ce qui concerne les obligations de remise en état des sites miniers ; il a été admis, en effet, au niveau de la Nouvelle-Calédonie, que l'arrêt d'exploitations minières avant 1976 libérait leurs exploitants d'obligations de remise en état de ces sites. A contrario, les exploitations déclarées ou en activité après cette date doivent obligatoirement faire à terme l'objet de remise en état.

Si l'exploitation minière depuis l'origine jusqu'en 1976 ne prenait pas en compte l'impact sur l'environnement il est à noter, que malgré l'absence de textes réglementaires, dans la pratique on n'observe plus, et ce de manière assez générale, de comportements totalement anarchiques dans la conduite des exploitations minières.

Aménagement du littoral, remblais et dragages

L'aménagement de la bande littorale dans la zone urbaine de Nouméa et la construction de certaines routes littorales sur la mer, par endiguement et remblaiement, ont conduit à la destruction de portions très importantes de mangroves et de récifs frangeants dans toute la zone urbaine. La mangrove est fortement dégradée dans la région de Nouméa où 30 % de la mangrove a été détruite depuis 1960.

La pollution industrielle et domestique

La croissance économique et l'augmentation de la consommation des ménages néo-calédoniens génèrent une augmentation de la production de déchets. En Nouvelle-Calédonie, elle est estimée à environ 400 kg/an/habitant en habitat urbain, et de l'ordre de 200 kg/an/habitant en habitat « rural-tribal ». Ces chiffres apparaissent globalement plus faibles que ceux observés en métropole (plus de 500 kg/an/habitant pour les déchets ménagers et assimilés et les encombrants).

Malheureusement si environ 100 % de la population de l'habitat urbain bénéficie d'une collecte d'ordure ménagère, il reste encore des dépotoirs sauvages que l'on tente de résorber.

L'assainissement est embryonnaire sur l'ensemble de la Nouvelle-Calédonie sauf à Nouméa ou la municipalité finance depuis plus de 10 ans un schéma directeur d'assainissement de la ville (collectif et non séparatif).

La pollution industrielle est à ce jour significative seulement dans l'agglomération de Nouméa avec l'usine métallurgique de Doniambo et le quartier industriel de Ducos.

Exploitation des ressources

La pêche artisanale regroupe les professionnels, peu nombreux (350 embarcations), les plaisanciers et la pêche vivrière, qui est la plus importante. La production lagonaire totale est de l'ordre de 4,500 t, dont plus de 70 % pour la pêche vivrière et plaisancière. Les poissons dominent la production lagonaire (environ 50 %), avec les holothuries « bêches de mer » et les coquilles de trocas toutes deux destinées à l'exportation.

L'exploitation des ressources du lagon ne cause pas de problèmes majeurs. La principale pression de pêche se situe dans la partie sud du lagon, où les pêcheries artisanales, essentiellement vivrières, sont actives et où leur impact est amplifié par la pêche de loisir ou la chasse sous-marine (114 t/an). Des pressions ont également été enregistrées sur les peuplements en Province nord, autour de Kone et de Nepoui.

Avec des chutes de rendement sensibles ces dernières années, les stocks de bêche de mer (environ 100 t/an, poids sec) et du troca (250 t exportées en 1996), en revanche, sont dits surexploités.

La collecte de loisir d'organismes marins

Cette collecte existe mais n'est pas quantifiée.

L'exploitation des coraux

A l'issue d'une étude de stocks, l'exploitation professionnelle des madréporaires à des fins d'ornementation ou à des fins médicales connaît un développement limité. La réglementation en vigueur n'autorise la pêche du corail que sur le récif de Tetembia. Une concertation actuelle des services compétents vise à proposer une nouvelle réglementation plus restrictive. La production de corail à des fins médicales n'atteint pas 2 t.

Le tourisme et les activités de loisir

L'industrie de tourisme est encore faible et l'impact touristique sur le milieu n'est pas encore notable. Cependant il est à craindre des perturbations dues au nourrissage de poissons, qui bouleverse les réseaux trophiques, et à une destruction des platiers les plus fréquentés par piétinements.

Les activités de plaisance et la pêche de loisir en mer sont importantes, avec environ 12 000 embarcations, dont plus de 60 % dans le Grand Nouméa. Malgré la réglementation et un prélèvement individuel faible en moyenne (10 à 13 kg par bateau et par sortie), la plaisance applique une charge conséquente sur les stocks halieutiques.

L'augmentation importante de la flottille plaisancière ces dernières années, ainsi que celle du rayon d'action de ces unités, a pu entraîner une certaine dégradation par ancrage autour des sites du lagon sud les plus fréquentés, ainsi qu'une certaine pollution par rejets d'eaux usées dans les secteurs de mouillage.

Trafic maritime dans le lagon et risques de pollution

Le minerai de nickel est transporté par voie maritime dans le lagon. Les minéraliers de 25 000 tonnes effectuent des rotations entre les différents centres miniers du Nouvelle-Calédonie et l'usine métallurgique de Doniambo à Nouméa ; le débit total de déchargement à Nouméa peut atteindre 1800 t/heure environ.

Ces opérations notamment le chargement constituent des risques de pollution pour le lagon.

Les risques concernent également les déversements accidentels d'hydrocarbures et de produits chimiques transportés par voie maritime dans le lagon. Un petit accident pétrolier a eut lieu en 1996 dans le lagon sud-ouest, détruisant quelques centaines de mètres de mangroves.

Aquaculture et eutrophisation des eaux

En 1999, la production de crevettes a atteint 1800 tonnes pour une superficie de bassins aquacoles de 450 ha. Les eaux usées des fermes aquacoles sont rejetées au lagon provoquant un apport d'éléments nutritifs, entraînant une hypersédimentation et une certaine eutrophisation des eaux. Actuellement le problème est limité à un envasement très localisé des zones de rejets. L'étude de l'impact des rejets est en cours (IRD-IFREMER).

Les réglementations

La Nouvelle-Calédonie est une collectivité d'outre-mer. L'organisation institutionnelle de la Nouvelle-Calédonie résulte aujourd'hui des accords de Nouméa (5 mai 1998), concrétisés par la loi organique n° 99-209 du 19 mars 1999 relative à la Nouvelle-Calédonie.

L'État

En matière d'environnement en Nouvelle-Calédonie, l'État assure :

- le suivi et l'application des conventions internationales : Washington par exemple ;
- la mise en place et le suivi du plan POLMAR en cas de besoin.

La Nouvelle-Calédonie

La Nouvelle-Calédonie est compétente en matière de réglementation zoo et phytosanitaire (article 22, 10° alinéa de la loi organique).

Les Provinces

Depuis les accords de Matignon, la compétence environnement est dévolue aux trois provinces (Figure 2) qui assurent :

- la réglementation générale des espèces notamment celle de la chasse et de la pêche ;
- la réglementation des aires protégées (délibération 108 du 9 mai 1980).

La loi organique confie maintenant aux provinces la responsabilité du domaine maritime et délègue l'exercice des droits d'exploration, d'exploitation de gestion et de conservation des ressources naturelles biologiques et non biologiques des eaux intérieures. Les provinces prennent les dispositions nécessaires, après avis du conseil coutumier.

Il n'existe pas de cadre juridique global ni de loi cadre (étude d'impact obligatoire, code de l'environnement) permettant d'orienter les actions à entreprendre en matière d'environnement. Les réglementations en vigueur sectorielles pour la plupart s'avèrent désuètes ou inadaptées au contexte contemporain. L'application de cette réglementation est insuffisante et notamment en raison de la faiblesse des moyens de contrôle.

L'article 213 de la loi organique prévoit la création d'un conseil consultatif de l'environnement qui devra être mis en place comme instance de proposition et de concertation.

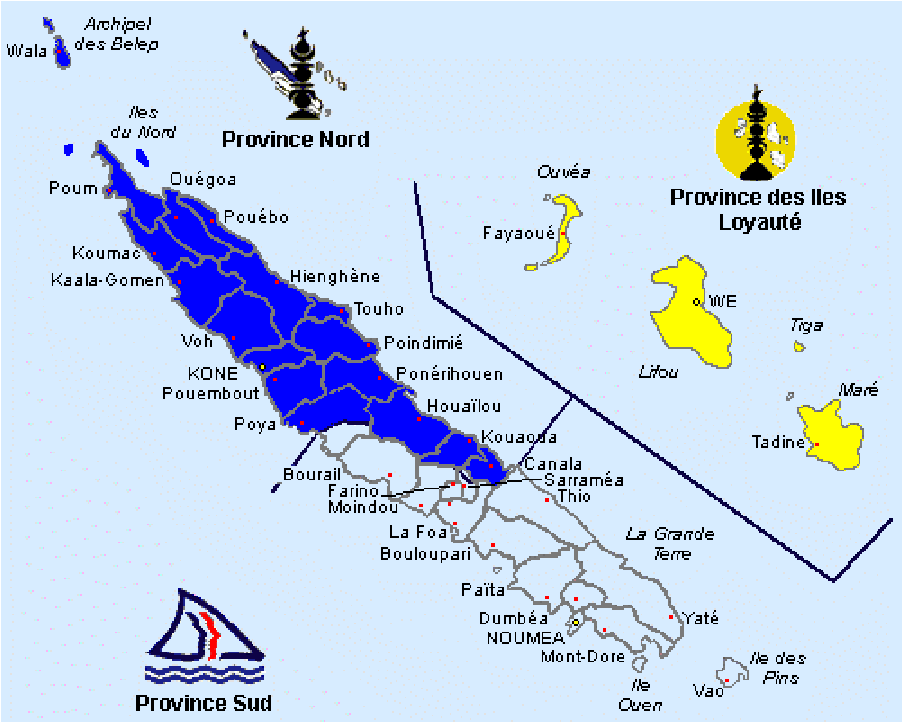

Figure 2
Présentation des 3 Provinces.

La réponse des acteurs

Jusqu'à la provincialisation, la réponse des acteurs a été limitée à la réglementation des espèces et des périmètres protégés. Depuis, les provinces affichent l'environnement comme un des objectifs des contrats de développement, ce qui a permis de mettre en œuvre les premiers outils de gestion.

Conservation

De nouvelles études scientifiques sont demandées par les collectivités aux organismes scientifiques existants (ZoNéCo, IRD, IFREMER, I.A.C, CNRS, UNC…) pour créer ou ajuster les réglementations et/ou de créer de nouvelles aires protégées.
Certaines actions de conservation ont été réalisées avec le concours des autorités coutumières (crabes de cocotiers).

Gestion

Parmi les conventions internationales seules celle de Washington est appliquée en Nouvelle-Calédonie. La faune marine de Nouvelle-Calédonie comporte en effet plusieurs espèces rares ou menacées inscrites à l'annexe I de la CITES comme les baleines, le dugong, et les tortues, d'autres sont en annexe II comme les Tridacna (bénitiers) et les coraux.

La superficie des aires protégées marines de Nouvelle-Calédonie (37 000 ha) représente 2,8 % de la surface des lagons.

Le parc du lagon sud a bénéficié d'aménagements accompagnés de moyens humains et matériels nécessaires à la gestion. Les aires protégées de la province Sud sont gérées par le Service de l'Environnement. Ces aires sont balisées et une centaine de corps-morts permettant de mouiller sans dégrader les coraux ont été posés. Le nettoyage des îlots est sous-traité à une entreprise locale qui assure également la réalisation d'infrastructures légères et l'approvisionnement en bois de récupération des coins feu. La surveillance des réserves est assurée par 2 bateaux, mais également par les agents de police (gendarmerie maritime). Les procédures sont instruites par le parquet de Nouméa et les pénalités (contraventions) peuvent aller jusqu'à la saisie des équipements, notamment des bateaux.

D'autres communes se dotent petit à petit de moyens nautiques de surveillance (Moindou, Bourail, Poya).

La Province nord et la Province des îles sont toutes deux tournées vers le développement et la mise en place de leurs équipements de base ; elles s'orientent vers un développement de l'exploitation des ressources du lagon, pour lesquelles des études ont été demandées afin de définir les possibilités d'exploitation soutenable.

La Province nord s'oriente vers une prise en compte des problèmes de pollution et dégradation en amont, au niveau terrestre, ainsi que vers la mise en protection d'aires marines.

Une politique de revégétalisation des sites miniers a été mise en place, en 1999, près de 130 MFCFP ont été engagés pour réhabiliter d'anciennes mines.

Il est également prévu, dans le cadre de SYSMIN (fonds européen), la réalisation d'un travail d'inventaire des zones dégradées portant sur l'ensemble de la Nouvelle-calédonie ; cet inventaire sera complété pour chacune d'entre elles, d'un état des lieux et de la définition des travaux de remise en état à réaliser. Cet important travail pourra déboucher sur une hiérarchisation des sites à traiter, accompagnée d'une estimation du coût des travaux projetés. Il appartiendra ensuite aux instances décisionnelles de mettre éventuellement en œuvre les crédits nécessaires à ces réalisations.

Éducation

Des actions concernant l'environnement, menées par les écoles et les associations ont été soutenues par les collectivités qui ont aussi participé à la création et à l'aide du Centre d'Initiation à l'Environnement.

La production de supports pédagogiques (plaquettes, livrets, affiches) et celle de campagnes de sensibilisation (feux, propreté, protection des lagons) se sont intensifiées.

Dès 1997, la province Sud a confié à un bureau d'études local l'évaluation de l'état des récifs proches de Nouméa. Cette initiative a débouché sur la création d'un Observatoire des récifs coralliens (ORC) animé par des bénévoles plongeurs confirmés, pour mener à bien des levés répétitifs sur des zones prédéfinies sur l'ensemble de la Nouvelle-Calédonie. Les informations sont transmises au réseau mondial de surveillance des récifs coralliens (GCRMN, Reef Check).

Si les associations jouent un rôle très actif dans le domaine de la sensibilisation et de l'éducation des populations (le centre d'initiation à l'environnement, association de sauvegarde pour la nature, action biosphère, association symbiose) les médias ont aussi un rôle essentiel et couvrent généralement toutes ces activités.

Un sentier sous-marin, un chemin pédagogique dans la mangrove sont en voie de réalisation à proximité de Nouméa.

Depuis octobre 1999 il a aussi été mis en place sous la présidence du Haut-Commissaire un comité local de l'Initiative Française des Récifs Coralliens (IFRECOR) regroupant de nombreux partenaires appartenant à quatre collèges différents : représentants politiques et administratifs, scientifiques, associatifs et sociaux professionnels, le secrétariat est assuré par le Service d'État de la Direction de l'Agriculture, de la Forêt et de l'Environnement.

Il s'agit d'une instance de rencontre, de concertation, de proposition et de coordination pour la protection et la gestion durable des récifs coralliens.

Ce comité a établit un plan d'action local listant les actions à entreprendre en faveur des récifs coralliens qui devrait être pris en compte dans le schéma d'aménagement et de développement de la Nouvelle-Calédonie que prévoit la loi organique et qui a pour but de planifier les futures actions à proposer aux contrats de développement entre l'État et les collectivités de la Nouvelle-Calédonie.

Conclusion

La gestion des récifs coralliens en Nouvelle-Calédonie est une problématique liée à l'insularité qui se caractérise par : une problématique de bassin versant. Toute action sur le milieu terrestre induit en effet un impact en aval sur les lagons (érosion, sédimentation assainissement, pollutions…). Les coûts de dépollution, traitement, recyclage, restauration sont plus importants qu'ailleurs du fait de la faible population (environ 210 000 h) et de l'isolement des circuits établis du marché (ex : traitement et recyclage des déchets…).

Figure 3
Récif côtier à l'île des Pins (Nouvelle-Calédonie).

Les problèmes d'environnement liés aux fortes densités de population sont pour l'instant concentrés sur l'agglomération du grand Nouméa (grand Nouméa : environ 60 hbt/km^2 et reste de la Nouvelle-Calédonie 4,4 hbt/km^2). Les lagons sud autour du grand Nouméa constituent dès lors un enjeu de protection important vis-à-vis de toutes les dégradations et nuisances provenant des populations et activités de cette agglomération. Sur le reste de la Nouvelle-Calédonie l'impact de l'exploitation minière est ponctuel mais non négligeable.

Mais dans l'ensemble, si l'état des récifs coralliens de Nouvelle-Calédonie est bon, la vigilance est nécessaire compte tenu de la croissance constante. Les collectivités en prennent conscience et la mise en place des outils IFRECOR, SAD et bientôt du conseil consultatif de l'environnement en est une manifestation.

The status of coral reefs and marine resources of Samoa

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Introduction

The Samoan Islands

Samoa (previously known as Western Samoa) consists of two large islands and several small ones (14) with a total land area of 2935 km^2, located between latitudes 13-17 degrees South and longitudes 171-173 degrees West (Figure 1). The exclusive economic zone (EEZ) is a mere 120 000 km^2 and the coastline is estimated at about 403 km (Pernetta 1990). The two larger islands are formed from the outpourings of volcanoes, the mouths of which are aligned approximately east-west along the high central spines (*tuasivi*) of the islands (Nunn 1998). The smaller islands are the remains of individual cones.

Samoa is located near the southern edge of the intertropical convergence zone. The southeast trades blow for 82 per cent of the dry season and 54 per cent of the wet season. According to Wright (1963), the fact that the island chain lies parallel to these trade winds results in the absence of the strong 'windward' and 'leeward' effect found in most other Pacific islands. During the wet season, the trade winds are periodically displaced by the eastern extension of the Australasian low-pressure

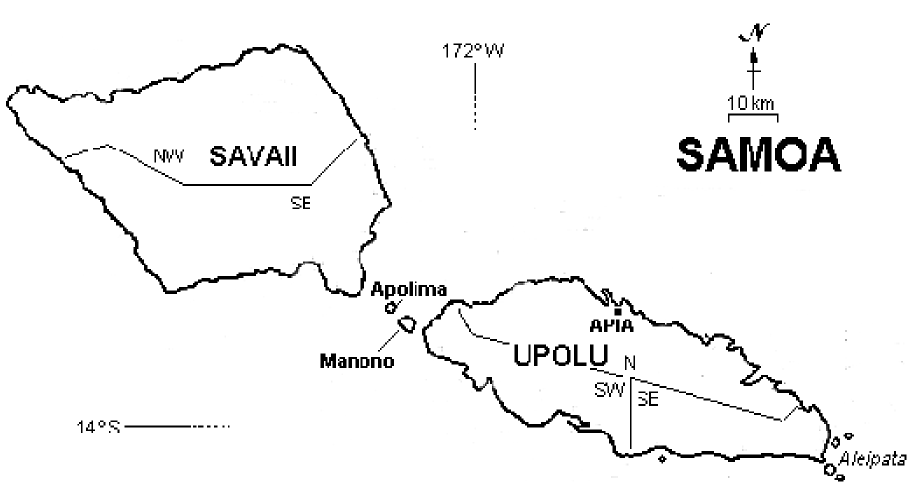

Figure 1
Map of Samoa.

area and by cyclone systems generated near Kiribati and Tuvalu. These have their greatest impact on the weather on the north-western and western sides of Upolu and Savai`i Islands. The annual temperature variation is 1-2°C, averaging 26-27°C at sea level. The range of mean daily temperatures is 6-8°C in January, and 7-9°C in July in most places (Chase and Veitayaki 1992).

The Samoan coral reefs and marine habitats are summarised in Krämer (1902-1903, 1994-1995); Mayor (1924); Dahl (1972), Johannes (1982); Wells and Jenkins (1988); Morton *et al.* (1989), Taule`alo (1993); Anon (1993), Zann and Mulipola (1995); Green (1996) and Zann and Vuki (1998). The coral reefs are limited and fringing in nature, due to the past volcanic activities and the subsequent sea level rise. Previous barrier reefs were covered by lava flow and deep-sided volcanic cones prevented coral reef formations. The shallow and usually murky lagoons on the northern side of the islands (to 2 m depth) are often encircled by fringing reefs, which can extend seaward to 3 km. On the southern, windward shores the lagoons are 2-3 m deep and clearer. The reef systems around Samoa were severely affected by the two major cyclones, *Ofa* and Val in the early 1990s. Some of the reef systems, however, recovered relatively fast and five years later lush coral diversity were seen in most front reef areas.

The Samoans have continued to rely on their coral reef ecosystems for their well-being. As Krämer (1995) stated; “Samoan coral reefs, which may be looked upon as the natives’ pantry and are thus in the economy of that people of greatest significance”. The inshore reefs are becoming severely degraded and threatened mainly by human activities (Green 1996). In 1974, Samoa was the first Pacific Island country to set up a national marine reserve, the Palolo Deep National Marine Reserve. Other marine conservation initiatives are currently undertaken by the Fisheries Division (FD) of the Ministry of Agriculture, Forestry, Fisheries and Meteorology (MAFFM), and under the International Union for Conservation of Nature (IUCN) within the Division of Environment and Conservation (DEC) of the Department of Lands, Surveys and Environment (DLSE).

Acknowledgments and arrangements

The Tables and the map of Samoa (Figure 1) are found after the Reference section. This report although generally follows a format developed by previous neighbouring countries, modifications were needed to address the local scenario. Efforts were made to compile and up-to-date status of coral reefs and marine resource issues that are affecting the Samoa islands.

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Coral reef biodiversity

Background

The current knowledge on marine biodiversity in Samoa, is inadequate in most areas. The majority of research on the marine fauna and flora was carried out by overseas scientists during the colonial era. In the early 1900’s, Samoa became one of the most researched and well-known areas in the Pacific

(Schmidt 1928). However, most of the published studies were written in foreign languages or are not accessible by locals. It is therefore, difficult to compile an up-to-date database of what is known from the islands, with the exception of marine algae, and mangrove forests.

Fragmented reports on some marine biota from Samoa are cited here (see bullet points below), though the authors have not seen most of these reports. The need to document and create a database on the biodiversity of Samoa is most important and must be made a priority for the Government. It is a sad fate for Samoa to see many marine animals and plants becoming extinct with little or no effort made to document or conserve them. Too often traditional songs, poems and tales recite the abundance of many marine species that are no longer seen today. Fishing methods that were often associated with certain marine species are fast becoming a thing of the past, and it is further exacerbated by the lack of interest by the youths of today.

Fauna

Garlovsky (1972) documented a vernacular listing of Samoa's fauna, including marine organisms, in a teacher's handbook, which included English, scientific and Samoan names. Zann (1989) compiled a scientific checklist in English and Samoan, of marine fishes and other marine organisms excluding the plants. This list is very much incomplete, however it is an ideal beginning for a marine biodiversity database for Samoa. The status of important marine and fresh-water fishery resources (including fin-fishes, crustaceans, molluscs, seaweeds, bêche-de-mer, sea urchins, *palolo*, and jellyfish) have been documented by Bell and Mulipola (1995); see section 3.1.1. The list below briefly summarises some of the past research on marine organisms from Samoa.

- Shrimp – Banner (1966), King (1980, 1984);
- Rock (spiny) lobsters – George (1972); King and Bell (1991);
- Deep-water and Reef slope Snappers – Mizenko (1984), King *et al.* (1990);
- Palolo worm – Gray (1847); Mac Donald (1858); Stair (1897); Friedländer (1898); Burrows (1945); Caspers (1961, 1984); Smeltzer (1969);
- Corals – Eade (1980); Krämer 1995;
- Crown-of-thorns Starfish – Garlovsky and Bergquist (1970);
- Ostodes (mollusca) – Girardi (1973);
- Poisonous fishes – Jordan (1929);
- Flying fish – Toloa *et al.* (1998);
- Fresh and brackish water gastropods – Starmuhler (1986);
- Turtles – Hirth (1970); Witzell (1972); Witzell and Banner (1980);
- Foraminifera – Cushman (1924);
- Nautilus – Saunders *et al.* (n.d);
- Fisheries Resources - Bell and Mulipola (1995).

Fishes

Fishes of Samoa were first reported from the middle of the 19th Century (Hombron and Jacquinot (1853). Since then a number of scientific expeditions have been made to research fishes from Samoa. The latest compilation by Wass (1984) summarises most of the fishes of Samoa. Although Wass's collections were mostly from Tutuila Island, American Samoa with few from Upolu Island, the two groups (Samoa and American Samoa) may be considered to be geographically and biologically similar (Skelton 2000). Wass (*ibid.*) listed 991 species representing 113 families and 284 new records for

Site	Area surveyed	Fish species richness	Fish density	Fish biomass	Coral cover
Faleasi`u	Reef front, Depth: 10 m	Moderate	moderate	low	moderate
Vaitele	Reef front, Depth: 10 m	Moderate	high	moderate	high
Fagaloa	Reef front, Depth: 10 m	Moderate	moderate	moderate	high
Eva	Reef front, Depth: 10 m	Low	low	low	moderate
Lefaga	Reef front, Depth: 10 m	Moderate	moderate	moderate	moderate
Sa`anapu	Reef front, Depth: 10 m	Moderate	moderate	low	low
Poutasi	Reef front, Depth: 10 m	High	high	moderate	low

Table 1
Fish communities and habitat characteristics at survey sites on the island of Upolu. (source: Green 1996).

Samoa. Of the total, 890 are considered shallow-water or reef-inhabiting species (generally found at depths <60 m); 56 are considered deeper bottom fishes (associated with the bottom at depths of 60-500 m); and 45 are considered pelagic surface species (frequenting offshore waters above the thermocline at depths < 200 m). About 40 fishes are known only from Samoa and most are undescribed. Wass (*ibid.*) noted that it is likely that the "endemic" fishes of Samoa will be found once extensive collections are carried out in neighbouring archipelagos. This number will need to be revised once smaller fish species such as gobies and blennies are identified. The numbers may well be 200-300 more than those currently known (Seeto pers. comm.). The fishes of Samoa are now included in FISH BASE™ a software programme developed by the International Centre for Living Aquatic Resource Management (ICLARM).

A status report of reef fishes undertaken by Samoilys and Carlos (1991), highlighted a reduction in biomass and size of fish in shallower and more heavily fished areas, while high biomass was found in less fished and deeper reef slopes. This was confirmed by Green (1996) after surveying seven sites on Upolu island. She observed an increase of fish species richness with depth, with deeper habitats having more species than shallower sites (Table 1).

Corals

Little is known of the diversity and the number of coral species found in Samoa and their status needs to be confirmed with modern treatment. Krämer (1995) and Gosliner *et al.* (1996) listed about 50 hard coral species from Samoa. This number is low, as neighbouring archipelagos such as Fiji contains 163 species (Seeto pers comm.).

The state of coral communities of Samoa was said to be severely impacted by recent cyclones (Zann 1991). A survey of several sites of Upolu island conducted by Green (1996) reported that despite the cyclones and other impacts on the coral reefs, the reef fronts were in reasonably good condition (Table 1). Most of the sites surveyed supported healthy coral assemblages, with dense stands of plate corals present, which were not observed in any of the other islands in the archipelago. Furthermore, the reefs at Fagaloa and Vaitele, were exceptionally in good condition with lush coral communities and diverse fish communities (Green 1996). The shallower lagoonal sites were severely affected indicating an immediate threat as compared with the front reef sites. Some dead corals and structural damage were observed at some reef sites, and Green (1996) suggested that it may be due to crown-of-thorns starfish outbreaks and dynamite fishing.

Reptiles

Three species of marine turtles are reported from Samoa: Green, Hawksbill and the Olive Ridley. In 1999 a leatherback turtle was caught on a longline for tuna in Samoan waters (Bell, pers comm.). The Hawksbill turtle feeds and breeds mainly on the small islands off Aleipata district, while the Green and the Olive Ridley is known to feed but not breed in Samoa. Turtles are considered as important tokens or taboo animals to many coastal communities. Although it used to be a delicacy of the local people, conservation efforts have managed to protect them from being harvested. A tagging programme initiated by SPREP is still ongoing with fishers bringing caught turtles to the Fisheries Division to be tagged. A tagged turtle from Samoa is reported to be breeding in the French Polynesia area (Toloa 2000), and turtles tagged in Tahiti have been caught in Samoa. There are two sea snake species reported, however, little is known of their status.

Flora

Reviews of early botanical research of Samoa may be found in Reinecke (1896), Krämer (1902-1903, 1994-1995) and Schmidt (1928). Further reference to the Samoan marine plants is to be found scattered among literature from the middle of the last century to the middle of this century. Mangroves are uncommon, but the Vaiusu mangal near Apia, Upolu Island is considered to be the largest in eastern Polynesia. The Sa`anapu mangal is considered to be an important fish nursery habitat in Samoa (Chase and Veitayaki 1992). Samoa is not well endowed with seagrass beds with only two species of seagrass recorded (Hartog 1970; McMillan and Bridges 1982). These marine ecosystems are poorly understood (Taule`alo 1993) but are increasingly degraded by anthropogenic activities (Horsman and Mulipola 1995; King and Fa`asili 1998).

