PACIFIC REGIONAL OCEANIC AND

COASTAL FISHERIES DEVELOPMENT PROGRAMME

(PROCFish/C/CoFish)

NIUE COUNTRY REPORT:

PROFILE AND RESULTS FROM IN-COUNTRY SURVEY WORK

(May to June 2005)

by

Mecki Kronen, Dave Fisk, Silvia Pinca, Franck Magron, Kim Friedman, Pierre Boblin, Ribanataake Awira and Lindsay Chapman

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PROCFish/C and CoFish staff work (or used to work) for the Secretariat of the Pacific Community, BP D5, 98848 Noumea Cedex, New Caledonia under this EU-funded project. All PROCFish/C and CoFish staff work as a team, so even those not directly involved in fieldwork usually assist in data analysis, report writing, or reviewing drafts of site and country reports.

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- Dave Fisk, consultant hired to conduct invertebrate surveys in Niue.

[1] CoFish and PROCFish/C are part of the same programme, with CoFish covering the countries of Niue, Nauru, Federated States of Micronesia, Palau, Marshall Islands and Cook Islands (ACP countries covered under EDF 9 funding) and PROCFish/C countries covered under EDF 8 funding (the ACP countries: Fiji, Tonga, Papua New Guinea, Solomon Islands, Vanuatu, Samoa, Tuvalu and Kiribati, and French overseas countries and territories (OCTs): New Caledonia, French Polynesia, and Wallis and Futuna). Therefore, CoFish and PROCFish/C are used synonymously in all country reports.

TABLE OF CONTENTS

APPENDICES

EXECUTIVE SUMMARY

The Pacific Regional Coastal Fisheries Development Programme (CoFish) conducted fieldwork in Niue from May to June 2005. Niue is one of the 17 Pacific Island countries and territories being surveyed over a 5–6 year period by CoFish or its associated programme PROCFish/C (coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme). The aim of the survey work was to provide baseline information on the status of reef fisheries, and to help fill the massive information gap that hinders the effective management of reef fisheries.

Other programme outputs include:

- implementation of the first comprehensive multi-country comparative assessment of reef fisheries (finfish, invertebrates and socioeconomics) ever undertaken in the Pacific Islands region using identical methodologies at each site;
- dissemination of country reports that comprise a set of 'reef fisheries profiles' for the sites in each country in order to provide information for coastal fisheries development and management planning;
- development of a set of indicators (or reference points to fishery status) to provide guidance when developing local and national reef fishery management plans and monitoring programmes; and
- development of data and information management systems, including regional and national databases.

Survey work in Niue covered three disciplines (finfish, invertebrate and socioeconomic). Given its small size, Niue was treated as a single site, with large areas surveyed and a country profile developed. The socioeconomic survey covered all 14 villages, and the resource surveys covered most of the coastline except for the very exposed southeast coast.

Survey work was conducted by a team of four programme scientists, a consultant, and local attachments from the Fisheries Department and other sections within the Department of Agriculture, Forestry and Fisheries. The fieldwork included capacity building for the local counterparts through instruction on survey methodologies in all three disciplines, including the collection of data and inputting the data into the programme's database.

With a land area of 259 km^2, Niue, located at latitude 19°S and longitude 169°W, is the smallest independent territory in the Pacific but the largest limestone raised coral island in the world. Its coastline consists of cliffs with 'staircase' terraces (intertidal fringing reef flats *tofola*), and the narrow, subtidal fringing reef quickly descends to over 1000 m within 5 km of the shore. There is no barrier reef or lagoon and beaches are limited to some pockets around Avatele and other small areas scattered over the island. The prevailing southeast trade winds divide Niue's coastline into a very exposed eastern part that is subject to high seas, and a more sheltered western part. As a result, more reef habitat is found on the western coast, where most fishing occurs. Much of the south and east sides of the island are entirely devoid of reef flats (Dalzell *et al.* 1993). The coral reefs have suffered repeatedly from cyclone damage, particularly from Cyclone Ofa and Cyclone Heta, the most recent (Jan 2004). Cyclones, especially Heta, have substantially reduced the coastline's coral cover except for several sheltered areas in the west and southwest. This degraded habitat, with its low complexity, and the lack of connectivity with larger reef systems, supports a marine resource that is naturally very limited, with small population size and low biodiversity.

Results of fieldwork in Niue

The key issues for Niue with respect to management of coastal fisheries resources are that the island:

- is geographically isolated from other Pacific reef systems that could be a source of replenishment / recruitment;
- is small in overall size and in the area of intertidal and reef habitats; and
- has low diversity of coral reef habitats compared to what is normally present in Pacific island systems.

Socioeconomics

Socioeconomic fieldwork was carried out in all 14 villages in Niue, covering 47% of all households (218/468). Results suggested that people in Niue do not depend on fishing for food or income, but continue to fish for traditional values and frequently exchange seafood. There is no official seafood export, although an estimated ~5 t/year seafood is exported as gifts for relatives overseas. The average fresh fish consumption was estimated to be 31.1 kg/person/year (of both reef and pelagic fish), which is lower than the regional average (35 kg). Survey data suggested a total annual reef finfish catch of 53.4 t, which meets about 77% of the consumption needs of Niue's total island population (69.3 t/year). In addition, there is an estimated production of 76.2 t/year from mid-water and trolling fishing, bringing the total finfish catch to 129.6 t/year. The impact of finfish fisheries is moderate, with ~4 t/km^2/year on the total reef area. The invertebrate fishing pressure imposed on the total coastal reef-flat area and the 1.9 km^2 of accessible reef flats is surprisingly high: ~7 and 18.3 t/km^2/year respectively. CPUE and annual productivity are rather low; however, due to the limited accessible reef area, both finfish and invertebrate fishers may cause severe problems in some areas and for certain susceptible species.

