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Niue sustainable coastal fisheries pilot project: Literature review and pilot baseline survey

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Abbreviations

COTS	crown of thorns starfish
ICWM	integrated coastal and watershed management
ID	identification
IWP	International Waters Project
PSA	participatory situation analysis
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
USP	University of the South Pacific

Units of measure

ha	hectare
km	kilometer
m	metre
min	minutes

Executive summary

The International Waters Project (IWP) aims to strengthen the management and conservation of marine, coastal and freshwater resources in the Pacific Islands region. It is financed through the International Waters Programme of the Global Environment Facility, implemented by the United Nations Development Programme, and executed by the Secretariat of the Pacific Regional Environment Programme (SPREP), in conjunction with the governments of the 14 participating independent Pacific Island countries.

IWP in Niue is involved in the establishment of a pilot project on sustainable coastal fisheries. During 2003, the Niue IWP National Programme completed a series of island-wide village consultations and a participatory situation analysis (PSA) on coastal marine resources. Through this process, two villages (Alofi North and Makefu) were selected as sites for the initial pilot projects, which are designed to address the priority environmental concerns of local residents with respect to sustainable coastal fisheries.

Many community members share the perception that coastal marine resource are being depleted, and a range of possible causes were put forward as the reasons for the perceived depletions. The next step in the process of addressing these concerns is to undertake a scientific baseline assessment of the proposed pilot sites, and to validate the village perceptions. This work commenced with a review of existing information and a reconnaissance trip in November–December 2003 (which forms the basis of this report); the work will continue during 2004. However, as a result of impacts to Niue's reef system caused by Cyclone Heta (which struck in early January 2004), the terms of reference for the baseline work were revised, and may be further expanded after consultations and assessment from during a second visit (in April 2004) to complete the initial baseline assessment.[1] Cyclone Heta was a severe (category 5) cyclone that damaged many nearshore coastal features and coastal infrastructure on the western side of the island. The most destructive waves were from the northwest, and impacted the coastal areas of the two pilot villages.

This report includes a review of information relating to Niue inshore fisheries and includes both written information from reports and publications as well as information from consultations in November–December 2003 with relevant community members. Pilot data collected during an initial visit to Niue by the author is also included as part of the review process. The pilot data was collected during familiarization surveys of reef flat and slope habitats to gauge the degree of variation and patterns in the distribution of key species and biological communities. During the 2003 visit, information on possible sources of land-based pollution was investigated to validate the concerns of local communities. In addition, an assessment of potential harvest impact was carried out by reviewing published reports as well as by mapping and describing the degree of access to reef flat resources via "sea tracks".

A review of the status of coastal marine resources in Niue based on previous studies showed that prior information is scarce and often in a form that does not assist in assessing long-term trends in resource availability. A lack of data frustrated efforts to validate possible causes of resource depletion from land-based activities. Inconsistency in survey methodology in previous studies also hindered the assessment of long-term trends in resources. Although there may be a correlation between perceived resource depletion and the principal human habitation and activity area (Alofi Harbour), it is probable that a major contributor to resource depletions is the limited natural carrying capacity of coastal habitats, which are under constant pressure from high harvest levels. When coupled with natural disturbances (cyclones, storms, bleaching) and large variations in species replenishment (due to the isolation of Niue from

[1] For details of the baseline assessment and Cyclone-Heta related impacts, see Fisk 2007a.

other similar reef systems), it is clear that the result will be wide fluctuations in resource availability and abundance, on both spatial and temporal scales. It is possible to hypothesise that the perceived depletion of stocks could be attributed to interference with recovery processes following major natural perturbations, through a combination of localised pollution effects and widespread overharvesting. Such a situation requires a management strategy that takes into account these aspects of Niue’s coastal habitats and resources. One obvious strategy will be to identify areas that can significantly contribute to fisheries sustainability via a series of strategically selected, long-term, and highly restrictive coastal habitat protection measures.

The impacts of Cyclone Heta in January 2004 will contribute to depletions in specific resources on the west coast in particular. The rate of recovery will be largely determined by the level of harvesting that will occur over future years, as well as by the natural rate and specific characteristics of the regeneration processes of this reef system. An unhealthy coastal marine environment will no doubt inhibit this process. It is therefore imperative that the full extent and impact of Cyclone Heta be understood and incorporated into an overall strategy for sustainable management of Niue’s coastal resources.

1 Background

1.1 Niue Overview[2]

The nation of Niue consists of a single island of 261 km^2, and is the largest raised coral atoll in the world. It is situated in the South Pacific (Latitude 169º 55'W, Longitude 19º 02'S), approximately 480 kilometres (km) southwest of Tonga, 660 km south of Samoa, and 930 km west of the Cook Islands. The relatively low diversity of animal and plant species found on Niue is determined largely by three factors:

1. Niue's isolation from other landmasses limits the number of species reaching the island.
2. Niue is relatively young geologically. The upper terrace formed during interglacial periods that occurred prior to 500,000 to 900,000 years ago (Schofield 1959); the animals and plants arriving in Niue have thus had limited time to evolve.
3. Niue is relatively small and provides a restricted range of habitats (e.g. it lacks a reef lagoon), which limits species numbers and degree of endemism (the only known endemic marine organism is a sea snake)

Niue consists of an uplifted coral limestone plateau perched on top of a submerged volcano. The central plateau is slightly dished in shape with a rim at about 68 m above mean sea level, dropping to about 30 m in the centre, suggesting a former lagoon. A narrow lower terrace 100 m to 200 m wide at about 28 m above sea level surrounds this central plateau. The coastline is rugged, and consists of precipitous cliffs that drop straight into the sea, except for the west coast, where there is a wave-cut rock platform 20 m to 80 m wide and then a very steep drop-off.

The island is composed of three types of pure limestone: reef rock, beach conglomerate and cemented or loose coral sand. The ground surface is often jagged with exposed sharp rock outcrops and boulders, with pockets of topsoil of varying depth between them. There are no watercourses on the island. Rainfall infiltrates quickly through the thin layer of topsoil and down the cracks and cavities in the base rock. The permanent groundwater table is found about 60 m below the rim of the central plateau, indicating a mounded body of fresh water above mean sea level. Springs of fresh (brackish) water leak out from the base of the cliffs. Many caves occur around the coastline and in the centre of the island; the latter caves often contain pools of freshwater. There are wide chasms showing evidence of the uplifting process.

The climate of Niue is hot and moderately wet in the summer months (October to April), and drier and cooler in the winter months (May to September). Annual rainfall averages around 2000 mm but varies widely from year to year (from a high of 3175 mm in 1924 to a low of 1070 mm in 1931). Maximum daily temperatures vary seasonally from 27°–31° C. Niue lies well within the tropical cyclone belt and significant cyclones have occurred with an average 10-year frequency. More recent cyclones include Ofa in 1990, with recorded wind speeds of 185 km per hour (kph), or 100 knots. Cyclone Heta struck in early January 2004, and was among the most destructive cyclones in living memory. Previously unheard of wave heights extended destructive waves above the western cliff heights; unconfirmed reports indicate wind gusts were up to 300 kph. The southeast trade winds blow steadily for most of the year but particularly between April and October, maintaining a steady breeze of between 10 kph and 20 kph during the day. The tidal range is on the order of 1.5 m, with a corresponding fluctuation of 100 mm in the groundwater table.

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[2] Section 1.1 was reproduced (with relevant sections modified) largely from Niue's National Biodiversity Strategy and Action Plan (see Government of Niue 2001).

The inability of Niue's soils to hold surface water for long periods results in a steady and rapid outflow of water to the coastal environment wherever springs are located. Niue has no lagoon and the depths increase rapidly offshore, reaching over 1000 m within 5 km of the shoreline. A narrow fringing reef encircles most of the island with a thin layer of corals; richer coral growth is found at the upper crest and at the deeper edge (at 30-40 m depth, before the dropoff into very deep water). The total area of reef flat and subtidal reef has been estimated at 620 hectares (ha).

The coral reefs of Niue have been subject to damage by cyclones, as well as by some fishing techniques, such as the use of explosives and poisons. Many Niueans fish, although few rely on fishing as a primary income source. Most fishing and invertebrate collecting occurs on the side of the island that is protected from the prevailing southeast tradewinds. The natural inaccessibility of the eastern coast means that this area plays an important role in marine conservation.

1.2 Introduction

The International Waters Project (IWP)[3] is a 7-year, USD 12 million initiative concerned with management and conservation of marine, coastal and freshwater resources in the Pacific islands region, and is specifically intended to address the root causes of environmental degradation related to trans-boundary issues in the Pacific. The project includes two components: an Integrated Coastal and Watershed Management (ICWM) component, and an Oceanic Fisheries Management component (the latter has been managed as a separate project). It is financed by the Global Environment Facility under its International Waters Programme. The ICWM component is implemented by the United Nations Development Programme and executed by the Secretariat of the Pacific Regional Environment Programme (SPREP), in conjunction with the governments of the 14 independent Pacific Island countries: Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. The ICWM component focuses on integrated coastal watershed management, and supports national and community-level actions that address priority environmental concerns relating to marine and fresh water quality, habitat modification and degradation and unsustainable use of living marine resources through a 7-year phase of pilot activities, which started in 2000 and will conclude at the end of 2006.

The theme and location of each pilot project was selected on the basis of community and government consultation. Each project is expected to have adopted an interdisciplinary approach involving the three pillars — economic, social and environmental — of sustainable development. Each project is intended to address the root causes of degradation affecting one or more of four focal areas:

- marine protected areas
- coastal fisheries
- freshwater resources
- waste reduction.

IWP's pilot project on Niue addresses community-based sustainable resource management and conservation issues associated with the focal area of sustainable coastal fisheries. The Niue IWP National Programme has completed a series of island-wide village consultations and a participatory situation analysis (PSA) on coastal marine resources. From this process, two villages — Alofi North and Makefu — have been selected as sites for the initial pilot projects

[3] IWP is formally titled Implementation of the Strategic Action Programme of the Pacific Small Islands Developing States.

to address the priority environmental concerns of local residents.

Many community members share the perception that coastal marine resource are being depleted, and a range of possible causes were put forward as the reasons for the perceived depletions. The next step in the process of addressing these concerns is to undertake a scientific baseline assessment of the proposed pilot sites, and to validate the village perceptions. This work commenced with a review of existing information and a reconnaissance trip in November–December 2003 (which forms the basis of this report); the work will continue during 2004. However, as a result of impacts to Niue's reef system caused by Cyclone Heta (which struck in early January 2004), the terms of reference for the baseline work were revised, and may be further expanded after consultations and assessment from during a second visit (in April 2004) to complete the initial baseline assessment.[4] Cyclone Heta was a severe (category 5) cyclone that damaged many nearshore coastal features and coastal infrastructure on the western side of the island. The most destructive waves were from the northwest, and impacted the coastal areas of the two pilot villages.

This report includes a review of information relating to Niue inshore fisheries and includes both written information from reports and publications as well as information from consultations in November–December 2003 with relevant community members. Pilot data collected during an initial visit to Niue by the author is also included as part of the review process. The pilot data was collected during familiarization surveys of reef flat and slope habitats to gauge the degree of variation and patterns in the distribution of key species and biological communities. During the 2003 visit, information on possible sources of land-based pollution was investigated to validate the concerns of local communities. In addition, an assessment of potential harvest impact was carried out by reviewing published reports as well as by mapping and describing the degree of access to reef flat resources via "sea tracks".

The outcome of stakeholder consultations with government and local residents during November–December 2003 has been reported in an earlier document (Fisk 2003) but relevant information from those activities is also included in this report.

Information from the 2003 visit and the literature review constitute a view of the situation on Niue pre-Cyclone Heta, which struck on 5 January 2004, and severely impacted the marine and terrestrial environment, and most of the infrastructure in and around Alofi and the western side of the island. It is expected that a re-evaluation of the review conclusions will have to be carried out following a post-Heta visit and before the baseline activities can commence.

1.2.1 Structure of this Report

The structure of this report includes a review of existing knowledge (from previous studies, reviews, and consultations), followed by a pilot survey (including testing of methods), and a general assessment of coastal resources and sources of land-based pollution (to validate the communities concerns and perceptions regarding the status of marine resources).

Pilot surveys were carried out with the support of the two IWP Niue staff (Mr Sione Leolahi, and Mr Logo Seumanu), and two student attachments (Ms Sharon Eveni, and Ms Vanessa Marsh).

1.2 Objectives of the baseline phase

The objectives of the baseline assessment phase are to:

1. Assess the validity of community perceptions regarding coastal fisheries resource problems and their causes, as identified during participatory problem analysis exercises and consultations with local stakeholders;

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[4] For details of the baseline assessment and Cyclone-Heta related impacts, see Fisk 2007a.

2. Develop a strong biological basis for community decision making and management actions; and
3. Establish a baseline for biological evaluation of effectiveness of management measures.

1.3 Aims

The aims of baseline activities are to:

1. Review the existing knowledge of coastal resources in Niue, with emphasis on the pilot sites;
2. Validate the identified priority environmental concerns in the pilot sites and their probable causes (thought to be related to declining availability and degradation of marine resources);
3. Identify which of the validated causes and concerns are likely to be best dealt with at the village and/or National level;
4. Test survey methods, potential scope of work, and logistical requirements as part of the initial review process;
5. Conduct baseline surveys within the pilot sites to assess the current status and health of coastal resources, with particular emphasis on fishery species of concern;
6. Include a capacity building component into the baseline work to ensure that village volunteers and national staff are capable of conducting future monitoring in relation to the marine protected areas and sustainable fisheries;
7. Make recommendations for consideration of options for management for the villages, based on the outcomes of the baseline survey in association with other social or economic surveys;
8. Following the final decisions on management solutions, develop a monitoring and evaluation plan, including establishment of permanent baseline monitoring sites where specific quantitative data will be collected over time to demonstrate success and lessons learned for both national and regional knowledge; and
9. Include training of local villagers during the permanent baseline monitoring phase so that they can conduct regular monitoring of the permanent baseline sites in the future.

This report includes outcomes of activities related to the first four aims above.

2 Review of existing information

This review is a summary of existing available information about coastal resources in Niue, with emphasis on the pilot sites of Makefu and Alofi North. It incorporates knowledge from current users of the area such as local divers and fishers who may not have been part of the PSA process (SPREP 2003) conducted prior to this visit. During the author's visit, no direct consultations were carried out with local villagers; however, consultations were held with relevant government staff and individuals from the private sector. Consultations focused on questions relating to broad scale processes and disturbances and their extent, timing, and perceived impact. For example, good information was obtained on the timing, extent and impact of prior coral bleaching events. Details of the people consulted during the first visit are presented in Appendix 1.

2.1. Major natural disturbances of coastal marine habitats

The current status of Niue's natural resources have been shaped in part by past natural disturbances (particularly major events). Human disturbances (including harvesting) additionally impact resources, and in many cases can exacerbate the effects of natural disturbances. Table 1 summarises the major acute disturbances that (i) were recalled by local residents (see Appendix 1) with strong marine interests, and (ii) were recorded in published literature (in the case of cyclones occurring before 1990). The disturbance mechanisms were inferred by the author from the nature of the disturbance.

2.2. Species of specific concern to villagers

Detailed information was recorded during the PSA phase with respect to the concerns of villagers, and possible causes. Many fish and reef resources were perceived to have declined in abundance in Alofi North and Makefu (see Table 2 for a summary; IWP National Programme 2004). Though the list is probably not exhaustive, it does give an indication of where perceived declines have been most apparent. It can also provide guidance for determining the possible cause of such declines. To verify these perceived declines, accurate species identification is important. It is also important to verify the scientific names for the species listed, as local names can sometimes include multiple species groups or can indicate different life stages of the same species. A number of Niuean names can also refer to the same species on occasion. For these reasons, it is recommended that future work should include the production and use of visual charts with the majority of important fishery species illustrated, along with the equivalent Niuean names. Staff of the Secretariat of the Pacific Community are believed to be preparing posters identifying common marine invertebrates, but it is not known when this will be available. However, some basic but essential biological information should be made available to reconcile local beliefs and scientific knowledge, which will help in correcting some incorrect local beliefs regarding cause and effect with respect to marine species.