Algae

The recent compilation of algae from Samoa and American Samoa by Skelton and South (1999) listed 198 taxa, comprising 15 Cyanophyceae, 89 Rhodophyceae, 33 Phaeophyceae and 61 Chlorophyceae. This represents about 50-60 percent of the potential algal flora from Samoa (Skelton and South 1999). Furthermore, a floristic survey of the algae of the Palolo Deep National Marine Reserve is nearing completion (Skelton 2000), and preliminary results reveal a total of 128 species of which 89 are new records, bringing the total of known marine algae from Samoa to 287. Four red alga from Palolo Deep are recognised as new to science, *viz Amansia paloloensis, Ceramium upolense, Ceramium kramerii* and *Ceramium rintelsianum* (South and Skelton 1999; 2000). *Ceramium rintelsianum* is found only from Palolo Deep Reserve, however, extensive research of the flora of neighbouring islands may reveal the presence of this alga. A floristic survey of the algae of Samoa is currently being proposed and will begin in mid-2000 (Skelton, in prep.).

Coral reef scientists have often overlooked the important role of algae in tropical marine environments. Recent research has emphasised the important role of algae in the marine environment, primarily as primary producers, which form complex associations with high species diversity (Dahl 1972). Coralline algae are important in cementing coral reefs (Keats 1996). The shading provided by some large algae often helps cool some benthos during hot sunny weather (Jompa and McCook 1999).

There are three kinds of algae that are consumed by the people: *Caulerpa racemosa*, *Caulerpa* sp., and *Halymenia durvillei* (previously reported as *Gracilaria verrucosa*) (Bell and Mulipola 1995). Two seaweeds were introduced to Samoa for aquaculture purposes from Fiji: *Kappaphycus alvarezii* and *K. denticulatum* (Bell and Ropeti, 1995). Their establishment was not successful.

Seagrasses

The distribution of seagrasses throughout the Pacific region is patchy, with Samoa having two seagrass species reported: *Halophila ovalis* and *Syringodium isoetifolium* (Hartog 1970). McMillan and Bridges (1982) were of the opinion that *H. ovalis* reported by Hartog (1970) from Samoa is probably endemic or belongs to *Halophila minor*. Furthermore, a recent collection was made of a species of *Halophila* from the Palolo Deep Marine Reserve at 25 m depth, which morphologically resembled *H. minor* (Skelton 2000).

Seagrass beds are limited in Samoa, with perhaps the best community found around Manono Island and in the northern part of Upolu Island, where the substratum is generally of soft muddy sand. Although Zann and Mulipola (1995) reported an increase in seagrass and algal community as a result of high nutrients, prolonged exposure to such environment can result in the eventual death of seagrass and algae (Coles and Long 1999). More research is needed to document the distribution and the productivity of seagrass beds in coral reef ecosystems from Samoa.

Mangroves

Samoan mangroves are at the eastern limit for the Indo-Pacific distribution of this group (Vodonaivalu 1983; Woodroffe 1987; Boon 1997). Most of the mangrove forests occur on the coastal areas of Upolu Island with only a few in Savaii Island (probably because of recent volcanism in destroying major habitats). The greatest mangrove forests occurs on the north-west coasts of Apia at Vaiusu Bay (the largest of the eastern Polynesia; Anon 1991) and the south coast at Safata village (Boon 1997). The uses of mangroves in Samoa include: fishing grounds, charcoals, mending canoes, poles for fish traps, tool handles, dye, tannin, nets and artwork, bird hunting ground, medicine, childrens' playground, coastal protection and others.

According to Vodonaivalu (1983), Samoan mangle (which includes mangroves, shrubs and epiphytes - 36 species in total) is highly specialised. Three mangrove communities are recognised: mangrove forest consisting mostly of *Bruguiera gymnorrhiza*, mangrove scrub (rarely more than 5 m high) consisting of a mixture of both *Rhizophora mangle* (= *Rhizophora samoensis*) and *Bruguiera*, and *Xylocarpus* mangrove (Pearsall and Whistler 1991; Schuster 1993). Schuster (1993) and Boon (1997) stated that the mangrove ecosystems of Samoa are suffering from inappropriate land development especially around Apia. For example, in 1978 about 0.65 ha of mangroves were cleared for aquaculture development, which subsequently closed in 1983 (Schuster 1993). In addition, alteration of river courses, in-filled lagoons, dumping of rubbish and industrial wastes, and the discharge of raw sewage into mangrove ecosystems exacerbate the problem. The protection of mangrove ecosystems is controlled under the Lands and Environment Act 1989. Samoa is yet to establish a National Mangrove Management Plan (Schuster 1993).

Littoral plants

Whistler (1992) has documented the littoral or coastal (littoral) plants of Samoa. A total of 76 species are recorded, which includes trees, shrubs, herbs, vines and grasses. The status and role of these littoral plants is not fully understood and research into this area is recommended.

Endemic, extinct and endangered species

Endemic marine species in Samoa are relatively rare or not well documented. Some marine animals and plants like the 40 fish species reported only from Samoa (Wass 1984) and a red alga, *Ceramium rintelsianum* found from Palolo Deep Reserve (South and Skelton 2000) may well be present in neighbouring islands. Research into many of the neighbouring islands fauna and flora is lacking and should be encouraged. It can be safely said that endangered or threatened marine organisms include most of the animals and few plants targeted by the people from the inshore and the coral reefs. The lack of knowledge of the biodiversity of the coral reef and related ecosystems will no doubt hindered conservation efforts and thus more and more species will become extinct.

Zann and Mulipola (1995) reported *Tridacna squamosa* as functionally extinct from Samoa. Extinct species may possibly include the giant clam *Hippopus hippopus* with only shell remains found, however, very little information is known of this species from Samoa. It has been re-introduced and the Fisheries Division currently hold a few mature specimens at its lagoon nursery.

The grey mullet, *Mugil cephalus* and milkfish, *Chanos chanos*, seem to have seriously declined. The populations of the giant triton *Charonia tritonis*, a predator of the crown-of-thorns starfish, have reduced dramatically due to over-fishing for the ornamental trade. The mangrove crab *Scylla serrata*, is facing localised threats from being over-fished, e.g. within the Safata Bay. The boom in the bêche-de-mer industry in the early 1990's caused a decline in the numbers of target species, and thus the industry collapsed a few years after.

Introduced species

Introduction of aquatic species in Samoa began in the early 1900s, when mollies (*Poecilia mexicana*) were introduced to control mosquitoes. Numerous projects and undertakings involving the introduction of marine organisms have since taken place and are outlined in Tables 9 and 10 (Bell and Ropeti 1995; Bell and Mulipola 1998). In 1999, 300 green snails (*Turbo mamoratus*) were introduced from Tonga for reef stocking purposes, while over 10 000 giant clams were introduced from American Samoa and Fiji in the 1998/1999 period. The impact of these introductions on the marine environment is not known.

Threats to coral reef biodiversity

Fishing

The decline in marine resources is attributed to overexploitation and the use of destructive and overly efficient fishing practices and environmental degradation (King *et al.*, 1995). Furthermore, population increase will play a major part to the deterioration of the marine environment.

Subsistence, artisanal and commercial fishing

The reliance of the people of Samoa on seafood goes back to the settlement of the island some 2500 years ago. The varieties of marine organisms that are used are many, and were easily obtained from shallow lagoons and relatively accessible reefs. Exploitation of these areas has traditionally been for subsistence purposes. Varying degrees of commercialisation are now a major factor in the exploitation of these marine resources.

The state of the inshore fishery is documented and analysed by Bell and Mulipola (1995), Horsman and Mulipola (1995) and the Fisheries Division Annual Reports (Fisheries Division 1999; see Table 2-6). According to Horsman and Mulipola (1995) fish landings have declined dramatically from 250 mt in 1986 to just over 50 mt in 1994. The two cyclones *Ofa* and *Val* devastated and affected much of the inshore fishery in 1990-1992 as well as the offshore fishing fleet. Funding aid in the development of the fishing fleet saw the increase in offshore and bottom fish landings. Bottom-fish were over-fished by an estimated 30 per cent of the maximum sustainable yield (MSY) in 1992, which eventually lead to the collapse of the fishery.

Tables 2-6 outline the estimated total volumes and values of reef and lagoon finfishes as well as other marine products sold in the domestic market in the 1998/99 period. Finfishes from the reef and the lagoon are the major fishery that contributes approximately 65 % to the domestic market as shown during the 1998/99 statistics of total fishery landing volumes. The dominant fish species is the parrotfish (*fuga*) 24.8 %, unicornfish (`*ume*) 17.6 %, emperorfish (*mata`eleele*) 11. 8%, surgeonfish (`*alogo*, *pone*) 11.4 % and mullet (`*anae*) 10.9 % (Table 2).

The two marine crustaceans that are commonly sold domestically are *Panulirus* lobsters and the mangrove crab, *Scylla* sp., which comprise 58 % and 35 % respectively of the total estimated landings (Table 3). It is estimated that 14 mt of crustaceans were sold at the Apia Fish Market in 1998/99. Giant clams was the dominant bivalve harvested and sold, while octopus was the dominant species sold domestically for the molluscs group during 1998/1999 period (Tables 4 and 5).

Fin-fish major groups	Tot Wt (kg)	Tot Value (SAT)	1998/99 Wt (%)	1997/98 Wt (%)
Bigeye scad	545.63	3,137.37	1.1	1.7
Emperors	6,012.05	34,569.29	11.8	13.1
Goatfish	1,461.26	8,402.25	2.9	2.4
Groupers	1,904.70	10,952.03	3.8	2.6
Milkfish	92.31	530.78	0.2	0.3
Mojarras	86.68	498.41	0.2	0.3
Moray eel	2,048.31	11,777.78	4.0	5.1
Mullets	5,510.36	31,684.57	10.9	20.7
Other fish	570.14	3,278.31	1.1	1.4
Parrotfish	12,576.11	72,312.63	24.8	14.8
Rabbitfish	490.53	2,820.55	1.0	1.2
Snappers	722.97	4,157.08	1.4	1.5
Soldierfish	1653.8	9,509.35	3.3	1.5
Surgeonfish	5,763.04	33,137.48	11.4	9.9
Topsail drummer	374.62	2,154.07	0.7	0.7
Trevally	1,424.00	8,188.00	2.8	4.2
Unicornis	8,917.25	51,274.19	17.6	18.1
Wrasses	598.03	3,438.67	1.2	0.7
Cooked wrapped fish		14,121.11		
Coconut cooked moray eel		57,029.03		
Total	50,751.79	362,972.95		

Table 2
Total volume of main finfishes landed and sold at the Apia Fish Market and other outlets (Fugalei, Retailers, Roadsides, etc.) in 1998/1999 (source: Fisheries Division 1999).

Species	Total Wt (kg)	Total Value (SAT)	1998/99 Wt (%)	1997/98 Wt (%)
Freshwater crayfish (Ulavai)	541.09	4,328.72	3.9	
Lobsters (Ulasami)	8,124.43	64,995.44	58.0	33.5
Mud crabs (Pa`alimago)	4,912.51	39,300.08	35.1	57.2
Reef crabs (Kuku)	219.34	1,754.72	1.6	7.1
Slipper lobsters (Papata)	206.43	1,651.44	1.5	1.8
Other crabs (Isi pa`a)	2.10	16.8		0.4

Table 3
Total volume of main crustaceans landed and sold at the Apia Fish Market and other outlets (Fugalei, Retailers, Roadsides, etc.) in 1998/1999 (source: Fisheries Division 1999).

Species	Total Wt (kg)	Total Value (SAT)	1998/99 Wt (%)
Giant clams (faisua)	5,910.2	70,922.64	51.0
Cockle (tugane)	5,677.7	7,097.12	48.0
Other bivalves	0.92	11.04	1.0
Bottled items (fole/fatuau/tio)		743.06	
Total	11,588.82	78,773.86	

Table 4
Total volume of main bivalves types landed and sold at the Apia Fish Market and Other Outlets (Fugalei, Retailers, Roadside, etc.) in 1998/99 (source: Fisheries Division 1999).

Other Mollusc species	Tot Wt (kg)	Tot Value (SAT)	1998/99 Wt (%)	1997/98 Wt (%)
Octopus (fe`e)	7,802.19	35,109.86	97.8	99
Turbo shell (alili)	146.03	657.14	1.8	
Others	32.38	145.71	0.4	1
Cooked turbo		3,356.13		
Cooked octopus		52,770.35		
Cooked sea-hare		8,140.53		
Total	7,980.6	100,179.72		

Table 5
Total volume of other mollusc by species landed at the Apia Fish Market and Other Outlets (Fugalei, Retailers, Roadside, etc.) in 1998/99 (source: Fisheries Division 1999).

The estimate for the subsistence (village-based) fishery landings for 1998/99 period was 4,400 mt (Fisheries Division 1998/1999). In 1990, the subsistence fishery landings were between 3,200 mt to 4,600 mt (King 1990; Zann and Mulipola 1995). Mulipola (1997) estimated the subsistence fishery landings to be around 4,200 mt for 1996, while King and Fa`asili (1997) suggested a value of 4,600 mt for the subsistence fishery landings for the whole of Samoa in 1997.

Fishery Products	Tot Value	Avg. price (WST)
Jellyfish (Ofu alualu)	5,941.8	4.52
Gonads (Fagu ape)	3,527.0	11.70
Sea cucumbers (Fagu fugafuga)	14,862.6	9.80
Digestive of curryfish (Fagu sea)	90,667.8	15.00
Lollyfish (Fagu loli)	20.3	2.00
Scylomia/Anemone (Ofu lumane/matalelei)	33,715.1	6.00
Sea urchins (Tuitui, Sava`e)	555.1	3.60
Caulerpa (Ofu limu)	70,051.96	5.60
Total	219,341.66	6.47

Table 6
Total volumes of other invertebrates sold in processed and cooked forms at Fugalei Market and Roadsides (Vaiusu) in 1998/99 (source: Fisheries Division 1999).

Aquarium fish trade

The export of aquarium fish from Samoa began in 1986, however, the operation was only active for one year. The development was started again at the end of 1992 by one operator. The 1993/94 period export of aquarium fish amounted to 65 527 fishes comprising mainly of *Pomacentrus* and *Chrysipttera* sp., *Labroides* spp., *Amphiprion* spp., and *Paracirrhitus* spp. The same company continued to operate in the 1994/95 period, exporting 30 405 fish specimens consisting mainly of assorted damsels, wrasses and angelfish. During the 1996/97 period, two licenses were issued for the export of aquarium fish. One of these operators was also licensed to export a limited amount of corals. Table 7 summarises aquarium organisms exported for the 1996/97 period.

One exporter was in operation in the 1997/98 period, exporting «bio-rock». The exporter was licensed to export 200 pieces of bio-rock, each measuring not more than 30 cm x 30 cm x 30 cm, per week. A total of about 3,890 pieces were exported during the year.

The 1998/99 period saw two exporters in operation with licences granted to harvest and export a maximum of 200 pieces of bio-rock each per week. A total of 7526 pieces were exported. At the beginning of the year 2000 two exporters have been granted licences to export aquarium products. One operator is permitted to export only bio-rocks while the other can export fishes and other organisms including live corals and bio-rocks.

Pollution

The threats to the marine environment by various forms of human induced pollution are unfortunately becoming too big a problem to comprehend. Since 1954 or possibly earlier, pollution and sediment deposition have resulted in a steady replacement of corals with seagrasses and algae. This has resulted in a collapse of some reef species and a tenuous future for others (Zann 1991). The

Organism category	1996 Quantity (# pieces)	Value (USD)	1996/97 Quantity (# pieces)	Tot. Value (SAT)
Tropical fish	183	164.12	183	126.48
Algae	5	1.25	5	3.00
Anemones	730	798.70	880	1383.60
Bio-rocks	495	437.00	2729	8931.24
Crab	22	1.10	22	2.64
Live corals	1677	4 472.25		
Sea cucumber	128	38.49	128	248.38
Sea urchin	10	4.90	10	11.76
Shellfish	272	1,071.60	1504	4255.20
Snail	1025	51.25		
Soft coral	40	124.90	40	159.60
Starfish	40	28.05	90	96.84
Sand			5	2.40
Unidentified	397	455.00	397	1090.80

Table 7
List of species quantity and value exported during 1996 and 199/97 for the Aquarium Market (source: Mulipola unpubl.).

high frequency and unregulated use of pesticides, herbicides and other chemical poisons will undoubtedly be a major factor in the destruction of the coastal ecosystem.

At present the public solid waste collection only covers the Apia urban area and excludes most of the rural areas. Consequently, many households dispose off their wastes either by burning them, or discarding them on the river banks, streams, mangroves or beaches. The increase in demand for imported products (which are mostly packaged in non-biodegradable material), and subsequent burning or dumping them in the current manner will contribute to the demise of the marine environment. Direct pollution as a result of sewerage out-falls, oil spills , and industrial wastes will further exacerbate the problem. This can be highlighted by a recent solvent spill from a leaked fuel tanker docked at the Apia Wharf, in August 1999. Efforts to contain the spill were limited to basic material (cloths), and the extent of the impact to the marine environment is unknown due to lack of equipment and expertise.

Sedimentation and siltation

Poor land practices in some places in Samoa have caused high siltation and eutrophication in lagoonal areas from run-offs. Zann and Mulipola (1995) commented that increased sediment and nutrients were probably responsible for the widespread die-back between 1970 and 1985 of lagoon corals on the northern reefs. Land based activities are the main causes of this problem, which include poor agricultural and forestry practices, land clearing, housing, road construction activities and lagoon dredging.

Development

Coastal and land developments are increasing almost daily, and as such the marine environment becomes more stressed. The building of coastal roads or housing developments can often result in the destruction of coastal areas, wetlands and other natural areas. Furthermore, sand, coral and gravel mining is often carried out locally or on a nation-wide scale. The alteration of coastal areas is often part of foreshore development that is associated with some tourism developments. This will continue to be a threat to marine biodiversity unless immediate actions are taken. Environmental impact assessments may help to reduce such threats as well as giving control to village chiefs for monitoring.

Tourism

Tourism has been recognised as one of Samoa's principal growth sectors. In 1997 the gross foreign exchange earnings from tourism was SAT$101.8 million, which is four times larger than export earnings. This significant contribution to the national economy as well as the local economy through employment and income has brought strong support from the Government. Key steps and measures are taken to enhance and entice investors and the tourism industry.

The potential risk to the marine ecosystem from tourism is a result of poor planning, especially in foreshore land development (reclamation). Waste and sewerage disposal and management could become a major problem as the size of tourist facilities expands without any effective regulatory framework. Furthermore, an increase in careless tourists trotting over corals and taking marine organisms can exacerbate the problem. Although environmental impact assessments are required for every tourism project, the absence of relevant effective regulations and procedures have often resulted in this requirement not being strictly administered (Va`ai 1998). There is a need to develop a code of conduct for tourists, similar to that developed in Fiji (Carswell pers comm.).

Climate change

The fist Intergovernmental Meeting on Climate Change and Sea Level Rise for the South Pacific Region was held in Majuro, Marshall Islands in 1989. Subsequently, SPREP was mandated to undertake preparatory missions to prepare reports on the impacts of climate change. Chase and Veitayaki (1992) prepared this report for Samoa, and their findings are incorporated below. Furthermore, Samoa is party to the United Nations Framework Convention on Climate Change (UNFCCC). Like all signatory parties to the UNFCCC, Samoa is obligated to provide National Communications, which, include amongst other things, a national greenhouse inventory, plans and measures for implementing the UNFCCC. In 1999, two Samoan Government officials attended the SPREP sponsored Vulnerability and Adaptation Assessment course held at the University of the South Pacific, in preparation for National Climate Change Planning (Nunn and Tuqiri 1999).

Potential impact of climate change in Samoa

Chase and Veitayaki (1992) outlined three major potential impacts of climate change: sea level rise; increasing temperature, rainfall and evapo-transpiration; and increase in frequency and severity of cyclones. Some additional impacts of climate change are included below.

Sea level rise

Sea level rise is likely to be associated with many climate-related factors such as the rise in sea surface temperatures (SSTs), the increase in frequency and severity of cyclones and high levels of carbon dioxide in the atmosphere and in the marine environment. The response of coral reefs of Samoa to sea level rise is therefore, difficult to ascertain. Chase and Veitayaki (1992) pointed out that sea level rise might be a ‘powerful force’ in improving the conditions of the lagoonal environment. Given various climatic factors that are associated with sea level rise and their consequences, which may include the weakening and degradation of reefs, the above scenario is unlikely.

The lowlands and intertidal areas along the coast will be affected by sea level rise. Ports, landings, harbours, breakwalls and buildings on reclaimed lands will need to be relocated or raised. Apia, which is largely built on encroached coastal land and marshes, could be inundated by a significant rise in sea level. The Faleolo international airport, which is located at about 1 m above sea level, could also be at risk. Some village areas may become uninhabitable and need to be relocated.

Increase in temperatures, rainfall and evapo-transpiration

The effect of increased air temperature is perceived to be minimal according to Chase and Veitayaki (1992). This is evident by current moves to adapt to hot situations. The increase in air-conditioned buildings, and adoption of new planting techniques in the plantation are some of the measures that Samoa is resorting to. The increase in SSTs will be a major factor that will affect the livelihoods of many Samoans. The inshore and offshore fishery is expected to be severely impacted, and coral bleaching will become prevalent.

Samoa has a relatively high annual rainfall and this is predicted to increase if global temperatures rise. The poor water retention of the Samoan soil due to its volcanic history will likely result in increased water run-off resulting in soil erosion and high sedimentation in freshwater and in lagoonal waters. Flooding will be a major problem for those living in low lying areas as well as those living by rivers.

Between rainfall periods, dry periods will become drier facilitating greater evapo-transpiration rates. Water catchment areas will rapidly dry up and hydroelectric stations will become ineffective. The supply of freshwater to the public will be compromised.

Increase in cyclone frequency and severity

The continuing stresses imposed by various climatic factors and anthropogenic activities on coral reefs will lead to their becoming non-resilient to strong wave action. Some parts of Upolu Island along Luatuanu`u and Solosolo are constantly affected by strong wave action due to the lack of protection from coral reefs. The back-to-back severe cyclones *Ofa* and *Val* in 1990-92 caused widespread damage to the marine environment. Live corals were uprooted from the front reef slope and dumped along the leeward side of the reef crest mainly to the northern part of Savai`i and Upolu islands, creating emerged “coral islets”. The frequency and severity of cyclones will no doubt accelerate destruction in low-lying areas affected by sea level rise. Strong winds may assist in water circulation however, they are most likely to create havoc for coastal inhabitants.

Coral bleaching

The 1997-1998 period revealed a high incidence of coral bleaching due to elevated sea surface temperatures (SSTs) in the Indian Ocean and some parts of the Pacific Ocean (Wilkinson 1998). The central part of the South Pacific escaped the brunt of the bleaching although some localised bleaching was seen in inshore areas as a result of prolonged exposure to extremely low tides. This was seen at Palolo Deep National Marine Reserve, which suffered bleaching on the eastern side of the main Deep from early 1998. The front reef slope was surveyed in July and September with no bleaching event seen (Skelton 1998). It is interesting to note a recent report from Australia by Jompa and McCook (1999) highlighting the importance of *Sargassum* canopy in lessening the impact of coral bleaching on inshore reefs. Samoa has in the past experienced coral bleaching due to high SSTs, although this has not been documented.

The recent coral bleaching event in the southcentral Pacific had insignificant effect to Samoan coral reefs, as compared to Fiji. There are reports of coral bleaching around the Apia vicinity and in some rural areas, both the intertidal and subtidal zones (Trevor and Toloa pers comms).

Mechanisms to address climate change impacts

The Division of Environment and Conservation plays an active role in raising public awareness in climate change issues. Newspaper articles, weekly radio programmes and frequent visits to schools are part of this campaign. Some of the mechanisms that have been proposed include the following:

formulation of regulations which stipulate the need for environmental impact assessments (EIAs) for all Government projects;
- National Disaster Plan;
- preparing material for Cabinet discussion;
- documenting and evaluation of mangrove swamps and other marine nurseries;
- installing of equipment to monitor sea level rise in collaboration with the Flinders University, Australia.

Further possible actions may include:

- human resource development within the Government departments;
- closer collaboration between Government departments, the private sector, non governmental organisations (NGOs) and regional and international organisations;
- voicing concerns to the international community through existing mechanisms;
- leadership seminars;
- workshops at the village level;
- enhance and strengthen monitoring efforts on land, in the atmosphere and in the marine environment.

Conservation and monitoring initiatives

The need to develop long term monitoring sites is important for the future management of marine resources. The participation of villagers in monitoring activities is paramount and should be encouraged. Furthermore, the need to develop more conservation areas must be encouraged with the support of all concerned persons.

To date, only one national marine reserve is recognised, the Palolo Deep National Marine Reserve. There are plans to extend the Reserve to become a coastal marine park (Galuvao pers. comm.). A number of proposed national parks and reserves were highlighted by Wells and Jenkins (1988) and are listed below:

- Aleipata and Nu`utele Islands. This is now a marine park and is part of the IUCN project;
- Cape Puava Forest in northern Savai`i, covers approximately 800 acres and has fringing reefs off its narrow coastline;
- Satuimalufilufi/Fuailolo`o reef on Upolu (about 3.2 km straight-line length and in good condition) has been proposed as a coral sanctuary; it is associated with the proposed Apolimafou reserve (120 acres)

which is primarily a bush and reed swamp). The area is close to a hotel development and the airport;

- Fusi/Tafitoala fringing reef on Upolu (3.2 km) is a proposed coral sanctuary associated with a proposed 120 acre reserve of mangrove forests;
- Aganoa (200 acres) on Upolu is a coastal beach with associated fringing reef;
- Salamumu (240 acres) on Upolu is also a coastal beach with fringing reef and a small rocky islet (Nu`unavasa Island);
- Nu`usafe`e Island proposed reserve (230 acres) off Upolu is believed to be of coral origin. The 3.2 km fringing reef has been proposed as a coral sanctuary;
- Leanamoea (340 acres) on Savai`i is a coastal area which includes a freshwater spring; the associated 3.2 km fringing reef, reportedly in a moderately good condition, has been proposed as a coral sanctuary.

The status of these proposed sanctuaries or reserves is not known at this stage. Two important initiatives are currently underway for the establishment of marine conservation areas in Samoa. The AusAID-assisted Village Extension Programme under the Fisheries Division and the IUCN project under the Division of Environment and Conservation are largely built on a similar platform and are outlined below.

Marine protected areas

Palolo deep national marine reserve

The Palolo Deep Reserve was established and formalised in 1974 and proclaimed on the 5th December 1979. The Reserve encompasses an area of 137.5 ha (1.38 km^2) comprising the Deep, a small land area, a fringing reef, shallow inshore flats; it extends seaward to 500 metres. The Reserve is administered by the Division of Environment and Conservation, and is managed by Siaki Laban To`omalatai and his family who reside on site.

This unique Marine Reserve is likely to be affected by pollution and siltation, and Hunter (1977) reported a decline in visibility between 1970 and 1977, because of sedimentation from neighbouring land development. The proximity of Palolo Deep to the main Apia Harbour increases its vulnerability. The Reserve's accessibility coupled with the colourful thriving corals, array of marine life and calm and safe water makes it one of the top attractions to visitors (Dahl 1978).

The Palolo Deep Reserve was surveyed by Lovell and Toloa (1994) as part of a management plan development. The status of the management plan is unclear and a new survey was carried out in 1999 (Toloa pers. comm.). The benthic marine algae of Palolo Deep has been thoroughly documented by Skelton (2000). The Palolo Deep received severe bleaching of up to 70 per cent of live corals in the inshore reef flats during the severe el Nino southern oscillation (ENSO) weather in February 1998 (Wilkinson 1998). A field report by Skelton (1998) found a high coral recovery in the inshore flats, some five to six months after bleaching, while the front reef slope corals were not affected.

AusAID-assisted fisheries division's village extension programme

The Village Extension Programme is a community-focussed fisheries project, which encourages villages to define key problems, discuss causes, propose solutions and take appropriate actions. Information at each of these stages is provided by various village groups, including women's groups and untitled men's groups, and is recorded by trained facilitators. The extension process is lengthy, as customary protocols need to be followed in each village; thus it may take up to several months for the whole process. At the completion, a Village Fisheries Management Plan (VFMP) is produced. This (VFMP) is an agreement between the village and the government and it sets out the resource management conservation undertakings of the community, and the servicing and technical support required from the Fisheries Division.

The Programme initially had 62 villages participating, however, three withdrew due to internal disputes within the village and the remaining villages have established 54 fish reserves, 35 in Upolu, 15 in Savaii and 4 in Manono (Table 8). The village undertakings ranged from enforcing government legislation to the protection of critical habitats such as mangrove forests. Some villages have chosen to establish fish reserves, which bans all fishing activities from certain parts of their traditional fishing areas. Some villages have allowed their fish reserves to be fished only on special occasions to provide food for example a village meeting (*fono*), church activity, or the *Palolo* (Palolo worm spawning) season.