Finfish resources

Reef finfish resources in Niue appear to be very poor, possibly due to the fact that there is no lagoon, and the remoteness and small size of the island, as well as the frequency of cyclones, rather than fishing pressure. Live-coral cover was extremely low (<2 %) on most parts of the north and west coasts, reflecting the path of Cyclone Heta. Only the east coast (29% live-coral cover), the sheltered bay of Tamakautoga (40% cover), and a tiny reef near Tuapa (10% cover) were not too severely impacted by the cyclone. Correspondingly, two types of fish communities occurred around Niue. The first type was localised in Tamakautoga and Tuapa, where habitat was characterised by highly complex, tabular and branching coral reefs; the second type of fish community was found in low-complexity, encrusting coral habitats all around the island. The bay of Tamakautoga therefore appears to serve as a biodiversity refuge. Fish assemblage at the Namoui MPA was poor, with no net benefit after more than seven years of protection. Finally, the reef near the fish processing plant seemed under a strong nutrient influence with an unusual amount of turf.

Invertebrate resources

Invertebrate surveys were conducted through broad-scale (manta-tow technique) and finer-scale assessments. Results showed a steady decline in the number of giant clams on Niue reefs since 1990. *Tridacna squamosa* has dramatically declined in the last decade to a point where it is now commercially extinct[2], and unlikely to recover without assistance. *T. maxima* is also showing a significant decline in recorded density and size range, attributed to fishing pressure and the effects of Cyclone Ofa (1990) and Cyclone Heta (2004). Clam densities are low to a point where reproductive success and subsequent recruitment could be significantly negatively impacted. However, recruitment is occurring in some areas at low densities.

The commercial topshell *Trochus niloticus* has not become established in Niue following introductions in 1992 and 1996. Clearly, the severity of cyclone impact on shallow slope communities is a contributing factor; however, no individuals were found in the Tamakautoga area, where cyclone impacts were minimal.

There are very few sea cucumber species available for commercial fishing on Niue. The exposed environment of Niue plays a large part in defining the fishery. Prickly redfish, *Thelenota ananas*, may present a future prospect for fishing. Black teatfish are insufficient to support commercial fishing and, based on the environment present in Niue, white teatfish stocks are unlikely to present an option for commercial fishing. Surf redfish, *Actinopyga mauritiana*, would not support commercial fishing.

Recommendations

Based on the survey work undertaken and the assessments made, the following recommendations are made for Niue:

- The quality and quantity of reef finfish resources in Niue will only allow limited subsistence use; expansion of the fishery is not possible without causing overfishing.

- Any additional survey work on finfish and invertebrates should focus on the species that are of most concern for Niuean people and which are the main focus of current harvest activity, especially in the most targeted areas, i.e. the western coastline between Hikutavake in the north and Avatele in the south. This would include an assessment of the status and population dynamics of: *nue, telekihi* and *ulihega* for finfish fisheries and, for invertebrates, *alili* or *Turbo* spp., *matatue* (the vermetid mollusc *Dendropoma maximum*) as well as *papahua* (the oyster *Chama isostoma*). Though not a major focus for Niueans, the status of nocturnal crustacean species (especially crayfish and crabs) should also be targeted for study.

- Biochemical analyses of the reef in front of the fish processing plant needs to be conducted as this area seemed to be under strong nutrient influence.

- The protection status of the Namoui MPA needs to be continued and all resources within it monitored for future changes. The size of this MPA may need to be enlarged to strengthen protection. Serious consideration should be given to afford special protection to the currently most productive and diverse coastal marine communities in Tamakautoga (and possibly parts of Avatele), which would significantly enhance the potential recovery of other sections of the west coast marine communities.

[2] Referring to a scarcity such that collection is not possible to service commercial or subsistence fishing, but species may still be present at very low densities.

- Any future releases of trochus should consider first placing the transplanted shells in protective cages within well-circulated pools and releasing them to the reef in stages. Staged release acclimatises the shells to local conditions: carefully placing them in areas where there is epiphytic growth and potential food sources will ensure the transplanted shells have the best chance of survival.

- Careful low-level harvests of prickly redfish, *Thelenota ananas*, may be considered only after there is some recovery to reefs. However, careful spatial monitoring of this resource will need to be in place to ensure the fishery is stopped before catches and sizes indicate ‘growth’ (size) or recruitment overfishing.

- There can be no harvesting of black teatfish (*Holothuria nobilis*), white teatfish (*H. fuscogilva*), or surf redfish, *Actinopyga mauritiana*, with the current low stock levels. However, these stocks need to be monitored as, in future years, good recruitment could offer opportunities for periodic harvests when conditions allow.

- A total ban needs to be placed on the collection of clams for a minimum period of 3–5 years as an exercise in enhancing the recovery of severely depleted stocks. The ban should at least include the north and northwest slope and reef-flat habitats (e.g. between Makefu and Mutalau), where cyclone damage was greatest. If this is not possible, a closure of more areas to preserve localised areas of adults at densities that promote successful spawning events and cross-fertilisation could be considered.

- The adoption of specific management systems is essential to achieve the long-term viability of invertebrate stocks; these management regimes will have to be controlled by the community at scales larger than the current village boundaries.

- Present densities of coralivore starfish (such as COTS) are not a concern to Niue; however, following the recent disturbance (cyclone), increased monitoring to forewarn of an outbreak is needed.

- Coral re-growth will need to be monitored following Cyclone Heta.

RÉSUMÉ

De mai à juin 2005, les agents du Projet de développement de la pêche côtière (CoFish) ont conduit des travaux sur le terrain à Niue. Niue est l'un des 17 États et Territoires insulaires océaniens qui ont fait l'objet d'enquêtes, échelonnées sur 5 à 6 ans, menées par les agents du projet CoFish ou de son projet associé PROCFish/C (composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique). Le but de ces enquêtes était de recueillir des données de référence sur l'état des ressources récifales et de combler l'énorme manque d'informations qui entrave la gestion efficace de ces ressources.