Table 1. Major acute natural disturbances affecting Niue

DISTURBANCE	MECHANISMS	TIMING	IMPACTS
Cyclone	Wave action; sediments; Freshwater input.	1959	?
Cyclone	Wave action; sediments; Freshwater input.	1960	?
Cyclone	Wave action; sediments; Freshwater input.	1968	?
Cyclone	Wave action; sediments; Freshwater input.	1979	?
Cyclone Ofa	Wave action; sediments; Freshwater input.	December 1990	Moderate to severe damage to land and coastal marine habitats; major destruction in north, west, and south sectors; metal debris in harbour area.
Harbour Wharf Extension	Nutrient input	2000	Blasting and removal of reef substrate.
Bleaching event	Elevated sea surface temperatures	March-June 2001	Low to moderate mortality to shallow corals especially on western side of island.
Crown of thorns starfish outbreak	Coral cover reduction and coral mortality.	?	Significant reduction in live coral cover.
Cyclone Heta	Wave action; sediments; Freshwater input.	January 2004	Very severe damage to coastal land and marine habitats; major destructive coastal sectors: north, west, and south.

Note: Earlier (pre-1990) cyclone dates were obtained from published literature. Disturbance mechanisms inferred by the author based on the nature of the disturbance. See Appendix 1 for list of people consulted.

The list of species (Table 2) from the PSA village consultation process (IWP National Programme 2004) for Alofi North and Makefu, indicated that far more invertebrate and other reef resources were thought to be declining, as compared to fish species. The composition of the "other reef resources" included ten species (or species groups) of molluscs (note that some Niuean terms refer to multiple species groups), two species of holothurian, one sea urchin species, ten crustaceans (mainly crab species), and three "seaweed" species. All of the "other reef resources" are mainly found on the reef flat and intertidal habitats, with some present in the shallow slope habitat. In addition, three of the six fish species of concern use the reef flat habitat when sufficient water is present.

The community perception is that over harvesting could be occurring and that there is a need to manage reef flat resources in a sustainable manner; it highlights the importance of maintaining healthy nearshore seas and healthy reef flat habitat with minimal land based impacts. It is important to note the significance of the reef flat habitat (which is targeted mainly by women) as a source of resources during adverse sea conditions, when it is too rough to fish offshore using boats.

Table 2. Fish and reef resources identified by communities as having declined in abundance in areas associated with the pilot sites.

VILLAGE CONCERN	SCIENTIFIC NAME (Common Name)	HABITAT	ALOFI NORTH	MAKEFU
1. Inshore Fish				
Nue (drummers)	*Kyphosos bigibbus* (Insular Rudderfish)	Slope mid-water		✓
Ika tea (threadfin) or *Ika sea*?	*?Polydactylus sexfilis* (Six feeler threadfin)			✓
Lakua (skippers)		Shoreline/ Intertidal	✓	✓
Mohe aho (parrot fish)		Slope & reef flat	✓	✓
Monega (parrot fish)		Slope & reef flat		✓
Kolala (surgeon fish)	*Acanthurus achilles* (Achilles Tang)	Slope & reef flat		✓
2. Other Reef Resources				
Alili (mollusc)	*Turbo setosus; T. petholatus; T. argyrostomus; T. chrysostomus; Australium calcar;* (Turbo)	Crest	✓	✓
Segame (mollusc)			✓	✓
Hihi-hihi muitea (mollusc)			✓	✓
Ugako (vermetid mollusc)	*Serpulorbis colubrinus* (small worm tubes)*; Dendropoma maximum* (large worm tubes)	Inner mid-reef flat	✓	✓
Matatue (mollusc)				✓
Papahua or *Papaaua* (jewel box oyster mollusc)	*Chama iostoma* (Oyster)	Mid-reef flat		✓
Matapihu (false limpet mollusc)	*Siphonaria cf sirius*	Mid-outer reef flat		✓
Mama Matatue (mollusc)			✓	✓
Gege (clams)	*Tridacna maxima, T.squamosa*	Slope & reef flat		✓
Feke (octopus)			✓	✓
Sepulupulu (bêche-de-mer)	*Holothuria atra*		✓	✓
Loli (bêche-de-mer)	*Holothuria leucospilota*	Reef flat	✓	✓

VILLAGE CONCERN	SCIENTIFIC NAME (Common Name)	HABITAT	ALOFI NORTH	MAKEFU
		pools		
Kina (short spined sea urchin)	*Echinometra mathaei*	Outer Reef flat		✓
Tatukumiti (shellfish)			✓	✓
Fufu (shellfish)			✓	✓
Paka tahi (crab)			✓	✓
Tagau (Crab)			✓	✓
Tutu (Crab)			✓	✓
Uga (coconut crab)	*Birgus latro*	Shoreline - inland		✓
Tohitohi (sea crab)				✓
Tapatapa (crab)			✓	✓
Kamakama (crab)				✓
He (sea crab)				✓
Limu kai (Seaweeds)			✓	
Limu tahi (Seaweed)			✓	
Limu fua (Seaweed)			✓	

Some scientific identifications were still to be confirmed at this writing. See Fisk 2007a and 2007b.

2.3. Review of causes and concerns

Many of the concerns relating to infrastructure and land-based sources of pollution that were considered in past studies and during consultations may not be of immediate relevance following the devastation of Cyclone Heta. These issues should be addressed when rebuilding the country from the effects of the cyclone, however, to avoid repeating past mistakes by using inappropriate technology, designs, and locations. A post-cyclone review will have to be completed and incorporated into this assessment before recommendations can be made for minimisation of land-based impacts on coastal habitats. In addition, to address possible overharvesting of resources will require more stringent and possible more restrictive resource management, so as to allow sufficient time for recovery from the impacts from of the cyclone.

Two main reports are relevant to this discussion, the national assessment of the priority environmental concerns of Niue (Butler 2003), and the PSA conducted in 2003 (IWP National Programme 2004). Butler's report presented a summary of issues and concerns dating back to 1991. His sources of information were published reports on the environment, and consultations with government and village representatives. The PSA report was more inclusive than Butler's assessment, with respect to consultations with village members, yet it essentially covered the issues highlighted by Butler in the previous year with one major exception. Butler (2003) noted that there appeared to be little awareness by local people of fisheries problems, which contrasts with the PSA analysis the following year, which found a high degree of awareness of coastal fisheries issues within the local community. Butler's report did note however, that coral reef stock depletions have been an issue of concern in some sectors of the community from at least the early 1990's (Government of Niue, 1991, in Butler, 2003).

Pollution and sedimentation were seen as causal agents of resource stock decline, along with over harvesting and destructive fishing practices (sources include Government of Niue 1991; Lane 1994; and SPREP 2001; all quoted in Butler 2003). This indicates that the main fisheries issues and perceived causes have been identified as present for at least 13 years. This correlates with the period following the last major destructive cyclone (Ofa) in 1990; stock declines will now be exacerbated by the impacts of Cyclone Heta. It is possible to hypothesise that the depletion of stocks can be attributed to interference with recovery processes following a major natural perturbation, through a combination of pollution effects and overharvesting. While some progress has occurred in this time period, such as the signing of a number of relevant international conventions and the passing of national legislation relating to fishing practices and pollution management (Butler 2003), there appear to have been few effective practical measures undertaken to address the causes underlying concerns over the status of Niue's inshore fisheries resources. As with the PSA (SPRP 2004) report, Butler (2003) noted addressing the continuing decline in stocks requires:

1. proper enforcement of fisheries regulations,
2. the design and implementation of practical fisheries management arrangements;
3. re-establishment and application of traditional conservation and fishing practices, and
4. improvement in public awareness programs.

While it is likely that lack of resources and capacity are the primary reasons for the lack of action, there are other social and economic reasons as well. Lack of capacity and resources to carry out appropriate activities has led to insufficient baseline and trend data for the government to use as a basis for good management decisions.

2.3.1 Concerns exprssed by pilot villages

The PSA report (IWP National Programme 2004) summarised the villagers' perceptions of the major concerns with coastal fishery resources and the causes for those concerns. In general, discussions with key government personnel established a similar set of concern categories, and in most cases, a shared belief in the causes of the concerns. The priority concerns for Alofi North and Makefu can be grouped under four general categories:

- Declining availability and degradation of marine resources
- Coastal pollution
- Contamination and pollution of groundwater (only in Makefu)
- Fish poisoning (ciguatera — only in Alofi North).

The above priority concerns can be applied to varying degrees to the whole of Niue, which underlies the significance of the pilot sites in setting the framework for the remainder of the country.

Table 3 summarises the concerns that arose in Alofi North and Makefu during the PSA activities (IWP National Programme 2004). Only concern relating to coastal fisheries issues that were listed in the PSA report table have been included, with topics of concern that were thought to be leading to resource decline separated into those that are associated with (i) habitat degradation, (ii) human activity (i.e. harvesting), or (iii) normal marine species behaviour. Also included a column detailing where primary responsibility will likely lie for addressing each issue (i.e. villages or the national government). This is discussed in Section 2.4 below.

The PSA report (IWP National Programme 2004) noted that workshop participants used the terms *degradation* and *decline* synonymously, as they spoke of resource degradation when specifically referring to the presence of fewer numbers of fish or invertebrates. In addition, decreased harvests were frequently seen to result from habitat degradation (of reef flats and pools). However, in the modified table from the PSA report presented below, human harvest activity could be identified as having a significant impact on resource decline. This difference between the villagers' perceptions and the more likely causal agents from a biological point of view is an issue that has to be addressed through education and awareness.