Village	Date Established or Surveyed	Village	Date Established or Surveyed
Matafa`a	?/97	Satapuala	?/97
Safa`ato`a	14/01/97 14/04/99	Fasito`outa	?/97
Gagaifo	30/07/98	Tauo`o	21/06/96
Sa`anapu	?/97	Moamoa	21/06/96
Poutasi	16/07/97	Fasito`otai	22/06/98
Mulivai	?/97	Vailuutai	28/07/98
Fusi, Safata	30/01/97 09/07/97	Faleula	12/05/99
Fausaga, Safata	?/97	Fagali`i	30/11/98
Tafitoala	16/01/97 07/97	Faleapuna	23/03/98
Saleilua	01/09/99	Saoluafata	22/06/98 02/03/99
Salua tai	?/97	Solosolo	07/05/98
Lepuia`i	15/11/96	Sato`alepai	13/12/96
Apai	27/11/96	Sale`aula	13/12/96
Faleu Tai	15/11/96	Puapua	?/97
Faleu Uta	15/04/98	Fagamalo	?/97
Salua Uta	27/11/96 14/07/97 02/03/99	Fagasa	?/97
Samatau	14/09/98	Vaito`omuli	?/97
Lalovi, Mulifanua	17/06/99	Papa	06/08/99
Fuailolo`o, Mulifanua	17/06/99	Auala	18/12/96
Saleaumua	?/97	Asaga	?/97
Mutiatele	04/02/97	Falealupo	27/02/97
Lotopue	02/04/97	Sapapali`i	06/08/98
Vailoa	14/05/98	Lelepa	15/04/99
Malaela	02/05/97	Manase	21/07/99
Satitoa	04/02/97	Fagae`e	02/11/99
Ulutogia	?/97	Vaovai	01/12/99
Utufaalalafa	24/08/98	Eva	02/12/98

Note: (*) indicates no report or record of survey found, but the year is given in the management plan. Villages with more than 1 date, are re-surveys.

Table 8
List of villages with Fish Reserves established under the Fisheries Division Extension Programme (source: Trevor unpub.).

The Fisheries Division reciprocates by providing technical advice on how to care for the marine environment and the development of alternative sources of seafood. The Research Unit within the Fisheries Division undertakes surveys of Fish Reserves in participating villages. A general survey of the area normally takes into account the physical characteristics of the propose reserve. The technique used are subjective and the need to standardised a survey and monitoring method was realised and thus the Village Level Coral Reef Monitoring Project was initiated (South *et al.*, 1998: see section 4.2).

IUCN conservation areas

The International Union for the Conservation of Nature is currently working with the Division of Environment and Conservation of Samoa in identifying and establishing conservation areas in Samoa, under a 5-year project called, *Samoa-Marine Biodiversity Protection and Management*. The project goal is to provide for the protection and sustainable use of threatened coastal marine biodiversity in Samoa. Its objective is to empower local communities at the Aleipata and Safata districts to effectively protect and manage coastal marine biological diversity and help them achieve sustainable use of marine resources. Phase 1 of the project deals with Management Planning with expected outputs to include:
- preparation of Marine Protected Area Management Plan;
- designing alternative income generating (AIG) activities;
- strengthening capacity and building environmental awareness.

Phase 2 deals with management implementation with outputs including:
- implementing MPA Management Plan;
- implementing AIG activities;
- strengthening capacity and building environmental awareness.

Monitoring programmes

Monitoring of reef resources targeted by artisanal and commercial operators is the responsibility of the Fisheries Division. All marine products sold at the Fish-Market, the Fugalei Market and the Salelologa Market are recorded by the Fisheries Division. These market surveys are carried out weekly and the results are summarised in the Fisheries Division's annual reports.

Fisheries division monitoring programmes

As part of the Village Extension Programme villages are encouraged to establish fish reserve. The fish reserve site and size is determined by the villagers with assistance from the Research Unit of the Fisheries Division. The Fisheries staffs are now trained in the Australian Institute of Marine Science (AIMS) monitoring methodologies and carry out baseline surveys to determine the suitability of a site. The fish reserves are normally resurveyed on a yearly basis.

The data collected from the baseline surveys are entered into a Microsoft Access™ database. A report is written usually by the survey team leader and this information is then relayed back to the village through the Extension Unit of the Fisheries Division, and a copy is also available for public perusal at the Fisheries Library.

Village level coral reef monitoring project

In 1998, a pilot Village Level Coral Reef Monitoring Project was initiated in collaboration between the Fisheries Division, the Division of Environment and Conservation and the International Ocean Institute – Pacific Islands. The project provided monitoring equipment and assisted in training

Fisheries and Environment staff in scientific monitoring methodologies. In turn, the staff trained 46 villagers from six villages from the islands of Upolu, Savai`i and Manono. The project aims to encourage villagers to monitor their own resources with minimal assistance from the Government, and to establish a sustainable monitoring programme that is transferable to other sites. The results are yet to be analysed, however, it is important to note that most of the sites monitored are in lagoonal areas where coral growth is usually limited.

Project	Species	Year started	Responsible agencies	Purpose	Organism source	Status
Turtle hatchery	Hawksbill (*Eretmochelys i mbricata)*	1970/1971	Fisheries Division	Augment local turtle populations	Local (turtle eggs dug up from nests)	Closed in 1983
Seaweed culture	*Kappaphycus alvarezii* and *K. denticulatum*	1975	??	Culture experiment? Details not known.	Introduced but details not known	
Marine shrimp	Tiger prawn, *Penaeus monodon*	1979	Fisheries Division/FAO	Experiment on growth in baitfish ponds for commercial	CNEXO (now AQUACOP), Tahiti	Never developed
Mussel (marine)	Philippine green mussel, *Perna viridis*	1981	Fisheries Division/Canadian Aid/UNDP	Culture/feasibility experiment Tahiti	CNEXO (now AQUACOP), spats source identified	Discontinued by 1990 but plans to re-visit if
Giant clams	*Tridacna* spp. & *Hippopus* spp.	1987	Fisheries Division/SPADP	Restocking/farming Solomon Islands, Fiji, American Samoa	Palau, Tokelau, Australia,	On-going
Oyster	Pacific oyster, *Crassostrea gigas*	1990	Fisheries Division/SPADP	Culture trials for commercial	Kuiper Mariculture, California, USA	No follow-up after harvest in 1991 but plans to re-investi- gate.
Top shell	Trochus *Trochus niloticus*	1990	Fisheries Division/FAO	Seeding for resource enhancement	Fiji	plans to continue
Seaweed	Euchema	1991	Fisheries Division/SPADP	Culture trials	Fiji	Discontinued in 1992
Giant clam	*Tridacna derasa*	1995	Fisheries /SPADP/AusAID/Villages	Reserve stocking & Aquarium	American Samoa	on-going
Mullet/rabbit-fish		1997	Fisheries/AusAID	Culture trials	Local	just started

Table 9
Chronology of mariculture and resource enhancement activities/projects in Samoa (source: Bell & Ropeti, 1995; Bell & Mulipola, 1998).

It is pertinent to report here the results made during the training of the Fisheries Division and the Division of Environment and Conservation staff in July 1998 (see South *et al.*, 1998 for more detail). The training was carried out at the main reef surrounding the capital, Apia (Mulinu`u reef), employing manta towing technique and under water visual census (UVC). Mulinu`u reef was one of the most badly affected areas during cyclones *Ofa* and *Val*, but now has recovered rapidly with fast growing *Acropora* species. Upturned table corals were seen in many parts of the reef front, with turf algae rapidly colonising them. The training results revealed the percentage of live coral cover as patchy, mostly in the 11-30 per cent cover. Dead coral cover was low at 1-10 per cent. The presence of coral scars from crown-of-thorns starfish was noted but the scars were relatively small. The UVC was carried out along a 50 m transect, counted an average of 18 butterfly fish (Chaetodontidae), 45 surgeonfish (Acanthuridae) and 20 parrotfish (Scaridae). The main fish sizes seen were less than 20 cm with only a few between 21-40 cm size. The presence of goatfishes (Mullidae) was poor with a total of 5 fishes seen by one of the participants. This is possibly attributed to the habitat of goatfishes, preferring relatively calm lagoons with sandy substrata.

IOI-Pacific islands global coral reef monitoring network node

Samoa is part of the newly established South-central Pacific Node under the Global Coral Reef Monitoring Network (GCRMN). It is envisaged that the National Co-ordinator will be identified and formalised soon and that coral reef monitoring activities to start. It is anticipated that the National Co-ordinator will be based at the Fisheries Division, however, close collaboration will be formed with local NGOs and other government departments. The priority for Samoa is to form an enthusiastic team of coral reef surveyors, identify sites and to begin monitoring. Monitoring equipment and qualified staff already exist within the Fisheries Division and the Division of Environment and Conservation, therefore costs will be minimised. The data will feed directly into the Node Centre, co-ordinated by the International Ocean Institute – Pacific Islands at the Marine Studies Programme of the University of the South Pacific, and will also be kept at the Fisheries Division.

Management capacity

The managing of the marine resources is improving mainly due to the harmonising of State laws and customary system. The Government have recognised the importance of involving the village chiefs and the public in management and conservation efforts. In turn, the village chiefs are encouraging their people to heed national laws and regulations for the betterment of the nation. The proactive approach taken by the Fisheries Division, the Division of Environment and Conservation as well as some NGO's such as the Si`osi`omaga Society and the Fa`asao Savai`i can only enhance the current efforts in management of the marine ecosystem.

The increased in qualified personnel in Government departments and easy communication with regional and international organisations mean there is no time better to enhance and promote marine management and conservation efforts like now. There is however, limited expertise in some areas such as marine taxonomists. This problem is perhaps not unique to Samoa as often overseas experts are brought in from America, Australia, New Zealand, Japan or Europe and often at great expense, to assist countries in the region. Good leadership in all aspects of conservation, monitoring and management is a must and support must be forthcoming from politicians, the chiefs and everyone in Samoa. The promotion of research must be encouraged as it is often difficult to manage resources without understanding the overall process.

The use of legislation to regulate fishing and promote research, development, conservation and monitoring efforts must recognised the *fa`a Samoa* (Samoan way). Importantly is the need for legislation to be formulated with the involvement of the people from the beginning and they need to be practical and enforceable.

Legislation

There is a need to co-ordinate and combine many sections relevant to marine resource conservation and management that are scattered in different legislation. Such a guide will assist the public and Government staff in understanding the law better, and by the same token manage the resources effectively. The following legislation pertains to the management and conservation of marine resources.

- Samoan Constitution 1960 (stipulates that all land lying below the line of high-water mark shall be public land);

- Land Ordinance 1959 (amended in Fisheries Act 1988, part VIII: 27 [2a-b]; controls coastal aquaculture activities);

- Agriculture, Forests and Fisheries Ordinance 1956;

- The National Parks and Reserves Act 1974 (provides for the establishment of Marine Parks and Reserves);

- Fisheries Act 1988 (promotes the conservation, management and development of fisheries and the licensing and control of foreign fishing vessels, as well as the protection and preservation and development of fisheries: the Act is in the process of being repealed);

- The Lands, Surveys and Environment Act 1989 (to ensure and to promote the protection of natural resources and environment);

- Village Fono Bill 1990; (verifies the power and authority of the village *fono* in the management of marine resources and also considers some of the decisions or penalties handed out by village councils that are appropriate to traditional culture);

- The Water Authority Act 1992/1993 (controls the discharge of pollutants into coastal waters);

- Fisheries Regulations 1996 (sets out regulations for certain marine species, fishing practices and fishing aggregating devices);

- Village Bylaws 1998 (promote the protection, conservation, management and sustainable development of the fishery waters and marine environment of each individual village in the AusAID-assisted Fisheries Extension Programme; so far, 51 Fisheries By-laws have been gazetted).

In addition to the above, some new legislation is currently in progress, which includes the Shipping Bill (to incorporate international conventions dealing with marine pollution), Fisheries Bill (will repeal the Fisheries Act 1988) and the Ports Authority Act (to control ship borne pollution).

The national parks and reserves act 1974

The National Parks and Reserves Act 1974, provides empowering legislation for the establishment of Marine Parks and Reserves. Marine Parks are characterised as public lands of 600 hectares or more, or islands, to which the public is guaranteed freedom of entry and access subject to any controls necessary for the preservation of the park's features. Reserves (which may be nature reserves, recreational reserves, historic reserves, or 'others') may include areas of territorial sea, although customary fishing rights are guaranteed, and the Minister of Agriculture, Forestry, Fisheries and Meteorology may restrict access to and activities within them (Wells and Jenkins 1989).

The fisheries act 1988

A new Bill is currently proposed to repeal the Fisheries Act 1988. The Fisheries Act 1998 incorporated a legislation that governed issues relating to the marine environment. Two previous Acts, namely the Fisheries Protection Act 1972 and Fish Dynamiting Act 1972 were repealed and amended were the Exclusive Economic Zone Act 1977 and the Land Ordinance 1959. The Fisheries Act 1988 has three important parts, relevant to marine conservation and monitoring. Part II, sections 3 and 4 gives the scope of the Act, and prohibits certain fishing activities. Part IV, section 10 authorises scientific research with approval of the Minister. Part VII, section 25 provides for Regulations to be made to, *inter alia*, to regulate and manage any fishery, control harvesting methods, prevent marine pollution and regulate aquaculture activities. The latter part outlined above has resulted in the formulation of the Fisheries Regulation 1996 and various Village By-laws.

The lands, surveys and environment act 1989

The Lands Surveys and Environment Act 1989 encompasses natural resource protection, environmental management and pollution control. The Act is the mandate of the Division of Environment and Conservation, which has two main sections: *Environmental Management, Planning and Education*; and *Biodiversity, National Parks and Reserves*. The Division of Environment and Conservation supervises environmental management activities of other departments, monitors and controls coastal pollution and the effects of climate change on key coastal ecosystems (including coral reefs and mangroves) and oversees natural resource management such as sand mining. It also has principal responsibility for the management of parks and reserves (including the Palolo Deep National Marine Reserve).

Village bylaws

Bylaws are important as they are the first step whereby a village lets the country know of their wish to protect, conserve and increase their marine resources. For this reason the Government and other villages will be aware of the problems and concerns this village has and can assist in the most appropriate ways. The Village Bylaws are formulated by the Attorney Generals office, after close collaboration and consultation between the village and the Fisheries Division. Once it is finalised, the signature of the Director of Agriculture, Forestry, Fisheries and Meteorology is needed, before it is gazetted for public scrutiny. The Bylaws are enforced after 7 days of being first publicised, and the enforcers are the village councils. The shortfall of Village Bylaws is that they only cover people of that village. The village council cannot arrest neighbouring villagers from fishing in their traditional fishing grounds as it would contravene the “public land section” of the Constitution (Skelton and South, 1998).

Customary marine tenure

Traditionally, the Samoans had elaborate customs of ownership and control of fishing rights (Bulow, 1902). The right to fish in reef, lagoon and mangrove areas was owned by adjacent villages, families or chiefs but these customs have largely disappeared as far as reefs and lagoons are concerned, in part

Common name	Species	Stage/Age	Date	Amt sent	Amt received/ alive	Agency responsible	Source	Purpose	Local distribution
Marine shrimp	*Penaeus monodon*	post-larvae	early 1979	~1,000	~1,000	Fisheries/FAO	CNEXO(AQUACOP), Tahiti	Culture trial	Vaitoloa baitfish ponds, Upolu Is.
Mussel, Philippine green mussel	*Perna viridis*	spats	June, 1982	40,000		Fisheries/FAO? or Canadian funds?	CNEXO(AQUACOP), Tahiti	Culture trials	Mulinuu lagoon & Fisheries harbour, Upolu
	Perna viridis	spats (93 days old)	February, 1983	70,000		Fisheries/FAO? or Canadian funds?	CNEXO(AQUACOP), Tahiti	Culture trials	Safata Bay on Upolu Asau Bay on Savaii
		spats	December, 1983	90,000		Fisheries	CNEXO(AQUACOP), Tahiti	Culture trials	Safata Bay on Upolu Asau Bay on Savaii
		spats	August, 1985	60,000		Fisheries	CNEXO(AQUACOP), Tahiti	Culture trials	Fagaloa Bay, Upolu Island
		spats	October, 1987	100,000	~50,000	Fisheries	CNEXO(AQUACOP), Tahiti	Culture trials	Asau Bay, Savaii Island
		spats	October, 1988	70,000	did not reach Samoa	Fisheries	CNEXO (now AQUACOP), Tahiti	Culture trials	shipment mistakenly off-loaded in Fiji/condemned
		spats	November, 1988	100,000	did not reach Samoa	Fisheries	CNEXO (now AQUACOP), Tahiti	Culture trials	shipment was not off-loaded in Wellington, NZ/lost
Seaweed	*Kappaphycus alvarazii & K denticulatum*		July & Dec., 1975	420 lb K. alvarazii , 80 lb K. denticulatum		?	?	Culture trials?	Vaiusu-Faleula Lagoon?
	K. alvarazii (Euchema)		25 March, 1991	10-20 kg	10-20 kg	Fisheries/SPADP	Fiji	Culture trials	Aleipata & Mulinuu, Upolu Island
	K. alvarazii (Euchema)		6 June, 1992	15 kg	15 kg	Fisheries/SPADP	Fiji	Culture trials	Aleipata, Upolu Island
	K. alvarazii (Euchema)		17 July, 1992	168 kg	168 kg	Fisheries/SPADP	Fiji	Culture trials	Aleipata, Upolu Island
	K. alvarazii (Euchema)		July, 1999	20 kg		Fisheries/SPADP	Fiji	Culture triala	Savaii Island: Asau; Upolu Island: Saluafata, Mulifanua
Trochus	*Trochus niloticus*	mainly juveniles	August, 1990 October, 1990	50 78	50 78	Fisheries/FAO	Fiji	Seeding	Namu'a and Nuutele Islands received 40 each
Oyster (Pacific)	*Crassostrea gigas* (had a few live spats of Manila clam)	single cultchless seeds (2-20 mm)	June, 1990	4,500 diploid 56,000 triploid	4,500 diploid 56,000 triploid	Fisheries/SPADP	Kuiper Mariculture, California, USA	Culture trials	Fusi Safata Bay, Upolu Island
Giant clams	*Tridacna derasa*	yearlings	May, 1988	983	423	Fisheries/SPADP	MMDC, Palau	Culture	Fisheries & Moataa Lagoon on Upolu Islan
	T. squamosa	broodstock	1989	21	21	Fisheries	Tokelau Islands	breeders	Fisheries hatchery
	T. gigas	juveniles	Sept., 1990	700	300	Namu'a Farm	Cairns, Australia	Culture	Namu'a Farm at Aleipata Upolu Is.
	Hippopus hippopus	post-larvae	Nov., 1990	150,000	?	Fisheries	ICLARM, Honiara	Culture	Fisheries hatchery but none survived
	T. gigas	juveniles	27 May, 1991	10,000	500	Namu'a Farm	Orpheus Island hatchery	Culture	Fisheries/Namu'a Farm at Aleipata, Upolu Islanc
	T. gigas	juveniles	July, 1991	10,000	10,000	Fisheries	Orpheus Island hatchery	Culture	Fisheries/Namu'a Farm at Aleipata, Upolu Islanc
	T. derasa	juveniles	July, 1992		4,950	Fisheries/SPADP	Fiji Fisheries	Culture	Fisheries/Namu'a Farm
	T. squamosa	juveniles	July, 1992		270	Fisheries/SPADP	Fiji Fisheries	Culture	Fisheries/Namu'a Farm
	T. derasa	juveniles	February, 1993		1,700	Fisheries/SPADP	Fiji Fisheries	Culture	Fisheries/Namu'a Farm
	T. squamosa	juveniles	February, 1993		50	Fisheries/SPADP	Fiji Fisheries	Culture	Fisheries/Namu'a Farm
	T. squamosa & T. derasa	juveniles	20 Sept., 1993	6,000	5,800	Fisheries/SPADP	Fiji Fisheries	Culture	Fisheries/Namu'a Farm
	T. derasa	juveniles	1995	10,000	10,000	Fisheries/AusAID	DMWR, American Samoa	Reserve stocking & development	Moamoa & Tauoo village reserves, Upolu
	T. derasa	juveniles	1996	10,000	10,000	Fisheries/AusAID	DMWR, American Samoa	Reserve stocking & development	Fasitoo (Upolu), Faleu, Lepuiai, Salua & Apai villages on Manono Island

Table 10
Marine organism introductions into Samoa for aquaculture, reef seeding and other purposes, sorted by organism common name (source: Bell & Ropeti, 1995; Bell & Mulipola, 1998). [1] Updated February 2000.

	T. derasa (with a few specimens of *T. maxima* and *H. hippopus)*	juveniles	August, 1997	20,000	20,000	Fisheries/AusAID	DMWR, American Samoa	Reserve stocking	Tafitoala, Fausaga, Fusi Safata villages on Upolu Island & Asau, Auala, Fagasa, Sataua, Fagamalo, Pu'apu'a, Asaga, Faala and Vaitoamuli villages on Savaii Island
	T. derasa & T. squamosa	juveniles	July, 1998	2,034	2,034	Fisheries/FAO	Fisheries, Fiji	Reserve stocking	Locall villages
	T. derasa	juveniles	July, 1998	1,500	1,500	Fisheries/AusAID	DMWR, American Samoa	Reserve stocking	Local villages
	T. derasa	juveniles	18 June, 1999	1,041	1,041	Fisheries/FAO	Fisheries, Fiji	Reserve stocking	Ulufaalalafa, Solosolo Sapapalii, Papa & FD nursery
	T. gigas	juveniles	18 June, 1999	1,026	1,026	Fisheries/FAO	Fisheries, Fiji	Reserve stocking	Ulufaalalafa, Solosolo Sapapalii, Papa & FD nursery
	T. derasa	juveniles	24 June, 1999	5,000	5,000	Fisheries/FAO	DMWR, American Samoa	Reserve stocking	14 villages & FD nursery
	T. derasa	broodstock	24 June, 1999	30	30	Fisheries/FAO	DMWR, American Samoa	broodstock	29 to FD nursery, 1 died during quarantine
Green snail	*Turbo marmorata*	Juveniles	April, 1999	300	300	Fisheries/SPADP	Tonga Fisheries	Reef stocking	quarantine at Fisherie for 3 weeks, released 1 at Papa Puleia on 18 M 1999, 50 to be release at Saluafata & 150 at Namu'a Is.

KEY: SPC = Secretariat for the Pacific Community; FAO = Food and Agriculture Organization;
SPADP = FAO South Pacific Aquaculture Development Project; DMWR = Department of Marine & Wildlife Resource.

Table 10 (suite)
Marine organism introductions into Samoa for aquaculture, reef seeding and other purposes, sorted by organism common name (source: Bell & Ropeti, 1995; Bell & Mulipola, 1998). [1] Updated February 2000.

because, following the constitution, all land lying below the line of high-water mark in now public land, and all people have the right to navigate over the foreshore and fish within the limits of the territorial waters of the state (Bell 1985). The recent introduction of modern technologies together with increasing population pressure has led to unsustainable practices, which is a result of western-style government.

The introduction of State rules often undermines the traditional custom, however in recognition of this conflict the State passed the Fono Act 1990, which gives the authority back to village chiefs to control their traditional fishing grounds. The recent introduction of Village By-laws through the AusAID-assisted Fisheries Extension Programme further promotes village "ownership" and management of adjacent lagoon and reef fishery resources.

Constraints

Some of the constraints that are faced include the poorly focused and over-taxed fisheries administration, lack of research and management capabilities, environmental deterioration, over-fishing through the use of destructive and overly efficient fishing methods, and the poor use of fisheries management tools and regulations (King *et al.*, 1995). The lack of qualified personnel in marine related positions and the lack of priority given to monitoring and conservation efforts further exacerbates the problem. In the early 1980s the Fisheries Division employed 96 staff, by mid 1990s only 30 employees were left with only 5 having specialised fisheries training (Mulipola *et al.*, 1995). The lack of co-ordination and collaboration between government departments and NGOs may also be a constraint to coral reef conservation and monitoring. The need to include stakeholders, council of chiefs (*ali`i ma* *faipule*), fishers, and the public is vital and must be integral to all monitoring and conservation efforts. The need to document the biodiversity of Samoa by reviewing past research and also by encouraging future scientific research with the involvement of locals is important.

Discussion

More research on the marine biodiversity of Samoa is needed. Very little is known with the exception of the fin-fishes and the flora which have been recently documented by reef scientists (Wass 1984; Zann 1989; Whistler 1992; South and Skelton 1999, 2000; Skelton 200). The coral reef system was severely affected by cyclones *Val* and *Ofa* in the early 1990s, however, a recent survey undertaken by Green (1996) revealed a fast recovery rate for most of the corals in the front reef. Industrialised areas such as Vaitele and Fagaloa were found to be in extremely good condition as were many other sites on Upolu island. By contrast the inshore lagoons were found to be much degraded and are threatened by coastal activities (Green 1996).

Although no endemic or rare species are found, this may merely reflect our current lack of knowledge of the coral reef biodiversity. Endangered animals, which include *Tridacna* spp., *Mugil cephlaus*, *Chanos chanos*, *Charonia tritonis* and *Scylla serrata* continue to decline in numbers as no nation-wide conservation effort is identified. This may result in the extinction of some animals such as the giant clam *Hippopus hippopus*, and the collapse of some fisheries, such as the bottom water fish and the bêche-de-mer fisheries. The decline in fishery stocks may be attributed to over-fishing, pollution, sedimentation and siltation, inappropriate development, careless tourism development and climate change. Over-fishing is a major problem; as the population increases, food consumption will also increase, the number of fishers will increase and the efficiency of fishing gear will improve. Pollution in rural communities will increase due to the increase of non-biodegradable products. The predictions that climate change effects will become more frequent, unpredictable and more severe need to be considered by leaders of the country and solutions should be highlighted and made known to the community.

The marine resources from the inshore and reefs are documented by the Fisheries Division through data collecting at local sites (markets, retailers and roadsides). This is carried out on a weekly basis throughout the year. The knowledge of the wild stock in most species is not known but downward trends can be seen over the years with the decline in fish catches.

Marine conservation efforts are currently being addressed through two different initiatives by two different government departments. There is a clear need for these conservation efforts to work together to achieve maximum success. Through these conservation efforts, sound monitoring activities must also be recognised and be part of management plans. The notion of including village participants as part of the monitoring activities should be encouraged as efforts have already been made through the Village Level Coral Reef Monitoring Project and the Village Extension Programme. Long term monitoring sites should be established in some of the proposed conservation areas. There is also a need to survey much more and in detail the coral reefs and threats to the inshore fishery of Samoa as advocated by Green (1996). In particular, a detailed survey of the condition of the shallow lagoons around the island would be invaluable.

Training of Fisheries and Environment staff in marine biota must be emphasised. Taxonomists, ecologists and biologists are lacking in government departments and this should be addressed.

Recommendations

The following lists some of the important issues that need to be considered for the better management of the coral reefs and the marine resources of Samoa.

- Appoint a National Coordinator responsible for coordinating all coral reef activities, including monitoring, training, research and liasing with all concerned parties;
- Establish a database to document the biodiversity of the marine resources of Samoa, which should include *inter alia* previous research, lists of organisms reported, distribution of organisms, results of monitoring activities, etc.;
- Efforts be made to enhance and build up human resource development, which must include specialised training and higher levels of education in taxonomy, scientific research, management and policy making;
- Develop and implement an Integrated Coastal Management (ICM) National Plan, which should define the roles of each Government department, local NGOs and regional/international NGOs, as well as including a synopsis of all relevant legislation dealing with marine resource conservation and management;
- Encourage the formulation of a National Sustainable Development Bill or Resource Management legislation, which should restate and reform the law relating to *inter alia* the use of marine and coastal resources;
- Activate previous recommendations made by UNEP/IUCN (1988) on proposed conservation areas in particular coral reefs;
- Identify long-term conservation areas and carry out baseline studies;
- Encourage and develop appropriate curriculum for schools at all levels;
- Encourage participation in all international Conventions and Agreements that Samoa is party to, including the Convention on Biological Diversity, the Ramsar Convention, and the United Nations Framework Convention in Climate Change;
- Establish a national action plan to prevent, reduce or minimise the deterioration and degradation of the marine and coastal environment from pollutants, including household refuse, industrial and agricultural waste and oil spills. The national action plan should also stipulate fines for those responsible for the offence as well as holding them responsible for any costs incurred in preventing, reducing, minimising or removing such pollutants;
- Include climate change issues in management and conservation efforts.