Le projet visait en outre à obtenir les résultats suivants :

- Réalisation de la première évaluation comparative exhaustive des ressources récifales de plusieurs pays (poissons, invertébrés et aspects socioéconomiques) jamais entreprise en Océanie, selon des méthodes identiques sur tous les sites ;
- Diffusion de rapports nationaux comprenant un ensemble de « profils des ressources halieutiques récifales » pour les sites étudiés dans chaque pays, servant de base au développement de la pêche côtière et à la planification de sa gestion ;
- Élaboration d'un ensemble d'indicateurs (ou de points de référence de l'état des stocks), pour faciliter l'établissement de plans de gestion des ressources récifales à l'échelle locale et nationale, et celui de programmes de suivi ;
- Élaboration de systèmes de gestion des données et de l'information, dont des bases de données régionales et nationales.

Les enquêtes conduites à Niue couvraient trois disciplines : poissons, invertébrés et aspects socioéconomiques. Vu sa superficie, Niue a été considéré comme un site unique. Des zones étendues ont été étudiées et un profil de pays établi. L'enquête socioéconomique portait sur les quatorze villages, et les enquêtes sur les ressources couvraient la majeure partie du littoral, sauf la côte sud-est, très exposée à la houle et au vent.

Les enquêtes ont été réalisées par une équipe de quatre scientifiques de la CPS, un consultant et des stagiaires locaux du Service des pêches et d'autres sections du Département de l'agriculture, de la foresterie et de la pêche. Durant les travaux de terrain, l'équipe a formé les agents de Niue aux méthodes d'enquête et d'inventaire utilisées dans chaque discipline, notamment la collecte de données et leur saisie dans la base de données du Projet.

Niue, dont les terres émergées s'étendent sur 259 kilomètres carrés, est situé par 19° de latitude sud et 169° de longitude ouest. C'est le plus petit Territoire indépendant du Pacifique, mais la plus grande île corallienne élevée du monde. Son littoral est formé de falaises, avec des terrasses en « escaliers » (platiers frangeants intertidaux, ou *tofola*). Le récif frangeant subtidal, étroit, plonge en pente raide à une profondeur de plus de 1000 m à moins de 5 km du rivage. Il n'y a ni récif barrière ni lagon, et les plages sont limitées à quelques poches, autour d'Avatele et à d'autres petites zones disséminées sur l'île. Les alizés dominants divisent la côte de Niue en une partie orientale, qui subit de plein fouet ces vents et est exposée à une mer houleuse, et une partie occidentale plus abritée. On trouve donc un habitat récifal plus étendu sur la côte ouest, où se pratique surtout la pêche. Une grande partie des côtes sud et est de l'île est entièrement dénuée de platiers (Dalzell *et al.* 1993). Les récifs coralliens ont subi à plusieurs reprises des dégâts, en particulier dus aux cyclones Ofa et Heta, le plus récent (janvier 2004). Les cyclones, notamment Heta, ont gravement endommagé le couvert corallien de la côte, hormis plusieurs zones abritées, à l'ouest et au

sud-ouest. En l'absence de connectivité avec les grands systèmes récifaux, cet habitat dégradé, peu complexe, abrite des ressources marines naturellement très limitées, caractérisées par une population réduite et une faible biodiversité.

Résultats des travaux de terrain à Niue

Les problèmes posés à Niue par la gestion des ressources halieutiques côtières s'expliquent par le fait que l'île :

- est géographiquement isolée des autres systèmes récifaux du Pacifique, qui pourraient être une source de renouvellement des stocks et de recrutement ;
- est petite de par sa superficie globale et l'étendue des habitats intertidaux et récifaux ; et
- présente une faible diversité d'habitats des récifs coralliens par rapport à celle qui est normalement présente dans les systèmes insulaires océaniens.

Aspects socioéconomiques

Des enquêtes socioéconomiques ont été conduites dans les 14 villages de Niue, auprès de 47 pour cent des ménages (218/468). Les résultats montrent que les habitants de Niue ne tirent pas leur nourriture ni leurs revenus de la seule pêche, mais qu'ils continuent de pêcher par tradition et échangent souvent des produits de la mer. Il n'y a pas d'exportation officielle de produits de la mer, mais on estime à 5 tonnes par an environ les produits de la mer exportés à titre de cadeaux envoyés à des parents vivant à l'étranger. La consommation moyenne de poisson frais est estimée à 31,1 kg par personne et par an (poissons de récif et pélagiques), chiffre inférieur à la moyenne régionale (35 kg). D'après les données recueillies, les prises annuelles totales de poissons de récif s'élèvent à 53,4 t, qui répondent à 77 pour cent environ des besoins de la population totale de l'île (69,3 t par an). En outre, les captures annuelles, pêchées en pleine eau et à la traîne s'élèvent à 76,2 t environ, ce qui porte les prises totales de poissons à 129,6 tonnes par an. L'impact de la capture de poissons est modéré. Environ 4 tonnes par km² et par an sont pêchées sur l'ensemble de la zone récifale. Il est surprenant d'observer que la pression de pêche d'invertébrés qui s'exerce sur toute la surface des platiers côtiers et sur 1,9 km² de platiers accessibles est élevée : 7 et 18,3 t/km²/an respectivement. Les prises par unité d'effort et la productivité annuelle sont assez faibles ; toutefois, du fait de l'exiguïté de la zone récifale accessible, la pêche de poissons et d'invertébrés peut causer de graves problèmes dans certaines zones et affecter certaines espèces fragiles.