Table 3. Summary of causes and concerns in relation to inshore fisheries

Based on consultations with village members at Alofi North and Makefu (IWP National Programme 2004). Causal agents (the dominant agent or agents in terms of coastal ecology) have been hypothesised by the author. A number of causal agents are left as unknown or unlikely to be addressed because of the uncertain connection between the concern and the likely cause(s). The most appropriate management level for effectively addressing these concerns is also suggested by the author as being either the village (V) or national (N) level.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Habitat degradation					
Overuse by visitors degrading area (such as Matapa Chasm and Talava Arches) or tourist activities invading area (M)	Overuse of tracks (walking and cars) may increase erosion along tracks when it rains; and walking on reef flat may trample sensitive organisms	Cause–effect data unavailable; Personal observations confirm erosion (water) on tracks but little or no evidence of trampling.	Concentra-tion of use through ease of access.	V; N	The provision of tracks services local needs by providing good access to the sea for fishing and harvesting as well as recreation, but tourists also benefit. Design of tracks can minimise impacts, i.e. by sealing surfaces, minimise vegetation clearance, minimising rock and other substrate interference.
Unknown impacts of introduced species by yachts and ballast water from cargo ships (e.g. starfish) (AN, M)	Introduced species transported in ballast water. Volume of cargo is relatively small per visit so amount of discharge is low.	Data unavailable; no recorded introduction that has caused a problem.	Physical nature of Niue coastline.	N	Niue is dependent on sea transport for most provisions and harbour facilities are minimal so unloading is offshore for large boats and onshore for small boats that do not require ballast water. Unless the situation changes in favour of large cargo vessels, this probably will not be a significant issue.
Overharvesting and impacts from traditional fishing methods such as fish poisoning — using roots (from Tuha or kava niukini) or fruits (from the kieto [*Diospyros samonensis*] tree). The impact of Tuha is lethal to all marine life including coral and seaweeds and recovery of marine life is very slow (AN, M)	Broad-spectrum poisons are used in confined areas like pools to target a few species only. A wide range of non-target species and all sizes of target species are usually affected.	No cause-effect data but logically this will be a significant factor in over harvesting resources. Data required on frequency of poison use and where is used.	Lack of awareness of impact of activity.	V, N	Traditionally used poisons are from locally available materials, so are low in cost. Modern chemicals (e.g., chlorine) are costly but easy to obtain and act in a similar way to traditional poisons. Education is important o that users understand the indiscriminate and very negative effects of these methods; legislation should be adopted by the national government.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Harvesting					
Coral damage from the use of non-traditional fishing methods (e.g. hammers, axes, and crowbars) when reef gleaning (AN, M)	Metal implements can be defined as non-traditional tools for gleaning. Efficient tools also encourage over-harvesting of resources at rates higher than traditional harvest levels. Substrate damage is deep and neighbouring organisms can be damaged as well.	No quantitative data available to show cause and effect. Most small organisms collected with modern tools result in minimal disruption to substrate. Larger organisms (e.g. octopus) may be harvested with resultant high substrate damage.	Lack of awareness	V	Traditional sharing of food and a merit system that values quantity encourages high harvest rates. Efficient tools exacerbate the harvest rate. Traditional management mechanisms not effectively addressing this factor by restricting quantity, frequency, and usage of areas.
Over-harvesting (in specific reef areas (AN, M))	Areas with easy access tend to be used more frequently, as they allow access by more people and greater harvest time per tide cycle.	No before-after data available on harvest pressure to confirm effect. Well-constructed and maintained tracks to shoreline are present (pre-Heta), which did channel activities to those areas.	Low economic alternatives	V, N	Traditional sharing of food and a merit system that values quantity encourages high harvest rates. Traditional management mechanisms not effectively addressing this factor by restricting quantity, frequency, and usage of areas. Modern management tools like harvest exclusion zones not sufficient, or not effective or not enforced.
Over harvesting due to nets (Tautau ika) catches large numbers of small size fish. It also occurs everyday, resulting in overfishing (AN)	Gillnets can 'catch' for as long as they are deployed, and depending on mesh size, nets catches most fish to the size of the net mesh.	No data available but could be collected (esp. for mesh size, and frequency of use).	Modern fishing tools more efficient than traditional means.	V, N	Enforcement of fisheries regulations required, and possible review and alteration of regulations if they are too lenient with respect to fish size catches. Seasonal and location restrictions may be required to enhance stocks. Education required to help fishers understand potential impacts of nets.
Destruction of breeding holes (Feke) (From use of axes and hammers when harvesting?) (AN, M)	Animals that hide can be extracted by breaking away the surrounding substrate. Strong modern tools are very useful for this purpose.	No data available but relevant catch effort data would indirectly indicate the degree of damage.	Lack of awareness of impacts.	V, N	Ineffective local management by VC. Enforcement of fisheries regulations required, and possible review and alteration to regulations to address this issue of 'collateral' damage.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Overly concentrated use of some reef resources due to lack of easy access to sea tracks (AN, M)	Areas with easy access tend to be used more frequently, as they allow access by more people and greater harvest time per tide cycle.	No before-after data available on harvest pressure to confirm the claims. Well-constructed and maintained tracks to shoreline are present (pre-Heta) which did channel activities to those areas (pers.obs.).	Low economic alternatives	V, N	Traditional sharing of food and a merit system that values quantity encourages high harvest rates. Traditional management mechanisms not effectively addressing this factor by restricting quantity, frequency, and usage of areas. Modern management tools like harvest exclusion zones not sufficient, or not effective or not enforced.
Over harvesting because of introduction of modern fishing gear (M)	Increase in catch per unit effort can be a result of improvements in the tools used in catching and harvesting resources.	No data available for Niue, but in theory and from experiences in other countries it is a valid argument. Fishing effort may be quite low due to the low resident numbers but gear efficiencies can still maintain high fishing effort.	Lack of awareness of additional impact of new technolo-gies.	N	Fisheries regulations required to be drawn up, and enforced, to address this issue. Data also required to indicate the amount of resources sent overseas to relatives, which may result in continuous high harvest rate despite a falling resident population.
Displacement of seasonal fish such as kaloama, atule, ulihega, big eye scad, skipjack tuna and flying fish from reef edge, drawn away by FAD's. These fish used to be caught by canoes but no longer. (AN, M)	There may be a correlation between decreases in nearshore catches and the introduction of offshore FADs. Inter-annual variability in fish abundance may also correlate with the introduction of FADs. FADs are proven to attract fish especially when they are in low densities, making them more vulnerable to fishing.	No data available to indicate a shift in distribution patterns of fish that is related to the deployment of FAD's.	Lack of EIA considera-tions of impacts or lack of information exchange.	N	Lack of research done to validate or refute the claim. Information may be available from examples of other countries with FADs.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Residents concerned the reduction in fish catch results in more reef gleaning. (AN, M).	Displacement of fishing effort from one habitat to another often is a consequence of stock depletion in certain areas.	No data available for Niue but is a well-accepted consequence of localised depletions of certain stocks.	Lack of government capacity and funds.	N	Lack of data available to validate or refute the claim. Fisheries research into subject required. Lack of awareness of impact. Decline in national economy.
Lack of traditional practices of feeding and caring of fish and fishponds - ava ika. This practice undermined but is important to protect important fish stocks (AN, M)	Traditional management and farming methods may have enhanced the harvest of more fish at a frequency that follows consumption rates. Reef flat deep pools were sealed to retain fish and they were fed and then harvested as required.	No data available but in theory may be a mechanism to increase local harvest levels, though it would require a source of fish food and careful management to succeed.	Erosion of traditional manage-ment mechanisms	V	Fish retaining areas could conflict with some tourist features. The availability of modern freezers mean that live fish do not have to be 'farmed', though the feeding and caring for fish is a method that would enhance the yield from near shore habitats.
Traditional practice of keeping all fish. Some people keep to old ideas that all fish caught should be kept, as was practiced in the past. This was done due to uncertainty of sea conditions and the need to maintain food security (M)	The taking of all available target species if caught, does not allow protection for any size or life stage to grow into breeding adults. There is a belief that all caught animals need to be kept because it enhances the production of more individuals.	No data available, but believed by locals to be widely practised. Taking more to produce more is not logical at the harvest levels that can be attained in the present day.	Lack of awareness and education.	V, N	Lack of education and understanding of the impacts of taking all fish or organisms at each harvest time. Strong fisheries regulations that are enforced are needed to reduce the take of under sized animals and to improve sustainability of fisheries sectors.
People from other areas using reef resources without permission. (AN, M)	Over-harvesting in some previously lower-use areas can in the short-term result in an unsustainable level of fishing effort by shifting the fishing effort. Lack of village-based management also can be an outcome due to the lack of communication to people outside a village.	No data for Niue to show a sustained high harvest effort correlating with stock depletions for certain locations. Gleaners from different villages were harvesting outside their village areas when I was there in December 2003.	Changes in lifestyle and social fabric.	V	Village laws hard to enforce without effective communication, and there may be a lack of knowledge of different village management regimes. May be lack of respect between villagers from different parts of the country.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
People from other areas not respecting local rules (eg tabu areas, seasonal closures use of proper baits, or harvesting methods) (AN, M)	Same as above.	Same as above.	Same as above.	V	Same as above.
Spearfishing - Residents concerned it is scaring fish away from protected fishing holes or impacting on fish reef stocks (AN, M)	Fish that are pursued by spearfishers learn to avoid contact or the proximity to people, therefore catch rates are reduced. Spearfishing (esp. at night) is very efficient and can lead to localised depletions.	No data available for Niue but information from other examples indicate that spearfishing can be unsustainable.	Lack of government capacity.	V, N	Regulations required to manage certain unsustainable harvesting with spear guns (eg, night spearing if it occurs).
Night diving, which is bad because (? Not completed in PSA report). (AN, M)	Same as above.	Same as above.	Uncertain.	N	See comment above
Night reef fishing with torches – residents say with past use of handmade traditional torches people did not harvest as much; now they can see better and catch more (AN, M)	Example of the introduction of modern tools that greatly enhances fishing efficiencies for the reasons outlined on the left.	No data available for Niue, but locals know they can catch more by having more reliable, brighter, and long lasting light sources.	Modern techniques introduction .	V, N	Fisheries regulations may not be keeping up with trends in tools or gear used to harvest resources. Village management not recognising and applying self management options that take into account the increase in harvest from the use of torches, leading to over harvesting.
Diving on fishing grounds (AN, M)	People avoidance by fish may be due to spearing but the general presence of diver-associated noise may cause some fish to stay away from the well-used dive areas.	No data to show this cause and effect. There is relatively low diving activity in Niue so it is not likely to be a significant effect.	Fish behaviour disturbance	N	A coastal management plan is required to separate conflicting uses of the near shore resources.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Netting of fish by foreign boats out at sea (M)	Purse seine nets can be very exploitative with low natural stock sizes.	Licensed tuna boats mainly use long lines and not purse seine nets. Poor available data for catch effort for the foreign fleet, but indications are that the boats visit seasonally and not all year round.	Lack of government enforcement or concern.	N	Relevant information has to be obtained on target species stock sizes, and the catch effort of licensed vessels that do not unload in Niue. If available, the data has to be communicated to local residents.
Crabs like uga and kalahimu being harvested during spawning season (AN, M)	The taking of animals when carrying eggs or young offspring severely reduces the ability of these species to sustain future generations.	No data are available on the prevalence of this behaviour but there appears to be no common practise that addresses this concern.	Lack of awareness.	V, N	Fisheries regulations need to prevent this practice and enforcement may be required.
Traffic is running over crabs (AN, M)	Land crabs and coconut crabs move between the shoreline and the inland forest area, requiring them to cross the main road ringing the island.	Daily road mortality of land crabs from cars was evident and is high during lunar migrations, but there are no data to validate cause and effect, particularly in relation to general depletion of marine resources, or depletion in land crab numbers.	Lack of EIA.	N	The road is positioned so that it is inevitable that the migrating crabs have to cross it to get to the sea. An EIA probably would have considered it and recommended under road bypass tracks to prevent crab use of road. The road also acts as a convenient place for locals to collect the land crabs for use as fish bait, and as a place to capture coconut crabs on their spawning migrations to the sea. Fisheries regulations do not target the management of land crabs though there are regulations relating to coconut crabs. Cars driven at speed reduce the opportunity of drivers to avoid running over crabs.
People are not using enough resources	There is a belief in the certain sections of the community that if resources are not used, they do not sustain their presence in the longer term.	There is no information to support this belief, though ecological theory states that communities left undisturbed for long periods (either by man or natural disturbances), will show a succession of	Lack of awareness and eduction.	V	Education of ecological processes is required, particularly when over harvesting is justified in terms this belief. The remoteness of Niue with respect to other similar marine systems means that there is probably limited replenishment of species from distant places.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
		species relative abundance that results in a fewer number of larger dominant species.			
Animal Behaviour					
Aao taking over alili (AN)	Some people believe that hermit crabs (aao) are more abundant now than previously and that this is because the crabs are eating the turbo shell animal (alili) and taking over the shells.	No data are available to show an increase in hermit crab numbers, and there is no biological evidence to suggest the crabs are overtaking live turbo shells. More vacant turbo shells may be a result of greater mortality of turbo species but there is no evidence to show this.	Lack of awareness and education.	Neither	Lack of education and knowledge sharing.
Segame being eaten by ugauga (AN)	Belief that algae (segame?) are eaten by crabs marine crabs (ugauga).	No data to show increase in crabs or decrease in algae, to extent that crabs are affecting algal abundance.	Lack of awareness and education.	Neither	Lack of education and knowledge sharing.
Eggs of uga eaten by feke (M)	Belief that coconut crabs eggs are eaten by octopus (feke).	Not likely to be true as uga eggs are too small to be caught by octopus, and eggs float away from reef areas are being released, i.e. away from octopus hunting grounds.	Lack of awareness and education.	Neither	Lack of education and knowledge sharing.
Increased numbers of dogs and wild pigs eating resources (like uga) (AN, M)	Uga (coconut crabs are susceptible to predation from carnivores like pigs and dogs.	No data to support increase in feral animals.	Lack of government funds and capacity.	V	Lack of research to address any indicator of cause or effect. Lack of feral animal management
Increased predation by birds – Motuku (Heron) (M)	Local belief that heron birds are becoming more abundant to extent they	No data to show increase in heron numbers.	Lack of awareness	Neither	Lack of education and knowledge sharing.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
	are reducing near shore fish abundances.				
Change of fish habits – they do not appear to be where they are supposed to be in protected fishing holes (AN, M)	Fish behaviour may be changing to the extent that protected areas may not be used by fish in the same way as in the past.	No data to show lack of positive response by fish to protected areas or in change in fish behaviour.	Natural processes.	Neither	Wrong choice of protected area habitat. Miss understanding of traditional knowledge. May be natural alteration in holes (pools) previously known to be favoured by certain fish species.
Degradation of Coastal Habitat					
Damage to the reef flats from siltation – residents concerned about makatea (silt) running into reef flat zone from the storm water drains and development of sea tracks, car parks, and picnic areas. Siltation also said to affect caves and pools on reef flat (AN, M)	Sedimentation observed to be more prevalent and seen in certain areas. Sediment smothering and interfering with feeding and growth of benthic organisms. Nutrient enrichment via increased runoff of land material.	No data available to demonstrate mortality due to sedimentation nor to increased sedimentation/erosion of near shore areas. Sediment runoff observed in developed areas. Theoretically probable if sediment runoff in sufficient quantity to affect Niue habitats adapted to low sediment loads.	Poor government planning.	N	Shoreline development and steep drop to reef flat results in rapid flow of rainwater and high erosion rates. Impact assessments required for all coastal developments to minimise impacts.
Development of sea tracks using dynamite and other harmful chemicals (AN, M)	Development disturbances perceived to correlate with stock depletions.	No data to demonstrate cause and effect though is theoretically possible that increased erosion occurred from development (see above saltation issue). Also have possibility of explosive material based on nitrates and phosphates to add some elements to the marine habitats but more likely that the effect is through erosion mechanisms.	Poor government planning.	N	Shoreline development and steep drop to reef flat results in rapid flow of rainwater and high erosion rates. Impact assessments required for all coastal developments to minimise impacts.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Wharf construction project has blasted around this area and damages coral (AN)	Disturbances from development may include physical damage and nutrient release from the reef substrate.	No before –after data available to validate or refute claim. Physical local damage to habitat would have occurred.	Poor government planning.	N	Impact assessments required for all coastal developments to minimise impacts.
Development of small pools? (M)	Not clear as to cause, but may relate to growth and infilling of pools over time due to coral and algal growth.	No data to address claim, though relatively fast growth of living edges of pools is sometimes evident, especially in cases where there is regular water exchange with the open ocean, (providing good growing conditions for corals and coralline algae).	Natural processes.	V, N	None
Dying coral from overexposure to heat and sun, sea to calm, this may be related to global warming and climate change (AN, M)	Unusual exposures to air and sunlight can kill organism not adapted to such exposures.	No data to support the cause and effect though local stories have confirmed some periods of unusually low tides on Niue.	Natural processes.	Neither	Long-term tidal range fluctuations may expose more live coral than the usual tides.
Growth of corals narrowing swimming holes (M).	Swimming holes and pools in the reef flat will naturally fill in over time from growth of coral and coralline algae. This may restrict access for purposes of harvesting of fish etc from these holes. It will also gradually reduce the favourable conditions in this habitat as a living place for certain species.	Pools with connections to the open ocean have strong water flushing which is beneficial to rapid growth of corals and coralline algae. Growth is fastest in the upper pool rim, leading to its eventual sealing off. Many pools do show varying degrees of edge growth. This natural process could not be seen as having a significant contribution to the	Natural processes	Neither	None

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
		widespread decline in fisheries yield.			
Traditional treatment of 'Fou' sticks used for skirts from the bark were placed in these swimming holes. (M)	Branches from the beach hibiscus (fou tree) are soaked in seawater prior to being stripped of the bark that is used in producing skirts. The holes were good locations where soaking could be carried out without them being washed away. The soaking process draws out many compounds in the bark, which may be toxic to some organisms.	The bark may contain saponins and other compounds that can be toxic or 'unpleasant' to fish and other organisms. No such activities were observed during the first visit, though hibiscus trees were observed growing in the vicinity of the shoreline. The high flushing rates of many swimming holes mean that very high quantities of fou bark would	Pollution	V	Traditional practices.
Lack of protection (village regulations) of sea shrubs (AN, M)	Not certain of the intent of this issue though it possibly may refer to the disturbance of coastal shrubs leading to increased erosion and flow of sediment into the sea.	Some evidence of small scale and large scale clearing of understory vegetation was evident, but there were no strong indications of high erosion occurring, except associated with sea track development.	Lack of awareness.	N	Large sea track development (road and boat ramp construction) was leading to increased erosion during high rainfall events at least in the short term. There obviously has to be a trade off between the needs of providing better sea access for locals and protection of the shoreline coast.

Coastal pollution[5]

1. Source: Sewage and household wastes

[5] Coastal pollution was commonly seen as contributing to habitat degradation and fish poisoning (ciguatera).