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The status of Solomon Islands coral reefs

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The coral reefs along the shores of the double archipelagic chain of steep, mountainous and commonly volcanic islands comprising Solomon Islands (5-12°S, 152-170°E; 28,370 km^2) are mainly narrow, fringing and intermittently distributed. Their collective biomass is, however, large because of the coastline length of the 1000 islands. Long barrier reefs and expansive intertidal reef flats are uncommon; and Ontong Java, a northern outlier, is the only large atoll (70 by 11-36 km). The largest coral reefs usually occur where large lagoons are protected by raised or semi-submerged barrier reefs or by raised limestone islands, e.g. Marovo and Roviana Lagoons and Marau Sound.

There is recent coral bleaching, coincident with higher than usual sea temperatures. There is also historic evidence of periodic tectonic uplift during earthquakes and of sediment from volcanic activity burying reefs. Apart from these, the biggest threat is the coincidence of rapid population growth, high unemployment and relatively new opportunities to generate cash such as selling reef fish for restaurants and fish and corals for aquaria. Without alternative opportunities for cash income, the more lucrative reef species will be exhausted, and such alternatives are scarce.

Prevalent widespread logging causing huge plumes of sediment to be discharged from the rivers draining the logged catchments is having a major impact on lagoons and coral reefs. A good example is southern Marovo Lagoon, an area also affected by a scheme to plant oil palms on logged over unstable hill country thereby creating more fluvial sedimentation. The effects of such sedimentation are not being monitored. Nor are the effects of other types of pollution near Honiara (readily visible from the air) and from other industrial developments such as oil palm extraction plants and fish canneries. Gold mining on Guadalcanal, and proposals to mine gold and nickel in New Georgia could also potentially degrade coral reefs.

There is little legislative protection for coral reefs in the Solomons. The only policy is embodied in the government's policy on fisheries that aims to secure optimum social and economic benefits for the people by exploiting fisheries resources within limits. In the absence of reef census research, reliable catch returns and monitoring programmes it is difficult to set appropriate limits. The Environment Act 1998 aims to prevent, control and monitor pollution in nearshore waters. The Wildlife and Protection Act 1998 regulates the export and import of plants and animals to comply with CITES; although the Solomon Islands are not signatories. Law enforcement is, however, generally weak. The only marine protected area (MPA), designated in 1975 to protect turtle nesting grounds, did not succeed because locals asserted their customary fishing rights and destroyed the turtle hatchery. The Solomon Islands Government and The Nature Conservancy have tried to revive this MPA, and it may yet prove to be the first with community support in the tropical South Pacific.

As yet, very little scientific work has been carried out on the coral reefs of the Solomon Islands. There is an urgent need to describe, quantify and catalogue the biota of the reefs, especially for base-line studies of potential impacts, and to undertake near-shore oceanographic research. Reliable statistics on the quantities of various reef species eaten and exported are also needed.

Introduction

There is a dearth of reliable information about coral reefs and coral reef ecology in the Solomon Islands. Although many coral reef species are being exploited, directly for sustenance and for cash, there is little information on their sustainability and on the ecological consequences of reef fisheries. There is little information on the long-term ecological effects that industries like logging and mining have on lagoons and coral reefs. Fundamental to measuring changes to the reefs is the need for reliable baseline studies. Few of such studies have been done in the Solomon Islands, and currently there is little in the way of expertise and material resources to undertake them.

This is in a country with a rapidly increasing population that is predominantly rural, coastal and where the annual per capita income is considerably less than $US1000. Coupled with new opportunities for converting reef resources to cash, and increased logging, mining and plantation development – activities that inevitably increase erosion and the turbidity of coastal waters – the situation in Solomon Islands does not bode well for the health and vigour of its coastal marine life.

In this report we describe coral reef fisheries, current and potential threats to reef ecology, and problems for conservation. We conclude that overfishing, continued logging and new land developments such as oil palm plantations are detrimental to coral reefs and lagoons. Of concern is the likelihood that most fisherfolk are probably oblivious to the likely ecological consequences of overfishing. Weak enforcement of fisheries regulations and the difficulties of creating marine protected areas are also problems.

Geography

The Solomon Islands are the northern group of a huge arc of islands delimiting the Coral Sea east of Queensland. The archipelago, orientated northwest to southeast, stretches about 1700 km between Bougainville at the eastern extremity of Papua New Guinea and the northern-most islands (The Banks Group) of Vanuatu. The six main islands are: Choiseul, Santa Isabel, New Georgia, Guadalcanal, Malaita and Makira. They are arranged roughly in a double chain with the two “strands” enclosing a relatively sheltered sea area comprising New Georgia Sound (“The Slot” of World War II), between Choiseul, Santa Isabel and New Georgia, and Indispensable Strait between Malaita and Guadalcanal (Figure 1).

In terms of land area (28 370 km^2), Solomon Islands is the third largest island nation in the South Pacific, after Papua New Guinea, and New Zealand. Its very much larger sea area of 1.34 million km^2, as delimited by its 200 mile EEZ, is twice that of neighbouring Vanuatu, slightly larger than that of Fiji, and a little smaller than the individual sea areas of Cook Islands, New Caledonia and the Northern Marianas Islands. The total area of internal waters and within the 12-mile zone, where most of the coral reefs occur, is 0.3 million km^2.

Geologically the archipelago was formed recently (about 25 million years ago) by tectonic plate movement, earthquake, and by considerable submergence and emergence (Maragos 1998). Thus coral

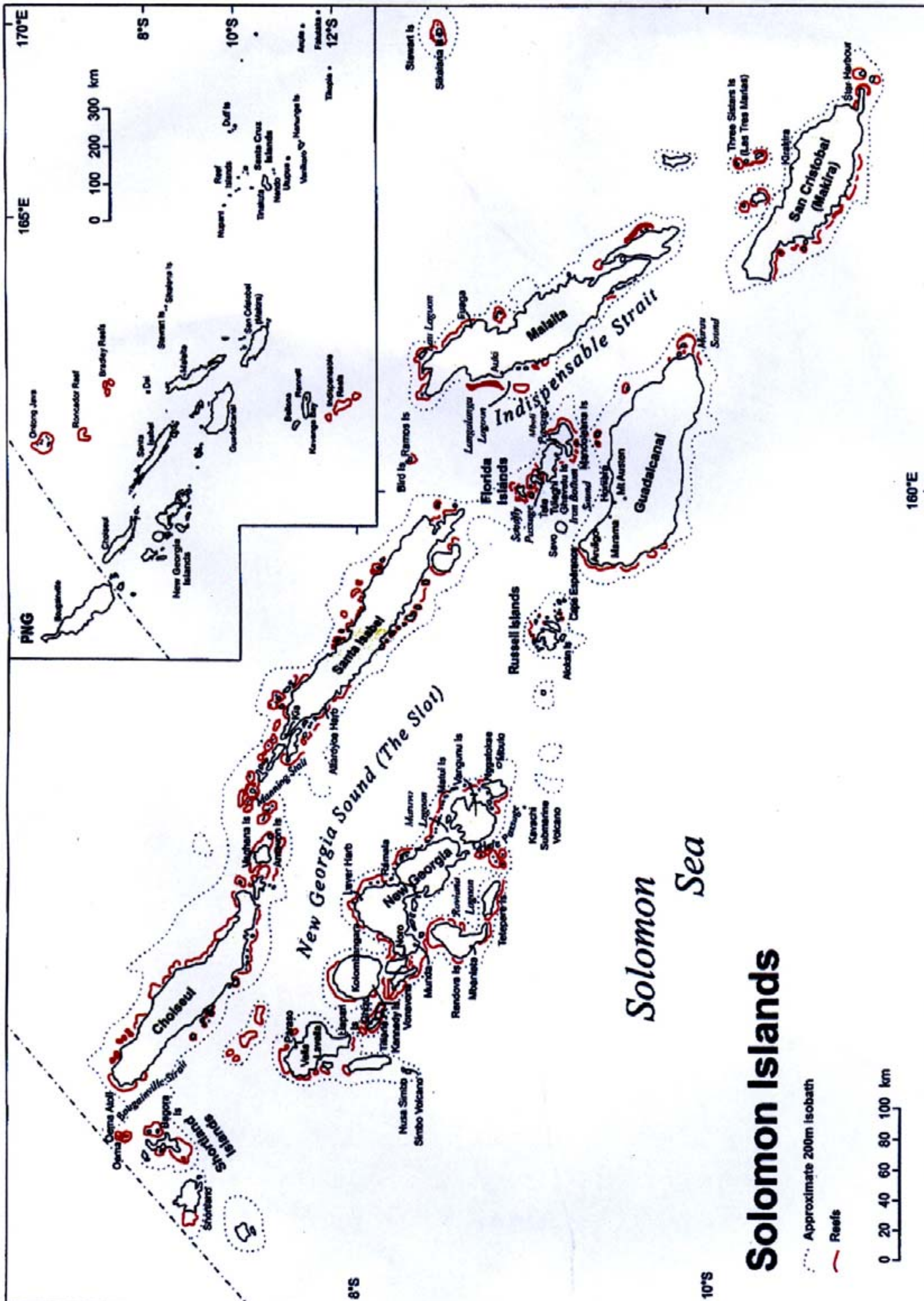

Figure 1
Map of Solomon Islands showing approximate coral reef regions (adapted and modified from Wells and Jenkins 1988).

is found high on the slopes of Mount Austen behind Honiara. Of a total of about 1000 islands (comprising small islands, atolls and islets), most are raised volcanic limestone islands with the reefs predominantly fringing on the steep slopes of the volcanic islands (Maragos 1998). The six largest islands, listed above, rise steeply from the sea and each has a central mountain spine with peaks up to 2450 m. Large coastal plains only occur on Guadalcanal, particularly in the northeast. Solomon Islands is situated within the 'Pacific Ring of Fire' belt and still has active and dormant volcanoes. The two active volcanoes are: the Kavachi submarine volcano south of Vangunu in eastern New Georgia, and the Tinakula volcano far to the east in the Santa Cruz Group. Dormant volcanoes, that still emit fumes, are Savo Island between Florida Islands and Guadalcanal, Simbo volcano on Nusa Simbo Island and Paraso volcano on Vella Lavella.

Two main climate systems affecting the Solomon Islands are the southeasterly trade winds (*Ara*) that blow from May through to October and the northwesterly monsoon winds, (*Koburu*) that blow from December until March. Fine, sunny, relatively calm weather normally occurs during the months of April and November. Being close to the equator, air temperature in the Solomon Islands does not vary considerably. Mean daily temperature throughout the year is on average 28°C ± 2°C. Minima as low as 23°C normally occur in the early morning hours during the Ara season. Daily maxima are normally 30°C. Rainfall ranges between 3-5 metres per year. There is generally more precipitation during the wet *Koburu* season than during the relatively dry *Ara* season.

Sea surface temperatures in the Solomons are consistently in the high twenties with a small annual variation. At Honiara, situated at 9.5°S and about mid-latitude for the archipelago, the mean monthly sea surface temperatures measured over 65 months from July 1994 until November 1999, ranged from 27.4 to 30.1°C. The average of the 65 monthly means was 29.08°C. Minimum and maximum daily temperatures within this period were 26.5 and 31.6°C. The coolest temperatures commonly occur between August and October and the highest temperatures between January and March. Sometimes the mean monthly sea temperature is above 29.5°C for four or five consecutive months (data from Solomon Islands Meteorological Service).

Tides in the Solomon Island are diurnal; i.e. it takes almost 24 hours for the tide to rise and fall. The spring range is about 1.4 m and the neap range about 0.45 m. The tidal curve is asymmetric; the tide falls much faster than it rises (see Womersley and Bailey 1969 fig. 129). In the latter half of the year, the low tide tends to occur at about midday. But from about October, the time of low water shifts so that in the other half of the year the time of low tide moves to about midnight (Morton and Challis 1969; Womersley and Bailey 1969).

Human history

The Melanesians first discovered and settled in Solomon Islands 4000-6500 years before present, with the Polynesians settling in the outlying Islands and atolls at about 2000-3000 years before present. The indigenous people of the Solomon Islands are a diverse group. There are a total of about 87 languages and dialects. The common language among the different language speakers is Pidgin. English is the official language used in governments and business. The majority of the population is Melanesian (94.2%). Polynesians comprises 3.7%, Micronesians 1.4% and those of Chinese or Caucasian descent the remaining 0.7% of the population (Leary 1993). Kiribati people, who were resettled by the British Government in the 1960's, are included as Micronesians in the compilation above.

European 'discovery' of Solomon Islands, was at first a hit and miss affair. The Spanish, who came from Peru, hit upon Santa Isabel in 1568, and over a period of six months found the other large islands. Returning in 1595 to start a colony, they missed the main islands, so tried unsuccessfully to colonise the much smaller, and highly malarial Santa Cruz Islands. A second colonisation attempt in 1606 found only the minuscule Duff Islands and went on to attempt to colonise Espiritu Santo in Vanuatu – again unsuccessfully.

Perhaps because mapmakers plotted the Solomons far to the east of their correct position, the islands were spared further European contact until 1767 when a British sea captain, Philip Cataret, stumbled on Santa Cruz and Malaita. A spate of British, French and American explorers followed. Then came traders, various missionaries and territorial claims in the north by Germany and in the south by Great Britain. During some international island "horse trading", Germany ceded her northern claims in 1897 to Great Britain in exchange for Britain relinquishing its claims to Western Samoa. Bougainville, naturally part of the Solomon archipelago was, perhaps unfortunately, left in German control, and so today is part of Papua New Guinea. The British administered the islands as a Protectorate; but were not overly generous on expending money on it. During World War II the fight for control over an airstrip near Honiara on Guadalcanal was a major turning point of the war. Thereafter the Japanese retreated as the Americans advanced; but not without exceptionally violent and bloody battles on land, sea and air.

After the war, Britain continued to administer the Protectorate until independence in 1978. Solomon Islands was one of the last British colonies to become independent. It is now a democratic state with a modified form of Westminster government and with the British Monarch as Head of State. The provisional population (1999 census) was 408,358.

Politically the nation is divided in to nine provinces: (1) Temotu (Santa Cruz Island, Reef Islands, Tikopia and other smaller eastern outer islands); (2) Makira & Ulawa; (3) Guadalcanal; (4) Central (Russell, Savo and Florida Islands); (5) Malaita (Malaita, Ontong Java and Sikaiana) (6) Isabel; (7) Western (New Georgia Group, Simbo and Vella Lavella); (8) Choiseul and (9) Rennell & Bellona; in addition to the Honiara Town Council.

Tenure and ownership

It is important that tenure and ownership be discussed in regard to coral reefs in Solomon Islands. Most coral reefs are owned under the customary marine tenure system that is recognised under the Solomon Islands Constitution. The owners are an integral part of the reef system and a holistic approach must always be taken when discussing coral reefs. The success or failure of conservation efforts on coral reefs largely depends on the attitudes of the communities owning them.

Coral reefs and adjacent coastal areas such as lagoons are owned under a kinship group based ownership. The clan or the tribe normally owns the reefs (fringing or barrier) under customary rights (Oreihaka and Ramohia 1994). The ownership details vary from area to area. Skewes (1990) described such a system as complex and dynamic and an important part of Solomon Islands culture. Documented examples are the Nggela system (Foale 1998), Lau in north Malaita (Akimichi 1991) and Marovo lagoon (Hviding 1988). The studies by Foale (1998) will be reviewed here to illustrate the nature of such an ownership system.

According to Foale (1998), the reefs in Nggela are regarded as an extension of the land, and boundaries of coastal properties are extended seaward to divide reefs or adjacent sea, resources that are contained within these areas are owned by the tribes (*Kema*). There are four *Kema*, subdivided in turn into 7 clans (Vike). The *Vike* are the primary owners of reefs or sea. In cases where small islands or islets are owned, the *Kema* or *Vike* also own the adjacent reefs. Primary rights to property and *Vike* affiliation are inherited matrilineally. Utilisation and management of resources within the coral reefs is done through the *Vike*.

Reefs or seas can be transferred across *Vike* through *Huihui*. During the *Huihui*, the ‘owners to be’ make a feast for and present money (traditional and modern) and gifts to the original owners. Food and gifts are also presented to the other elders (chiefs and village leaders) of the community who would witness such a transfer. The ‘owners to be’ must not eat any food that is prepared for the original owners. A *Huihui* normally occurs where ownership is transferred from the patrilineal side or when land is bought from another *Kema* or *Vike*. The important role played by the tribes or clans owning the reefs in utilisation and conservation of coral reefs will be discussed later, especially on matters pertaining to marine protected areas and conservation efforts.

The coral reefs of Solomon Islands

Solomon Islands Bibliography to 1980 by Sally Edridge is an exceptionally thorough compendium of information on the Solomon Islands including publications about: voyages, the earth and life sciences, oceanography and geography. It contains lists of studies pertaining to individual islands, and provides detailed author and subject indexes (Edridge 1985).

Distribution and description

The geomorphology of Solomon Islands coral reefs was described by Stoddart 1969a-c. Wells and Jenkins (1988) provided a summary of Solomon Islands reefs. The coral reefs are mainly fringing and intermittent around all of the islands (Figure 1), and although certain areas appear to be coral-free on the map, e.g. the northern and southern coasts of Guadalcanal, even those coastal tracts usually support a narrow fringing zone of corals on the steeply sloping seabed. The only areas devoid of corals are on sandy beaches and near major river mouths.

Some of the largest areas of coral reef occur where there are large lagoon complexes variously protected by volcanic islands, raised islands, sand cays or by barrier reefs. Significant areas are:-

- around the Shortland Islands near Bougainville
- inside barrier reefs along the northeastern shore of Choiseul
- on either side of Manning Strait between Choiseul and Santa Isabel Islands, and extending along the southwestern shore of Santa Isabel
- in the Ghizo – Vonavona –lagoonal area on New Georgia’s southern shore
- encircling Vangunu in southeastern New Georgia and along the northeastern coast area past Ramata almost to Lever Harbour (Marovo Lagoon)
- in the north at Lau Lagoon and west at Langalanga Lagoon in Malaita
- in eastern Guadalcanal (Marau Sound).

Long submerged barrier reefs running for tens of kilometres, like the Great Sea Reef in Fiji, are rare in the Solomons; though there are smaller examples. These include:- reefs along the northeast coast of Choiseul; near Ghizo and near Munda in New Georgia; off Star Harbour in eastern Makira; northeast of the Russell Islands; across the entrance of Kangava Bay on the south coast of Rennell, and around Utupua Island in the easterly Santa Cruz Islands. In the Reef Islands, a line of four reefs stretches westwards for 21 km, while the Great Reef slightly further north is about 25 km long.

Atolls are relatively uncommon. The only large atoll is Ontong Java, a northern outlier. This atoll is about 70 km long and 11-36 km wide with a wide reef flat enclosing a lagoon of about 1400 km^2. Sikaiana Atoll (Stewart Islands), about 200 km northeast of Malaita, is a small triangular atoll about 10 km wide with a 45 m tall remnant of the original volcano. The surrounding reef drops steeply to great depths, so the band of coral is narrow. Far to the west in Bougainville Strait lies Oema Atoll. Rennell and Bellona are raised atolls with coastal cliffs and fringing reefs.

There are also several mid ocean reefs, infrequently visited, but covered with coral. These include Roncador and Bradley reefs lying south of Ontong Java, Indispensable Reefs south of Rennell, and several small shoals north of the Santa Cruz Islands.

Most of the 67 war ships and transports sunk during World War II lie in waters too deep for coral growth. The largest concentration of these wrecks is in Iron Bottom Sound between Guadalcanal and Savo Island. Some, transports, smaller vessels and aircraft that sank in lagoons and shallow waters are now important artificial reefs for corals. Many are in the western Solomon Islands near previous Japanese anchorages and harbours.

The importance of mangroves

Almost all the Islands in the Solomon Islands have mangroves. According to Oreihaka (1997), there are 26 species in 13 families, representing a total of 43% of the world's mangrove species. Mangroves occupy a total area of 52,500 ha (Solomon Islands National Forestry Inventory 1995). Besides growing in estuaries and protected shore, mangroves also grow on coral platforms, as seen for example in the Mboli or Siota Passage in Nggela (Florida Is.).

Mangroves probably play an important role in protecting coral reef biota, especially filter feeders like corals, by their ability to filter out and bind much of the sediment that comes down the rivers. This may be especially important in areas that have been logged. They are also an important component in the process of recycling nutrients within lagoons Although Milton *et al.* (1995) claimed very few coral reef fishes use mangroves as nursery areas, a few do, and some fish, including bait fish species, in search of food, migrate regularly between the two habitats.

Mangroves are very important to most Solomon Island communities as fishing grounds for crustaceans, molluscs and fish. Propagules of the mangrove *Bruiguiera gymnorhiza* are eaten as a vegetable in parts of Malaita and are sold routinely in the Honiara market.

Mangroves are an important habitat for bait-fish that normally migrate between lagoonal areas, especially coral heads within the lagoons, and mangroves. Although the bait-fish are not a major dietary component of coral reef fishes, they did comprise a quarter of the diet of nearly 30 predatory reef fishes whose stomach contents were examined by Blaber *et al.* (1990b).

Capturing bait-fish for the tuna pole and line industry provides employment for several Solomon Island villages. About 2000 tonnes of bait-fish were harvested in the Solomons in 1988 (Blaber and Copland 1990). So if the bait-fish stocks declined because of loss of mangrove habitat, then in addition to this loss of sustenance, there would be less opportunity for villagers to earn cash.

Simply put, if large areas of mangroves are destroyed for timber and firewood, as has occurred in Asia, then the ecological and economic ramifications will be detrimental to coral reefs. There will be increased sedimentation on the reefs and more pressure on harvesting reef-dwelling species to replace the declining mangrove fisheries.

Coral reef biota

Wells and Jenkins (1988) who provided a preliminary treatment of selected islands of the Solomon Islands along with coral reef types, and reviewed the coral reefs of these islands, concluded that very little scientific work has been done on the coral reefs of Solomon Islands. In her bibliography, Edridge (1985) listed just 14 publications on coral reefs and atolls – mainly geomorphological; but there are various taxonomic reports on reef biota.

The current status of coral reefs in the Solomon Islands is relatively unknown (Oreihaka 1997). According to the Solomon Island Fisheries Division, a complete inventory of coral reefs in the Solomon Islands is still to be made. This should include coral cover and a detailed study of taxonomy, ecology and the biology of both soft and hard corals and other non fisheries resources such as sponges.

Currently there are no published ecological descriptions of the subtidal zone of Solomon Islands reefs. Nor are there any popular photographic publications similar, for example, to Underwater Guide to New Caledonia (Laboute and Magnier 1979). Some general accounts of coral reef ecology in the Indo-Pacific are very useful however, because they describe different types of coral reef formation and list many of the species found in Solomon Islands. An excellent reference is the Indo-Pacifc Coral Reef Guide by Allen and Steene, published in 1994 and currently in its fifth edition (1999).

In addition to the collections made by early explorers, the Californian Academy of Sciences expedition to western Polynesia and Melanesia in 1933 led by led by Charles Templeton Crocker, resulted in short reports on seaweeds (Setchell 1935); fishes (Seale 1935); and reptiles and amphibians including a new sea snake (Slevin 1934).

Some information on the marine flora and fauna resulted from the voyage of the Danish oceanographic research vessel *Galathea* from 1950-52, when a group of scientists led by Torben Wolff, spent a month on Rennell Island in 1951 (Wolff 1952). Shortly afterwards, in 1953, Rennell and Bellona were explored by scientists from the British Museum of Natural History. Then in August-September 1962 another scientific party, again directed by Wolff, re-visited Rennell Island during the Danish *Noona Dan* expedition 1961- 62 (Wolff 1963). Most of the results of these three expeditions were edited by Wolff, and published by the Danish Science Press in seven volumes (Wolff 1958-1976).

Much of what we know about the coral reefs of the Solomon Islands resulted from a British Royal Society expedition in 1965 organised and led by E.J.H. Corner. This expedition, including scientists from Britain, Australia and New Zealand, aimed at examining the biogeographical relationships between the Solomon Islands and other island systems in the western tropical Pacific (Womersley and Bailey 1969, p.433). Professor John Morton lead the marine group of the Expedition which studied coral coasts of the southern Solomon Islands in the period June to December 1965.

The group's main study areas (listed northwest to southeast) were: Ghizo and Rendova Islands in western New Georgia; the entire Marovo Lagoon from Nggatokae in the south to Lever Harbour at the northeastern end; the Russell Islands; the eastern part of the Florida Islands; northwestern Guadalcanal from Honiara to Lambi beyond Cape Espérance; the Marau Sound area of southeastern Guadalcanal and the Kirakira area on the northern shore of San Cristobal Island, or Makira as it is now commonly called. For a list and map showing the main study areas of Morton's marine party see Stoddart (1969a Fig. 48 and p. 357).

A discussion of the geological and biological observations, some of them preliminary, filled most of Volume 255 (pages 187-548) of the Philosophical Transactions of the Royal Society of London B. The papers comprising the marine biology section were about: coral reefs and sand cays (Stoddart, 1969a-c); marine algae (Womersley and Bailey, 1969, 1970); polychaetes (Gibbs, 1969); opithisthobranch molluscs (Challis,1969a and Miller 1969); the interstitial fauna of a sandy beach (Challis 1969b) and the biomorphology and zonation of Solomon Island shores (Morton and Challis, 1969).

Morton and Challis (ibid) described the appearance and composition or "biomorphology" of Solomon Islands coral reefs, at least in the intertidal zone, which they compared with W.A. Stevenson's "universal scheme" of intertidal zonation (Morton 1974, 1990 and Morton and Challis 1969).

Stoddart and Morton and Challis remarked that the coral reefs of the Solomons were less spectacular than reefs they had seen elsewhere. "Those experienced in coral reef ecology by common consent remark that the Solomon Islands reefs lack the luxuriance of those in other parts of the Pacific, in particular the rich Great Barrier Reef and the widespread atoll and small island formations" (Morton and Challis 1969:483). Stoddart (1969a) concluded that the poverty of modern coral growth was attributable to the fact that most of the coastlines are recently elevated with steep and often vertical gradients that few corals are able to colonise. Leary (1993) remarked that this conclusion probably reflected the sites that the Royal Society Expedition visited, and did not necessarily reflect the whole of Solomon Islands.

Weber was of a similar view and stated …"The paucity of reef development and the widespread mortality of corals in shallow water environments should not, however, be misconstrued to indicate either the absence of a thriving coral reef fauna or an attenuation of reef coral diversity. The coral collections reported on here demonstrate that virtually all the Indo-Pacific hermatypic scleractinians are present in the area, and the Solomon Islands region ranks near the top in terms of worldwide reef coral generic diversity" (Weber 1973: 397).

Although some observations using scuba were made on the Royal Society's expedition (see Stoddart 1969b: Section 5.2, p.397 "Observations of submerged levels at Matiu Island"), scuba was apparently little used as a survey tool for marine biologists on the expedition. Since then, however, routine use of scuba for biological surveys has revealed the coral reefs of the Solomon Islands to be some of the richest in terms of species (Maragos 1998). Solomon Islands coral reefs are included with some of the world's best dive sites.

During the Royal Society Expedition, corals along the sublittoral fringe (at and just below the low tide mark) at several localities, e.g. near Honiara and Tete Island in the Sandfly Passage of the Florida Group, were found to be recently dead. Morton and Challis (p. 483) described the prevailing colours of the corals as grey or dull khaki brown and how at some places, during midday low spring tides, there was a slight pervasive odour of dead or moribund corals. They speculated that the combined effects of high illumination and air temperatures during unusually low tides or high rainfall might have caused the corals to die.

Their description of the dead and dying corals is, however, very similar to the phenomenon now called coral bleaching (described below under "natural threats") that coincides with higher than usual sea surface temperatures (29-32oC). Because the highest seasurface temperatures in the Solomon Islands typically occur in the last and first quarters of the year, the corals that Morton and Challis described may well have become bleached several months before the Expedition arrived in June 1965. By that time the corals would have been coated with an epiphytic brown algal scum, and they would have probably been decomposing.

Taxonomic studies

Flora

Algae play some very important role in coral reefs, especially as primary producers, in cementing coral reefs and as shade for coral benthos during sunny weather (Wilkinson and Buddemeier 1994). This important role by the algae is often overlooked by many coral reef scientists. Descriptions of littoral (rockpool) diatoms were provided by Foged (1957). Setchell (1935) listed nine seaweeds from Malaita, and several taxa from Sikiana Island and from Bellona. Levring (1960) identified algae collected from Rennell Island. Womersley and Baily (1970) recorded a total of 233 species of algae from Solomon Islands comprising: 14 Cyanophyta, 121 Rhodophyta, 27 Phaeophyta and 71 Chlorophyta. They described the Solomon Islands flora as not very diverse with a low seaweed diversity compared to other places. There has not, however, been any comprehensive collection of marine algae from the Solomon Islands using scuba; in particular crustose coralline species are yet to be investigated.