Ressources halieutiques

Les ressources de Niue en poissons de récif semblent très pauvres, ce qui s'explique probablement par l'absence de lagon, l'isolement et la faible superficie de l'île, ainsi que par la fréquence des cyclones, et non par la pression de pêche. La couverture de coraux vivants était extrêmement limitée (moins de 2 pour cent) sur la majeure partie des côtes nord et ouest, où le cyclone Heta est passé. Seule la côte est (29 pour cent de la couverture de coraux vivants), la baie abritée de Tamakautoga (40 pour cent) et un petit récif près de Tuapa (10 pour cent) n'ont pas été trop gravement touchés par le cyclone. En conséquence, il existe deux types de populations de poissons autour de Niue. Le premier se situe à Tamakautoga et Tuapa, où l'habitat se caractérise par des récifs coralliens très complexes, tabulaires et branchus ; le deuxième se trouve dans des habitats peu complexes, à coraux encroûtants, tout autour de l'île. La baie de Tamakautoga semble donc servir de refuge de biodiversité. La composition par espèce dans l'aire protégée de Namoui était réduite, et ne présentait pas d'accroissement net au bout de plus de sept ans de protection. Enfin, le récif voisin de l'usine de transformation de poisson semble subir une forte influence des nutriments, avec une quantité inhabituelle de terre.

Invertébrés

Les enquêtes sur les invertébrés ont été conduites sous forme de relevés à grande échelle (par la technique « *manta tow* ») et à échelle plus fine. Les résultats mettent en lumière un déclin régulier du nombre de bénitiers sur les récifs de Niue depuis 1990. Les stocks de *Tridacna squamosa* ont subi une diminution spectaculaire au cours des dix dernières années, au point qu'ils n'ont désormais plus d'intérêt commercial[3], et qu'ils ne se reconstitueront probablement pas sans aide. *T. maxima* accuse aussi un déclin important en termes de densité et de taille observées, ce qui s'expliquerait par la pression de pêche et les effets des cyclones Ofa (1990) et Heta (2004). Les bénitiers sont si peu denses que le succès de la reproduction et le recrutement ultérieur pourraient être compromis. On observe toutefois un recrutement dans certaines zones à faible densité.

Introduit à Niue en 1992 et 1996, l'essai d'exploitation commerciale du troca *Trochus niloticus* ne s'est pas transformé. La gravité des dégâts du cyclone sur les populations habitant des pentes peu profondes y a certes contribué. Mais on n'a pas non plus trouvé d'individu dans la zone de Tamakautoga où le cyclone n'a pas eu d'effets conséquents.

Il y a très peu d'espèces d'holothuries présentant un intérêt commercial à Niue. L'environnement de Niue joue un grand rôle dans la définition de la pêcherie. L'holothurie ananas *Thelenota ananas* pourrait présenter un certain potentiel. La quantité d'holothuries noires à mamelles n'est pas suffisante pour justifier une pêche commerciale, et pour des raisons environnementales, les stocks d'holothuries blanches à mamelles ne se prêteront probablement pas à la pêche commerciale. Quant à *Actinopyga mauritiana*, elle ne la supporterait pas.

Recommandations

Sur la base des enquêtes conduites et des évaluations réalisées, les recommandations suivantes s'appliquent à Niue :

- La qualité et la quantité de ressources en poissons de récif de Niue ne permettront qu'une exploitation limitée à des fins de subsistance ; il ne serait pas possible d'étendre la pêche sans causer une surpêche.

- Tout travail complémentaire d'enquête sur les poissons et les invertébrés devrait être axé sur les espèces qui intéressent le plus les habitants de Niue et qui sont ciblées par les activités de récolte actuelles, en particulier dans les zones les plus exploitées, c'est-à-dire le littoral occidental, entre Hikutavake au nord et Avatele au sud. Il faudrait évaluer l'état et la dynamique de la population de : *nue, telekihi* et *ulihega* (poissons) et de *alili* ou *Turbo* spp., *matatue* (mollusque vermétide *Dendropoma maximum*) et *papahua* (huître *Chama isostoma*) (invertébrés). Bien que les habitants de Niue ne les ciblent pas

[3] Désigne un degré de rareté tel que la collecte n'est pas envisageable à des fins commerciales ou vivrières ; des espèces peuvent toutefois être présentes à de très faibles densités.

spécialement, l'état des espèces de crustacés nocturnes (en particulier les écrevisses et les crabes) devrait être également étudié.

- Des analyses biochimiques du récif devraient être réalisées en face de l'usine de transformation du poisson, cette zone semblant être fortement exposée aux nutriments.

- Le statut de l'aire marine protégée de Namoui doit être maintenu, et l'évolution de toutes les ressources présentes suivie de près. Il faudrait élargir cette AMP, afin de renforcer la protection. Il conviendrait d'envisager de prendre des mesures particulières de protection des ressources marines côtières de Tamakautoga (et si possible de certaines parties d'Avatele), les plus productives et diverses à l'heure actuelle : cela améliorerait grandement le potentiel de reconstitution d'autres parties des populations marines de la côte ouest.

- Tout réensemencement futur de trocas devrait commencer par le placement des coquilles transplantées dans des cages de protection, dans des bassins à bonne circulation d'eau, avant leur lâcher progressif sur le récif. Le lâcher progressif permet aux coquillages de s'acclimater aux conditions locales. En les disposant soigneusement à des endroits où il y a une végétation épiphyte et des sources de nourriture potentielles, on assure aux animaux transplantés les meilleures chances de survie.

- La récolte prudente et modérée d'holothuries ananas (*Thelenota ananas*) ne pourra être envisagée qu'après la reconstitution des stocks sur les récifs. Il faudra toutefois assurer un suivi spatial attentif de cette ressource, de manière que la pêche soit interrompue avant que les captures et les tailles ne dénotent une surpêche affectant la taille ou le recrutement.

- Le niveau actuel des stocks n'autorise pas la récolte d'holothuries noires à mamelles (*Holothuria nobilis*), d'holothuries blanches à mamelles (H. *fuscogilva*), ni d'*Actinopyga mauritiana*. Il faut cependant surveiller ces stocks car, au cours des années à venir, un bon recrutement pourrait permettre des récoltes périodiques si les conditions le permettent.