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Wastes and sewage discharge from septic tank leakage or toilets without septic systems (such as some water seal/ flush toilets and long drops) polluting sea area (AN, M)	Soakage of toilet waste into the ground is necessary in the absence of a full reticulated sewage system with accompanying treatment. Toilet wastewater contains high nutrients with nitrogen and phosphorus compounds, which can cause adverse effects on many calcifying reef organisms.	All occupied households have septic systems of varying proficiencies, and it is theoretically feasible that the porous nature of the soils will lead to rapid transmission of waste fluids, poss. w/o sufficient time for total absorption of the compounds of concern before they enter the coastal environment. Indicators such as high macro algae abundance in intertidal areas were not present.	Lack of government manage-ment and regulations	N	Limited training and capacity of VC. Lack of Management by Health Department. Lack of government standards. Lack of public knowledge of impacts. Not an immediate priority of government.
Waste and sewage draining into caves and crevasses and that leads into sea area. (AN, M)	Same as above	Same as above	Same as above	N	Same as above
Lack of proper drainage system and contamination by pollutants from stormwater flowing into coastal areas and reefs (AN, M)	Stormwater management currently consists of re-direction of major road runoff towards the shoreline (some drains flow directly onto the reef flat, others through caves or the substrate surface)	Stormwater does flow off the roads and rapidly onto the coastal areas. There was no definitive evidence that	Lack of government standards.	N	Same as above.
Wastes and sewage discharge from pig styes draining into sea area.*(AN, M)	Nutrient enrichment of water flowing from piggeries can be attributed to the crowded conditions of the pens with the resultant concentration of waste.	Eight piggeries are located along a major fault line inland from Alofi North village houses. One piggery in Makefu is located on the seaward side of the main road. No data are available to	Lack of manage-ment of farming practices.	V, N	Lack of management by Health Department. Not an immediate priority of government.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
		validate the flow of waste from the piggeries.			
Sewage draining from resort and hotels going into reef area (pollution source and smells) (M)	Soakage of toilet waste into the ground is necessary in the absence of a full reticulated sewage system with accompanying treatment. Toilet wastewater contains high nutrients with nitrogen and phosphorus compounds, which can cause adverse effects on many calcifying reef organisms.	All resorts and hotels have septic systems but may be inadequate to cope with high use periods. It is theoretically feasible that the porous nature of the soils will lead to rapid transmission of waste fluids possibly without sufficient time for total absorption of the compounds of concern before they enter the coastal environment. Indicators such as high macro algae abundance in intertidal areas were not present.	Lack of government manage-ment and regulations	N	Limited training and capacity of VC. Lack of Management by Health Department. Lack of government standards. Lack of public knowledge of impacts. Not an immediate priority of government.
Lack of facilities such as toilet facilities (such as around Utuko swimming area). (M)	Some heavy use tourist sites may require toilet facilities for the same reasons as explained above.	Some sea tracks and swimming locations have toilet facilities. Some low use sites do not have these facilities. There was no definite proof of such a cause (with or without facilities), either within the bounds of the sea tracks, or in the immediate reef flat areas.	Lack of government manage-ment and regulations	N	Limited training and capacity of VC. Lack of Management by Health Department. Lack of government standards. Lack of public knowledge of impacts. Not an immediate priority of government.
Dumping of wastes and sewage from yachts and ships into sea. (AN, M)	Ships and yachts usually have containment facilities on board boats so if they are discharging into the near shore areas whilst at	No data are available to validate this possible cause. There is a clear season for visiting yachts, and more regular visits by	Low motivation for enforce-ment, education,	N	Lack of shore facilities. Lack of government enforcement.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
	anchor, it could be a localised problem for the harbour area.	large supply ships but not observations were offered as to this being a regular occurrence.	and awareness.		
2. Source: Toxic wastes					
Oil pollution run off into the coastal area (Sites mentioned - Amanau area toxic wastes)(AN, M)	Unmanaged oil spillage will eventually contaminate surface and sub surface water. Oils contain toxic hydrocarbons and potential nutrients through chemical breakdown.	Considerable areas of oil spillage were observed on the ground that was associated with activities using oil and petrol in the Amanau industrial area. No clear evidence was found to validate that run off from this area was affecting the coastal habitats.	Government with few resources or capacity	N	Not a government priority. Lack of proper disposal system and possibly poor management standards demanded of the government.
Unsafe storage of petrol and fuel tanks (bulk fuel depot). Residents concerned storage tanks are too close and petrol and diesel runs off into the sea (AN, M)	Transferring fuel to and from the storage tanks can result in some spillage. Fuel contains toxic compounds as well as nutrient when compounds are broken down.	Containment walls were present to prevent serious spill accidents, but a stormwater drainage system was present to drain away rain water, so there is the potential to	Poor location of tanks	N	Government with few resources or capacity. Not an immediate concern of government.
Leaks during transfer from tanker (AN, M)	Fuel has to be transferred from tankers anchored offshore to shore facilities because of the small harbour.	No information to validate the cause but is highly likely that spillages will occur some times. Fuel will float on the seas surface and unless winds blow it onshore, it will be dispersed away from the shoreline and will evaporate rapidly.	Physical nature of Niue coastline.	N	Inadequate funds available for large port development
Oil from ships (AN, M)	Automatic bilge discharges from ships adjust internal	No information available but it is a common issue	Physical nature of	N	Ship designs.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
	bilge levels. There is usually a lot of oil mixed with bilge fluids.	associated with all ship activities.	Niue coastline		
Batteries being dumped into the sea (M)	Convenience of getting rid of used batteries.	No evidence during pilot surveys of two villages. No other information to validate extent and frequency.	Lack of awareness of impact of activity.	V, N	Lack of waste collection / recycling facilities
Pollution from ballast water (M)	Same as "Oil from ships" above	Same as "Oil from ships" above	Same as "Oil from ships" above	N	Same as "Oil from ships" above
3. Source: From solid wastes					
Ocean littering, for example plastics, empty cans and people treating the sea as dumping place (AN, M)	Some toxic effects may be associated with rubbish, depending on the contents. Also some physical effects of rubbish accumulations. Generally rubbish is an eyesore but a symptom of general disregard for coastal areas by some individuals.	Some evidence of rubbish in the coastal environment.	Government with few resources or capacity. Government not accountable	V, N	Imported products with non-recycling leftovers. Limited recycling on Niue. Limited number of rubbish bins available.
Rubbish and littering (around Alofi wharf area, sea tracks, and roadsides) (AN, M)	Same as above	Same as above	Same as above	Same as above	Same as above
Dumping of household rubbish in coastal area, or caves and crevasses (M)	Same as above	Same as above	Same as above	Same as above	Same as above
Waste fishing lines and plastics dumped by fishermen and by boats, yachts and cargo boats into the sea and reef (M)	Same as above	Same as above	Same as above	Same as above	Same as above

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
Concerned about rubbish (for example mooring ropes) at tourist and swimming sites (Utuko) (M)	Same as above	Same as above	Same as above	Same as above	Same as above
Rubbish from boats and ships swept into sea and drifting into shore (M)	Same as above	Same as above	Same as above	Same as above	No information given to ships or yachts. No restrictions by government on ship and yacht dumping of waste.
Steel and pipes rusting in the sea and the possible bad effects on fish feeding on these (AN, M)	Metal objects slowly degrade in the sea, and there is the likelihood of a chronic heavy metal release into the environment.	Extensive metal present in harbour sub tidal habitat.	Government with few resources or capacity.	N	Lack of government resources to deal with issue. Lack of government and individual concern with what is in the water.
Dumping of dead animals (at dump, along roadside, into caves, into sea) (AN, M)	Convenience of disposal.	No evidence during my visit.	Government with few resources or capacity. Government not accountable.	V	No guidelines on proper disposal. No concern by public of coastal environment.
Cemeteries close to coastal areas and if graves not sealed properly can pollute water (AN, M)	Common activity accepted by the community.	Large numbers of gravesites present along the coastline, though there are cemetery locations in Alofi North and Makefu.	Limited productive land.	V, N	No government guidelines. Traditional beliefs and desires regarding ancestors.
Sickness from Ciguatera poisoning					
Using of explosives at wharf area. Residents concerned that this contributes to the poison fish (AN)	Expansion of wharf facilities required the use of explosives. The breakage of rock and the explosive material contributes to the	Difficult to validate and to correlate ciguatera with a single prior event with no persistent effect.	Necessity of improved wharf facilities.	N	Physical nature of Niue coastline.

VILLAGE CONCERN (AN = Alofi North, M = Makefu)	EXPLANATION	VALIDATION	ROOT CAUSE	VILLAGE (V) or NATIONAL (N)	UNDERLYING FACTORS (From IWP National Programme 2004)
	introduction of nutrients into the sea.				
Contamination of groundwater					
Vai pamu pupu (paraquats/grammoxone) impacts of these leaking into deep water lens contaminating drinking water (M)	Herbicides and pesticides used extensively in agricultural production. Surplus and persistent chemicals will be transferred to groundwater and potentially flow out to coastal habitats.	No data available. No regular monitoring of groundwater monitoring bores (piezometers).	Government with few resources or capacity.	N	Lack of awareness of use. Inadequate restrictions on imports of chemicals. No viable alternatives available. Government encouraged use of chemicals.
Wastes and sewage discharge from septic tank leakage or toilets without septic systems (such as some water seal/ flush toilets and long drops) (M)	Same as relevant sections above.	Same as relevant sections above.	Same as relevant sections above.	N	Same as relevant sections above.
Waste from pig styes down into water lens (M)	Same as relevant sections above.	Same as relevant sections above.	Same as relevant sections above.	N	Same as relevant sections above.
Waste oil (M)	Same as relevant sections above.	Same as relevant sections above.	See preceding sections.	N	Same as relevant sections above.

2.4. National and village-based actions to address resource depletion concerns

Table 3 lists the most appropriate management level (national government or village) to address each of the particular concerns raised in the PSA process. In a number of cases, the best approach will be a complementary and coordinated approach that combines elements from from both levels. The combined management solution often refers to the need for a village to take appropriate steps in the local context (through villagers upholding village councils directives), but with nationally applied and enforced legislation to address resource use by people who are not from the local village. In a country as small as Niue, national-level enforcement of laws can be difficult because of the closeness of the community; it is generally preferred that rules be administered at the village level.

Issues relating to harvesting will require both national leadership in the form of appropriate legislation and enforcement, and village based awareness and respect for the limits to harvesting. National leadership with respect to harvesting would have to address the management of harvest techniques, where harvesting is carried out, the export of products, as well as local point of sale restrictions on the size and reproductive condition of harvested organisms. Village-based management needs to include support for national restrictions on the location of harvesting activities, improved understanding of natural processes, and application of laws and restrictions by means of village management systems.

The level of awareness and understanding of natural processes appears to be quite variable within communities and is generally low (SPREP 2004). As an example of the level of understanding, the issues outlined in the "Animal Behaviour" section of Table 3 illustrate a basic misinterpretation of normal functions of animals in the coastal system and of the degree to which they influence events, which was confirmed during the consultations.

Specific concerns outlined under "Degradation of Coastal Habitat", "Coastal Pollution", and "Groundwater Contamination" are issues and areas of management responsibility that are best addressed nationally, principally through effective planning, impact assessment, and controls on the type and location of development activities through appropriate legislation. Village-based management responsibility in these areas will be in the form of applying laws that influence individual behaviour; management success will be achieved at the village level, providing national leadership is appropriate and effective.

Ultimately, successful management of coastal fisheries will require a national approach; lessons that can be learned from the IWP pilot village project should enhance the future effectiveness of village-level implementation of nationally coordinated management strategies.

The major concerns that came out of village consultations were degradation of coastal marine habitat, fish poisoning, and decline of marine resources. A number of perceived causes were put forward, which can be summarised under two topics: (a) sources of pollution and toxic substances, and (b) fishing pressure.

2.5. Possible sources of land-based pollutants

Possible land-based sources of disturbance that may be influencing resource availability and quality are varied (Table 3 above) but can be summarised under the following topics: nutrient enrichment, toxic chemicals and pollutants, sedimentation, disease and pathogens, and chronic leaching of a mix of chemicals and dissolved metals.

During the first visit by the author in December 2003, attention was given to the potential presence, and pathways, of land-based sources of disturbance that may be influencing resource availability and quality. The literature review and PSA work (SPREP 2004) also highlighted some of these issues, which needed to be confirmed through direct observation and discussions with relevant government personnel and the local community.

The most obvious potential pathways for land-based pollutants to enter the coastal environment are through water runoff via stormwater drains (and other waste water pipes) and sea access tracks, and water seepage through porous substrata, especially water flows through caves and crevice pathways. The presence of outflow from these potential pathways to the reef flat habitat can potentially correlate spatially with species harvest patterns, with implications for the management of harvest activities. In general these mechanisms operate through irregular acute events, with the exception of seepage (which is dependent on rain events). Natural seepage and outflow points were always present to some degree, and coastal marine organisms would have adapted to them, but this may not be the case with present outflow points and pathways.

2.5.1 Potential pollutant sources

A number of current and former waste and dump and/or storage sites are located around Niue with most located in the central and southwestern sectors of the island. There are also probably a number of unofficial sites where items such as batteries and sump oil are regularly disposed of. The main issue with the treatment of waste is in the prevention of contamination of the artesian freshwater supply. It is also important to prevent pollutant leakage to the coastal environment through freshwater outflow points around the perimeter of the island. Evidence of this possible pathway has not been thoroughly investigated or proven, but the potential exists due to the low degree of soil formation and rapid absorption of surface water.

Table 4 presents a summary of those sites that may either currently contain persistent organic pesticides (POPs), chemicals, and other toxic substances, or that may be future sources of such pollutants (pers.comm., B. Graham and Natasha Toeono; UNDP 2002). Currently most solid waste was dumped at a site near the airport at Fonuakula, and no attempt is being made to control land filling (UNDP 2002). Hospital and quarantine wastes were disposed by burning in simple incinerators. A 1998 survey identified that there were potentially 1000L of PCB-contaminated oil contained in three disused electricity transformers. In addition a total of 1.5 tonnes of waste pesticides (including small quantities of ethoprophos and chlordane) were stored at two locations; and one site contaminated with oil (rated as minor) at the Department of Public Works. There were no known stockpiles of DDT and no proof that there has been contamination.

Table 4. Potential pollutant sources

Sites and activities that may be sources of pollutants that can impact the freshwater lens and consequently the coastal environment. General sites are listed first followed by sites used for specific activities, starting in the north and then in a counter-clockwise direction around the island.

SITE / LOCATION	ACTIVITY	POTENTIAL POLLUTANTS	STATUS (pre-Cyclone Heta)
Former village solid waste dump sites: all villages	Domestic solid waste disposal sites	Nutrients, heavy metals, possible toxic chemicals	Most closed now
Alofi North and Makefu villages	Pig pens close to major fault line and on cliff tops	Nutrients	Operational (7 along fault line behind Alofi North and 1 near cliff in Makefu)
Visiting yacht waste	Shore disposal of solid waste (cans and plastics), and toilet waste disposal into sea in harbour	Nutrients	Seasonal: outside cyclone period
Outside Mutalau (N end)	Future waste dump site	Nil at present	Not operational
Vaipapahi Agricultural Research Centre: inland between Namukulu and Toi village	Two fertiliser storage sheds	Nutrients in the form of nitrogen and phosphorus	Operational
Alofi township	Fuel storage	Hydrocarbons	Operational: stormwater drains from bund walled area
Alofi township	Commercial clothes laundry	Nutrients especially phosphates	Operational: waste water directly discharged onto shoreline
Amanau	Waste oil storage	Hydrocarbons	Operational
Amanau (Health Department)	Battery storage	Heavy metals	Operational
South of Opaahi near start of inland road at Talipouli	Public Works Department storage of agricultural chemicals, fuel, and oil	Hydrocarbons, POP's, pesticides?, herbicides?	Operational
Fonuakula, near airport	Domestic solid waste buried and covered with topsoil	Nutrients, heavy metals, possible toxic chemicals	Operational for approximately another 5 yrs (from December 2003)
Huihui (near airport)	Asbestos storage site	Asbestos fibres (unlikely input to coast)	Operational but due to be shipped to NZ for disposal in mid-2004
Cave in Anokula – Tafalalo area	Cave thought to have been used in past to dump pesticides	Pesticides	Not used now?
East end of airport runway	Liquid / solid waste from septic systems	Nutrients	Operational
Vaiea Farm	Timber treatment with creosote	Toxic chemicals	Operational
Vaiea Village	Possible domestic solid waste site	Nil at present	Not operational
Tololi	Fertiliser storage shed and pit used for dumping of agricultural left-overs	Nutrients, chemicals	Operational

Studies have noted that Niue's soils contain unusually high natural radioactivity of an obscure origin (Fieldes et. al. 1960 and Schofield 1967; cited in Wells and Jenkins 1988). The original references cited above that discuss this phenomenon could not be accessed, and there appears to be no further reference to this subject in subsequent environmental reports or assessments.

2.5.2. Contaminant pathways

Contaminant transport onto the coastal environment can occur via a number of pathways. To verify potential transport mechanisms, consultations with relevant government personnel as well as field observations and general descriptions were conducted. These focussed on:

1. **The hydrology and water-substrate chemistry of Niue**. The absorption and groundwater flow rates of the artesian freshwater lens are not known at present, but this information is important in carrying out future impact assessments associated with development planning. The multiple potential pathways that exist between inland sources and the coast should also be understood; some work has been completed in this regard. A number of piezometers (bore holes used for testing groundwater) have been established around the island, but the author has been unsuccessful to date in accessing data from any relevant groundwater studies. Niue's Health Inspector (Sione Hetutu, pers. comm.) indicated that analysis of nutrient and chemical levels in groundwater would commence in late 2003 or 2004, with future monitoring of coastal waters also expected. He cited a study carried out by the South Pacific Geoscience Commission (SOPAC) and local government personnel tracking leachate pathways from an old solid waste dump site (the "Fonuakula site", used for over thirty years) in the Opaahi area using dyes. Dyed water entered the reef flat in the Opaahi area, which is a clear example that materials such as contaminants can be transported down these pathways, thereby contaminating coastal waters.
2. **Freshwater outflows from natural seepage areas**. As a corollary to the presence of potential sources of freshwater-based pollutants, any obvious outflow points could be recorded as part of the reef flat resource study as they are easy to identify, even if not flowing at the time of investigation. An example of this type of information that was collected during the pilot survey is shown in Table 5 for the small length of reef flat at the northern end of the Namoui Marine Reserve. A total of 5 caves with evidence of freshwater flows were recorded over a distance of approximately 200 m of coastline, indicating the presence of substantial outflow points every 40 m of coastline on average. This average figure for freshwater outflow points does not indicate the variability in water flow rates of these features, as three of the five caves were located in a very short section of the survey area, i.e. within approximately 30 m of each other. With a good topographic map and a GPS locations of caves and seepage points can be recorded. Though it will not be possible to record all seepage points that are located below the low water mark, this information will hopefully be incorporated into the baseline surveys.