Seagrass beds, that are typically inshore of coral reefs, play an important role in binding sediments and reducing surface erosion. They are also a source of food for reef-dwelling animals including turtles and dugongs (Oreihaka 1997, Leary 1993). Womersly and Bailey (1970) reported 7 species of seagrass for Solomon Islands including *Cymdocea sp.*, *Halodule sp.*, *Halophila sp.*, *Syringodium sp.* and *Enhalus sp.* which are common. No detailed survey of sea grasses in the Solomon Islands has been undertaken, so additional genera and species are to be expected.

Fauna

Fishes

The Templeton Crocker Expedition collected 36 marine fishes on Rennell, 20 on Bellona and three on both islands. The Danish expedition to Rennell added another 19 that were described in some detail by Rofen (1958). Wolff (1969) noted that Rennell Islanders recognised about 200 species from pictures in T.C. Marshall’s Fishes of the Great Barrier Reef (1964). Numerous expeditions to the Solomon Islands that collected fish are listed by Munro (1967) in Fishes of New Guinea, and by Wolff (1969). ICLARM FishBase’97 also have the list of currently known fish species in the Solomon Islands, which also includes the reef fish species of the Solomon Islands.

A joint survey of the fish of Santa Cruz in Temotu Province was undertaken by: The Australian Museum, Smithsonian Institution, Field Museum of Natural History, Milwaukee Public Museum and Solomon Islands’ Fisheries Division in 1998. The survey recorded 725 species, many being from coral reefs. A preliminary examination of the collection turned up ten new species, and the likelihood of several other new species (McGrouther 1999).

Currently a comprehensive checklist (not illustrated) of fishes from Solomon Islands and Bouganville by Johnson Seeto nears completion. A 1998 draft by Seeto (johnson.seeto@usp.ac.fj) lists over two thousand species of marine and freshwater species.

Many fishes of Solomon Islands reefs are cosmopolitan within the Indo-Pacific region and thus appear in regional descriptive accounts. In most cases, however, the distributions are too general or vague to isolate those species found in the Solomon Islands. One exception, that maps species distributions, is Guide to Angelfishes and Butterflyfishes by Allen *et al.* (1998).

For the non-specialist to identify Solomon Island reef fishes it is therefore necessary to accumulate and carry a small library including publications such as: Allen 1975; Coleman 1981; Amesbury and Myers 1982; Fautin and Allen 1992; Lieske and Myers 1994; Randall, Allen and Steene 1997; Randall 1998 and Myers 1999.

Invertebrates

Many common invertebrates were named and illustrated in the publications by Morton listed above and in Morton and Challis (1969). Otherwise there are very few publications that deal specifically with invertebrate taxa from the Solomon Islands. Abbott (1957) listed 118 molluscs collected on the

Danish and British visits to Rennell. There are the papers on polychaetes and opithsobranch molluscs resulting from the 1965 Royal Society expedition mentioned above. Bergquist *et al.* (1971) provided a description of 31 sponges collected on the Expedition and described major sponge habitats; Weber (1973) a description of the genetic diversity of scleractinian reef corals. McElroy (1973) identified 15 species of holothurian (sea cucumber) in the shallow waters of Ontong Java lagoon in the northern Solomon Islands. Holland (1994) reported 18 species, that are commercially harvested in the Solomon Islands.

Guille *et al.* (1986) describing the sea urchins and related echinoderms of New Caledonia lagoon and Lévi (1998) on New Caledonian sponges are useful references for identifying these phyla in Solomon Islands waters.

Many conspicuous Solomon Islands invertebrates can be identified using Gosliner *et al.* (1996) who provided a well illustrated account of coral and coral reef animals of the Indo-Pacific region. The Solomon Islands is listed as a locality for about 280 species. Veron (1986:630) also provides distribution maps of various coral species in Australia and the Indo-Pacific. According to Veron (1986) there are about 60 genera of hermatypic (reef-forming) corals in the Solomon Islands.

There is scant information on Solomon Islands mollusca. The Solomon Islands Museum Association published a first volume booklet on marine shells of the Solomons, but only on cowries (Kenworthy 1972). It is, however, possible to identify almost all Solomon Islands seashells from publications illustrating shells from around the world. A useful general reference is Abbott and Dance (1990). Cone shells may be identified from Röckel *et al.* (1995); cowries and cone shells from Lorenz and Hubert (1993) and nudibranchs and sea snails from Debelius (1996).

Although there are numerous crustaceans in Solomon Islands, little research or assessment has been done on this group.

Coral reef fisheries

Size of the fishery

The export of inshore fisheries resources harvested from reefs and lagoons, excluding any tuna, has earned the Solomon Islands between ten and twelve million Solomon Dollars each year for the last three years (ca $US 2-2.4 million pa at Jan 1999 exchange rate). The quantities and values of the main species harvested are listed in Table 1. In 1998 the total exports (FOB) from the Solomon Islands were estimated to be $US 141 million (World Bank website source), so the value of the inshore fishery (i.e. excluding the lucrative tuna industry) is in the order of 1-2%.

The annual domestic consumption of coral reef and lagoon species is variously estimated at 10-14,000 tonnes. It is difficult to put a dollar value on this domestic consumption, some of which is traded and sold in local markets and much of which is eaten directly by the fisherfolk and their families. But if we value the domestic catch in terms of the same volume of tinned tuna that might be consumed locally in the absence of fresh fish, then the domestic market is probably worth at least as much as the export earnings.

About half ($SBD 5.8 million) of the inshore fishery export earnings are derived from the sale of Trochus and trochus-like gastropods. The export of sea cucumbers processed as bêche-de-mer earns $SBD1.9 million, sharkfins $SBD 1.6 million, live reef fish $SBD 1.3 million and spiny lobsters $SBD 0.63 million. Currently very little reef fish are exported chilled or as fillets.

Products		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Green snail	Kg	22,345	5,090	4,927	7,441	4,476	3,903	3,138	3,620	3,332	1,971	614	942	0	0	0	0	2
	SI$	49,952	12,335	20,177	27,869	38,528	80,336	124,088	122,685	185,951	110,990	35,955	73,372	0	0	0	0	50
Trochus shell	Kg	405,020	468,700	499,903	662,346	445,216	460,065	371,693	306,569	87,475	50,890	24,090	66,516	0	5,490	113,287	31,922	181,200
	SI$	323,442	533,967	768,232	1008,911	2,045,169	3,814,538	4,541,445	5,466,707	1,444,601	751,829	347,996	1,165,862	0	385,640	2,027,850	919,360	3,144,525
Blanks for buttons	Kg	0	0	0	0	0	0	0	0	0	54,075	74,535	137,494	80,405	36,338	42,520	22,981	59,490
(Trochus niloticus)	SI$	0	0	0	0	0	0	0	0	0	3,291,625	3,547,458	3,886,364	2,290,000	2,484,488	3,767,008	2,562,702	2,681,766
Black lip oyster	Kg	15,156	42,376	14,903	31,157	28,301	23,502	31,226	31,432	43,666	27,948.0	26,007	300	0	0	0	0	0
(Pinctada																		
margaritifera)	SI$	10,629	67,950	26,322	63,479	186,472	251,233	416,264	546,536	629,914	424,737	456,288	3,332	0	0	0	0	0
Brown lip oyster	Kg	2,270	3,570	2,400	6,520	4,887	6,103	11,537	1,922	11,479	0	0	0	0	0	0	1,000	0
(Pteria. Penguin)	SI$	1,617	3,523	4,032	10,965	13,042	27,480	68,461	13,239	93,134	0	0	0	0	0	0	9,671	0
Gold lip oyster	Kg	3,373	3,879	0	0	5,974	9,300	21,826	25,662	13,871	4,800	1,196	0	0	0	0	0	0
(Pinctada. Maxima)	SI$	2,226	11,993	0	0	54,714	88,262	234,672	273,318	250,124	54,491	19,856	0	0	0	0	0	0
Clam shell	Kg	10,244	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0
	SI$	68,826	0	0	80	0	0	0	0	0	0	0	0	0	0	0	0	0
Tabu shell	Kg	0	0	0	0	0	0	0	0	0	0	3,412	3,286	0	12,100	0	0	0
(*Nassarius sp.*)	SI$	0	0	0	0	0	0	0	0	0	0	40,391	39,769	0	283,332	0	0	0
Shell ornaments	Kg		0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,493	117
	SI$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55,742	0
Other molluscs	Kg	9,351	54,421	4,996	21,485	10,566	10,031	10,997	2,785	18,302	6,745	0	0	219,997	99,082	264,976	34	65 plus 2,760 pices
	SI$	73,572	66,871	56,803	106,348	142,429	147,304	116,161	34,523	112,746	134,717	0	0	2,405,639	1,840,612	2,111,342	150	5,787
Turtle shell	Kg	0	1,318	0	1,841	2,432	1,975	3,099	2,854	1,528	1,263	0	0	0	0	0	0	0
	SI$	0	24,561	0	44,198	168,104	232,273	508,802	719,250	542,250	491,170	0	0	0	0	0	0	0
Crayfish	Kg	0	0	0	0	0	0	0	0	0	0	0	0	22,894	2,902	0	18,213	13,312
	SI$	0	0	0	0	0	0	0	0	0	0	0	0	643,491	215,301	0	134,147	638,943
Prawns (farmed)	Kg	0	0	0	0	0	0	0	0	0	0	5,330	404	0	0	0	37,887	16,251
	SI$	0	0	0	0	0	0	0		0	0	45,726	15,648	0	0	0	1,031,436	420,660
Other crustaceans	Kg	0	0	0	0	0	0	0	0	0	0	0	0	0	18,128	11,376	0	20
	SI$		0	0	0	0	0	0		0	0	0	0	0	429,043	274,795	0	0

Bêche-de-mer	Kg	9,259	44,291	13,616	134,184	146,376	146,958	87,095	118,896	622,385	715,414	316,388	284,630	219,339	113,090	202,860	227,020	106,753
	SI$	51,755	251,872	74,880	733,793	939,533	1,469,117	721,236	1,880,957	7,631,952	10,227,486	3,161,069	2,577,134	1,732,575	1,260,332	2,413,086	4,034,809	1,897,501
Shark fin	Kg	N/A	N/A	N/A	N/A	4,456	2,073	4,931	1,923	3,073	6,678	3,972	2,283	201,738	0	0	19,630	14,001
	SI$	N/A	N/A	N/A	N/A	134,842	102,799	144,865	84,319	265,596	1,121,931	629,592	252,068	1,068,746	0	0	1,469,796	1,595,487
Shark meat	Kg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	203,086	26,855
	SI$	0	0	0	0	0	0	0	0	0	0	0	0		0	0	215,694	13,878
Crocodile skin	Kg	0	N/A	0	N/A	6,445	820	7,452	844	0	0	0	0	0	N/A	0	0	0
	SI$	0	14,516	0	10,873	32,093	99,852	187,438	17,246	0	0	0	0	0	563,160	0	0	0
Reef fish1	Kg	0	0	0	0	0	0	0	0	0	0	0	0	143,000	85,573	0	0	260
	SI$	0	0	0		0	0	0	0	0	0	0	0	N/A	481,013	0	0	N/A
Live fish	Kg	0	0	0	0	0	0	0	0	0	0	0	0	0	31,830	43,518	54,463	129,810
	SI$	0	0	0	0	0	0	0	0	0	0	0	0	0	318,300	435,180	544,630	1,298,100
Aquarium fish	Pcs	0	0	0	0	0	0	0	0	0	0	0	0	0	84,935	3,606	58188	80,039
	SI$	0		0	0	0	0		0	0	0	0	0	0	221,001	10,818	174,098	239,721
Coral	Pcs	0	0	0	0	0	0	0	0	0	0	0	0	0	175,203	2,467	84,755	58,181
	SI$	0	0	0	0	0	0	0	0	0	0	0	0	0	587,584	289,970	203,628	211,785
Aquarium invertebrates[2]	Pcs	0	0	0	0	0	0	0	0	0	0	0	0	0	37,826	5,396	13,944	15,211
	SI$	0	0	0	0	0	0	0	0	0	0	0	0	0	176,917	13,2500	126,852	98,041
TOTAL	SI$	582,019	987,588	950,446	2006,516	3,754,926	6,313,194	7,063,432	9,158,780	11,069,712	11,069,712	8,284,331	8,013,549	8,024,812	9,811,750	11,343,299	11,482,715	12,246,244

Source: Statistics Office and Fisheries Division, Solomon Island Government. The weights of live fish exported for 1996-1999 are from Johannes (1999).

Table 1
Marine exports from the Solomon Islands, 1983-1999 (excluding tuna)

Notes for Table 1
N/A means 'not available'.
[1] There is no reliable value for exports of reef fish in 1995 and 1999.
[2] Includes hatchery produced clams exported through the aquarium trade; mainly molluscs Tabu shell is exported to Papua New Guinea where it is used as shell money. Aquarium fish, corals and assorted invertebrates are exported in number of pieces and not kilograms. Assorted invertebrates were exported for aquaria; they were mainly molluscs. Exchange rate: Solomon Island dollar (SI$) per US$1: 4.9334 (Jan. 1999); 4.8156 (1998); 3.5664 (1997). 3.4059 (1995) and 3.2914 (1994).

Setting the sharkfin industry aside, because that is mainly a bycatch of purse-seining for tuna, the two biggest earners are trochus and sea cucumbers – both showing clear signs of overfishing. When these fisheries falter, as they most certainly will at the current rate of extraction and without any effective harvest controls, then if export earnings are to be maintained, the emphasis will inevitably shift to reef-dwelling fin fish. Already some of the more popular finfish species, e.g. the cods and groupers, are overfished in some areas.

If the Solomon Islands is looking for new opportunities for generating export earnings, then inshore fishery resources are unlikely to fill that bill. The existing fishery is mainly based on species already being overfished, while a rapidly growing rural population is likely to make increasing demands on the resources of reefs and lagoons for domestic consumption.

Echinoderms

Sea cucumber for bêche-de-mer

From the earliest days, the traders encouraged Solomon Islanders to hunt various reef dwelling species such as turtles, pearl oysters (for their shell) and sea cucumbers (for bêche-de-mer). As early as 1845 the Sikaiana People were curing tons of bêche-de-mer to offer the trader Andrew Cheyne. During the late 1870's and early 1880's, up to 90 ton of Solomon Island bêche-de-mer was landed in Sydney per year (Bennett 1987). Bêche-de-mer is a Chinese delicacy, not quite a luxury food but sought after for flavouring soups and for its homeopathic, medicinal and aphrodisiac properties (Adams *et al.*, *in* 1992).

Today, sea cucumber, is one of the most important commercial commodities in Solomon Islands. The sea cucumber catch peaked in 1992 with 715 Mt but averaged around 200 Mt since then (see table 1). The catch trend over the last decade indicates a declining resource. For a summary of sea cucumber biology and the South Pacific bêche-de-mer fishery, see Preston (1993). Adams *et al.* (1992) and Skewes (1990) provide summaries of the Solomon Island fishery.

During the 1960's and 1970's the main species exported from the Solomon Islands were the black teatfish (*Holothuria nobilis*), white teatfish (*H. fuscogilva*), and blackfish (*Actinopyga miliaris*). In the 1990's, during something of a boom in the bêche-de-mer industry, the Solomon Islands along with other Melanesian countries started fishing a much wider range of species, the prices of which ranged from $SBD 1.60 - 40.00 per kg.

In 1991 in Temotu Province, for example, the four main species in terms of quantity were: tiger fish, *Bohadschia argus* (27%) @ $SBD 5.00 per kg; brown sandfish, *Bohadschia marmorata vitiensis* (18%) @ $SBD 3.30 per kg; lollyfish, *Holothuria atra* (18%)@ $SBD 1.60 per kg, and greenfish, *Sticopus chloronotus* (9%) @ $SBD 10.00 per kg. In 1992 a Western Province buyer bought 23 species of sea cucumber in which tigerfish, lolly fish and white teatfish, in approximately equal amounts, comprised 30% of the quantitiy and the most valuable species were white teatfish (29% of total value) and black teatfish (9%) (Adams *et al.* 1992)

Adams *et al.* (1992) made some pertinent comments on the economics of the bêche-de-mer fishery that are worth repeating.

1. It is often not appreciated that the exported item is dried to about 10% of its original wet weight. The exported tonnages should therefore be multiplied by ten to provide a live weight. Thus the 715 Mt exported in 1992 equates to over 7,000 Mt of live sea cucumbers which is a very significant fishery.

2. The bêche-de-mer fishery had increased dramatically in value, and in 1992 was second only to tuna in terms of overseas earnings. But whereas the tuna catch was sustainable at the 1992 catch rate, the bêche-de-mer catch wasn't – prophetic words given the decline in the bêche-de-mer exports since 1992.

3. The whole process of bêche-de-mer preparation from capture to grading and packaging is quite within the range of the local people and needs no injection of foreign capital.

4. The extremely diffuse, village level nature of the bêche-de-mer fishery means that the financial benefits are widely distributed amongst coastal villages with immediate and direct financial benefit.

A problem in managing the bêche-de-mer fishery is the multispecific nature of the fishery. The catch data are usually lumped; yet each species has its own habitat and ecological preferences. Lokani *et al.* (1996) reported that a common problem among all bêche-de-mer fisheries was the lack of management and overfishing particularly using scuba and hookah equipment. It is suspected that there could be local depletion of the resource in some parts of the country. In Ontong Java for example, the stock has dropped dramatically and as result, local communities enforce closed seasons (every 2 years). They later amended this ban to allow harvest of both sea cucumber and trochus (*Trochus niloticus*) for just one month every year. Probably the simplest and most effective regulation to conserve the species would be to enforce a ban on the use of scuba and hookah equipment as is the case in Fiji. This was strongly recommended by Adams *et al.* In 1992, and although there is technically now a ban in the Solomon Islands, the regulations have yet to pass into law.

The Solomon Islands Fisheries Division is currently supporting the International Centre for Living Aquatic Resources Management (ICLARM), the Australian Centre for International Agricultural Research (ACIAR) and overseas consultants in a research project to assess the potential for restocking and stock enhancement to manage tropical sea cucumber fisheries. Studies are underway into the reproduction of three important species; sandfish (*Holothuria scabra*), surf redfish (*Actinopyga mauritiana*) and white teatfish (*H. fuscogilva*). Studies show that it is possible to spawn and rear these species in the laboratory before reseeding the reefs (Ramofafia 2000).

As well as sea cucumbers, many people throughout Solomon Islands eat sea urchin species. *Tripneuster gratilla* is perhaps the most commonly eaten species.

Molluscs

Giant clams

The six giant clam species, *Tridacna gigas*, *T.derasa*, *T. squamosa*, *T. crocea*, *T. maxima and Hippopus hippopus*, found in the Solomon Islands have been exploited mainly for food at a subsistence level. Commercial harvesting of this resource, mainly for its meaty adductor muscle, developed in the 1970's and 1980's, however, because of the high value and demand for the product. The fishery reached its peak in 1983 when 10.2 tonnes of adductor meat were exported.

When harvested for their adductor muscles, the rest of the animal is usually wasted. In the case of the larger animals, divers cut out the adductor on the seabed to avoid bringing the heavy shells to the surface. There are reports of the mantles and viscera simply being cast into the sea. Considering that the adductor muscle barely comprises 10% of the wet flesh weight of the clam, and individual adductors typically weigh just a few hundred grams, any export of several tonnes represent harvesting tens of thousands of giant clams.

Giant clam exports dropped to just 60 kg in 1986; perhaps indicative of the heavy exploitation of the stocks. Asian fishing vessels poaching clams in isolated locations were a problem. In the 1980's, the Solomon Islands Government apprehended a Taiwanese vessel that had been poaching clams on the isolated Indispensable Reefs. The vessel had ten tonnes of frozen adductors on board (information from Fisheries Division). In 1996 a Honiara-based company, Hai Way International, had a cargo of giant clam adductors confiscated at Henderson Airport when customs officers became suspicious that cartons labelled “bêche-de-mer” actually contained frozen adductors. The cargo amounting to about one tonne was incinerated.

Export of clams or clam products is now prohibited under fisheries regulation except clams that come from registered farms or a hatchery. Because of their relatively small size, hatchery-reared clams are popular with the aquarium trade. For about ten years clams have been bred and raised in hatcheries at the former ICLARM Coastal Aquaculture Centre at Aruligo near Honiara; the objective being to supply farmers with small clams that can be on-grown for the aquarium trade and to restock depleted reefs. A locally owned clam hatchery and nursery (Paruru Aquaculture), also designed to supply local farmers with juvenile clams, is under construction in Marau Sound.

Unfortunately both the ICLARM operation at Aruligo and the initiative at Marau have been compromised by the current violence on Guadalcanal, though there are proposals to enlarge ICLARM’s smaller field station on the island of Nusatupe near Ghizo. The Marau Sound facility is not operating at present.

Pearl oysters

Pearl oyster shells were one of the earliest important export commodities of Solomon Islands. We don’t know the export tonnages in the early days; but given that up to 40 tons of Solomon Islands pearl oyster shell was landed per year in Sydney during the 1880’s (Bennett 1987), the quantities must have been very high. The shells were, and still are mainly used to manufacture buttons and jewellery.

In recent times the Solomon Islands pearl oyster fishery peaked in 1991 with an export of 69 Mt earning the country about $SBD 1 million. Blacklip (*Pinctada margaritifera*), goldlip (*P. maxima*) and brownlip (*Pteria penguin*) and are the most commercially important species in the Solomon Islands. The blacklip oyster made up almost 70% of the 1991 export. Blacklip and gold lip oysters, the largest species in the genus, have thick , nacreous, mother-of-pearl, shells much used for manufacturing buttons.

In 1993 Sims noted that annual pearl shell production from the South Pacific was worth $US1million, and that the value of pearl shell had greatly increased in the previous decade. Skewes (1990) described how the value of black-lip shell from Solomon Islands increased from $US 741 per tonne in 1981 to $US 5,531 per tonne in 1989.

According to Philipson (1989), expanded production of button blanks within the South Pacific region could double the value of shell exports as most shell was (then) exported unprocessed. There is some potential for exporting dried pearl oyster meat for the Asian market (Sims 1993).

Stock assessment surveys have been carried out in Kia and Waghena areas in Isabel and Choiseul Provinces, and in the Florida Islands (Batty and Kile 1990). An average of 28 goldlip shells per hectare was found in the Kia area although in places the density was as high as 600 shells per hectare. It was concluded, however, that the quantity available would not support even a small pearl culture operation. Stocks were over-exploited in the Waghena area. As a management initiative to conserve pearl oysters, an indefinite ban on exporting pearl oysters was established in 1992. Farmed oysters are excluded from the ban.

A joint Solomon Island Fisheries Division and ICLARM project has shown pearl oyster farming to produce pearls and using wild spat is viable. A demonstration farm, producing black pearls from the blacklip oyster, has been established at Nusatupe, near Ghizo. Pearls were first harvested from this farm in May 1999, and the shells have been re-implanted to produce a second crop of pearls.

Greensnails

The main species of turban shells (fam. Turbinidae) harvested in the South Pacific are the green snail (*Turbo marmoratus*); the rough turban (*T. setosus*) and the silver-mouth turban (*T. argyrostomus*). The last two are mainly targeted for food and their shells usually discarded. *Turbo marmoratus*, the largest species with shells up to 20 cm in diameter and weighing 2 kg, has a nacreous shell highly prized for inlay work, lacquerware, jewellery and for buttons. The green snail is not an abundant resource in the South Pacific. Despite its scarcity, the demand for the pearl shell is such that the animal continues to command a premium price, making searching for this species worthwhile for fisherfolk (Yamaguchi 1993).

The export tonnages of green snail shell exported from the Solomon Islands and the unit value for the period 1970 to 1989 was graphed by Yamaguchi (1993, fig.2). The graphs are the inverse of one another. Exports declined from a peak of nearly 60 tonnes in the early 70's to less than 5 tonnes in 1989. In 1993 less than one tonne was exported. The unit value increased from less than one US dollar per kg in 1981 to about $US40 per kg in 1989. This is a clear example of a boom-and-bust fishery of a reef-dwelling species that takes three to four years to attain sexual maturity, at which stage it is probably close to the minimum size likely to be harvested for its shell (15 cm diameter).

In order to protect green snail resources, the Solomon Islands and other South Pacific nations, urgently need to assess current fishing (and it is difficult to estimate the weight of shell being harvested from increasing exports of cut shell) and legislation to protect remaining stocks. Minimum and maximum size limits and establishing marine reserves might protect remaining brood stock (Yamaguchi 1993).

Although no quantitative assessment has been done to determine the status of the Solomon Islands greensnail population, based on anecdotal reports and fisheries export data they are clearly much depleted throughout the Solomon Islands. The Overseas Fishery Co-operation Foundation (OFCF) of Japan in collaboration with Fisheries Division set up the "Atoll Project" at the Aruligo Coastal Aquaculture Centre to breed this important species with an aim of restocking depleted reefs. Efforts to collect brood stock from areas where greensnail used to be abundant were not as successful as anticipated partly because of difficulties in finding enough snails, and because of difficulties in getting the animals to spawn. This project is currently in limbo because of the closure of the research station at Aruligo and funding uncertainties. The brood stock at Aruligo was purportedly eaten.

Currently there are no specific regulations on taking greensnail for food or for export. Although there are no export restrictions, there are no records of any exports since 1995. In support of the OFCF/Fisheries Division Atoll Project to rejuvenate the resource, the Solomon Islands Fisheries Division has recommended that a total ban should be imposed on harvesting this resource. That recommendation has yet to be considered by government.

Trochus

Of the few *Trochus* and trochus-like species present in the Solomon Islands, collectively called "trochus" in this report, *Trochus niloticus* is the most important. Harvested since time immemorial as a subsistence food, commercial harvests, mainly for manufacturing buttons, began in the early 20th Century. Shortly after commercial harvesting commenced, it became apparent that trochus was all too easily overfished. The Pacific trochus fishery declined in the 1950's when garment manufacturers shifted from shell to plastic buttons; but the fishery revived in the 1970's when shell buttons became fashionable on high quality shirts (Nash 1993).

In the 1980's and early 1990's this species was the most important non-finfish resource in Solomon Islands in terms of export earning. Since the peak export of 660 tonnes in 1986, catches have declined. Trochus are harvested mostly by subsistence fishermen for food, and only the shells are exported. A feasibility survey carried out in 1988 recommended establishing button manufacturing processing plants. Two button blank processing factories established by the early 1990's produced 137 tonnes of button blanks in 1994. Currently one button blank processing factory is operational. As Adams *et al.* (1992) pointed out, if there is substantial fixed investment in button blank machines and factories, then it is vital that the stocks of trochus be managed to ensure a continuous supply.

Despite clear signs of overfishing there is no assessment of trochus stocks, no measure of fishing effort and scant information on catch (Skewes 1990). Some enhancement of the over-exploited reefs in the country is intended under the OFCF/Fisheries Division Atoll project. A reseeding trial at Alokan, Russell Islands, by Toru Komatsu of OFCF was successful and promising.

The only management measure to conserve trochus is a regulation that prohibits taking trochus smaller than 8 cm and larger than 12 cm when measured across the basal diameter. Growth rate studies of *T. niloticus* suggests that the snails live 10-5 years and possibly longer (Smith 1987 cited in Nash 1993). As with the bêche-de-mer fishery, probably the best regulation to conserve stocks would be to strongly enforce a ban all commercial harvesting using scuba or hookah equipment. On should be added between the words ban and all.

Other molluscs

Several other molluscs are important for food or culturally. Langalanga people produce shell money and shell money necklaces from four species of shells – romu (*Chama pacifica*), ke'e (*Beguina semiorbiculata*), kakandu (*Anadara granosa*) and kurila (*Atrina vexillum*). Some are becoming scarce as a result of this practice.

Subsistence fishers harvest gastropods like turban shell (*Turbo chrysostomus*), polished nerite (*Nerita polita*), false trochus (*Tectus pyramis*), cowry (*Cypraea tigis*); bivalves such as mangrove oyster (*Crassostrea mordax*), venus shell (*Gafrarium tumidum*) and mangrove mussel (*Modiolus agripetus*); chitons (*Acanthozostera gemmcita*) and cephalopods for food (squid and octopus) and shell (*Nautilus*).

There is a small souvenir shell trade where tourists buy a wide variety of shells in some retail outlets in Honiara and at the market. In general, tourist resorts, particularly those encouraging scuba diving, discourage such trade on their premises. Some of the rarest species such as the golden cowrie (*Cyprae aurentium*) command several hundred dollars each. In Honiara vendors travel door to door selling golden cowrie shells to collectors and entrepreneurs. If the tourist trade was larger, and if cruise ships were still making regular visits, then this shell souvenir industry in Solomon Islands would be much larger.