- Il faut totalement interdire la pêche de bénitiers pendant 3 à 5 ans au moins, pour donner aux stocks gravement appauvris le temps de se reconstituer. Cette interdiction doit frapper au moins la pente nord et nord-ouest et les habitats des platiers (entre Makefu et Mutalau par exemple) où le cyclone a causé le plus de dégâts. Si cela n'est pas possible, une fermeture d'autres zones pourrait être envisagée, afin de préserver des aires localisées où les adultes se trouvent à des densités propices à des épisodes de frai et de fécondation.

- L'adoption de systèmes de gestion particuliers revêt une importance capitale si l'on veut assurer la viabilité des stocks d'invertébrés à long terme ; ces régimes de gestion devront être contrôlés par-delà les limites actuelles des zones régies par les villages.

- La densité actuelle des étoiles de mer coralivores (*Acanthaster planci* par exemple) n'est pas préoccupante à Niue. Toutefois, après la récente perturbation due au cyclone, il faut surveiller de plus près ce paramètre afin de prévenir une invasion.

- Il faut surveiller la régénération du corail, après les dégradations causées par le cyclone Heta.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
BdM	bêche-de-mer (or sea cucumber)
B-S	broad scale
CoFish	Pacific Regional Coastal Fisheries Development Programme
COTS	crown of thorns starfish
CPUE	catch per unit effort
Ds	day search
D-UVC	distance-sampling underwater visual census
EDF	European Development Fund
EEZ	exclusive economic zone
EU/EC	European Union/European Commission
FAD	fish aggregating device
FAO	Food and Agricultural Organization (UN)
FFA	Forum Fisheries Agency
FL	fork length
GDP	gross domestic product
GPS	global positioning system
ha	hectare
HH	household
ICLARM	International Center for Living Aquatic Resources Management (now WorldFish Center)
IWP	International Waters Project
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MOP	mother-of-pearl
MOPt	mother-of-pearl transect
MPA	marine protected area
MSA	medium-scale approach
NCA	nongeniculate coralline algae
Ns	night search
NZAID	New Zealand Agency for International Development
NZD	New Zealand dollar (s)
OCT	Overseas Countries and Territories
PICTs	Pacific Island countries and territories
PROCFish	Pacific Regional Oceanic and Coastal Fisheries Development project
PROCFish/C	Pacific Regional Oceanic and Coastal Fisheries Development project (coastal component)
RBt	reef-benthos transect

RFID	Reef Fisheries Integrated Database
RFs	reef-front search
RFs_w	reef-front search: walking
SBq	soft-benthos quadrat
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SPC	Secretariat of the Pacific Community
SPREP	South Pacific Regional Environment Programme
UNDP	United Nations Development Programme
USD	United States dollar(s)
UVC	underwater visual census
WHO	World Health Organization

1. INTRODUCTION AND BACKGROUND

Pacific Island countries and territories (PICTs) have a combined exclusive economic zone (EEZ) of about 30 million km^2, with a total surface area of slightly more than 500,000 km^2. Many PICTs consider fishing to be an important means of gaining economic self-sufficiency. Although the absolute volume of landings from the Pacific Islands coastal fisheries sector (estimated at 100,000 tonnes per year, including subsistence fishing) is roughly an order of magnitude less than the million-tonne catch by the industrial oceanic tuna fishery, coastal fisheries continue to underpin livelihoods and food security.

SPC's Coastal Fisheries Management Programme provides technical support and advice to Pacific Island national fisheries agencies to assist in the sustainable management of inshore fisheries in the region.

1.1 The PROCFish and CoFish programmes

Managing coral reef fisheries in the Pacific Island region in the absence of robust scientific information on the status of the fishery presents a major difficulty. In order to address this, the European Union (EU) has funded two associated programmes:

1. The Pacific Regional Oceanic and Coastal Fisheries Development programme (PROCFish); and
2. The Coastal Fisheries Development Programme (CoFish)

These programmes aim to provide the governments and community leaders of Pacific Island countries and territories with the basic information necessary to identify and alleviate critical problems inhibiting the better management and governance of reef fisheries and to plan appropriate future development.
The PROCFish programme works with the ACP countries: Fiji, Kiribati, Papua New Guinea, Vanuatu, Samoa, Solomon Islands, Tonga, Tuvalu, and the OCT French territories: French Polynesia, Wallis and Futuna, and New Caledonia, and is funded under European Development Fund (EDF) 8.
The CoFish programme works with the Cook Islands, Federated States of Micronesia, Marshall Islands, Nauru, Niue and Palau, and is funded under EDF 9.

The PROCFish/C (coastal component) and CoFish programmes are implementing the first comprehensive multi-country comparative assessment of reef fisheries (including resource and human components) ever undertaken in the Pacific Islands region using identical methodologies at each site. The goal is to provide baseline information on the status of reef fisheries, and to help fill the massive information gap that hinders the effective management of reef fisheries (Figure 1.1).

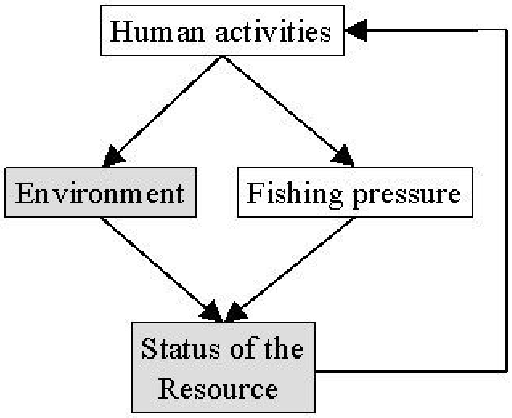

Figure 1.1: Synopsis of the CoFish/C multidisciplinary approach.
CoFish/C conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the basis for taking a precautionary approach to management, with an adaptive long-term view.