3. **Stormwater runoff points**. Locations of stormwater runoff points from major infrastructure, including tracks and roads to reef flats, storage areas and building stormwater outflows were compiled as part of the pilot surveys. Stormwater runoff usually carries sediments to the coastal habitat, along with possible low levels of nutrients and hydrocarbons from roads and fuel storage areas (note that no evidence of this was observed by the author in the short period available for investigations). Stormwater drains were noted in the village maps drawn up as part of the PSA work (IWP National Programme 2004), but additional details were recorded during the present survery (e.g. position with respect to roads and sea tracks, and condition). GPS points were recorded for all drain input points. A total of seven stormwater drains in Alofi North and three in Makefu drain from the inland side of the main road, through the villages, to a point on the ocean side of the road. The output points of these drains were in some cases located close to the road (these flow into coastal vegetation close to the shoreline); others directed flows over rocks and onto the reef flat. Stormwater also runs down roads and tracks associated with sea tracks for reef flat access. A number of these sea tracks were in the process of expanded development in December 2003, resulting in the grading, widening, and infilling of areas around the walking tracks and sea landing points. Until these disturbed areas are stabilised, increased sedimentation of reef flats in these areas will occur, with potential for short-term impacts. Current evidence of the degree of chronic impact (regular low level pollution) from these sources is quite low, though acute disturbances (like a single event with a fuel spill) could have a significant impact on coastal resources.

Table 5. Summary of coastal caves with evidence of freshwater outflows

All caves in the vicinity of the northern end of the Namoui Marine Reserve (Ana track). This area covered the reef flat from the northern Reserve boundary to the southern end of the reef flat, and a length of approximately 200 m.

CAVE NUMBER	GPS POSITION	LOCATION
1	No GPS position recorded	South of Ana sea track entrance from road. Closest to northern Marine Reserve boundary (between pilot TR #2 & #3)
2	19° 01.13′ S, 169° 55.36′ W	South of cave #1, 5m south of start of TR#3
3	19° 01.08′ S, 169° 55.38′ W	35 m south of TR#4 start
4	19° 01.05′ S, 169° 55.39′ W	5 m north of TR#4 start
5	19° 01.07′ S, 169° 55.39′ W	10 m north of TR#4 start

2.6. Harvest impacts

2.6.1 Ease of access from tracks to the reef flat habitat.

The relative ease of access from sea tracks to the reef flat has implications for management of harvest activities, the relative ease of access will determine the degree of use by gleaners as well as fishers. Tracks that are hard to negotiate tracks (due to a relatively long distance to the reef flat from the main road, unstable substrate for walking, or steepness of the track requiring climbing skills and/or significant strength) are less likely to be used by less mobile and able members of the community. Approximately 40% of the twelve sea tracks in the Alofi North and Makefu area were classified as having low or restricted access status, indicating that nearby reef flats (within approximately 2–300 m of the access point) of the 60% of tracks that are highly accessible probably receive the bulk of the harvest pressure (Table 6). Conversely, ease of access facilitates subsistence harvesting of marine resources and monitoring and enforcement; both are clearly more difficult where access is poor. The situation with respect to accessibility to, and availability of, coastal resources has been drastically changed by the impact of cyclone Heta. All tracks and paths have been significantly reduced or destroyed by wave action and reef flat resources have been greatly reduced in abundance and presence (see pilot survey data, below).

Table 6. Accessibility of pathways and sea tracks in the Alofi North and Makefu areas.

Tracks and paths were graded as to their relative accessibility with the consideration of ease of access for an average elderly woman who gleaned resources from the reef flat. High accessibility refers to tracks that have a gentle slope, were mostly sealed, and included either or both steps and road access. Medium accessibility tracks were characterised by two or the three above criteria, while a low access track or path included one or none of the above criteria.

SEA TRACK / PATH (South to North)	LOCATION	ACCESSIBILITY
Tongalahi Sea Track	19° 03.27' S, 169° 55.27' W	High – short distance to flat.
Omahi Sea Track	19° 02.90' S, 169° 55.07' W	High – wide sealed road to stairs
Togalupo Sea Track	19° 02.79' S, 169° 55.04' W	High
Vaila (?) Track	19° 02.69' S, 169° 55.03' W	Medium – no steps, steep at shore
Anamotuku Sea Track	19° 02.69' S, 169° 55.02' W	Low – no steps, steep at shore
Houme Track	19° 02.42' S, 169° 54.98' W	High – sealed road & track
'N end Namoui/Anono' Track	19° 01.19' S, 169° 55.33' W	Low – steep, no steps
2 tracks through caves (N and S sides of Coral Gardens)	19° 00.84' S, 169° 55.39' W	Low – rough, steep
Small used track Nth Coral Gardens	19° 00.53' S, 169° 55.02' W	Low – rough, steep at shore
Makefu Sea Track (S end village)	19° 00.15' S, 169° 54.91' W	High
Mid Makefu Village Sea Track (next to water tank)	19° 00.04' S, 169° 54.79' W	High
Avaiki Sea Track	18° 59.90' S, 169° 54.63' W	High

2.6.2 Socio economic and harvest (creel) surveys

Studies on use of marine products by Niueans has indicated a high proportion of meals include products from the surrounding seas. A nutrition survey conducted in 1987 by the Secretariat of the Pacific Community (SPC) (Badcock et al. 1993; quoted in Dalzell et al. 1993) concluded that 57% of meals by Niuean families consisted of fish and other marine organisms. Dalzell et al. (1993) extrapolated from this and other data to estimate that approximately 250 kg of marine products was consumed per day within Niue, representing an annual consumption of 92.3 t/yr (or 41 kg/yr per capita). This study did not differentiate between fish and other marine products, nor did they distinguish between resources harvested offshore or on coastal habitats. It was pointed out that these figures did not take into account the export of marine products overseas to considerable expatriate populations elsewhere in the world. Data on exports of marine products are fragmentary and do not record the exact weight or identity of what is being exported. However, by making some generalised estimates, Dalzell et al. (1993) estimated that about 5 t/yr was exported. This figure was very approximate as export levels are limited by the degree of air traffic between Niue and major cities with Niuean populations, especially in New Zealand and Australia.

Dalzell et al (1993) also conducted a socio-economic study of Niue's coastal fisheries, distributing a household questionnaire in 1990 to assess patterns of exploitation of fisheries resources, main fishing methods and types of gear employed, investment levels with respect to fishing activities, and the most common species taken by fisheries related activities. From this questionnaire, it was determined that approximately equal catches of fish were taken from reef and offshore waters in a time period preceding July 1990, with total production of fish estimated to be 115 t/yr. There is no time series information available on estimates of production or extraction rates before or after this survey. This level of harvest is approximately 23 t/yr higher than the consumption estimate by Badcock et al. (1993). When the export component of the catch is accounted for, along with the confirmed steady decline in Niue's population from emigration (2.5% per year, Kaluwin et al 1999), this estimate represents an increase in harvest effort over a relatively short time period. This estimated harvest level is also moderately high compared to published yields from reefs in other parts of the world, reflecting the high level and concentration of harvest effort in a limited available area (Dalzell et al., 1993).

A severe cyclone (Cyclone Ofa) in early 1990 had a reported severe impact on coastal habitats and presumably associated resources (Dalzell et al., 1993). The most severe impacts were on the western side of the island where almost two-thirds of the population lives (IWP National Programme 2004) and where presumably most of the harvest pressure would be concentrated.

Dalzell et al (1993) concluded that fish stocks at that time were in no real danger of being overexploited, and that some expansion of commercial fishing activity was possible. Unfortunately, these conclusions did not really discern between reef-associated fish stocks, general demersal stocks, and offshore fish stocks. Nonetheless, the belief by local residents that fish stock depletion exists is most likely correct, and is still relevant today in Niue. Results of the PSA consultation (IWP National Programme 2004) highlighted a national perception (albeit without good supporting data) of declining availability of marine resources, including fish stocks, baitfish, and reef flat invertebrates. Among the invertebrates, *alili* (turbo gastropods) were most commonly mentioned as specifically in decline, with over half of the villages referring to depletions in a range of crab species, *ugako* (vermetid molluscs in tubes), *hihi* (gastropods), seaweeds (*limu*), *tatukumiti* (mollusc), *feke* (octopus), *sepulupulu* (holothurian), *matatue* (oyster), and *matapihu* (mollusc).

More recent surveys have been conducted with respect to socioeconomic aspects of fisheries. These include a specific study of women and fisheries, principally relating to harvesting of inshore invertebrate species (Tuara 2000), and an ongoing study by SPC of fishing effort with respect to establishment of offshore Fish Aggregating Devices (FADs) (L. Chapman, pers. comm.). FADs work by concentrating certain fish stocks in specific areas, making it easier to catch these fish. It is not known if FAD's act as an attractant to fish that normally migrate through an area and perhaps would not normally remain as long in an area, or if they act as a specific reference point to return to each day. The latter explanation would result in a concentration of fish in the vicinity of the FAD and might draw fish away from more traditional areas where the fish were found. If the former explanation were correct, then the negative perception of the influence of FADs on fish harvests would not be valid. In all likelihood, both processes may be operating, depending on the species concerned and the seasonal variation in presence or abundance of specific stocks. No clear research results are available to clarify these concerns relating to FADs (L. Chapman, pers. comm.).

Tuara (2000) assessed the role of women in the fishery sector. She described the services available in government and non-government agencies and constraints and guidelines for assistance to women in fisheries. Little information of relevance to this review was available from her report. That is, no information was presented on specific species that were targeted, reasons for fishing, or the extent to which they observed rules.

The current SPC study (Chapman, pers. comm.) is focused on assessing the value of the established FADs in terms of fishing effort. It has an approximate two-year project life span (involving an initial survey and two subsequent annual surveys, beginning in December 2001 with follow up surveys in March 2003, and a final survey in late 2004). Information from this project will have some relevance to the IWP project, including the degree of fishing effort using various techniques that would be employed on the reef habitats, the frequency of these activities, the number of boats and canoes used for these activities, and awareness of marine protected areas (MPAs; currently including only the Namoui Anono Marine Reserve in the IWP pilot villages) and their effect on catch. The final survey will probably have to be re-evaluated in light of Cyclone Heta impacts. However, initial data from the first two surveys have been useful in indicating the importance of the coastal fisheries to a high proportion of households in Makefu and Alofi North (Table 7). Of the total number of families surveyed in Makefu and Alofi North, 88% of families regularly targeted fish and other marine products from the coastal reefs (same percentage for both reef fishing and gleaning activities). This figure was approximately ten percent higher in Makefu compared to Alofi North. In addition, 23% of households included members that regularly fished outside the reef for pelagic fish species. In all but one case, those families that included members who fished outside the reef also contained members who fished and gleaned on the reef. Other harvesting methods included spearing for reef fish (9% of households with at least one member), and use of nets (5%). The high percentage of families in Alofi North and Makefu that regularly undertake reef fishing and gleaning compared to offshore fishing would suggest that overharvesting could be occurring, as there is a relatively small area of habitat available for these activities.

Table 7. Summary of selected survey data collected by the SPC FAD research project.

It was estimated that approximately 57% of all families present in Makefu and Alofi North at the time of either survey were included in the surveys, with over 90% of families in Makefu and approximately 50% of families in Alofi North included. (Data supplied by L. Chapman).

VILLAGE	TOTAL FAMILIES SURVEYED	REEF FISH	GLEAN	SPEAR	NET	OFFSHORE FISHING
MAKEFU	18	17 (94%)	17 (94%)	3 (17%)	7 (6%)	5 (28%)
ALOFI N	25	21 (84%)	21 (84%)	1 (4%)	1 (4%)	5 (20%)
COMBINED	43	38 (88%)	38 (88%)	4 (9%)	2 (5%)	10 (23%)

2.7. Status of fisheries and associated marine resources

A review of the status of specific marine resources and fisheries species is addressed here by assessing the usefulness of the information provided in these studies for comparison with future surveys. The aim of this review is to look for data sets that may aid in validating the perceived causes of resource depletion, within the constraints of the adoption of the same sampling methods as used previously, or as is thought to be the current best way of approaching assessments of this nature.

The PPA analysis (IWP National Programme 2004) did not specifically refer to trends in specific organisms, so it is difficult to address the concerns referred to in this study. The only PPA references were in relation to some aspects of fish behaviour and to perceived impacts from predation on invertebrates by reef herons. In fact, this approach is a limitation of the usefulness of the PPA results in validating problems relating to species or defined resource groups. This is because non-specific analyses are carried out with participants who may have very different species or resource groups in mind when going through the PPA process.

2.7.1 Previous fisheries surveys

Two studies on the status of coastal marine resources have been completed in the last 10–15 years. These include field surveys for a preliminary stock assessment of selected macro invertebrates on some west coast reef flats, and on subtidal slope habitats for approximately two-thirds of the Niue coastline (excluding the east to southeast sector) in July 1990 (Dalzell et al. 1993). Results of a socioeconomic assessment conducted as part of this study are reviewed in section 2.6.2 above. Dalzell et al. (1993) estimated reef slope stock densities of giant clams and holothurians, along with assessments of crown of thorns starfish densities, and visually estimated per cent cover of coral. Collections of nocturnal crustaceans were carried out in three slope locations on the west coast. The slope manta tow surveys for selected macro invertebrates can be repeated to validate perceived trends in these stocks, although comparison of specific locations along the coast (such as in Alofi North and Makefu) is unlikely from the only report available from this study. The limited survey of nocturnal crustaceans on the west coast was not quantitative but indicative of the presence of certain species.

The second survey in November–December 1998 (Labrosse et al. 1999) of selected fish species and eight invertebrate species or species groups was restricted to two specific locations: within the Anono-Namoui Marine Reserve, and at Avatele on the southwest coast. Both intertidal reef flat and subtidal slope habitats were sampled. Descriptive habitat parameters were also recorded on the slope transects, which included granulometric (size) categories of substrata, and living organisms (fleshy algae and coral). Densities of giant clams, sea urchins, and holothurians were also recorded on slope habitats. In addition, densities of vermetid worm tubes (reported as polychaete worms), two drupe mollusc species, one holothurian species, one spondylus mollusc (possibly the jewel box oyster, *Chama isostoma)*, rapa snails, limpets, and trochus were recorded from a number of reef flat sites in the two locations. If survey methods are repeated in any future survey, some useful validation of perceived trends could be determined. However, the data presented in the report is very unclear as to the location and number and size of replicates used in the original survey, along with the pooling of species groups, which will limit the usefulness of such a comparison.

Giant Clams

The standing stock of giant clams on subtidal slope habitats in 1990 was estimated to be 24,252 *Tridacna maxima* and 3,815 *T. squamosa;* overall densities were higher in the west (117 clams/ha) than in the east (44 clams/ha). The results of the 1990 clam survey also indicated that of the two clam species found in Niue, *T. squamosa* was less common than *T. maxima.* There was a large difference in relative abundance of the two species between the west and east coasts (Tepa Pt. to the north point of Vaihaka was defined as the west coast, and Vaihaka to Vaigata was defined as the east coast (Dalzell et al, 1993). The west coast survey area showed a relative abundance ratio of *T. maxima*: *T. squamosa* of 11:1, compared an east coast ratio of 2:1, using the raw numbers recorded in their surveys. The overall clam densities were considered to be low compared to other areas in the Pacific and this was attributed to a general lack of suitable habitat, local fishing pressure, and possibly the immediate effects of cyclone Ofa in early 1990. A giant clam survey in 1998 at Anono-Namoui Marine Reserve and Avatele (Labrosse et al 1999) calculated lower clam densities in the Reserve (combined slope and reef flat mean of 15/ha) compared to Avatele (slope and reef flat mean of 54/ha).