Crustaceans

Locally various crabs and shrimps and the slipper lobster (*Parribacus caledonicus*) are an important protein source.

Crayfish/lobster

Panulirus pencillatus is the most commonly caught rock lobster of the several *Panulirid* lobster species found on the coral reefs Solomon Islands. Other lesser frequently caught species are *P. versicolor*, *P. femoristriga* and *P. ornatus*.

Before 1973, some short-lived lobster fishing operations had failed because of variable catches and mechanical problems. In 1990 Skewes reported there to be good numbers of lobster on the weather coasts of Makira and Guadalcanal, and in the Russell Islands and Western Province. Several larger operations established in 1995 failed within about a year for the same reasons as the earlier ventures. Almost 23 tonnes of spiny lobsters were exported in 1995. Since this was more than 10 times the sustainable annual catch estimated by Skewes, the crayfish stocks were probably being over-fished (Skewes 1990). Small-scale operators continue to buy and export lobsters despite a rapidly declining resource.

Fisheries regulations prohibit catching, trading or exporting crayfish of the genus *Panulirus* with eggs, whose eggs have been "scrubbed" or whose carapace length is less than 8 cm.

Other marine invertebrates

Corals

Corals are exported from the Solomon Islands for the aquarium trade. This is a relatively new industry in which two companies (Aquarium Arts and SI Marine Exports) are involved. Between 1996 and 1999, nearly 210 thousand "pieces" of marine life were exported. Many of these were live corals, representing 1% of the global trade in coral (Green and Shirley 1999). Eighty six percent (86%) were from Nggela, in the Florida Islands, 13% from east Guadalcanal and 2-3% come from the Western Province (Aquarium arts pers.comm).

Villagers in Nggela complain that the extraction of corals and coral organisms (including the juveniles of important fish species), especially the Sand Fly region, are depleting the reefs (Solomon Star 10 November 1999, p. 8-9). Almost all of the corals around the bird sanctuary island of Mandoleana (SE Florida Is.) have been damaged by harvesting of corals, fish or other species mainly for the aquarium trade (Tavasi pers.comm.). Considering that Solomon Islands contributes 1% of the global trade in corals and 86% of this were from Nggela, the pressure on the coral reefs of Nggela is that of concern.

It is possible to culture coral fragments in the sea until they attain the desired size and shape. In this regard, ICLARM has been conducting trials in the Marau Sound area.

Other invertebrates

The palolo worm, caught during its spawning season usually in October, is an important seasonal food especially in Nggela.

Various Solomon Islands invertebrates probably contain biologically active compounds of great interest to international pharmaceutical industries. Although there is interest in "bioprospecting" Solomon Islands reefs to take samples of a wide range of organisms to see which species may be likely contenders, the only bioprospecting to date was undertaken by Professor Phil Crews and his team from Santa Cruz University, USA in 1992. They were mainly interested in sponges.

The status of these other invertebrate resources are poorly known as no research or resource assessment survey has been done on any of them.

Finfish

Reef fish are harvested both for subsistence and for export. In terms of tonnage, the exploitation of finfish from coral reefs and lagoons is relatively small compared with the huge deep sea fishery based mainly on tuna. Export data for these species is, however, poorly differentiated in national fisheries statistics.

Fishing methods

The export industry is divided into the export of chilled or frozen fish and the export of live fish for food and for the aquarium trade. There is also a small bait-fishing industry (mentioned above) to supply bait for the tuna fishery.

According to Oreihaka and Ramohia (2000), who conducted a questionnaire on fishing methods in seven provinces, reef fishes are mainly caught by hook and line. Other fishing methods include gill nets, explosives and poison. From vast quantities of ammunition which were left behind in Solomon Islands after World War II, villagers cut open artillery and other shells to obtain powder to build explosive devices for stunning fish. Although this practice has waned in recent years, recent reliable information confirms that fishing with explosives still occurs in parts of the Western Province in the Marovo Lagoon and possibly elsewhere. Species of the plant *Derris* (one of the well known coastal species is *Derris eliptica*), that contain the chemical rotenone, and also the fruit of the *Barringtonia* tree, are used to poison reef fish.

Fisheries studies on coral reef finfish fisheries in the Solomon Islands include Oreihaka and Ramohia (2000), Blaber *et al.* (1990a, b) and the ACIAR funded study by Department of Primary Industries, Queensland (DPIQ) (1995). The DPIQ study, that aimed to develop a robust visual reef fish stock assessment method, found that the most abundant fish families were *Acanthuridae, Scaridae* and *Lutjanidae.*

In response to the concerns of local fisherfolk, Blaber *et al.* (1990a,b) and Leqata *et al.* (1990) conducted studies on the effects that bait-fishing (as chum for tuna) was likely to have on inshore subsistence fisheries. By catching fish in various ways and examining their stomach contents, they concluded that bait-fish were a relatively minor food source for the types of reef fish that the fisherfolk normally caught by fishing the bottom with weighted hand lines. Bait-fish comprised less than a quarter of the diet of 28 species of commonly caught reef fish; but were a much higher component in the diets of surface or mid-water fishes caught by trolling in the lagoons and outside the reefs. They concluded that the bait-fish industry would only impact on local food supply if the fisherfolk shifted emphasis to mainly eating fish that they caught by trolling. However Hamilton (1999) has shown that Blaber *et al.* (1990a,b) and Leqata *et al.* (1990) erred in this regard, grossly underestimating the importance of baitfish predators in the subsistence of Roviana lagoon area. Hamilton (1999) showed that barracuda was a major component of local catches. According to Hamilton (1999) the major discrepancies in the methods used by Blaber *et al.* (1990 a, b) were that they failed to investigate local knowledge with respect to temporal and spatial fishing patterns. Specifically, they did not consider the seasonal nature of fishing for baitfish predators which is normally from late August to December when most male fishing effort is directed towards catching barracuda. Since the surveys of Blaber *et al.* (1990a, b) were in July 1987 and January and early August 1988 they missed reporting this seasonal fishery. Hamilton (1999) also argued that the nocturnal nature of barracuda fishing was not considered as Blaber *et al.* (1990 a, b) conducted fishing during the daylight. Finally the lunar periodicity of fishing for the baitfish predators was not considered, yet Carangid species are known to concentrate in dense numbers within Roviana lagoon during the new and full moons (Hamilton 1999).

Domestic consumption

Although coral reef finfish contribute a significant portion of the protein diet of Solomon Islanders, relatively little is known about size of this fishery. Oreihaka (1997) reported that 83% of households in Solomon Islands engage in some fishing activities. Although a significant amount of reef fish are traded or distributed through urban markets such as Honiara, Ghizo and Auki, there appears to have been no attempt to estimate the quantities sold, by a daily census for instance. Skewes (1990) described site-to-site variation in the composition of catches, and reported that fish from the families *Lethrinidae, Scombridae, Carangidae, Lutjanidae and Serranidae* dominated domestic catches.

It is difficult to estimate the quantities of reef fish consumed by Solomon Islanders. Some statistics are only for finfish, and ignore crustaceans and other marine life. Others include nearshore species and offshore species like tuna.

Skewes (1990) suggested an annual subsistence harvest of 10,000 tonnes, based on an estimate of per capita consumption. This equates to about 25 kg per person per year and is close to a mean value for Melanesia of 23 kg per person per year (range 7-40 kg) claimed by Dalzell *et al.* (1996). An estimate by Oreihaka (1997) of 34.4 kg per person p.a. was higher and comprised 20 kg of finfish and the rest made up of shellfish and other species.

According to Coull (1993), the average per capita consumption of fish by Solomon Islanders in 1986-8 was 52 kg (about 25 times higher than the per capita consumption of groundfish in North America, and twice that suggested by Skewes). If the estimates of “subsistence” consumption by Skewes and of total” consumption by Coull are correct, then about half the fish consumed by Solomon Islanders are from the nearshore region and the rest is presumably pelagic– especially as tinned and fresh tuna. Dalzell *et al.* (1996) also estimated that about half of the total annual commercial catch for the South Pacific was from reefs.

Unless the consumption shifts to alternative protein sources, then solely based on population growth, the domestic consumption of reef fish could double to about 25-30 thousand tonnes by the year 2025.

The export trade

National fisheries statistics showed that 228.6 tonnes of reef fish and reef fish products were exported between 1996 and 1999 (see Table 1).

Until 1999, and for about a decade before, there was an industry exporting whole reef fish chilled in iced brine and individually packaged in waxed cartons. Much was air-freighted to Australia where the fish commanded a high price in restaurants. There has also been a small business in exporting fish fillets. For example, a company “Indian Pacific Seafood” exported chilled fish and some blast frozen fillets and fish from Ghizo via Honiara to Australia.

The chilled fish trade has been based mainly on the following types: snappers (e.g. short tail and long tail red snappers); fusiliers (e.g. Kusaka fusilier); breams (big eye), coral trouts, Napoleon wrasse and jobfish (e.g. rosy jobfish and green job fish).

Live reef fish trade

Although the live reef fish trade is new to the Solomons, the concept of accumulating fish in natural or man-made ponds or enclosures and then transporting the live fish in ships equipped with large tanks filled with circulating seawater is very old. “Wet wells,” watertight ship holds with holes for circulating seawater, were used as early as the Sixteenth Century in Holland. In the Seventeenth Century British shipbuilders started including wet wells because the British preferred fresh to salted fish. New Englanders built “well smacks” for carrying live fish such as cod from the fishing banks to Boston and New York. They found, however, that mortality was high in the crowded, oxygen-deprived wells, and that the swim bladders (sounds) of many deep water fish over-inflated so that the fishermen had to puncture the sounds to stop the fish rising to the surface (Kurlansky 1999, p.133).

Fishing for the live reef fish food trade began in 1994/95 with one company operating in Solomon Islands. The company wound up operations in 1997 and then recommenced operations on the distant reefs on Ontong Java under a different company name. The Solomon Island live fish trade was described by Johannes and Riepen (1995) and by Johannes (1999). Since both reports are unpublished reports to The Nature Conservancy, a summary of their findings is provided here.

The live fish trade centres on Hong Kong where the aim of the industry is to deliver live fish to restaurateurs in Hong Kong and in other coastal Chinese cities such as Guangzhou. Village-based fisherfolk in the Indo-Pacific are encouraged to capture reef fish by hook and line or by using cyanide. Special hooks are supplied to minimise deep hooking. Canoes with special seawater pens aboard are provided by the fishing companies. Fishermen are taught how to use hypodermic needles to release the air pressure in the swim bladders of fish caught in waters deeper than about 18 m – otherwise the fish drift helplessly at the surface. Rusty nails have however, sufficed for that purpose. Groupers and rock cods (subfamily Ephinephelinae) are favoured, and the fishers are encouraged to target spawning aggregations.

In the Solomon Islands, the live fish trade is concentrated mainly in the Roviana and Marovo lagoons in Western Province. The targeted species are flowery grouper (cod), *Epinephelus fuscoguttatus*, the squaretail coral trout, *Plectropomus areolatus* and the camouflage grouper or rockcod, *E. polyphekadion.* The returns to fishers were generally lower than what was paid to fishers in Philippines and Indonesia. The fishing company attributed this to relatively high transport costs, and to fish mortality en route.

From 1996 to 1998, about 130 tonnes of mainly groupers were exported from three Solomon Islands lagoon systems. According to purchase records of Ika Holdings Ltd, who bought most of the live fish captured in Solomon Islands, the amounts in 1996, 1997 and 1998 were respectively 31.8, 43.6 and 54.5 tonnes. These may be underestimates given that the amounts imported to Hong Kong as recorded by the Hong Kong Department of Agriculture in 1997 were slightly higher (44.4 Mt cf 43.6 Mt).

Live fish operations in Marovo lagoon lasted one to four years and in the Roviana lagoon one to two years. At sites where fish had been captured for the live fish trade for three to four years, the villagers reported a decrease in fish numbers and a decrease in fish size. At sites that had been fished for just one year there was no obvious depletion of stocks, but as Johannes (1999) commented, at the time of the survey it may have been too soon to judge.

After the fish are captured they are transferred to floating holding pens often owned by the fishing company. There they await collection by a larger vessel which, in the case of the Solomon Islands, transports the fish to more holding pens at Liapari, Vella La Vella, where the fish are fed bonito rejected by the tuna cannery at nearby Noro. Johannes questioned the usefulness of such food since coral trout are known to reject tuna outright. When the quantity of fish at Liapari amounts to about 15 tonnes, a large life fish transport vessel from Hong Kong is ordered.

Many fish die throughout this process for a variety of reasons including poor handling practices and siting of holding pens in places without adequate water circulation. In one 15 tonne shipment from Liapari, two thirds of the fish died before the fish transporter arrived in Hong Kong. There is also considerable wastage of non-targeted species caught adventitiously.

According to Johannes (1999), Solomon Islands fishers receive little more for live than for dead fish. He commented that if we take into consideration the fish wasted by the industry, then the live fish trade rather than being a “value added” industry is more likely a “value subtracted” industry.

In the Solomon Islands, primary reef owners were reported to be concerned about the depletion of reef fish and were planning closing of their areas to the live reef fish trade. Unlike the situation in

Philippines and Indonesia, no hard evidence of cyanide use was reported in the Solomon Islands, although some suspicious practices using hookah apparatus for divers have been reported. Johannes (1999) reported that villagers were aware of the consequences of using cyanide, and were unlikely to use it because they own their traditional fishing grounds and thus have vested interest in their protection. Poachers, however, may be less discerning.

On 6 February 1999 a moratorium was placed on the on live reef fish trade in Solomon Islands pending preparation of a management plan. There are signs that this is being lifted in May 2000 with the Minister of Fisheries being able to exercise discretionary powers on issuing new licenses. While the moratorium has been in place, stocks of reef fish have been gathered and held in various places in the Solomons. Currently (May 2000) two tonnes of coral trout and groupers have been held for more than 5 months in Roviana Lagoon. Previously two tonnes of trout and groupers in Roviana, held in the hold of a ship, were lost when the ship sank on 18 February 2000. One tonne of (mainly) coral trout is being held in pens on the atoll of Ontong Java.

Fish for the aquarium trade

In 1975 Dr Walter Starck, American marine biologist and icthyologist, suggested that selling fish for the American aquarium trade would contribute materially to the national income of the Solomons. He commented that small reef fish, which reproduce swiftly and grow quickly, fetch the same prices as food fish 50 to 100 times their size (Boutilier 1975).

Some 224 coral reef species are exported from Solomon Islands for the aquarium trade. Of these 79% are fish and 17% corals. The remainder are juveniles of giant clams, sea horses, and starfish. Unlike the live fish food trade, the items exported for the aquarium trade are typically despatched by air.

The fish are captured mainly by being frightened into nets. Commonly areas of intertidal reef are broken apart with crowbars at low tide in order to capture the fish. Scuba divers also capture fishes in nets. According to several dive resort owners in the Solomons, e.g. at Uepi Island in Morovo, and in Vanuatu, one of the varieties of fish quickly depleted because of the aquarium trade are anemone fish, mainly species of *Amphiprion*.

In the Philippines, the use of sodium cyanide for collecting aquarium fish began in 1962. Using the poison to capture fish is illegal, but because enforcement is lax, some 80-90% of aquarium fish exported in the late 1980's was captured using cyanide. The persistent use of the poison is because many of the collectors are so poor that they cannot afford boats, nets and other equipment, and for convenience. The collectors also claim some of the higher priced species are difficult to catch in nets, and that net-caught fish are often devalued by the scratches and cuts in the process (Hingco and Rivera 1991).

According to Pyle (1993) – who provides a comprehensive description of the industry – when the fish are collected by methods other than sodium cyanide, the levels of post-collection mortality are generally low, in the order of 1-2%. Mortality during transit is higher, averaging at about 5-10% for shipments from the Pacific Region.

The procedure for transporting the fish in the Solomons is to place the fish individually inside perforated containers like plastic drink bottles. This is to prevent the fish fighting. The containers are transported in large buckets of seawater by boat to Honiara, with the fishermen replenishing the water en route. In Honiara the fish are graded, the fishermen paid, and the fish are held in special tanks where they are fed until three days before being sent overseas (to prevent faeces accumulation). They are air-freighted in plastic bags of oxygenated seawater packed in styrofoam boxes.

Growing worldwide demands for high quality ornamental aquarium fish " captured in an environmentally sustainable way" is leading to an industry certification programme being run by the

South Pacific Forum Secretariat and the international Marine Aquarium Council (MAC). This is to be funded by the Canadian International Development Agency (CIDA) through the Canada-South Pacific Ocean Development (C-SPOD) Program. A two-year pilot certification program starting in 2001 will involve Solomon Islands, Cook Islands and an, as yet, unidentified third Forum country member (Press release, Forum News 3 May 2000).

Much depends on what is meant by, and how one interprets, the nebulous term “environmentally sustainable”. The news release on the ornamentals certification programme emphasised the need to avoid destructive catching methods like poisons that damage corals. If, in this case, that is what “environmentally sustainable” is mainly about, then it is important not to be lulled into a sense of false security. The reefs can all too easily be denuded of fish by using benign methods like nets and traps. The key to sustainability is to promote projects like that of the Australian Institute of Marine Science (AIMS) which is to culture and grow ornamental aquarium fish from larvae netted at sea and on the reefs – larvae that would otherwise have a huge mortality.

Sharks

Sharks are an important part of fish fauna regulating the populations of various coral reef species. In some areas, they are an important subsistence food source. Oreihaka (1997) reported that sharks are normally caught as by-catch by tuna fishing vessels; their fins are removed and the bodies, often still live, are thrown away. Skewes (1990) observed that Carcharhinid sharks made up a large portion of the shark catches. Shark fin and shark meat export statistics since 1987 are given in Table 1. The steep increase from about 2 Mt in 1994 to 201 Mt in 1995 reflects the increase in bycatch caught by purse seine vessels fishing for tuna.

Other than catch data kept with Fisheries Division (and probably fishing companies), little is known about the status of the shark resource in the Solomon Islands. Although Skewes (1990) considered the stock to be under no major pressures, the steep increase in shark fin and meat export, even as a bye-catch, is a cause for concern. As with the coral reef finfish fishery, no regulation or management measure for conserving stocks are currently in place.

Reptiles

Historically the two most commercially important reptiles have been turtles and saltwater crocodiles. Turtles are commonly found within coral reef areas, especially on seagrass beds. Although crocodiles are occasionally sighted in lagoons and inshore areas of Solomon Islands, they are not considered an important part of the coral reefs, and will not be discussed in this report.

Marine turtles

Solomon Islanders have used marine turtles for centuries as food and made ornaments from their shells. With the arrival of Europeans, turtles became a trade item and cash earner. By the 1890’s in New Georgia, a scarcity of turtles necessitated extending turtle hunting (and head hunting) as far afield as the Russell Islands and Choiseul and Santa Isabel (Bennett 1987).

Five species of turtle occur in Solomon Islands: the hawksbill turtle (*Eretmochelys imbricata*), the green turtle (*Chelonia mydas*), the leatherback turtle (*Dermochelys coriaces*), the olive or Pacific Ridley turtle (Lepidochelys olivacea), and the loggerhead turtle (*Caretta caretta*). The first three are common and nest in the country in low densities (McKeown 1977; Vaughan, 1981). The other two species (loggerhead and olive or Pacific Ridley) are rare. There are no records of loggerheads nesting in the Solomon Islands and only two reports of successful hatchings of Pacific Ridley turtles on Makira and the Shortland Islands. In many places, the loggerhead is believed to be a 'devil turtle' and considered poisonous.

The annual export of turtle shell from Solomon Islands peaked at three tonnes in 1989. Thereafter annual exports declined, perhaps because of overfishing. From 1983 to 1990, Leary (1991) and the Solomon Islands' Fisheries Division (unpublished statistics) recorded a total export of 18.7 tonnes of hawksbill turtle shells. Solomon Islands was the second largest exporter of turtle shell to Japan in 1990.

Export data can be used to estimate the number of hawksbill turtles killed in recent years. Assuming the average weight of exported hawksbill turtle shells to be 0.92 kg (75cm curved carapace length) the number of turtles killed between 1983 and 1990 was about twenty thousand; about three thousand per year on average. Groombridge and Luxmoore (1989), using Vaughan's (1981) data, estimated the annual nesting population of hawksbill turtles in Solomon Islands to be between 500 and 1000 females. Clearly a harvest of 3,000 turtles per year was unsustainable.

Therefore a total ban on exporting turtle shells and a closed harvesting season for all turtle species and turtle eggs from June to August and from November to January during the nesting seasons has been in place since 1993. Although subsistence use of turtle continues, there has been no commercial export of turtle shells since these fisheries regulations came into effect.

An extensive turtle research study undertaken throughout Solomon Islands by the Solomon Islands' Fisheries Division between 1973 and 1982 identified the Arnavon group (including the Vaghena area) as the most important hawksbill rookery in the country, supporting more than 600 nests per year (Vaughan, 1981). Only the Seychelles in the Indian Ocean has been reported to support more nests (Marquez, 1990). Vaughan, (1981) also identified Allardyce Harbour (Isabel), Hele Pass and Vangunu (Marovo), Bagora (Shortlands), Okaboi (Santa Cruz), Nanunga I. (Vanikoro) and Tetepare and Mbaniata (Rendova) as collectively supporting between 100 and 200 nests of hawksbill, green and leatherback turtles each year.

Because of the importance of the Arnavon Islands for the nesting of hawksbill and green turtles, the Government declared the area a wildlife sanctuary in 1980. But because locals were inadequately consulted and involved, they continued to hunt the turtles so that by 1989 the number of nests had dramatically declined from about 600 to 120-200. A new monitoring programme involving local people, and with assistance from the South Pacific Regional Environment (SPREP), has been going since 1991. This has resulted in an increase in the number of nesting hawksbill turtles in the area.

Despite partially protecting turtles by legislation and prohibiting all exports of shell, threats still exist. These include over exploitation for subsistence during the "open" season and poaching at other times.

Dugongs

Dugongs live in lagoons, coral reefs and seagrass beds. They are eaten in Nggela, parts of Malaita and Isabel. There is very little information on the number killed each year and on the productivity of the species. Anecdotal evidence indicates that dugong numbers have steeply declined particularly in the Kia area of Isabel Province presumably as the result of over-harvesting. In North Malaita where populations are still high, there are sometimes large numbers of dugongs in the Lau lagoon.

Human threats to coral reefs

The coral reefs of Solomon Islands are reported to be the least disturbed reefs in the Pacific (Maragos 1998). No recent studies have, however, been done to assess the state of these coral reefs and the validity of such a statement is under question. It should be noted that in some places, there has been a significant degradation of coral reefs. Listed below are current and potential threats to coral reefs.

Overfishing

Overfishing occurs when the population growth rate of villages and the fish catch for local consumption or sale, overtakes the natural productivity of the reefs,

If most of the large, reproductively mature organisms of a particular species are removed, then regeneration of that species on the reefs may be very slow. They may be replaced by more fecund, though possibly less desirable species thereby causing long-term changes to the food web of the reef. Selective removal of important herbivores or predators may cause significant ecological changes. Gathering large tritons to be sold to shell collectors, for example, probably causes the crown of thorns starfish to increase in numbers. A burgeoning crown of thorns starfish population may then physically destroy the corals to the detriment of many other species.

Subsistence fishing

The Solomon Islands has one of the fastest growing populations in the world (3.6%). Two thirds of the current population are teenagers or younger and 86% of the population is rural. Several factors conspire to keep ever-increasing numbers of Solomon Islanders at a subsistence level in a rural setting where inevitably they will place enormous pressures on edible fish and invertebrates just for sustenance. Already some areas are so overfished for local consumption that the reefs are almost devoid of the preferred edible species. The Lau Lagoon in north Malaita is a good example (Ramohia *et al.*, 1999).

With so many more mouths to feed, what are the alternatives to eating increasing quantities of reef animals? In many island societies the pressure on local fish resources is lessened by population control (often by emigration), by developing agriculture, and by other forms of industrial endeavour such as the development of light and heavy manufacturing and service industries.

A low incidence of birth control presumably because of religious and cultural beliefs, a tradition of having large families, improved infant survival and perhaps difficulties in obtaining birth control devices, ensures that the birth rate remains exceptionally high in the Solomon Islands. Emigration from the Solomon Islands is, however, small, and mainly internal, e.g. from northern Malaita to Guadalcanal. While alleviating the pressure in the more populated parts, and perhaps conserving reef resources at those localities, such internal movements inevitably create ethnic problems that indirectly impact upon coral reefs elsewhere and in other ways. Therefore, emigration is no pressure release valve.

There are of course alternative protein sources to fish and shellfish on the Solomon Islands. Some parts of the Solomon Islands, e.g. Guadalcanal, are exceptionally fertile and offer many opportunities for raising poultry, pork and beef. Neighbouring Vanuatu has a world famous beef trade. Equally good beef can be grown in parts of the Solomons, and there are some small herds, and yet the nation imports almost all of its red meat including beef from Vanuatu. Chickens for meat and eggs are raised locally and on a commercial scale, and until recently pork was raised commercially.

So why don't these alternative sources of protein relieve pressure on reef resources? One attraction of the reef is that the food is free and, until recently, can be caught with little difficulty. Animal husbandry like chicken farming requires financial outlay, organisation and continued investment for feed and facilities. And if you don't raise your own poultry or beef then you may have to buy such meat from the people that do. Although fishing may be easier, this has not deterred various Solomon Islanders from farming livestock. A major set back, however, is the current ethnic violence on Guadalcanal that has caused the closure of prawn, poultry, pig and cattle farms mainly because of land disputes.

Another reason is that there are few employment opportunities for Solomon Islanders who are therefore more-or-less forced to remain at the village subsistence level. Where there are opportunities in light industry, mining, plantation work and tourism, then people will migrate from their coastal villages to those places of employment where the cash that they earn is spent on alternative foods. Here again island politics hamper such development and are a disincentive to investors. Investors are conscious of the fact that if they require labour, some of which comes from other islands, then often there are ethnic problems. These can erupt causing destruction of vehicles and industrial plant while a panicky exodus of labour back to "home" islands means that operations must be down-scaled or closed. Honiara and other parts of Guadalcanal abound with examples of this phenomenon.

A dearth of ecological knowledge is one deficiency in indigenous management systems. For example, many fishers do not understand that a certain minimum population level is necessary to restock a coral reef population. They don't comprehend that prolonged fishing usually results in a significant decline in the populations and ultimately a complete exhaustion, of trochus stocks for example. As a result the fringing reefs of some villages in Mboli on Big Nggela are bereft of trochus and bêche-de-mer.

Some traditional fishing practices degrade coral reefs. These include walking and standing on corals when spear fishing or gleaning, breaking corals when retrieving fishing nets, anchoring, and fishing spawning aggregations.

One of the most damaging fishing methods is the use of several species of the coastal plant *Derris* spp, mentioned above. This unselective fishing method kills many species other than those targeted including even branching corals, the skeletons of which are reported to crack (Foale 1998).

Bêche-de-mer fishing also poses some threats to the coral reefs, because usually the intestines from gutted sea cucumbers are thrown into the sea. The intestines contain toxins and have been reported to kill coral reef fishes and corals when they sink.

Fishing for cash income

Probably the most serious and immediate human threat to coral reefs and lagoons of the Solomon Islands is over fishing as a result of trying to generate cash income. The money economy has become an integral part of life in even the most isolated of Solomon Islands rural communities, and it is here to stay. There is, however, an acute shortage of cash in the Solomon Islands, especially in rural areas.

In 1993, gross per capita income was A$947 - half that of Papua New Guinea, Vanuatu and Tonga. Only Tokelau and Kiribati had lower annual rates of income in the South Pacific. In reality the income of most Solomon Islanders is much lower. Some 86% of the population still lives in small rural villages more than half of which are directly situated on the coast. Income distribution is, however, skewed highly in favour of a small percentage of urban-based high income earners. In the early 1990's over one half of total income was received by 10% of households, mainly in Honiara.

So the temptation to over-fish resources for cash is great. Almost all of the large molluscs, crustaceans, and echinoderms of commercial importance have been depleted to an extent where the Government has had to ban further commercial catches. The Islands abound with anecdotes such as how twenty to thirty years ago giant clams in Isabel Province were common place but are now rare. The decline of green snails is another oft-quoted example, as is the demise of the turtles. Kile (2000) discussed the overexploitation of six commercially important species.

Any increase in destructive fishing practices, such as the use of explosives or poisons, also constitute a major threat to the reefs and the lure of cash may cause these practices to increase.