Expected outputs of the project include:

- the first-ever region-wide comparative assessment of the status of reef fisheries using standardised and scientifically rigorous methods that enable comparisons among and within countries and territories;
- application and dissemination of results in country reports that comprise a set of 'reef fisheries profiles' for the sites in each country, in order to provide information for coastal fisheries development and management planning;
- development of a set of indicators (or fishery status reference points) to provide guidance when developing local and national reef fishery management plans and monitoring programmes;
- toolkits (manuals, software and training programmes) for assessing and monitoring reef fisheries, and an increase in the capacity of fisheries departments in participating countries in the use of standardised survey methodologies; and
- data and information management systems, including regional and national databases.

1.2 PROCFish/C and CoFish methodologies

A brief description of the survey methodologies is provided here. These methods are described in detail in Appendix 1.

1.2.1 Socioeconomic assessment

Socioeconomic surveys were based on fully structured, closed questionnaires comprising:

1. **a household survey** incorporating demographics, selected socioeconomic parameters, and consumption patterns for reef and lagoon fish, invertebrates and canned fish; and
2. **a survey of fishers** (finfish and invertebrate) incorporating data by habitat and/or specific fishery. The data collected addresses the catch, fishing strategies (e.g. location, gear used), and the purpose of the fishery (e.g. for consumption, sale or gift).

Socioeconomic assessments also relied on additional complementary data, including:

3. **a general questionnaire targeting key informants**, the purpose of which is to assess the overall characteristics of the site's fisheries (e.g. ownership and tenure, details of fishing

gear used, seasonality of species targeted, and compliance with legal and community rules); and

4. **finfish and invertebrate marketing questionnaires** that target agents, middlemen or buyers and sellers (shops, markets, etc.). Data collected include species, quality (process level), quantity, prices and costs, and clientele.

1.2.2 Finfish resource assessment

The status of finfish resources in selected sites was assessed by distance-sampling underwater visual census (D-UVC) (Labrosse *et al.* 2002). Briefly, the method involves recording the species name, abundance, body length and distance to the transect line of each fish or group of fish observed; the transect consists of a 50 m line, represented on the seafloor by an underwater tape (Figure 1.2). Mathematical models were then used to infer fish density (number of fish per unit area) and biomass (weight of fish per unit area) from the counts. Species surveyed included those reef fish of interest for marketing and/or consumption, and species that could potentially act as indicators of coral reef health (See Appendix 1.2 for a list of species.).

The medium-scale approach (MSA; Clua *et al.* 2006) was used to record habitat characteristics along transects where finfish were counted by D-UVC. The method consists of recording substrate parameters within twenty 5 m x 5 m quadrats located on both sides of the transect (Figure 1.2).

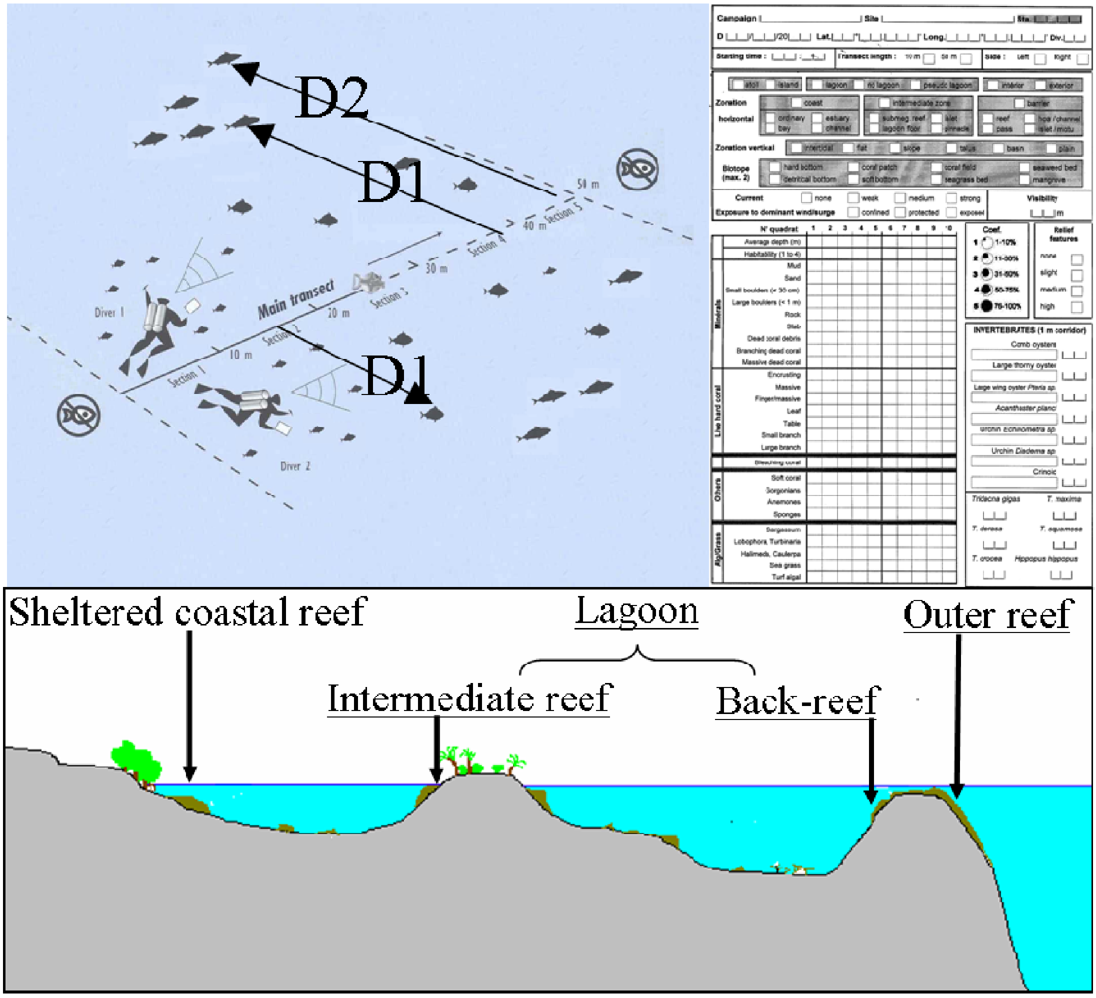

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys were conducted along 24 transects, with six transects in each of the four main geomorphologic coral reef structures: sheltered coastal reefs, intermediate reefs and back-reefs (both within the grouped 'lagoon reef' category used in the socioeconomic assessment), and outer reefs.