As with the pilot data (this study) only *T. maxima* was observed in any of the surveys from 1998. A similar difference in clam densities was also shown in comparisons of reef flat and slope habitats at both locations. Labrosse et al (1999) used different methods than the earlier Dalzell et al (1993) survey (see below), so it is difficult to directly compare the two survey results. However, Labrosse et al (1999) noted that fishing pressure may have caused the observed lower densities recorded in 1998 compared to 1990. The significant conclusion from these data is that there has been a drastic decline in numbers of *T. squamosa* since 1990, and that densities of *T. maxima* have also probably been severely depleted.

Quantifying the extent of clam depletions on a national scale will be possible if the same methods are employed, but currently the available data cannot be interpreted beyond what has been presented above. However, the surveys of Labrosse et al (1999) and subsequent SPC surveys of slope habitats in the Namoui/Anono Marine Reserve may be used as a basis for complementary surveys by IWP for assessments in Makefu and Alofi North, if assessment methodology is the same. The IWP pilot programs will possibly address the root causes of clam depletions, with positive responses in clam populations detected.

The size structure of *T. maxima* was recorded in 1990 at three west coast sites (Avatele, Alofi, Namakulu; Dalzell et al 1993). Results indicated that clams were generally small (median size range of 12–14 cm in length). During this survey, very few clams were observed on the western reef flat transects used for holothurian estimates. No size measurements were recorded in 1998 (Labrosse et al. 1999), although densities on the reef flat appeared to be much higher compared to the 1990 survey results of reef flat sites.

Limited reef flat and slope surveys on the west coast locations associated with Alofi North and Makefu villages during the IWP pilot work in December 2003 (this study), indicated that clam densities were extremely low on both reef flat and slope habitats (see Section 2.9 below). In the current study, no clams were observed in any of the structured surveys, although 2–3 individuals were observed on reef flats and slopes, whilst testing the survey methods. Dalzell et al (1993) discussed possible mechanisms to enhance the viability of clam stock regeneration in Niue. The PSA analysis (IWP National Programme 2004) also indicated community interest in the viability of establishing breeding facilities for clams to enhance wild stocks.

Holothurians (bêche-de-mer)

Five species were observed on Niue reefs in 1990 (Dalzell et al, 1993) from both reef flat transect surveys and slope habitats. All five species (*Holothuria atra*, *Holothuria nobilis*, *Thelenota anas*, *Actinophyga mauritiana*, and *Bohadschia* spp.) were observed on the west coast subtidal slope with *H.* atra and *T. anas* being the most dominant. *H. atra* was extremely abundant on the reef flat with a mean of 347 individuals/ha. The second most abundant holothurian on the reef flat was *T. anas* (3.9 individuals/ha). Subtidal slope habitats carried densities of *H. atra* and *T. anas* at 16.8/ha and 17.5/ha, respectively.

In 1998, Labrosse et al (1999) recorded holothurian densities of 6/ha and 33/ha on the subtidal slopes at Namoui Marine Reserve and Avatele, respectively. Reef flat habitats carried 8/ha and 0/ha at Namoui MR and Avatele, respectively. Labrosse et al (1999) noted that 98% of holothurians were of one species, *H. atra,* and compared data from similar survey locations with the data of Dalzell et al (1993), concluding that densities were much lower compared to the earlier survey. Note that survey methods were quite different so caution needs to be exercised regarding the significance of the differences. Pilot data on reef flat holothurians (this study) indicated that three species were present at much higher densities combined, and for *H. atra* (303.7/ha; Table 7) using methods similar to both former surveys. An additional very abundant reef flat species, *Holothuria leucospilota*, was not mentioned in either former studies, which is unusual. It is possible that former surveys did not distinguish between the two separate species, as both are superficially similar. *Actinopyga mauritiana* was recorded in low densities on the reef flat in the pilot study and in the 1990 survey (Dalzell et al, 1993), though the latter report did not present separate data on the other low abundance species, which were pooled. Limited subtidal surveys in the present study did not record other species mentioned in Dalzell et al (1993), i.e. *Holothuria nobilis*, *Stichopus chloronotus*, and an unidentified *Bohadschia* species. In contrast, an unidentified filter feeding species was observed on the reef flat in the 2003 pilot study (see section 2.8.1 below).

Because of the above differences in survey methodology and lack of report details, it will be difficult to quantify changes in abundance of these organisms from these surveys and any future surveys that may be carried out. Only descriptive comparisons will be able to be made between previous and future surveys by using gross stock density comparisons that will generally be not specific to locations (e.g. village reef areas of Makefu and Alofi North).

Sea Urchins

Sea urchin densities (mainly *Diadema setosum*) were recorded for subtidal slopes in 1998 (Labrosse et al 1999). Densities differed between the Marine Reserve and Avatele, with fewer (mean of 13/ha) in the former, compared to the latter (mean of 29/ha). When the reef flat and subtidal slope habitat were compared, high numbers were present on the slope compared to the reef flat at the marine reserve, but conversely high numbers were observed on the ref flat compared to the slope at Avatele. The different pattern of urchin relative abundances between the slope and reef flat may be a consequence of prior cyclone impacts, though it had been eight years since the last severe cyclone in 1990 (Cyclone Ofa). A more likely explanation is that habitat suitability or harvest pressure is responsible for differences between the marine reserve and Avatele. No urchins were observed in the limited slope surveys carried out as part of the pilot assessment (this study). However, see in section 2.8.1 regarding the small burrowing urchin, *Echinometra mathaei,* which was very common and abundant on west coast reef flats.

Trochus

Trochus were introduced to the shallow subtidal habitat just below the crest from boats in 1992 and 1996 (Gillett 2002, S. Leolahi pers. comm. 2003). Introductions in August 1992 were in the vicinity of Makapu (99 shells) (recorded as Hakapu), Patuoto near Tamakautoga (47 shells), and at Matalave and Makatutaha near Namakulu (77 shells). A second introduction was carried out in August 1996 at Tamakautoga and Namakulu (total of 311 shells). It is not known how successful these introductions have been, though there have been encouraging signs. Labrosse et al (1999) recorded low densities of 0.016 trochus/ha on the intertidal reef flat in 1998, though it was not stated where the trochus were found (they surveyed the Namoui Marine Rerserve (including Makapu) and Avatele (towards the south of Tamakautoga). Small dead trochus shells have also been observed on small sand and rubble accumulation areas at the base of the shoreline cliffs in recent years (S. Leolahi, pers. comm.).

Specific surveys focusing on the presence and size structure of introduced trochus would have to be drawn up to verify if successful transplantation has occurred. This would entail searches of reef crest habitats and would require very good sea conditions to achieve.

Other Molluscs

Reef flat macro invertebrates utilised by villages also include a range of molluscs. A number of these species and species groups were surveyed by Labrosse et al (1999) at Namoui Marine Reserve and Avatele, but the only data reported were overall combined densities from the two locations. These molluscs included: "tubeworms" (probably vermetid molluscs, *Dendropoma* cf *maximum*; 1.46/ha), gastropods *Drupa morum* (0.108/ha) and *D. ricinus* (0.040/ha), "spondylus" (probably the purple edge jewel box oyster', *Chama isostoma*; 0.056/ha), gastropod "*Rapa rapa*" (1.132/ha), and "limpets" (probably including the false limpet *Siphonaria sirius*, though this was not specified in the report, 0.02/ha).

The methods trialled during the pilot surveys in December 2003 (this study) were different to the Labrosse et al. (1999) study, as the unit area and number of replicates were quite different between the two studies (the number of replicates or the total sample area were not given in the earlier 1998 survey). However, densities of some macro invertebrates within and adjacent to the Namoui Marine Reserve estimated in the pilot surveys are considerably higher than those recorded by Labrosse et al (1999). For example, for *Dendropdium* cf *maximum* (2473/ha in 2003, 1.46/ha in 1998); *Chama isostoma* (6073.5/ha in 2003, 0.056/ha in 1998); and *Siphonaria sirius* (436.4 in 2003, 0.02/ha in 1998). The 2003 estimates are probably from a smaller sample area so it would be expected that more equal comparative density estimates would be lower than those calculated here. The relative density ranks for three species surveyed both times are different between 1998 and 2003 as well. That is, in 1998 *Dendropoma* cf *maximum* ranked highest compared to second in 2003, *Chama isostoma* ranked second in 1998 and first in 2003, and *Siphonaria sirius* ranked third in 1998 and 2003.

It is possible that the two surveys were conducted in different areas and the difference in relative densities may be due to localised clumping of these organisms from gregarious settlement, with sampling methods not adequately addressing these patterns.

The pilot survey data that was trialled in December 2003 and repeated as a post-Cyclone Heta investigation included most of the above molluscs except for *Drupa* spp and *Rapa* spp. These data are presented in the relevant sections below and can be repeated in the future.

Echinoderms

Crown of thorns starfish (COTS, *Acanthaster planci*) were surveyed on the approximately two-thirds of the island reef slope in the 1990 survey (Dalzell et al., 1993). Only nine adult COTS were recorded in 9.2 ha of survey area, that is, a density of 0.98 individuals/ha, which is quite low and probably within the range of normal density levels for a coral reef. Follow up surveys have not specifically targeted COTS, though they are included in the manta tow baseline survey data set below. The method is quite comparable to Dalzell et al., (1993), except that the width of each tow observation in the baseline work here was approximately half of that carried out in 1993. No COTS were observed during the baseline surveys (see below).

Crustaceans

Dalzell et al. (1993) conducted a small evaluation of the scope of availability of tropical spiny lobsters (*Panulirus pencillatus*, *P. longipes*, *P. versicolor*), slipper lobsters (*Parribacus caledonicus*), and two large reef crabs (*Etisus spendidus*, red reef crab; *Carpilius maculatus*, three-spot crab). Collections of these crustaceans from three night dives on the west coast resulted in thirty-seven *P. pencillatus* spiny lobsters with equal males and females in that sample, and carapace lengths from 6.4 to 11.5 cm. Thirteen specimens of *P. longipes* were all male with 6.9 to 9.9 cm carapace lengths. Twelve *P. versicolor* were all female with eight carrying eggs.

The method employed in the Dalzell et al. (1993) survey could not be repeated as described in the report. It appears that it was an attempt to register the presence/absence of night active crustacean species of commercial value for that particular survey time only (in July 1990).

Fish

The only quantitative fish resource surveys have been conducted at Namoui Marine Reserve and a comparative site outside the reserve at Avatele in 1998 (Labrosse et al (1999). Densities of selected fish and biomass were estimated for commercial fish that were present. A total of one hundred and three fish species were recorded belonging to nineteen families. Out of this pool of species, seventy-nine species were noted for their potential for marketing and/or subsistence consumption. Twelve species accounted for 49% of the total fish density, and 57% of the total biomass.

Species numbers and densities were similar at both sites from the Labrosse et al. (1999) study, but total biomass per unit area was higher at Avatele compared to the marine reserve site. In comparison to studies elsewhere in the Pacific, biomass at the marine reserve was among the lowest reported for Indo-Pacific fringing reefs. In contrast, biomass at Avatele was comparatively among the highest recorded in studies from elsewhere in the Indo-Pacific. Differences in species-weight relationships was suggested as a reason for the large biomass difference between the sites, as there was no significant difference in densities between locations for the principal families recorded.

Demographic and trophic structures did not differ at the marine reserve and Avatele locations (Labrosse et al 1999). Trophic analysis showed a clear predominance of micro-herbivorous fish with respect to density and biomass. This group was four to five times more abundant than macro-carnivores or piscivores.

Live coral

Visual estimates of subtidal slope live coral were recorded from manta tows in 1990 by Dalzell et al. (1993), and in 1998 by Labrosse et al. (1999). Very different methods were used in the studies so comparisons can only be descriptive. In addition, assessments similar to Dalzell et al. (1993) were recorded as part of the pilot surveys in 2003 (this study).

In 1990, live coral cover in the west coast and the north coast (Tepa Point to Liha Point) varied greatly from < 5% to 35% cover (mean of 9% cover). Live coral on the east coast, south of Liha Point, was relatively higher with a mean of 57.5% cover. The west and north coasts were more affected by Cyclone Ofa (in 1990), which accounted for the difference in cover between the east coast and elsewhere. Dalzell et al (1993) used a parameter of total coral cover, which appeared to be different to live coral cover, without explaining the term. Presumably, total coral cover referred to a combined cover of live and dead coral, or may also refer to soft coral cover as well. Without confirmation of this, it is hard to confidently dissect the data to arrive at the important dead coral cover term.

Coral cover on subtidal slope habitat was estimated in 1998 at Namoui Marine Reserve and Avatele locations, using a point-intercept method (Labrosse et al. 1999). Unfortunately, no data were given for live coral cover, instead a combined index of "living-organism" cover was noted (approximately 50% cover), but this included a combined cover of algae, soft coral, as well as hard coral. Hard coral types were mentioned but they were not the usually used descriptors for coral growth forms (e.g. unusual terms used were tubular coral and stony coral) so it was difficult to assess the type of communities that were present. However, the authors stated that coral colonisation had been "significant and relatively homogeneous" throughout the Namoui Marine Reserve, despite this site being particularly impacted by Ccyclone Ofa.

Neither of the above studies mentioned the coral communities on the reef flat or in the deep pools and channels that are present on the flats as well. These pools are important refuges for mature corals as well as many other reef vertebrate and invertebrate species.

Live hard coral on the subtidal slope between the harbour and the southern boundary of the marine reserve in 2003 averaged 25%, with dead coral cover at a mean of 13% cover. Plate coral (mainly *Acropora paniculata*) on the lower slope below 15 m depth showed low levels of disease and partial breakage. This was possibly due to the impacts of previous storm damage. The effect of severe bleaching of hard corals was evident by the abundance of dead (but still attached) coral, and by the species that were apparently most affected (predominantly *Acropora* spp.). At all sites, the dominant coral growth form was the relatively fast growing plate or corymbose *Acropora* spp., followed by massive forms. It was thus likely that coral recovery had been very good in the period between 1990 (Cyclone Ofa) and 2003, though the effect of bleaching in years prior to the most recent survey reduced coral cover by up to 50% in some locations along the west coast. By December 2003, coral cover at the few survey sites used in the pilot study (below) ranged from approximately 15% to 35% cover. Cyclone Heta in early January 2004 has resulted in a reduction in cover to less than 1% in the same areas surveyed in December 2003.

Some pools and channels in the reef flat are important sites for a range of coral species that are rare elsewhere, especially on the slope. This is because the pools especially are well flushed with water but are relatively protected from wave surge compared to slope colonies. Very few deep pools or channels are present in the pilot sites of Alofi North and Makefu, though elsewhere they are very common features of the reef shoreline.

Habitat characteristics

Labrosse et al (1999) included a basic description of benthic organism and habitat indicators in terms of percent cover of the substrate. All "living organisms" were combined into a single figure for per cent cover so little of value can be extracted from the data. An additional assessment of granulometric types of the substrate was low on data presentation as well, except for the conclusion that a high percentage of "rock" was present (>80%). The definition of rock in this study referred to "rock of organic or non-organic origin", with no size range used in the description. The size and description of rock is presented as being different to "big blocks" of 30-100cm, and "coral heads" of more than 100cm diameter. No interpretation of this data was given, which would have been useful in an assessment of cyclone damage (such as the damage from the recent Cyclone Heta in January 2004). Some aspects of these habitat descriptions may be of use as part of a baseline description in the third phase (permanent baseline sites) of the IWP project work. In particular, the description of the structure and relative topography of the substrate may be useful as part of the records of recovery and re-emergence of typical reef characteristics following Cyclone Heta in 2004.