Of particular concern is the live fish trade, an industry with a poor track record in Indonesia and the Philippines (Pet-Soede and Erdmann 1998, Erdmann and Pet 1999). What happened there can just as easily occur in the Solomon Islands, particularly when Indonesian and Philippine companies target Solomon Islands reefs for species already depleted on their own reefs. In the near future a cash-strapped Solomon Islands Government may permit such activity to generate revenue from issuing licenses and to encourage employment. If licenses are refused, the Solomon Islands State may still be hard pressed to prevent live fish traders from running a clandestine industry with villages in the remoter parts of the archipelago. The fishing companies tend to target remote reefs far from prying eyes. Erdmann and Pet (*ibid*) reported how the remotest reefs of Indonesia are the most destroyed. The instance where Taiwanese fishing boats plundered the giant clam stocks of Indispensable Reef may soon have parallels in the live fish trade.

The developing aquarium trade is also of concern, particularly the mass extraction of corals and the selective removal of juveniles of important or keystone coral reef fishes.

Currently the aquarium trade is posing great dangers to the coral reefs on Nggela – one of the major suppliers to the aquarium trade. An inspection at Aquarium Arts revealed that a lot of the species obtained were also juveniles of species commonly eaten or sold. This is an additional pressure on species that are already over-harvested. The coral reef fishery on Nggela may be heading blindly towards collapse.

It is difficult to see how rural Solomon Islanders will not be tempted to convert their various reef species into cash when opportunities for doing so arise, even if they know the ecological implications of doing so. This is easier as village society changes and local authority power and traditions for conserving marine resources are eroding. While it is easy for salaried workers writing reports such as this to advocate strong conservation measures; it is quite another matter for rural folk earning just a few hundred US dollars per year. For them, selling tritons, blue tangs and anemone fish to shell collectors and the aquarium trade, for short-term gains to purchase medicines, pay school fees, make motor repairs or to purchase electronic equipment, is just part of the monetary economy that government and aid agencies promote.

Lime production for betel nut chewing

Chewing betel nut is an addictive habit widespread in the Solomon Islands. Fruits of the palm *Areca catechu* are chewed with the leaf of a pepper tree, Piper betel, and calcium oxide powder obtained by burning staghorn (*Acropora* spp) corals. Bowden-Kerby (pers.comm.) estimated that the 6 million kg of lime produced each year for betel nut chewers comes from burning about 10 million kg of live *Acropora* corals. The result is that reefs in all of the lagoons in Malaita are depleted of *Acropora* and other staghorn corals. This is an extraordinarily large consumption of lime by a population of just 0.4 million people. It has been calculated, however, that inveterate betel nut chewers consume about 20 kg of lime per year

Lime production is currently one of the biggest threats to corals in the Solomon Islands and some Non-Government Organisations are trying to alleviate this problem. Foundations for the People of the South Pacific and the Solomon Islands Development Trust have tried to work with rural communities to set up coral gardens both for the aquarium trade and for lime production. Coral gardens in Marau are reported to be progressing very well. Baeanisia (pers.comm.) also reported that coral gardens are progressing well in Langalanga Lagoon. Some communities are trying to use the corals sustainably for lime production. Boeni of Fuaga, in Malaita, reported that in their community, several staghorn coral patches are harvested on a rotation system.

Artificial Island construction

Constructing artificial islands, on which to build homes, also threatens coral reefs on Malaita. These artificial islands are concentrated within the Langa Langa lagoon, Lau lagoon and Ata'a area of north Malaita and at Fanalei and Walande in South Malaita. As the need for more artificial islands increases with the population, so too will the demands on coral as a building material.

An assessment of the impact of this practice on coral reefs was initiated by concerns expressed by the Rere Board of trustees of Foueda artificial Island in Lau lagoon. According to Ramohia *et al.* (1999) the Rere Board of Trustees complained (and lodged a legal suit) about the extraction of both live and dead corals for the construction of an artificial Island in Auri, where a new apostolic church was supposed to be built. The Rere Board of Trustees alleged that the extraction of corals damaged their fishing grounds. Ramohia *et al.* (1999) concluded, however, that coral extraction was not the only cause. Over fishing was also a contributing factor.

While this case reveals an awareness of resource owners on the importance of corals and the consequences if they are removed, their concerns were probably expressed because of what they presumed to be an intrusion by outsiders and the possibility of obtaining compensation from them. Should they themselves wish to build more artificial islands, then such environmental concerns about fisheries would probably be ignored.

Logging

The late 1970's and 1980's was the peak of logging activity in the Solomon Islands. Most of these logging activities were concentrated within the Western, Isabel, Choiseul and Makira Provinces, where logging continues. Smaller logging operations also occur in Russell Islands.

No study of the direct effect of logging activities (such as sedimentation or oil pollution) on coral reefs has been done in the Solomon Islands. Elsewhere in the tropics, logging has accelerated sedimentation rates, and in some cases, such as Segara Anakan Lagoon on the south Java coast, by reducing lagoons to tidal inlets and channels (Purba 1991).

Anyone flying over the Solomon Islands can see large plumes of yellowish-red sediment at the river mouths of recently logged catchments. Seen on the ground the catchments are criss-crossed with roughly formed roads and skidder tracks. The soil and clay, deeply churned by the skidders, is piled high along the edges of the tracks as if ploughed. Little attempt is made by the loggers to install any form of drainage. Typically there are no cross drains to minimise sediment movement. No attempts are made to bed down the skid tracks or roads after the logging is finished. There is practically no road maintenance. Washouts are either filled in until next time or the road is re-routed. Road runoff is often directed straight into streams and rivers rather than being directed into areas of forest that might filter out some of the sediment. Little effort is made to protect the vegetation along the edges of the streams and rivers. No efforts are made to build sediment traps where rivers run into the lagoons. Log sorting and storage areas are typically large, flat, quagmired, in-filled areas pushed out into the lagoons where wave action erodes away the margins.

These practices run counter to the logging code of practice that the Solomon Island Government requires logging companies to sign. Obviously the companies ignore the code. While some Government officers are concerned, enforcement is at best feeble.

All of the poor forest practices mentioned above are evident on Vangunu Island in southern Marovo where Silvania Products Ltd (SPL), a subsidiary of the Malaysian Kumpulan Emas Berhad conglomerate (KEB), has wrecked havoc in the rain forest since 1992. This is a company that, according to its own literature, prides itself with its environmental awareness and its engineering ability to construct roading systems that minimise sedimentation. In fact, in their recently logged areas (Lot 16 R515) there is total lack of attention to drainage even on their main roads.

In the Marovo area, in the vicinity of SPL logging area, villagers report huge sediment plumes following heavy rain. Once the rain has stopped the water may clear within 24 hours to a week. In the rainy season that means that the plumes are a semi-permanent feature. Nobody has studied the effects of such sedimentation on the lagoons and the coral reefs in the Solomon Islands, but, obviously, the sediment reduces water clarity.

As mentioned, corals are partly dependent on symbiotic algae to manufacture food, and the algae depend on light for photosynthesis. So it is the limits of light penetration in the ocean that dictate the lower vertical distribution limits of reef-forming corals (140-150 m depth in clearest oceanic water). Where lagoons and coastal waters are muddied by logging, then coral growth is reduced (commonly to less than 15 m depth) or prevented by diminished light penetration. This is directly a result of the suspended sediment in the water column and often because increased concentrations of nutrients from the sediment plumes enhances the growth of phytoplankton. As a result, the deeper dwelling corals die. Another damaging effect of sediment is that irrespective of depth, it smothers corals. Normally corals cope with sediment by a coating of mucus that is continuously shed. But with abnormal loads of sediment, the corals' defences are overwhelmed. Excessive energy goes into mucus production, and the animals also stop feeding (Lobban and Schefter 1997, Clark *et al.*, 1997, Segar 1998).

Kerrie (pers. comm.) of Adventure Sports in Ghizo reported that logging ships also contribute to coral reef damage. With a full cargo of logs, the ships occasionally touch bottom and in their efforts to break free they resort to kedging on anchors. Where this happens, the damage to the reefs is huge. Logging ships also dump garbage into the lagoons and over the reefs.

Plantations

The main plantations in the Solomon Islands are for coconuts (for copra), cocoa and palm oil. Most of these plantations are grown on fertile flat coastal plains where clearing the original vegetation, road construction, planting and so forth caused relatively little erosion. Some of the largest plantations are on the expansive coastal plains of Guadalcanal. Recently, however, there have been proposals to develop oil palm plantations on easily erodible hill country in other provinces. This has gained impetus as a result of the ethnic troubles on Guadalcanal which caused temporary closure of the long established oil palm plantations owned by Solomon Island Plantations Limited (SIPL). The Government wants to disperse such industries. Other proposals to plant oil palms will therefore probably be promoted, so it is instructive to consider the environmental impact of the Silvania oil palm project on Vangunu Island in southern Marovo Lagoon.

The Silvania oil palm project

In July 1999, the Solomon Islands Government gave approval for Silvania Plantations Products Ltd (SPPL), also subsidiary of KEB and a sister company to SPL, to clear the same area that SPL had already selectively logged (Lots 16 and 14) to plant oil palms. The Solomon Islands Government has proceeded with this project heedless of the concerns of landowners, resource users and environmental organisations.

SPPL proposes to plant 6000 ha and may enter into agreement with adjoining customary land owners to plant more. It plans to build an oil extraction plant on the site at Merusu. Many of the roads they require are already formed by their sister Company, although ironically SPPL will inherit all of the problems attributable to the careless way that SPL formed its roads without any attention to design or drainage.

The effect of this oil palm plantation on the slopes of Vangunu and Marovo Lagoon will, however, be much more intense than the earlier logging. This relatively steep erosion-prone area in a region of high rainfall is being completely clear felled by SPPL. The soils are highly prone to erosion and inherently infertile, with almost all of the nutrients bound up in the humus layer. There are proposals to fertilise the palms with NKP fertiliser (15:15:6.5 with trace elements) although apparently no chemical analyses have been made of the soil types in Lot 16. As Thistlethwaite (1999) points out in his draft environmental review of the project, it is important to analyse the soils to prevent excessive application that may eventually run into the lagoon.

Without doubt, the extensive earthworks and terracing (and the remedial work to the SPL roads) will cause massive sediment run off. It is happening already. Eventually once the palms are established, there is complete ground cover, and the roads are redesigned with proper drainage, then the discharge of sediment will decline. But in the interim there may be irreversible changes to coral reefs and marine resources of Marovo Lagoon, the very features for which the area is world famous.

We predict that this oil palm plantation is going to cause significant damages to the corals reefs and marine resources of Marovo Lagoon, and we are inclined to agree with Shearman (1999:1) who wrote …

"The acidic soils of Vangunu will require regular fertilisation for oil palm production, leading to fertiliser run off polluting the lagoon. The clear-felling of 6000 or more hectares will lead to enormous soil erosion and resultant siltation of the lagoon. Additionally, the large amount of toxic effluent produced during oil palm production may enter the lagoon causing severe pollution. The effect of the oil palm project on the Marovo coral reefs could include large scale death of coral through siltation or pollution, reduction in reef production and fish density and a general lowering of the abundance and diversity of marine resources (including bêche-de-mer and clams). The extent and severity of these impacts is unknown but is expected to affect at least the eastern side of Marovo lagoon between Vangunu island and Nggatokae. This impact would have severe consequences for the Marovo people including loss of food and commercial resources as well as reduction of tourism revenue for local ecotourism operators. Significant pollution would also jeopardise World Heritage listing, further restricting ecotourism potential"

The plantation development also involves the building of a small town, Merusu, for 1500 workers and which Thistlethwaite (1999) estimates will very soon have a population of 6000. Currently the entire population of central and southern Marovo is 8500. Clearly a town of this size is going to have numerous direct and indirect impact on the coral reefs nearby and on the resources of the lagoon. In addition there will be an oil extraction plant and bulk storage facilities for the oil and a new port, all of which may be detrimental to coral reefs and lagoons.

Sewage disposal

None of the urban centres in the Solomon Islands have any form of sewage treatment. The raw sewage is simply piped into the sea, and in some cases the end of the outfall is actually above the low tide mark. Honiara, the largest urban centre, has about nine sewage outfalls along its beach frontage and in most cases the submarine sections of the pipes have been broken by storms. The sewage plumes are clearly visible from the air as one flies west of Honiara. Fortunately there are no large and expansive coral reefs in the immediate vicinity of Honiara, but at other centres, e.g., Ghizo and Munda, new residential and industrial development may greatly increase the volumes of sewage that are discharged in close proximity to coral reefs. Apart from the health risk and reduced clarity of the water, the eutrophication may cause certain fundamental ecological changes such as the growth of algae where previously there was none. In the late 1970's sewage discharged into Hawaiian coastal waters resulted in the rapid growth of the alga *Dictosphaeria sp*. that smothered corals (Clark *et al.,* 1997)

Oil pollution

Accidental spillage of oil and diesel by logging companies is also a problem. In the Solomons there are reports by Horokou (1996, 1997) on the biological and ecological impacts of oil pollution by Eagon Forest Resource's logging operation on Vacho River in north-west Choiseul. In 1993 the timber company had spilled about 12 000 litres of oil into the river (Moseby and Read 1999). The result was a marked decline in river invertebrates (Horokou 1996). Similar spills could occur at sea level when the oil or diesel is unloaded, or there could be leaks from storage tanks. At sea level, any oil slick will probably spread around the margins of the lagoon.

Many villagers we have spoken with have reported that inter-island boats have carelessly pumped waste oil directly into the sea. Gregory Bennett, a Solomon Islands Fisheries Division officer, reported seeing bait-catching punts of the Solomon Taiyo Ltd dumping significant quantities of waste oil directly onto the coral heads at Patutiva in Western Province thus causing the death of many reef fish.

Solomon Islands is a maritime nation, and the disposal of unwanted or condemned vessels is a problem. Increasingly the Honiara foreshore is dotted with wrecked fishing vessels that for various reasons have ended up drifting ashore where they blot the landscape. For vessels still currently in use, but likely to fail certification, their owners may be tempted to abandon their vessels in the Solomons instead of removing them for scrap. The "ecologically sensitive" idea of turning the ships into artificial reefs may therefore have increasing appeal as a cheap alternative.

Villagers of Sandfly in Nggela reported that a few years ago, a prominent Honiara businessman towed an old ship from Honiara and dumped it close to a coral reef patch in Sandfly to form an artificial reef. Large quantities of oil leaked from the vessel, however, and killed corals and fish in the Sandfly region. This demonstrates that using moribund vessels as artificial reefs requires that the vessel first be meticulously stripped of most of its fittings (especially internal linings and glass) and carefully emptied of all lubricants, hydraulic fluids etc, before sinking. Otherwise pollution in one form or another inevitably follows.

Several villagers from Western Province reported seeing oil oozing from World War II wrecks especially the cargo vessels. Off Guadalcanal most of the large warships sunk in Solomon Islands in World War II are in deep water in Iron Bottom Sound where they are concentrated in a small sea area. If the fuel tanks of these vessels corrode at about the same rate, then collectively their oil could become a problem. Fortunately most of these ships lie several kilometres off shore.

The proposed *Silvania* oil extraction plant on Vangunu Island in Marovo lagoon will be three kilometres from the port and bulk storage facilities at Emma Point. Presumably the oil will be tankered by road to the port on roads already described above. As Thistlewaite (1999) correctly surmises, the risk of a major spill is greatest at the holding tanks and during loading where, of course, any spillage may be directly into the lagoon. Thistlewaite recommends that the bulk storage tanks be surrounded by a concrete bund high enough to contain all of the stored oil; only time will tell if this is done.

Ships ballast water

Log ships and to a much lesser extent, container ships, discharge ballast water as they load logs or reduce their draft. The continuing saga of non-indigenous organisms being translocated via ballast water across oceans is of mounting international concern (for a succinct review see Committee on Ships' Ballast Operations 1996). Marine and estuarine organisms uplifted from harbours like Madras, Hong Kong, Manila or Singapore by ships bound for the Solomon Islands will be discharged into Solomon Islands lagoons and in the vicinity of fringing reefs where they may become invasive species.

Currently there appear to be no reports of foreign marine life suddenly making an unwelcome appearance in Solomon Islands waters. This must, however, be weighed against the fact that the Solomon Islands marine flora and fauna is imperfectly known and that no efforts are made to search for adventive species in the vicinity of ports and log-handling areas. Yet another example of the need for baseline surveys.

Ships passing through Solomon Islands waters bound for other places also discharge foreign ballast water into the Solomon Islands sea. This is because fully ballasted bulk carriers, containing tens of thousands of tonnes of ballast water, and bound for Australia and New Zealand to load bulk cargoes, are strongly recommended to exchange their ballast water in mid ocean. This is to rid the vessels of their original harbour water (e.g. from Tokyo) and replace it with deep sea tropical water, which is considered to be a lesser quarantine risk.

What constitutes the deep sea as far as international recommendations are concerned are waters deeper than 500 m. Such depths occur quite close to shore all through the Solomons archipelago however. Because exchanging ballast water on the high seas is a lengthy, exacting procedure that can endanger a ship if the weather suddenly changes, ships' masters prefer to make the exchanges in calm seas. Popular exchange areas for New Zealand-bound vessels are the Bismarck, Arafura, Coral and Solomon Seas. The volume of foreign ballast water being discharged into the Solomons sea area during such exchanges is not known, but it could be millions of tonnes given that over 100 million tonnes of ballast water are discharged into Australian ports each year.

Coastal developments

Coastal developments such as the construction of roads, hotels and residential areas are potential threats to coral reefs. They invariably increase sediment run-off, and often cause an increase in sand

and coral rubble extraction for engineering purposes. Where hotels and resorts are situated on the shore there are usually proposals to build wharves and protective piers. This usually involves dredging the adjacent reef for rocks and infill material, with the bonus of creating a navigable boating channel at the same time. Such activities are invariably detrimental to coral reefs. Once the resort is established, however, resort owners may, by various means, protect the surrounding reef life to enhance scuba diving.

Tourism

Tourists have both positive and negative impacts on coral reefs. It depends on the type of tourist and how numerous they are. Tourism that encourages scuba diving is an incentive for resource owners to preserve the coral reefs. Dive operators have a vested interest in the coral reefs and in many places have taken measures to protect them. They are also valuable informants about the state of coral reefs. Careless or inexperienced divers can, however, contribute to coral reef damage as they break delicate corals with their fins, or by sitting on corals to take photographs. Tourists who want to go fishing and spear fishing are another matter, as are souvenir-seekers purchasing large quantities of shells.

Historically the Solomon Islands government has not vigorously promoted tourism. The current ethnic violence on Guadalcanal has reduced the tourist flow to a trickle, and the serious malaria problem deters many. Cruise ships no longer visit. If circumstances change and tourism grows, then larger numbers of Solomon Islanders will be employed in the service industry. This probably translates to fewer folk subsisting on reef resources. Against that, we must weigh the detrimental effects of constructing new coastal resorts, increased fishing to supply the restaurants, and the inevitable increase in collecting shells for the souvenir trade.

Natural threats to coral reefs and lagoons

Natural disasters

Periodically natural disasters such as ash showers from volcanoes, tectonic uplift, tidal waves and cyclones damage coral reefs in the Solomon Islands. In living memory powerful earthquakes, e.g. in 1931, 1939, 1950, and 1952-56, uplifted coral reefs by as much as a metre. Stoddart on the British Royal Society Expedition in 1965 suggested that large dead areas of coral he saw were a result of recent uplift, an explanation also promoted by Weber (1973). There are anecdotal reports of the stench of decomposing marine life on uplifted reef areas of Guadalcanal after a 7.25 Richter Scale earthquake in 1977.

Cyclones periodically devastate reefs, especially when they hit areas where wave action is usually slight. Weber (1973) offered this as an alternative to tectonic uplift as a cause of coral mortality on Guadalcanal. Unusually low tides coinciding with high air temperatures are damaging to corals at and near the low tide level. In 1983, for example, many corals on reef flats died because of a general lowering of sea level in the southwest Pacific as a consequence of the abnormal El Niño event of that year. Protracted periods of unusually low seawater salinity, as a result of excessive rainfall, damages corals inside lagoons, especially in the shallows.

Climate change

Coral growth is from 0.5 and 2.8 cm per year with the greatest growth rates in water shallower than 45 metres depth. In recent history these growth rates have been fast enough to maintain reefs in shallow water as either the seafloor subsides or the sea level rises, or both (Mielke 1989). If, however, the rate of rise in sea level exceeds coral growth rates, then reefs currently emergent at low tide might become submerged, while reef islands would be exposed to increased coastal erosion. Potentially the primary reasons for sea level rise are expansion of seawater and melting of ice caps (especially in Antarctica) as a result of global warming. According to the UN Intergovernmental Panel on Climate Change, the most probable forecast is for a rise in the global sea level average of about 65 cm by 2100 or about 6 cm per decade. Changes would not be uniform around the world however. Extreme models predict a 2 metre rise over the next Century (Lobban and Schefter 1997).

The impacts on Pacific islands of sea level rise, increase in temperature and ocean weather patterns have been discussed by Wilkinson and Buddemeier (1994). There are areas in the Solomon Islands that are very vulnerable to the effects of climate change, such as coastal erosion. In the longer term, low lying Islands, especially atolls, may be submerged by sea level rise. The Solomon Islands' input to the Pacific Islands Climate Change Adaptation and Assessment Programme (PICCAAP) has been co-ordinated through the Solomon Islands Meteorological Services.

Coral bleaching

Corals, together with anemones, hydrozoans and other invertebrates harbour symbiotic algae, which in the case of corals are called zooxanthellae (dinoflagellates of the genus *Symbiodinium*). Up to 60% of the photosynthates created by zooxanthellae photosynthesis are released through the plant cell walls directly into the coral tissue (Segar 1998). Without zooxanthellae, many corals would starve.

In the 1980's, instances of corals becoming bleached and then dying were reported from various locations around the world. The whiteness of the corals is because the zooxanthellae, normally responsible for the colour of corals, had vacated the coral colonies. Without the sugars normally produced by the algae, a coral colony degenerates and may die unless recolonised by zooxanthellae.

Sometimes the phenomenon appeared to coincide with El Niño conditions that caused a 1-2°C increase in tropical sea temperatures. According to Allen and Steene (1999) there were sixty bleaching events in all tropical seas between 1979 and 1990. Particularly severe coral bleaching in 1997-1998 (an El Niño year) caused an estimated 90% mortality of corals at various locations in the Indian Ocean, especially the Maldive Islands. In the Pacific the coral reefs of Palau were severely bleached such that about 75% of corals shallower than 15 m depth started to die.

Reef building corals are evidently living perilously close to their upper temperature limits, so that when temperatures exceed 29°C for several weeks, then bleaching starts. Temperatures in Palau were 30-32°C during the 1997/98 bleaching event. In shallow depths, a certain amount of bleaching is probably a seasonal event, perhaps caused by low tides coincident with heavy rainfall or high air temperatures. Under these situations, most corals are likely to recover. The bleaching events described here, however, were quite different by being protracted, and occurring to depths as great as 70 metres.

Information about coral bleaching in the Solomon Islands is scarce. A search for Internet web pages containing scientific observations about Solomon Islands coral bleaching produced very little amongst hundreds of references about coral bleaching elsewhere.

Whether coral bleaching has occurred in the Solomon Islands in recent years isn't known for there appears to have been no monitoring. It s possible that the dead and dying corals observed by Morton and others on the British Royal Society Expedition in 1965 may have been a case of coral bleaching.

Currently there is extensive coral bleaching in many parts of the Solomon Islands, coincident with serious bleaching in Fiji. Bleaching was first noticed in January and February 2000, and there are still reports of bleaching in May 2000. Observations at two reefs near Ghizo revealed extensive bleaching of plate and staghorn (*Acropora*) corals. Some anemones are similarly affected. Franck Boulay, manager of Solomon Sports Diving, Honiara, reports that the bleaching is bad in parts of the Florida Islands and that it is the corals on the outside of the reef rather than those inside the lagoon that are worst affected. Boulay claims, however, that he has not measured temperatures in the Florida Group above 29º C. Bilikiki Cruises Ltd. operate dive excursions to 20 sites in Nggela, 18 sites in the Russell islands, 3 sites in the Las Tres Marias Is. (Makira) and 15 sites in Marovo Lagoon. Scott Waring of Bilikiki Cruises reports that most coral reefs currently (May 2000) have about 20% of corals bleached with some of the shallow sites exhibiting bleaching as high as 50%. There are also reports of bleaching from Otong Java (Lam pers. obs.) and on reefs of Fuaga in Malaita (Boeni pers. comm.).

According to Scott Waring, the water temperature for the sites that Bilikiki Cruises visited in 1998 were on average 26ºC. In 1998 the average for the sites rose to 28ºC and from January to March 2000 increased to 30ºC. From September to at least December 1999 mean monthly sea temperatures at Honiara were between 29.5 and 30.0ºC.

Crown of thorns starfish

Damage to coral reefs by the crown of thorn starfish, *Acanthaster planci*, is reported sporadically in the Solomon Islands. Most sites in Western Province exhibit minor damage, though in Sandfly Passage, Tulaghi and Ghavutu in the Florida Islands there has recently been considerable damage attributed to the crown of thorns starfish (Scott Waring pers. comm.). Occasionally major outbreaks of crown of thorns have been reported at Mamara just west of Honiara. Triton trumpet shells predate crown of thorns starfish. Although large-scale harvesting of tritons for souvenirs could potentially contribute to increased numbers of starfish, factors other than just reduced predation seem to cause massive plagues of the starfish.

Coral reef conservation

Government policies, strategies and legislation

The Solomon Islands government is a party to several international agreements that are relevant to use and protection of its coral reefs: Biodiversity, Climate Change, Environmental Modification, the Law of the Sea, Marine Dumping, Marine Life Conservation, Ozone Layer Protection and Whaling.

The government does not have a specific policy on coral reefs, although these are embodied in the general national government policy on fisheries. This stipulates that the fisheries sector is to be developed and managed co-operatively with provincial authorities (where applicable), and that the exploitation of all fisheries resources within the fishery limits should be in a manner that secures optimal social and economic benefits for the people of Solomon Islands. The specific objectives are:

- to achieve and maintain self sufficiency;

- to improve cash income throughout the fisheries sector by way of assisting Solomon Islanders in developing their own resources through self-employment;

- to maximise participation of Solomon Islands nationals in commercial fishing and associated activities;

- to improve the foreign exchange position of Solomon Islands by encouragement of local processing of fisheries resources into value-added products; and

- to encourage the farming of aquatic resources.

According to Wells and Jenkins (1988) legislation prescribing measures for the protection and preservations of the marine environment was promulgated under the Delimitation of Marine Waters Act 1978 and the Fisheries Act 1972 (amended in 1977). The latter act has since been replaced by the 1998 Fisheries Act.

This Act provides for the management and development of fisheries in Solomon Islands. It highlights several principles that the Minister has to consider when exercising his powers and functions under this Act. One is that the Minister shall pay due regard to the principle that Solomon Islands fisheries resources shall be managed, developed and conserved so as to ensure resources are not endangered by over-exploitation; but are utilised at a level that ensure their optimum sustainable yield.

Another principle advocates sustainable development and applies the precautionary approach to conservation, management and exploitation of fisheries resources in order to protect the fisheries resources and preserve the marine environment. In this context, exploitation of fisheries resources in Solomon Islands shall be done through properly devised management plans. Marine conservation areas may be declared under this Act.

Other important legislation pertaining to the protection of coral reefs are:

- The Environment Act 1998 makes provision for and establishes integrated systems of development control, environment impact assessment and pollution control. It shall also prevent, control and monitor pollution. This Act caters for national and regional environmental concerns.

- The Shipping Act 1998 regulating matters on the protection of the marine environment and prevention of marine pollution from marine vessels. Under this Act, the Marine Division has the authority to prosecute violations of the Act. The Act incorporates various International Maritime Organisation (IMO) Conventions.

- The Wildlife Protection and Management Act 1998 that provides protection, conservation and management for wild life. Potentially it regulates the export and import of certain animals and plants to comply with obligations imposed under the convention on International trade in Endangered Species (CITES), although the Solomon Islands is still not a party to the CITES convention. According to the chief fisheries officer (Research), Mr Edward Oreihaka, the Government is still working towards becoming a signatory.

Two important documents that are helping effect the aims of this legislation are The National Environmental Management Strategies produced by SPREP and The State of the Environment Report produced by Leary under the auspices of the Solomon Islands Government in 1993. Priority 4 of the National Environmental Management Strategy is relevant to coral reefs. It recommends strengthening the database of resource information database, with great emphasis on reefs, estuaries and lagoons. Due to unavailability of funds, the recommendation has not been implemented.