Fish and associated habitat parameters were recorded along 24 transects per site, with an equal number of transects located in each of the four main coral reef geomorphologic structures (sheltered coastal reef, intermediate reef, back-reef, and outer reef). The exact position of transects was determined in advance using satellite imagery; this assisted with locating the exact positions in the field and maximised accuracy. It also facilitated replication, which is important for monitoring purposes.

Maps provided by the NASA Millennium Coral Reef Mapping Project (MCRMP) were used to estimate the area of each type of geomorphologic structure present in each of the studied sites. Those areas were then used to scale (by weighted averages) the resource assessments at any spatial scale.

1.2.3 Invertebrate resource assessment

The status of invertebrate resources within a targeted habitat, or the status of a commercial species (or a group of species), was determined through:

1. resource measures at scales relevant to the fishing ground;
2. resource measures at scales relevant to the target species; and
3. concentrated assessments focussing on habitats and commercial species groups, with results that could be compared with other sites, in order to assess relative resource status.

The diversity and abundance of invertebrate species at the site were independently determined using a range of survey techniques, including broad-scale assessment (using the manta tow technique) and finer-scale assessment of specific reef and benthic habitats.

The main objective of the broad-scale assessment was to describe the large-scale distribution pattern of invertebrates (i.e. their relative rarity and patchiness) and, importantly, to identify target areas for further fine-scale assessment. Broad-scale assessments were used to record large sedentary invertebrates; transects were 300 m long × 2 m wide, across inshore, midshore and more exposed oceanic habitats (See Figure 1.3 (1).).[4]

Fine-scale assessments were conducted in target areas (areas with naturally higher abundance and/or the most suitable habitat) to specifically describe resource status. Fine-scale assessments were conducted of both reef (hard-bottom) and sandy (soft-bottom) areas to assess the range, size, and condition of invertebrate species present and to determine the nature and condition of the habitat with greater accuracy. These assessments were conducted using 40 m transects (1 m wide swathe, six replicates per station) recording most epi-benthic resources (those living on the bottom) and potential indicator species (mainly echinoderms) (See Figure 1.3 (2) and (3).).

In soft bottom areas, four 25 cm × 25 cm quadrats were dug at eight locations along a 40 m transect line to obtain a count of targeted infaunal molluscs (molluscs living in bottom sediments, which consist mainly of bivalves) (See Figure 1.3 (4).).

For trochus and bêche-de-mer fisheries, searches to assess aggregations were made in the surf zone along exposed reef edges (See Figures 1.3 (5) and (6).); and using SCUBA (7). On occasion, when time and conditions allowed, dives to 25–35 m were made to determine the availability of deeper-water sea cucumber populations (Figure 1.3 (8)). Night searches were conducted on inshore reefs to assess nocturnal sea cucumber species (See Appendix 1.3 for complete methods.).

[4] In collaboration with Dr Serge Andrefouet, IRD-Coreus Noumea and leader of the NASA Millennium project: http://imars.usf.edu/corals/index.html/.

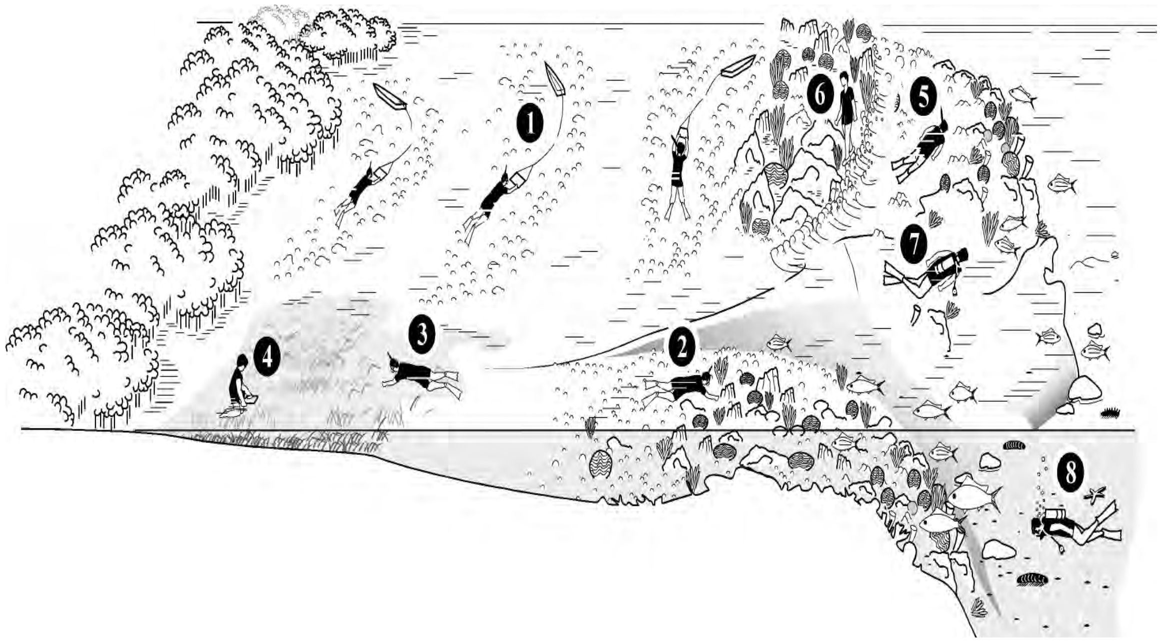

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal molluscs (4); searches to determine trochus and bêche-de-mer aggregations in the surf zone (5), reef edge (6), and using SCUBA (7); and deep dives to assess deep-water sea cucumber populations (8).