2.8. Methods used in previous surveys

Most the previously used methods for fish and macro invertebrate assessment in Niue are focused on the calculation of gross stock densities of the target species. In these studies, the unit sample area is extremely variable (Table 8), and hence is not repeatable on a site-by-site basis. Current stock densities at broad spatial scales (e.g. west coast, or national scale) can be repeated but this will not be very useful in assessing changes over time in target species at smaller scales such as village customary land separated into MPA and non-MPA areas. That is, previous studies will not be useful in assessing the success of new measures, including sustainable fisheries management tools such as establishment of MPAs or equivalent restricted harvest areas.

Table 8. Summary of methods employed to survey Niue reef resources in the past, in addition to the SPC PROCFish methods.

TARGET SPECIES	DETAILS OF METHODS USED IN PRIOR SURVEYS OF NIUE
Giant Clams; Corals; Holothurians, Crown of Thorns Starfish (COTS), Other Epibenthic Invertebrates.	Manta (Boat) Tows (Clams, Holothurians, COTS; Dalzell et al (1993): Tow Length x Width = 90m to 500m x 6m to 10m. Area Covered = 9.2 ha total, from 42 total tows. Habitat = Subtidal slope. GPS position = not recorded
	Manta (Boat) Tows (Clams, Holothurians, COTS, other invertebrates; PROCFish Methodology): Tow Length x Width = 300m to 350m x 2m. Replicates = 6 tows per station, 4 stations per zone, 3 zones per location Area Covered = 600 to 700m^2 per tow; Habitat = Sub tidal inshore, midshore, exposed oceanic habitats (usually 1-3m depth but occasionally to 5-8m). GPS position = recorded at start and end of tows (and estimate distance traveled).
	Belt / Quadrat -Transects (Holothurians only; Labrosse et al, 1999): Belt / Quadrat Length x Width = 50m x 6m (slope) / 5m x 5m (reef flat). Area covered per site = not provided. Habitat = slope & reef flat. No. Belts per Site = not provided slope or reef flat, (5 x 10m contiguous belts per transect (slope). GPS position = not recorded.
	Belt Transects (Holothurians only; Dalzell et al, 1993): Belt Length x Width = 10m x 6m (contiguous across reef flat). Area covered per site = not provided Habitat = reef flat No. Belts per Site = not provided, but no. transects per site ranged from 2-5. GPS position = not recorded.
	Belt Transects (Food and commercial macro invertebrates & other epibenthic invertebrates; PROCFish Methodology): Belt Length x Width = 40m x 1m. Replicates = 6 belts per station Area covered per site = 40m^2 per belt transect. Habitat = hard and soft bottom substrate. No. Belts per Site = not provided, but no. transects per site ranged from 2-5. GPS position = yes : representative of station position.
	Timed Swims (PROCFish Methodology) : Search Time = 15 mins per search.

TARGET SPECIES	DETAILS OF METHODS USED IN PRIOR SURVEYS OF NIUE
	Replicates = 2 x 15min swims per station (night snorkel); and 4 x 15mins day snorkel; 3 x 5min reporting blocks per swim for each of 2 divers; also, dives to 25-30m depths for white teat holothurians where possible. Habitat = slope and shallow crest. GPS Position = yes, representative of station.
Other Macro Invertebrates	Belt transects / Quadrats : (Dalzell et al, 1993) Belt Length x Width = 50m x 6m (sea urchins : slope) / 5m x 5m ('Tubeworms', 2 x *Drupa* spp, 'Spondyls', *Rapa rapa*, 'Limpets', Trochus, reef flat). Area covered per site = not provided. Habitat = slope (urchins only) / reef flat. No. Belts per Site = not provided (slope or reef flat). GPS position = not recorded. Belt Transects (PROCFish - SPC standard Protocol, Friedman (pers.comm.) : (see above)
Infauna Invertebrates (under surface of soft substrata)	Quadrats : Length x Width = 25cm x 25cm. Replicates = 4 x Quadrats every approx 5m along 40m tape measure transects used for epibenthic invertebrates) (total of 8 per transect). GPS Position = yes, representative of station.
Trochus, Greensnail, Po	Timed Dives (SCUBA) (PROCFish Methodology) : Search Time = 15 mins per search. Habitat = slope and shallow crest. GPS Position = yes, representative of station. Belt Transects (PROCFish Methodology) : : Belt length and Width = 40m x 2m. Replicates = 6 belt transects per station. Area covered = 2m wide Habitat = slope and shallow crest. GPS Position = yes, representative of station.
Reef Fish	Belt Transects (UVC) Labrosse et al (1999) : Belt Length x Width = 50m x variable width (range of visibility). Area covered per site = Variable, determined by clarity of water.

TARGET SPECIES	DETAILS OF METHODS USED IN PRIOR SURVEYS OF NIUE
	Habitat = reef flat and slope. No. Belts per Site = Variable, minimum frequency of '2 dives per 0.2miles'. GPS position = not recorded. <u>Belt Transects</u> (PROCFish, SPC standard Protocol, Friedman (pers.comm.) : Belt Length x Width = 50m x variable width (range of visibility), using 2 divers each side of transect. Area covered per ?Site/Location = Variable, determined by clarity of water. Habitat = reef flat and slope. No. Belts per Fishing Ground = 24 total transects per ground; 3 x 50m belts per reef flat and slope in coastal, patch, back, and outer reef areas (if present). Parameters = 250 edible fish species, fish numbers, fish length, distance from transect line.
Habitat Descriptions	<u>PROCFish Methodology</u> (as part of Macro Invertebrate Surveys) : Sample Unit = manta tow, belt transect, timed swim (?). Visual Estimate within sample unit = Parameters include : Relief / Complexity (rank 1-5); Ocean Influence (rank 1-5); Depth (m); % Cover Soft Sediment (M – S – CS); % Cover Rubble / Boulders / Consolidated Rubble / Pavement / Live Coral / Dead Coral / Soft Coral / Sponge / Fungiid corals / Crustose coralline algae / Coralline Algae / Other Algae / Seagrass; Notes on Species; Epiphytes (rank 1-5); Silt (rank 1-5); COTS number; Bleached coral (% of all live corals). <u>SPC Coastal Fisheries</u> (Reef Observatory) (as part of Visual Fish Census Survey Manual) : Transect = point intercepts at 1m intervals along 50m transect length. Replicates = 3 parallel transects per site and 3m apart. Parameters = similar to PROCFish Methodology (?). Photo / Video record = Photos or video taken along whole of transect line; <u>SPC Coastal Fisheries</u> (as part of SPC Underwater Visual Fish Census, adopted 2004?) : Transect = 50m length. Visual Estimate = every 10m along tape, with a 5m diameter circle sample area based on tape position, resulting in contiguous sample circles. Parameters = total of 37 indices in addition to PROCFish parameters listed above : Algae (macro algae, turf algae), Live coral life forms (encrusting, massive, sub-massive, digitate, branch, foliose, tabulate), abiotic (large boulders, (<1m), rocks (>1m), and Cyanophycae.

2.9. Pilot survey and testing of methods

Pilot surveys of reef flat habitats and slope habitats concentrated on two aspects: a description of the main species that are present in both habitats, and the application and adaptation of appropriate methods that will accurately reflect the distribution and characteristics of the target species. The latter focus involved testing and scoping of methods that could be adopted in the first phase broad scale survey (Fisk 2007b) and the second phase permanent baseline activity (including community monitoring; Fisk 2007a). It was also important to adopt methods that would be as compatible as possible with past studies, and with the methods used by the SPC Pacific Regional Oceanic and Coastal Fisheries (PROCFish) project for reef fisheries assessment.

2.9.1 Pilot data

A list of macro invertebrate species recorded in transects (see 2.9.2 below) during reef flat pilot surveys is presented in Table 8. A list of associated invertebrate and macro algae species present within the pilot sites will be developed and presented in the full baseline report from the next baseline phase work in Niue (Fisk 2007b). Most of the species in the extended list were photographed in 2003 and/or specimens collected for identification.

Holothurians

Only three holothurian species were recorded in pilot survey transects and all are detritus feeders on the substrate. All three were found in areas of the reef flat where there was sufficient water covering the reef flat and where some sand or gravel was present, ie, usually in shallow pools or depressions. Two of the three species (*Holothuria atra*, and *H. leucospilota*) were common (densities of 0.01/m^2 to 0.07/m^2, and 0.0/m^2 to 0.06/m^2, respectively) but neither is considered highly desirable for harvesting or for commercial value. The third species, *Actinopyga mauritiana*, is a desirable fisheries species, but it was relatively uncommon in all survey areas (densities of 0.0/m^2 to 0.03/m^2). A fourth holothurian species was observed in very low abundance in shallow pools that were usually close to the cliff base. This species is a filter feeder and has not been identified to date using any of the common reference books. Good photos of body characteristics were taken for identification by an appropriate specialist. One *Thelenota anas* individual (a commercial fisheries species) was observed in a sand gutter at 15 m depth on the slope in reconnaissance swims of the west coast slope in 2003 (this study). This compares to a total of 28 *T. anas* recorded in 7 variable tows along a similar area in 1990 (Dalzell et al. 1993). *H. atra* and *H. leucospilota* were also recorded in tows along a similar slope area by Dalzell et al. (1993). Only two of the ten reef flat transects were conducted in the Alofi area as part of the Dalzell et al. (1993) survey and a number of species were recorded in 1990 that were not observed during the pilot surveys. These species include *Stichopus horrens*, *Holothuria nobilis*, while *Holothuria leucospilota* was not recorded in 1990, although it was abundant and widespread in 2003. The latter species may have been lumped with *H. atra* in the 1990 study.

Molluscs

The molluscs used for quantitative pilot data included: *Serpulorbis colubrinus* (vermetid tube mollusc), *Chama isostoma* (jewel box oyster), and *Siphonaria sirius* (false limpet). Both the vermetid molluscs and the jewel box oysters could be very useful as indicators of harvest pressure in the short term as both have identifiable parts of their shells that remain on the substrate following harvesting. This was confirmed by a fortuitous overlap of our pilot surveys with a group of women who were harvesting both species in the Vailoapu sea track site. Live *S. colubrinus* ranged in abundance from 0.01/m^2 to 1.4/m^2 compared to dead *S. colubrinus,* which ranged from 0.1/m^2 to 2.1/m^2, indicating a high mortality rate. *C. isostoma* oysters recorded live densities of 0.0/m^2 to 3.3/m^2, and dead densities of 0.02/m^2 to 0.53/m^2. This is indicative of moderately high harvest pressure, but more importantly, these data can be monitored regularly to track harvest pressure and recruitment rates. The false limpet, *S. sirius*, was only surveyed at one of the two sites, however, densities ranged from $0.01/m^2$ to $0.09/m^2$. This density range is generally lower in comparison to the other two surveyed species although the limpets were mainly distributed in the inner to mid- reef flat area of the habitat, as were the other mollusc species.

All three species were abundant at most locations in the pilot surveys. However, the most numerous molluscs were small gastropods from a number of families. No pilot data were collected on these gastropods as most are still to be identified from photos and some collected specimens. A complete list will be compiled for the full baseline survey report.

The vermetid tube mollusc (*S. colubrinus*) can be very abundant in the inner and mid reef flat where it is regularly harvested in high numbers. Vermetid molluscs produce mobile juveniles that crawl away from the breeding adult and usually settle near the parent. Vermetids also produce swimming larvae that settle large distances from their parental source. This aspect of their biology and the pilot data (Table 9) suggests that the occurrence of vermetid molluscs have a strong gregarious distribution pattern, which has consequences for both appropriate sampling strategies for monitoring and assessment, and for management strategies. Strong gregarious settlement behaviour also means that there may be a possibility of artificially seeding areas with adults to enhance local settlement.

Jewel box oysters (*Chama isostoma*) are harvested for food from the reef flat habitat at low tide. The distribution of these oysters appear to be quite patchy, which may be a result of a natural characteristic for gregarious settlement or as a result of patchy micro habitat features that are suitable for settlement. Both explanations are possible because most oysters were generally found on slightly shallow or elevated parts of the reef flat and most oysters tend to show strong gregarious settlement patterns in other parts of the world. Both vermetid molluscs and oysters appear to favour the relatively shallower parts of a reef flat, with the oysters tending to be present on the shallowest parts.

Other significant fisheries species of mollusc (e.g. giant clams and turbo shells) were not specifically targeted in the pilot surveys. However, giant clams were not observed in any of the transects and only one was observed anywhere on the reef flat in both sites (the total area that would have been "searched"by four observers covered most of the reef flat for approximately 500m of coastline or approximately 2.5ha).

Coral cover, fish status, and other slope macro invertebrates

The status of slope communities on the west coast adjacent to the two pilot sites was assessed using a broad assessment protocol adapted from standard Global Coral Reef Monitoring Network (GCRMN) methodology. The method is known as manta tow assessments, which has been successfully applied in the Samoa Marine Biodiversity Assessment and Management Project. It is proposed that this would be an appropriate method to adopt in the first phase and as a broad scale assessment tool for evaluating the extent and severity of the impact of Cyclone Heta.

Table 10 is a summary of the data recorded during the manta tow pilot surveys. In summary, live coral cover was relatively low at >10% but less than 30% cover. In all cases, the live coral cover was less than 20%. Coral communities were dominated (in terms of per cent cover) by corymbose (pillow shape) or tabulate forms, but there was commonly an abundance of small massive colonies present as well. *Acropora* spp. Dead hard coral cover was relatively similar to live hard coral cover in three of the five sites, reflecting the effect of mortality due to a coral bleaching event the previous summer, particularly towards the Alofi North section of the coast (S. Leolani and B. Pasisi, pers.com 2003.). *Acropora* tabulate colonies were commonly observed with damaged and/or pieces missing to the edges, which probably was a result of storm damage.

Very few macro invertebrates were observed in any of the tows, including no COTS. Disturbance indices were restricted to low levels of coral disease and partial storm damage to tabulate *Acropora* species.

The dominant fish group were the Acanthuridae (surgeon fish), with fewer numbers of Scaridae (parrot fish) also present. Total fish abundance was very low as well. Some large indicator fish were observed (single maori wrasse, *Cheilinus undulatus*, and white-tip reef shark *Triaenodon obesus*; relatively plentiful peacock grouper, *Chephalopholis argus,* during the tows suggested that some large predator species are present on the inshore reefs, and that fishing pressure is at a level that is relatively low or selective towards species other than these.

The conclusions from this restricted data set are that there have been a number of medium to major disturbance events in recent years, and that the status of the benthic reef habitat was in a relatively early stage of recovery from separate disturbances. A protocol similar to the one used in the pilot survey will give good quantitative and descriptive data on a number of indicators that describe the physical state of the slope habitat, the major biological components present at that time, and present and recent past disturbances affecting the main structural components of the slope habitat. Such information will be very useful to determine the final approach to any MPA system for fisheries management, and the accompanying monitoring design to track effectiveness of that management. It is assumed that more detailed quantitative assessment and monitoring data will be collected to complement this broad scale approach.

Table 9. Data recorded in contiguous belt transects across the reef flat

Each pilot survey transect of the reef flat habitat 10m long by 5m wide, except for those marked with an *, which were 2.5m wide. Species recorded included all holothurians present (*Holothuria leucospilota, Holothuria atra, Actinopyga mauritiana*), live or dead mollusc tube worms (*Dendropoma* cf *maximum*), the bivalve *Chama isostoma*, and the false limpet *Siphonaria sirius*. GPS positions refer to the starting position of the belt, i.e. against the cliff face or at the base of a beach. The transects were placed perpendicular across the reef flat, starting from the base of a cliff or the base of a beach or rubble bank out to the crest.