In regard to the provinces, Tony Nori, (Acting Principal Fisheries Officer, Provincial development unit of Solomon Islands' Fisheries Division) has stated that the government is working on drawing up a fisheries ordinance for the provinces. This will regulate fisheries and management and provide for sustainable management of resources at the provincial level. Western Province already has an ordinance providing for the sustainable management of its resources called the Resource Management Order (RMO)

Indigenous management systems

Indigenous management through customary marine tenure has been recognised as an important component of the sustainable utilisation and conservation of inshore marine resources, in particular coral reefs and mangroves. Papers published on customary marine tenure, its relevance and implications for conservation and management include: Baines (1985), Hviding (1988, 1996), Hviding and Ruddle (1991), Johannes (1982), Pulea (1993), Akimici (1991) and Foale (1998). Hviding and Ruddle (1991) described the customary marine tenure system as a potentially valuable alternative for inshore fisheries management.

Johannes (1978) reviewed some traditional conservation measures employed in the Pacific including Solomon Islands. The most common methods of indigenous conservation and management practice currently in place are serial prohibitions on harvesting, limited entry and complete prohibition of access. In serial prohibition, access to coral reefs is prohibited for a certain period. Limited entry restricts the numbers of people entering an area. Complete prohibition may apply to areas of cultural significance, including coral reefs.

In most parts of the Solomon Islands, there are two main forms in which serial prohibitions are exercised and enforced. The reef owners may ask either a Christian leader (priest, pastor or minister) or a 'kastom man' to place a tabu on the reef or alternatively the group owning the reef may place a tabu on the reefs themselves. Prohibitions in the form of tabu from the Christian leader or 'kastom man' take the form of a 'conditional spell'. Foale (1998) has described serial prohibitions in Nggela.

One area with restricted entry is Ramos Island (also called Onogou Island) between Isabel and Malaita. It is widely believed in Nggela, Isabel and Malaita that the spirits of the dead rest on Onogou. Anyone travelling to this island must be accompanied by someone who can communicate with the spirits. Strict protocols must be adhered to and not to do so will usually result in death. Because of such strong inherent beliefs and the restrictive nature of fishing on the island, entry is limited. This has helped to conserve marine resources around the island.

Cultural and religious beliefs such as the practice of not eating certain foods at certain times of the year by certain groups, or a total prohibition of eating of certain species, also contribute to conservation. For example, in the Seventh Day Adventist (SDA) communities, only finfish are consumed, due to religious prohibitions on the consumption of anything without fins and scales. Robert Vavozo (pers. comm. 2000) reported a great abundance of invertebrates (especially crustaceans and holothurians) within the reefs of Dovele in Vella Lavella which is a SDA stronghold. The sale of these species is not prohibited under SDA religious regulations however. In reality their relative abundance relates to the distance to markets and the perishable nature of the lobsters.

Dietary preferences may aid the conservation of some species. In Nggela it is believed that eating turtles causes whooping cough and respiratory problems. Although turtles are still consumed in Nggela, the consumption rate is much lower than in Isabel and Malaita where these beliefs are not held. If, however, the ban on the sale of turtle shell were removed, then the catch rate would probably increase in Nggela and everywhere. In the Lau Lagoon in Malaita, dugongs are not eaten because of cultural beliefs.

In a survey on the status and management of inshore fisheries, Oreihaka and Ramohia (2000) reported the common perception among villagers that regulations instituted by national governments are more effective than traditional ones. Nonetheless, indigenous management systems, regardless of their deficiencies, are still important in the conservation and management of coral reefs and resources in the Solomon Islands. These practices form an important part of the life and culture of people. Any national conservation and management strategies must be sensitive to these practices. Oreihaka and Ramohia (2000) recommended that national management strategies on resource conservation should closely involve community leaders and resource owners.

Marine Protected Areas

A measure that potentially could be effective in safeguarding reef biota is establishing marine protected areas. If, for example 10% of the reef areas were protected and the protected areas were chosen strategically with regard to down stream effects, then reproductively mature fish and invertebrates within the areas will probably re-seed the over-fished regions. Smith *et al.* (1997) discussed the importance of marine protected areas as a refuge from fishing and in allowing target species to increase in abundance and body size, resulting in an exponential increase in egg production.

The problem is that all reef areas are “owned” by various Solomon Islanders who claim traditional fishing rights. To persuade them to relinquish fishing rights for a common benefit is a daunting task. The NIMBY (not in my backyard) attitude, that has proven to be a major stumbling block in establishing marine reserves in nations like New Zealand (where there are about 20 marine protected areas), will be will be an order of magnitude more difficult in the Solomon Islands. Then there is the problem of policing any marine protected areas that are established. This is important because if the local people agree initially to a marine protected area becoming established, then they are likely to change their minds if outsiders poach the reserves.

A variation on the marine protected area could be to allow certain reefs to lie fallow for several years and to rotate such areas around the islands so that all coastal villages are involved in the process – i.e. amplifying the indigenous serial prohibition. While the concept will not be foreign, the fact that the areas would have to be closed to fishing for years at a time instead of a few months would probably be unacceptable. And if such a system were established, then the venture would again depend on effective policing.

People in the rural communities live from day to day. On any day the most pressing concern is food for that day. Planning is uncharacteristic. Therefore the necessity to live just today normally out weighs the long-term goals of conservation. The common reply to the message of conservation when it is preached to the villagers is…“It is easy to be sitting in a comfortable chair in an air-conditioned office, with the government providing a roof above your head and a salary at the end of the month to be preaching conservation, come and live with us and know the challenges we face”. Any conservation project must therefore be holistic in approach and implemented bottom up rather than top down.

One of the biggest challenges in the declaration of marine protected areas in a society like Solomon Islands, where compensation is almost a way of life, is the provision of an alternative for the people. This need should not escape the planners and administrators. Marine protected areas and conservation measures must build within a frame work sustainable alternative projects. This does not mean cash hand outs however.

Five protected islands designated as bird sanctuaries that were listed by Wells and Jenkins (1988) are no longer protected. The acts under which they were instituted have been repealed (Biliki pers. comm.).

Plans are underway to set up a tourist resort on Mandoleana Island (one of the designated bird islands), though local people currently dispute ownership of the island. Since the islands lost what protection they previously had, the aquarium trade has contributed to significant degradation of coral reefs (Ishmael Tavasi, pers. comm. 2000). Tavasi stated that corals around the islands, especially around Mandoleana Island, have been broken and damaged. The current land dispute regarding Mandoleana Island has also been a major impetus for local people to destroy the coral resources on the Island. Each of the land owning claimants is trying to exploit the resources of the reefs to their fullest before any decision about the ownership is made. They may even protract negotiations to ensure they have ample time to "clean out" the reef resources before the island is designated a sanctuary.

Apart from the Arnavon Marine Conservation Area described below, the only area of Solomon Islands Reef that has been consistently protected for nearly two decades was the fringing reef immediately in front of the former Coastal Aquaculture Centre at Aruligo about 25 km northwest of Honiara. It was generally acknowledged that many of the species that were depleted elsewhere were relatively abundant in this reserve. Ironically, although the area was right in front of a research organisation, no effort appears to have been made to compare the biodiversity and the abundance of reef animals on this reef with adjacent reefs that were routinely fished. Sadly this opportunity was lost along with the research station was closed after being attacked in November 1999.

The Arnavon marine conservation area

The Arnavon Marine Conservation Area in Manning Strait between Isabel and Choiseul Islands was initially designated an off-limits area under a trespass law by the Ministry of Natural Resources in 1975, and was later included in the Provincial Protected Lands Bylaw in 1979. In 1980 a wild life sanctuary of 1000 ha was established within the Arnavon Islands under a local Government ordinance, principally to protect the nesting grounds of hawksbill and green turtles.

The reserve was, however, subsequently abandoned due to disputes over ownership of the Islands (Solomon Islands' Fisheries Division internal information paper). According to Wells and Jenkins (1988), the move to establish a protected area was not made in consultation with all parties who believe they had rights to that area under customary law. Wells and Jenkins (1988) further stated that an aggrieved party, in protest, destroyed a Worldwide Fund for Nature-funded turtle hatchery that had been established as part of a conservation programme – not an auspicious start.

Another endeavour to relieve pressure on the Arnavon Reefs was providing the villagers with new fishing equipment so that they could catch deep sea snapper and tuna – the rationale being that the deep sea fishery would compensate for the loss of the reef resources. The reef fish are, however, worth about the same as the deep sea fish, and their capture requires a lot less time at sea. What happened therefore, was that the villagers fished local reefs to greater effect, with their new equipment.

In 1992, renewed interest by the Government and landowners in reviving a protected area for the Arnavon Islands and surrounding marine areas resulted in the Environment and Conservation Division and the Fisheries Division of Solomon Islands and The Nature Conservancy re-establishing the protected area. A community-based management committee is supported by The Nature Conservancy. The Arnavon Marine Conservation Area may be the first successfully established marine protected area with community support in the South Pacific.

Future developments

There are plans to designate more sites as marine protected areas. The Solomon Island/Japanese Solomon Islands' Fisheries Division/ OFCF joint project on trochus and green snail reseeding of coral reefs is negotiating with landowners to declare Alokan Island in the south of Russell group as a marine protected area. The negotiations have been progressing well, and the chief has already closed the island from any fishing activities, especially night diving. Only fishing for church fundraising is currently allowed (John Legata pers. comm. 2000).

The Ghizo office of Worldwide Fund for Nature is also planning to declare Kennedy Island, near Ghizo as a marine protected area. A resource management order is currently being drafted but enforcement will be one of the biggest challenges. Plans are that dive operators will be involved and that a levy will be imposed to fund enforcement and protection of the marine protected area. Worldwide Fund for Nature is also planning awareness campaigns on rural communities especially on the ecology and reproduction of invertebrates. There are plans to produce videos aimed at showing local communities how reef organisms are ecologically interlinked and the implications of over fishing (Simon Foale pers. comm. 2000).

One of the fundamental problems in establishing marine protected areas anywhere is the ability of the governing body to demonstrate convincingly the effectiveness of the reserve. If it is argued that establishing the reserve will increase the diversity and the abundance of reef species, and improve the chances of re-seeding depauperate reefs, then this needs to be demonstrated. An initial baseline survey of the site and of controls is essential. Then a monitoring programme is needed to identify post-reservation effects. This is no small task. Long term monitoring of coral reef resources requires considerable scientific expertise, and continuity in terms of funding and personnel. It also requires that the staff involved have the appropriate taxonomic, sampling and statistical skills. Unfortunately, as is mentioned below, such facilities and resources are lacking in Solomon Islands.

While it is possible to contract out such baseline and monitoring work organisations like the University of the South Pacific, SPREP or ICLARM, continuity requires that the contract be long term funded, and that the research organisations have some realistic guarantee of safety.

Reef re-stocking

Restocking the reefs with some of the most overfished species is technically feasible, but has not been attempted on any large or meaningful scale in the Solomon Islands. A potential problem is the high mortality of transplants if left unprotected. For example, experience in giant clam cultivation suggest that mortality rates of unprotected juveniles might be prohibitively high relative to the cost of the spat (Munro 1993).

The Solomon Islands Government and ICLARM established the Coastal Aquaculture Centre, previously based at Aruligo, as a co-operative venture. The Centre succeeded in rearing giant clams (*Tridacna gigas*) for the aquarium trade and for reef re-stocking, and successfully demonstrated the captive breeding of bêche-de-mer for reseeding reefs. A Solomon Islands' Fisheries Division/OFCF project to re-seed coral reefs with trochus and green snail coral reef was also conducted at the Centre.

Concerns about depletion of reef fish harvested for the aquarium trade have prompted the Australian Institute of Marine Science (AIMS) and ICLARM to start a project to see if they can grow aquarium fish from fry caught in light traps and surf nets. Most fry perish before they colonise reefs, so the concept of growing fry in aquaria, where mortality would be much lower, is a good one. The project is still in its early stages. ICLARM is planing trials at Nusatupe.

The closure of the Aquaculture Centre at Aruligo after it was attacked, in November 1999, by a group of self-styled Guadalcanal militants from another part of the island, has however, severely disrupted these projects. Key scientific staff left Solomon Islands and stocks of animals in aquaria at Aruligo were purportedly eaten. With Solomon Island Government funding, ICLARM plans to compensate for the loss of facilities at Aruligo by enlarging its field station on the island of Nusatupe near Ghizo in Western Province.

Aquaculture

The development of aquaculture industries could potentially relieve pressure on reef resources. ICLARM has demonstrated the viability of a long-line pearl oyster farming industry in Western Province. There is real potential for developing such an industry in the Solomon Islands. Aquaculture ventures typically require considerable foreign investment, however, and this is unlikely while the economic future of the capital, Honiara, and the political stability of the nation is compromised by ethnic violence.

There is interest in encouraging villagers to cultivate and dry carrageen seaweeds like *Eucheuma* for the phycocolloid industry (Why 1985). Trial *Eucheuma* farming began in Solomon Islands in 1987 when a seaweed farming project initiated by Fisheries Division and funded by the UK's Overseas Development Administration, planted out seedstock of *E. alvarezii* obtained from Fiji (South 1993). Grazing by rabbit fish (Siganids) was a major problem until a shift to more exposed locations gave better results. By 1990 four farms produced an export of 2.5 tonnes (Skewes 1990). Despite these optimistic signs, the Solomon Islands *Eucheuma* industry collapsed. *Euchema. alvarezii* have colonised habitats and can still be found in former seaweed farming areas.

The financial return to the producers, relative to their effort is, something that needs to be carefully considered along with any assurances made to buyers about continuity of supply. The marine colloids industry depends on guaranteed supply. The scenario where a village is expected to produce consistently a container-load of good grade dried *Eucheuma* per month when the same amount of cash might be earned by selling fish from the reef, is something that must be realistically considered by anyone making a financial investment in such a venture.

Until recently there were two successful prawn farms in Solomon Islands. In 1998 they exported prawns worth $SBD1.3 million (Table 1). Both farms were situated west of Honiara. In 1999 all of the equipment of one farm was destroyed by members of the Isatabu Freedom Force (previously known as the Guadalcanal Republican Army) and the staff terrorised. The other farm, which struggled to operate under trying conditions for a year has also been forced to close. The number of Solomon Islanders put out of work by both prawn farm closures, some of whom have had to return to a subsistence life style, is indicative of how such aquaculture ventures may relieve pressure on coral reef resources.

Problems for conservation

Ineffectual enforcement

Despite some restrictions and regulations, there is little evidence to suggest that the Government of the Solomon Islands has successfully managed and conserved any of its commercially important reef species. Part of the problem is that even with the best of intentions the Government has little ability to enforce any of its regulations especially in remote areas. One of the authors (Hay) had to buy an adult leather back turtle captured by the Police Force near Aruligo in December 1999 to prevent the police officers from butchering the protected animal.

Measures to conserve stocks also need to be applied effectively and in a consistent and co-ordinated manner within Government, otherwise there is uncertainty and chaos. A tendency for some Government ministers to exercise discretionary rights without consulting their departments for advice is a problem. Such action fails to make use of the departmental information, for which, ironically, the Government may have paid large sums to obtain. It also destroys morale within the department as officers feel research is pointless if blithely ignored. And it undermines departmental officers in the eyes of the public and business community. It is difficult to prove any allegations of corruption concerning ministerial discretion in issuing fishing licenses.

As an example, because of declining populations of sea cucumbers, a national fisheries regulation banning the catching and exporting of the sandfish species (*Holothuria scabra*) became effective on 24 July 1997. On 29 February 2000, however, the current Minister of Fisheries arbitrarily lifted this ban without advising his Fisheries Division; the Enforcement Section was only made aware of the change in regulations through comments made by a commercial bêche-de-mer dealer. Currently a similar situation may be brewing in issuing licenses for the life fish trade. Such unilateral and arbitrary actions by politicians are a major threat to conserving marine resources in the Solomon Islands.

The inability of fisheries officers to enforce existing fisheries regulations, or even to monitor what is happening in such a huge archipelago, endangers coral reef resources. Currently, and for several years, the Solomon Islands Fisheries Division has had an acute shortage of operational funding. There is no money for research and very little for testing compliance in near shore waters. Without sufficient funds to secure existing facilities and equipment against theft; to maintain its equipment; to provide boats, motors, fuel, radio equipment; for travel and for aerial observations, then the Division is impotent.

Eroding indigenous management

At the village level, while indigenous management systems play an important role in conservation and management of coral reefs they have inadequacies. The success of prohibitions placed as a tabu from the Christian leader or kastom man depends upon the belief that going against this may result in a curse or bad luck. These tabus are still successful to some extent, though erosion of cultural values due to western European influences and the presence of social dissidents within the society has resulted in some failures.

Where the reef owners place tabu on a reef, the tabu has to be enforced and intruders chased away. Where the reef owners are in consensus, the tabu is successful. But disagreements between individuals of the social owning group may result in the continued harvest by some individuals regardless of the tabu. Poachers, especially at night, are a common problem on such closed reefs.

Johannes (1978) argued that the two main factors contributing to the demise of traditional marine tenure conservation are the introduction of a monetary economy and the breakdown of traditional authority. Crean (1999) supported this contention and suggested that fisheries management is an equilibrium between centralist and community-based forces where the focus is the exploitation and management of common property resources (CPRs). Crean (1999) further argued that national developmental aspirations and commercial activity has weakened traditional social hierarchies resulting in the marginalisation of customary law and the advent and promotion of an exogenous legal system through a modern centralised governing system. This in effect created a functional dichotomy in the coastal resources exploitation and responsibilities, resulting in a shift from community based management of coastal resources to a central-based management. The decline of traditional management controls and the adoption of new and more efficient fishing methodology to satisfy a `production oriented harvesting system' resulted in the decline of recuperative capacity of coastal ecosystems (Crean 1999). Oreihaka and Ramhia (2000) stated, most villagers perceive that such a centrally based management system would be the most effective. In contrast Crean (1999) also discussed how such a centrally based management system has succumbed to pressures in Shetland Islands, in the North Atlantic resulting in a shift to community-based management systems. Hopefully over time an equilibrium in Crean's (1999) model may be achieved which will result in better management of the coral reef resources of Solomon Islands.

Difficulties in establishing marine protected areas

Because all of the reef areas are custom owned, the concept of permanently setting aside areas as marine reserves is generally unacceptable. This is particularly so during a period when the population is being encouraged, even coerced, into embracing a western-style capitalist economy, and locking up the very resources that could be sold therefore appears to make little sense to villagers. This is discussed more fully under the section on marine protected areas above.

Lack of research facilities and espertise

Fundamental to marine conservation is having the ability to monitor how the various human effects listed above impact on coral reefs and lagoons. We need to be able to measure change, and that requires undertaking careful base-line studies. Also required is a clear understanding of nearshore coastal processes, e.g. an understanding of circulation patterns. These tasks require expertise in a wide range of marine science disciplines and "in house" analytical facilities, e.g. for analysing seawater chemistry.

In a country where primary school education is not yet compulsory and few Solomon Islanders have the benefits of more than two or three years of formal education, it may seem out of place to advocate for a much stronger marine biological research capability in the Solomon Islands. The economy is, however, heavily dependant on the tuna industry and the predominantly rurally based population is heavily dependent on reef fisheries for their very sustenance. So if fisheries resources are mismanaged, as some already appear to have been, the consequences may be severe.

Currently the only government funded facility likely to have any capability for nearshore oceanographic and marine ecological research is the Fisheries Division of the Department of Agriculture and Fisheries. Research is not, considered, however, to be a major divisional role. Most of its activities relate to running an observer programme on foreign-owned tuna vessels and in issuing licences.

This Division is also perpetually broke with substandard accommodation. Most of its equipment has been stolen, there are no laboratory facilities, and the library is poor. Morale is low, trained staff are leaving and there is little motivation for, or interest in, research projects unless someone else pays, and then they tend to be for desk-top or questionnaire type studies. The Division's coastal research capability is minuscule. It has little to no expertise in nearshore oceanography, water chemistry, phytoplankton, zooplankton, algae, invertebrates, soft bottom benthos, coral reef ecology, mangroves, and biosystematics. Little field work is accomplished. Initiatives for research invariably come from overseas agencies like WWF – rarely from inside the Country. The last major piece of original fisheries research requiring sampling and extensive field work was a bait-fish study over a decade ago (Hay pers. obs.).

In the absence of any effective government-funded research agency, that leaves the various non government agencies. The largest is ICLARM, previously based at Aruligo and now sharing the small island of Nusatupe near Ghizo with a relatively large airfield. As mentioned, ICLARM has been mainly interested in the aquaculture of overfished reef animals with the view to restocking reefs, starting new industries (e.g. pearls) and supplying the aquarium trade. Recently ICLARM began an environmental study to monitor the effects of logging operations on inshore marine ecosystems. This was in conjunction with the National Institute of Water and Atmospheric Research (NIWA) in New Zealand who, in the absence of any analytical facilities in the Solomon Islands, had to take all water and sediment samples back to New Zealand for analysis. Whether this study will continue in the light of current ethnic tension is uncertain.

The Japanese aid agency OFCF has funded research on restoring some overfished species, e.g. greenssnail, and has worked collaboratively with both ICLARM and Fisheries Division. OFCF joint projects are contingent on a Japanese-Solomon Islands fishing agreement acceptable to Japan.

The University of the South Pacific (USP), part owned by the Solomon Islands, has the potential to provide the Solomon Islands with much of the marine ecological expertise it requires. Most Solomon Islands marine scientists graduate from USP through its Marine Studies Programme at Laucala Bay in Suva. Currently USP has a Centre in Honiara; but it mainly teaches undergraduate courses, and there is little emphasis on marine sciences. A decade ago the University Council gave approval for relocating the University's Institute of Marine Resources from Suva to the Solomon Islands. Given its roles and goals, that Institute was best placed to fill several of the major gaps in research capability. In May 1999 the Solomon Islands Government gifted USP with a site and core facilities for the Institute at Aruligo. But because of terrorist activity, the facilities and site had to be abandoned, together with the adjacent Coastal Aquaculture Centre. So the task of relocating the Institute to Solomon Islands took a massive backward step. Currently USP and the Solomon Islands Government are working together on finding a new site for the Institute of Marine Resources.

Conclusions and recommendations

There are clearly numerous threats to the ecological stability of Solomon Islands reefs and lagoons. The impact of the Europeans, and more recently Asians, has been and is out of all proportion to their numbers. They have introduced international trade and new land practices such as logging, plantation development and mining that often cause excessive sedimentation in nearshore waters. In matters of fishing, as Boutilier (1975) suggested, it is possible that foreigners from temperate climes, where there tend to be huge numbers of relatively few coastal fish species, may apply bulk fishing techniques on the assumption that the same situation applies in the tropics – where, in fact, the reverse applies; i.e. there are many more species but in lower numbers.

Some activities, such as fishing and logging are currently damaging reefs. Others such as plantation development on hill country, new variations on fishing, pollution from industrial and urban development, and perhaps new mining ventures are potentially damaging. Precisely how damaging we don't know, because few studies have been conducted in the Solomon Islands. But on the basis of research done elsewhere, there is clear cause for concern.

The current and potential effects of human activities on coral reefs and lagoons need to be researched. Predictive cost benefit analyses including environmental costs and benefits for new ventures are vital; but for them to be meaningful there is an urgent need to monitor the effects of current activities. How else do we learn from our mistakes? Instead we have a situation where, as in the case of Silvania's southern Marovo plantation development, the only study the government commissioned, after granting permission for the project to go ahead and four years after *Silvania* commenced development operations, was a desk-top study assessment that expressed concerns like the social problems associated with an influx of labour and an absence of any marine ecological information. It seems somehow unlikely that such concerns will be heeded by the developers given their previous poor adherence to the government code practice for logging. They are hardly likely to fund a long-term marine survey.

What is really required is a robust monitoring programme to measure the long term environmental and social impacts of developments already underway, such as plantations. Only then are we likely to predict the impacts of expansions in the industry.

A perceived urgency to decentralise urban development because of the disruption that ethnic violence has caused in Honiara, coupled with the expediency of discharging raw sewage into the sea, as currently occurs in Honiara, could easily result in the rapidly growing towns like Auki, in Malaita, discharging large volumes of raw sewage to the detriment of local reefs. Plans to mine deposits of gold, nickel, copper and phosphate elsewhere in the archipelago are likely to be detrimental to lagoons and reefs because of runoff from land clearance, access road construction and associated port development.

Lasting solutions to environmental problems are usually those that people seek for themselves; but such solutions are only possible if most of the people actually perceive there to be a problem. Relatively few Solomon Islanders are aware of reports of coral reef destruction overseas. Even graphic television programmes like those by Jacques Cousteau showing methods and effects of overfishing in the Philippines have little impact in a country where there is no national TV channel, relatively few satellite dishes and many villages lack electricity. Compounded by the very high illiteracy rate, perhaps most fundamental problem of all that threatens coral reefs may be that most of the rural fisher folk are unaware that their reefs are really under threat.

There is no simple single solution to the overfishing problem but some definite improvements could be made. The government could outlaw wasteful practices such as the live reef fish trade by arguing that there is much less waste in exporting chilled or frozen fish for similar returns. It could outlaw or severely restrict the harvesting of fish like anemone fish for the aquarium trade by arguing that scuba diving tourists wanting to observe the fish in the field attract more foreign revenue. It could also heed the advice of Adams *et al.* (1992), which the Government commissioned, and prohibit, by law, the use of scuba and hookah equipment to harvest any reef-dwelling species. And finally the Government can, as it has done, prohibit further commercial exploitation of species that have clearly become scarce.

Restocking depleted species by re-seeding depopulated reefs with hatchery-reared animals is another approach, and the animals that best lend themselves to this practice are mainly shell fish and sea cucumbers. As yet, however, there has been no large-scale restocking programme anywhere in the Solomon Islands though the task is technically feasible.

Except for studies on the aquaculture potential and captive breeding for reef reseeding of giant clams, trochus, green snails and bêche-de-mer (all heavily overfished species) no studies have been done to asses the stock, ecology and biology of most of the fisheries on coral reefs. Initially it will be necessary to engage outside scientific expertise to undertake such tasks, but it is absolutely vital to develop a domestic skill base simultaneously. It is important that the expertise, the field data and the "memory" of such monitoring programmes remains within the country.

It is worth repeating here some of Wells and Jenkins (1988) recommendations plus some from the National Environmental Management Strategy:

- commercial fisheries development in reefs and lagoons should be undertaken with care as the Solomon Island fisheries resources are not as rich as they might appear to be;

- traditional knowledge of reef and lagoon fisheries should be used as a basis on which to build modern small-scale fisheries;

- coastal developments, such as road, hotel and other construction activities, should be undertaken with great care;

- a system of protected areas should be developed, with participation of customary landowners;

- there should be an improvement of environmental awareness and education. In this regards resource owners should be made aware of the resources they have, how to utilise them sustainably and the precautions they should take to protect these resources; and

- a strengthening of information database on reefs, estuaries and lagoons.

The coral reefs of Solomon Islands though reported to be one of the least disturbed by Maragos (1988) are probably the least known. Further studies need to be conducted to create an inventory of coral reefs in Solomon Islands. A lot of studies need to be conducted to determine the biodiversity of the coral reefs. The coral reefs support one of the biggest fisheries both for subsistence and artisanal purposes. The management of reef resources is, however, essentially boom and bust with belated, weakly enforced checks and controls. Studies on stock assessment, biosystematics and ecology of the fisheries resources need to be initiated and completed.

Mariculture is likely to relieve the pressure on reef resources, and for this reason most Pacific island nations, including the Solomon islands highlight aquaculture as a priority area in their fishery. Yet to date commercial mariculture in the South Pacific has been, with some notable exceptions, largely experimental, a failure or at best marginal (Veitayaki and South 1997). Part of the problem is that mariculturing predators requires a consistent supply of protein-rich feed in a region where protein is typically in short supply. With the exception of *Eucheuma* farming, most aquaculture ventures require foreign investment, and financial investors require some assurance of political and economic stability. That no such assurance is currently possible in the Solomon Islands is demonstrated by the recent closure of existing aquaculture industries.

Finally, if the people of the Solomon Islands are to safeguard the ecology of their reefs, then some how the entire rural community is going to have to adopt, collectively, a long-term plan for reef sustainability in place of a prevailing attitude where individual villages view reefs as a source of sustenance and cash for their day-to-day existence. The day-to-day method can only hope to succeed if the population is stable and there is little desire for economic growth. Neither applies in modern-day Solomon Islands where none of the statistics and trends bode well for coral reefs. A burgeoning, largely rural population with little opportunity for urban employment, and a desire for development, must depend increasingly upon nearshore marine resources both for food and for cash. At the same time the Government and foreign aid donors are encouraging Solomon Islanders to enlarge the coastal fishing catch. If the resources are frittered away and given little or no chance of renewal, then the resources will be lost and Solomon Islanders will face the same overfishing problems as Indonesian, Philippine, Mediterranean and Newfoundland fisherfolk, to name but a few examples.

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