SITE		**VAILOAPU SEA TRACK**		**NAMOUI SEA TRACK**					
DATE		**1 /12/03**		**2/12/03**					
GPS		**19° 0202 S 169° 5500 W**	**19° 0227 S 169° 5506 W**	**19° 0128 S 169° 5533 W**	**19° 0120 S 169° 5535 W**	**19° 0113 S 169° 5536 W**	**19° 0107 S 169° 5538 W**		
SPECIES	**BELT LENGTH.**	**TR #1 (n=3)**	**TR #2 (n=5)**	**TR #1 (n=5)**	**TR #2 (n=5)**	**TR #3 (n=5)**	**TR #4 (n=4)**	**TOTAL**	**DENSITY / HA**
Holothuria leucospilota	0 – 10m	9	9	2	7	0	0	27	
	10 – 20m	0	1	4	4	0	0	9	
	20 – 30m	0	0	6	0	0	0	6	
	30 – 40m		0	0	1	0	0	1	
	40 – 50m		0	0	0	0		0	
	Mean/m^2=	0.060	0.040	0.048	0.048	0.000	0.000	0.032	318.5
Holothuria atra	0 – 10m	3	7	3	1	0	2	16	
	10 – 20m	1	7	1	0	1	3	13	
	20 – 30m	0	3	3	0	1	0	7	
	30 – 40m		0	2	1	1	1	5	
	40 – 50m		0	0	0	0		0	
	Mean/m^2=	0.027	0.068	0.036	0.008	0.012	0.030	0.030	303.7
Actinopyga mauritiana	0 – 10m	4	0	0	0	0	0	4	
	10 – 20m	0	0	0	0	0	0	0	
	20 – 30m	0	0	0	0	0	0	0	
	30 – 40m		0	0	0	0	0	0	
	40 – 50m		0	0	0	0		0	
	Mean/m^2=	0.027	0.000	0.000	0.000	0.000	0.000	0.003	29.6
Serpulorbis colubrinus (Live)	0 – 10m	117	3	15	0	17	11	163	
	10 – 20m	75	5	1	5	4	12	102	
	20 – 30m	15	0	0	7	3	2	27	
(*Ugako* :	30 – 40m		0	2	2	4	3	11	
Vermetid mollusc	40 – 50m		0	8	9	1		18	
tubes)	Mean/m^2=	1.380	0.064*	0.104	0.092	0.116	0.140	0.262	2473.5
S. colubrinus (Dead)	0 – 10m	59	28	10	5	184	50	336	
	10 – 20m	79	20	5	8	109	37	258	

SITE		VAILOAPU SEA TRACK		NAMOUI SEA TRACK					
DATE		**1 /12/03**		**2/12/03**					
GPS		**19° 0202 S 169° 5500 W**	**19° 0227 S 169° 5506 W**	**19° 0128 S 169° 5533 W**	**19° 0120 S 169° 5535 W**	**19° 0113 S 169° 5536 W**	**19° 0107 S 169° 5538 W**		
SPECIES	**BELT LENGTH.**	**TR #1 (n=3)**	**TR #2 (n=5)**	**TR #1 (n=5)**	**TR #2 (n=5)**	**TR #3 (n=5)**	**TR #4 (n=4)**	**TOTAL**	**DENSITY / HA**
(*Ugako* : Vermetid mollusc tubes)	20 – 30m	21	30	1	6	121	69	248	
	30 – 40m		23	5	1	81	4	114	
	40 – 50m		4	11	5	27		47	
	Mean/m^2=	1.060	0.84*	0.128	0.100	2.088	0.800	0.819	78041
Chama isostoma (Live) (*Papahua* : Purple edge jewel box oyster)	0 – 10m	144	35	32	2	0	0	213	
	10 – 20m	303	53	0	0	0	0	356	
	20 – 30m	50	97	1	0	0	0	148	
	30 – 40m		27	0	0	0	0	27	
	40 – 50m		1	0	0	0		1	
	Mean/m^2=	3.313	1.704*	0.132	0.008	0.000	0.000	0.608	6073.5
C. isostoma (Dead) (*Papahua* : Purple edge jewel box oyster)	0 – 10m	9	3	3	6	8	0	29	
	10 – 20m	22	15	2	6	19	0	64	
	20 – 30m	0	11	0	2	42	8	63	
	30 – 40m		7	0	0	50	0	57	
	40 – 50m		0	1	0	13		14	
	Mean/m^2=	0.207	0.288*	0.024	0.056	0.528	0.040	0.185	1738.8
Siphonaria sirius (False limpet)	0 – 10m	0	1					1	
	10 – 20m	0	5					5	
	20 – 30m	1	5					6	
	30 – 40m		0					0	
	40 – 50m		0					0	
	Mean/m^2=	0.007	0.088*					0.044	436.4

Table 10. Manta tow data from sections of the west coast slope adjacent to the pilot sites.
Dom. Benthos = Dominant benthic organism; HC = Hard Coral;
Dom. Coral = Dominant Coral Growth Form; ACC = *Acropora* corymbose;
ACT = *Acropora* tabulate; MAS = Massive;
LC % = Live hard coral % cover; DC % = Dead hard coral % cover; SC % = Soft coral % cover; For % cover estimates, 1 = <10% cover, 2 = 10-30% cover, 3 = 30-50% cover;
Clams, Holo., Urch. = Number of Clams, Holothurians, Urchins;
Fish Abun. = Total fish abundance, L = low (<100 fish), M = medium (100-500 fish);
Fish Dom. = Dominant fish family; SUR = Surgeon fish (Acanthuridae);
COTS = Crown of thorns starfish number (No.) and Size (< or > 15cm diameter);
Disturbance = Coral Disease (<5% ACT = <5% of *Acropora* tabulate colonies with disease);
Other = Other major observations, here, recorded large indicator fish species such as Maori Wrass and Sharks. NB. GPS positions were also recorded for the start of all tows, and each tow was of 2 mins duration, all at a constant speed; Approximate positions of each tow number was also recorded on aerial maps.

Tow	Site	Depth (m)	Dom. Benthos	Dom. Coral	LC %	DC %	SC %	Clams Holo. Urch.	Fish Abun.	Fish Dom.	COTS No./Size	Disturbance	Other
1	N of Wharf	12	HC	ACC	2	0	0	H=1	M	SUR	0	Nil	
2	N of Wharf	15	HC	ACT	2	1	0	0	M	SUR	0	Nil	ACT with colony damage; 1x White Tip Shark
3	Vailoapu Sea Track	18	HC	MAS	3	2	0	0	L	SUR	0	Disease (5% ACT)	1xMaori Wrass
4	S of Vailoapu	15	HC	ACT	2	2	0	0	L	SUR	0	Disease (<5% ACT)	ACT with colony edge damage
5	S of Wharf	15	HC	ACT	2	2	0	0	L	SUR	0	Disease (<2% ACT)	ACT with colony edge damage
								0					

2.9.2 Testing of methods

Reef flat transects

The data from the reef flat transects produced high quality information that was probably comparable to previous studies if the relevant data from those studies had been available. The belt transect method can be easily adjusted to conform with PROCFish methods for reef flat invertebrates. Most other mollusc species of fisheries interest can be adequately sampled using the belt transect method, but the species with high abundance will have to be sampled using smaller transect dimensions, e.g. by using at least half the standard belt size (say 5 m x 5 m quadrats). A smaller standard sample size can be easily adopted using the same sample design and transect tapes that are used for the less abundant species.

The sample size of transects and the low densities of clams were inadequate to effectively sample the population on the reef flat. A timed search method (15 min search time per sample) that is adopted by PROCFish for clams and turbo shells would be a more effective method. Similarly, a 15 min search time sample for turbo shells will be more effective, as they are found in the extreme outer edge of the reef flat adjacent to channels where large waves tend to break.

Subtidal slope manta tows

Manta tows will be very useful to describe the broad scale patterns in the status of slope resources, including a number of damage indices (see Section 2.9.3). Quantitative data can also be collected on the distribution and abundance of selected macro invertebrate species by altering the tow time period to 15 min tows so as to equate to PROCFish protocols for certain species.

Subtidal belt transects

Belt transects on the slope require SCUBA diving, and this was not tested during the pilot surveys. However, this approach can be incorporated into the baseline surveys, providing there is access to the equipment.

2.9.3 Proposed methods for IWP Baseline Assessment

It is proposed to adopt the PROCFish methods for the majority of survey activities but with a few adaptations and additions.

In summary:

1. Manta tows of 2 min duration for the assessment of slope status, including damage indices that describe (a) no storm damage, (b) low storm damage: <10% of total number of colonies with partial breakage or scars evident, but colony attached to substrate, (c) medium damage: >10% - 30% colonies damaged, (d) high damage: >30% - <75% colonies damaged, (e) severe damage; 75% - 100% colonies detached or showing scars on colony surface. Replication: whole of pilot site areas.
2. Belt transects on reef flat habitats that are a standard sample unit of 10 m long x 5 m wide. Replication: minimum of 4 per site (will vary according to length of reef flat in each location).
3. Fish survey methods will have to be discussed with Niue Fisheries and SPC (see discussion this report). A series of belt transects with unit length of 50 m with a set belt width will have to be considered. In the PROCFish method, the width of each fish transect is set by the observed distance the survey fish are from the transect, so the density calculations of fish is highly variable in space and time. These data will not lend themselves to powerful statistical analyses, and possibly not to useful descriptive analyses that are required to measure the success of the management regime that will be applied in the pilot villages. A set transect width

for comparing fish censuses over time is more commonly used in fisheries type assessments, and this varies from 3 m to 5 m width.

3 Discussion

3.1 Differences in biological communities over time

As described in the review of previous surveys and revealed in some data from the pilot surveys, there has been a difference over time in the relative abundance and species of holothurians present on both reef flat and slope habitats. Some of the changes could be due to identification differences, but it is more likely that there has been a turnover of species (successional change in species presence) that may be related to irregular larval settlement events (irregular spatial and temporal recruitment), spatially variable impact of minor natural disturbances (such as storms, bleaching events), and possibly harvest pressure. It is very difficult to reach definitive conclusions on the relative influence of possible causes of resource decline, although there has been some anecdotal evidence of large-scale harvest activity on holothurians, suggesting that this is a significant factor in the described changes in holothurians.

However, changes in reef flat mollusc communities does suggest that harvest activities are contributing to the distribution patterns and decline in some species. This is particularly the case for giant clams, and possibly vermetid tube worms, jewel box oysters, and other gastropods.

Differences in fish communities over time are harder to explain due to the lack of comprehensive survey data from both direct observation of fish communities and trends in catch effort from creel surveys. The prevalence of ciguatera fish poisoning around the main wharf area and Alofi township that is not necessarily experienced elsewhere provides a correlation with as yet undefined nearshore impacts from human activities.

It is possible that for all coastal biological communities on Niue, replenishment from larval sources is an irregular event with unpredictable composition of the settlement groups of organisms. The relatively small available habitat coupled with its relative remoteness from other reef ecosystems probably contributes to this limiting characteristic of Niue reef communities. In addition, the frequency of natural disturbances in the form of storms, cyclones, and bleaching events will contribute to repeated disruption of natural successional processes that will have to be considered when fisheries management strategies are considered.

3.2 Land-based sources of pollution

Though no conclusive evidence can be obtained from the available information, there is clear circumstantial evidence that land-based sources of pollution can contribute to the condition of near shore reef communities, through a number of obvious pathways. Root causes relating to some pollution sources identified in PSA analyses (IWP National Programme 2004) may possibly be contributing to localised depletions, especially in the Alofi harbour area, but it is difficult to substantiate without clear evidence of a correlation of cause and effect. The correlation of land-based sources of pollution and resource depletions is more tenuous away from the principal human habitation areas. However, as a precautionary measure, careful future planning will be required to locate activities that unavoidably contribute pollutants into the environment in locations that minimise the potential for these substances to enter the obvious pathways that lead to the near shore environment.

The severe disruption to infrastructure and probably many natural processes and communities caused by Cyclone Heta will mean that a complete evaluation of all aspects of fisheries-related management is required before further initiatives can be undertaken. In particular, careful consideration will have to be made with respect to the amount of fishing pressure that can be permitted over the following 5–10 years if sustainability of fisheries is to be achieved. It is important that destructive fishing practices are reduced or preferably eliminated, as part of any management strategy.

3.3 Summary and recommendations

Aside from the possible correlations of resource depletion with the principal human habitation and activity area (Alofi Harbour), it is more likely that a major contributor to resource depletions is the limited natural carrying capacity of coastal habitats that are under constant high levels of harvesting. When this is coupled with natural disturbances (cyclones, storms, bleaching) and variable replenishment potential it is clear that the outcome will be wide fluctuations in resource availability and abundance on both spatial and temporal scales. Such a situation requires a management strategy that takes into account these characteristics of Niue coastal habitats and resources. One obvious strategy will be to identify areas that will contribute greatly to sustainable fisheries via a series of strategically selected coastal habitats that receive long-term protection.

The impact of Cyclone Heta in January 2004 will contribute to current low levels of specific resources on the west coast, and will influence the rate of replenishment of stocks due to the impact on the physical structure and composition of the reef communities. The rate of recovery will be largely determined by the level of harvesting that will occur in the future, as well as by the natural rate and specific characteristics of the regeneration of this reef system. An unhealthy marine environment will no doubt inhibit this process. It is therefore imperative that the full extent and impact of Cyclone Heta be understood and incorporated into an overall strategy for sustainable management of the coastal resources.

Inconsistency in survey methodologies in previous studies hinders assessment of long-term resource trends. This lack of survey method consistency probably reflects the difference in objectives of each of the studies, but also indicates that there is no accepted methodology that is applied across the Pacific. This makes it hard to decide on a survey methodology for the assessment activities in this project. Most likely, the methods to be applied in this project will follow as closely as possible the methods adopted by SPC and its PROCFish program, as this program was designed to address the issue of inconsistency in survey methodology.

A number of non-target fishery species will have to be included in monitoring to help eliminate the possibility of larval limitation as a cause of low species stocks.

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Appendix 1. People consulted

(First visit by the author, November – December 2003).

PERSON (PROFESSION)	SUBJECT	HOW CONSULTED
Annie Franklin and Ian Gray (Niue Dive Shop)	Natural and biological processes in sub tidal habitats (temporal and spatial trends)	Use of maps to identify and locate where and when events occurred (based on underwater impressions)
Ms Tagaloa Cooper (Environment Unit / Dept Community Affairs)	Land based environmental concerns; proposed developments	Meeting with IWP personnel and student assistant
Mr Lindsay Chapman (SPC Coastal Fisheries)	Data collected for SPC FAD research project on Niue	Personal interview
IWP Project Development Team	Update on pertinent issues and current status, overview of PSA outcomes and the role of the upcoming baseline surveys; addressing questions relating to baseline activities	Formal meeting with most members of PDT at Alofi North community hall
Mr Sione Hetutu (Health Inspector)	Sources of land based pollutants, previous studies	Meeting with IWP personnel and student assistant
Mr Sione Leolahi (IWP National Coordinator)	General detail on processes, distribution of specific organisms, past major disturbances, trochus transplants	Personal interview
Mr Brendan Pasisi (Niue Government Fisheries Advisor)	Fisheries data needs, complementary programs, previous disturbance events, local fisheries knowledge	Personal interview
Mr Logo Seumanu (Assistant IWP Project)	General detail on processes, distribution of specific organisms	Personal interview
Sisilia Talagi (Secretary to Niue Government	Briefing of baseline proposal, status of IWP program	Meeting with IWP personnel and student assistant