1.3 Niue

1.3.1 General

Niue (Figure 1.4) consists of a single uplifted coral island located at 19°S latitude and 169°W longitude, sharing marine boundaries with Cook Islands, American Samoa, Tonga and, to the south, international waters. The land area of Niue is 259 km^2, while the area of its exclusive economic zone (EEZ) is 390,000 km^2.

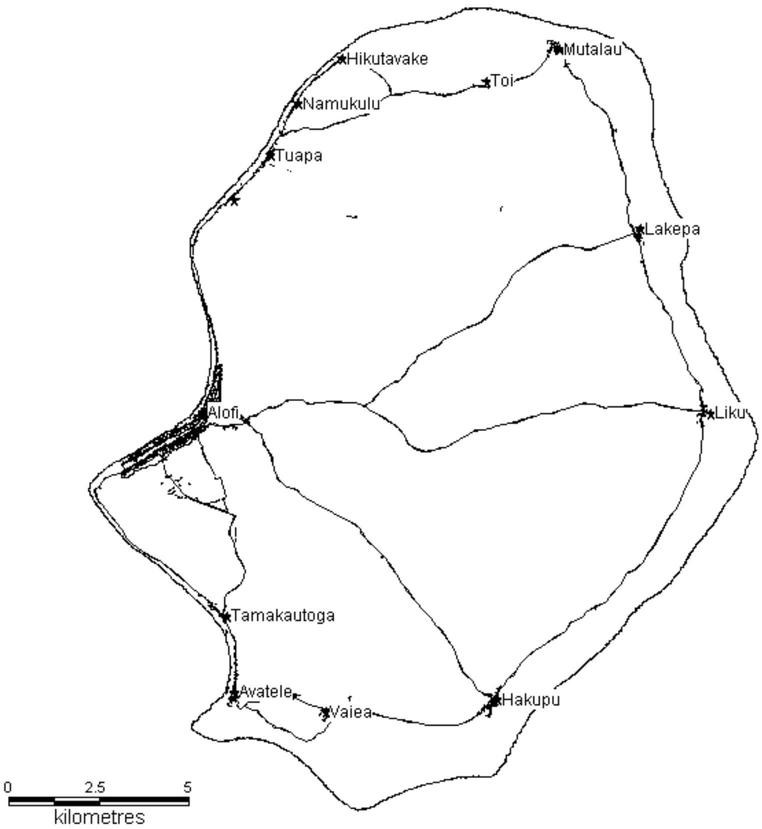

Figure 1.4: Map of Niue.

The island of Niue has a coastline of around 70 km, and is surrounded by a narrow, wave-cut platform (rather than a fringing reef), which rises with undercut limestone cliffs to a height of 20–30 m above sea level (Cartwright *et al*. 2003). Waters adjacent to the wave-cut platform drop off steeply, reaching depths of around 2000 m within 3–5 km of the shore. Niue has basically no coastal waters and no harbour. The wharf area at Alofi, the capital, is sheltered from the southeasterly trade winds, but fully exposed to westerly winds. As a result, more reef habitat is found on the western coast, where most fishing occurs. Much of the south and east sides of the island is entirely devoid of reef flats (Dalzell *et al*. 1993). In addition, the coral reefs of Niue have suffered repeatedly from cyclone damage, particularly from Cyclone Ofa and the most recent Cyclone Heta (January 2004). Cyclones, especially Cyclone Heta, have substantially reduced the coastline's coral cover, except in several sheltered areas in the west–southwest region.

The indigenous inhabitants of Niue are Polynesians, originating from Samoa in the 9^{th}–10^{th} century and Tonga in the 16^{th} century (IPS 1982). The 2004 mid-year population estimate was 1600 people (SPC 2005), with the numbers still dropping as Niueans move to New Zealand to live (~20,000 left in 2002 – Government of Niue 2003). The country's close economic and social affiliation with New Zealand dates back to 1901, when its sovereignty was transferred from Britain to New Zealand (Terry and Murray 2004). This has greatly influenced the island's social life and culture, and has created a high economic dependence. Niue is heavily dependent on aid, with New Zealand providing budgetary assistance and aid support as the main donor. Most of the aid goes towards supporting the public sector, which is the major source of full-time employment on the island (Cartwright *et al*. 2003). The economy of Niue is fragile and economic activity limited, with a small private sector, which is attributed to Niue's small population base (Government of Niue 2002). Exports are all from the primary sector and include taro, honey and small quantities of coconut, handicrafts and vanilla.

1.3.2 The fisheries sector

Fisheries in Niue comprise the offshore fishery for tuna and other pelagic species, the small-scale tuna fishery around fish aggregating devices (FADs), the deep-water snapper fishery, and reef fisheries for a range of fish and invertebrate species.

Offshore tuna fishery

Offshore tuna fishing activities around Niue have been limited. In the past, some fishing by Japanese, Taiwanese and Korean longliners was reported before the establishment of the Niue EEZ. Pole-and-line operations for skipjack tuna were conducted in Niuean waters in early 1980 through the Skipjack Survey and Assessment Programme (Kearney and Argue 1980; SPC 1984). Over a 3-day period a total of 91 skipjack (*Katsuwonus pelamis*) and 31 yellowfin tuna (*Thunnus albacares*) were tagged off Alofi and Beveridge Reef.

Tuna longline operations were conducted in Niuean waters from 1993 to 1997 by two to six Taiwanese vessels fishing under an access agreement. Over the five-year period, 790,000 hooks were set for a catch of 306 mt of albacore tuna (*Thunnus alalunga*) and 13 mt of yellowfin tuna (SPC 2000). In 2002 there were 21 licensed vessels from Taiwan and American Samoa fishing in the Niue EEZ, with an approximate catch of 50–100 mt (Tafatu 2006).

Domestic commercial or offshore longlining commenced in May 2005, with four small vessels landing 33 mt over a three-month period (Tafatu 2006). The number of licensed vessels increased to 13 by the end of 2005, with a total recorded catch of 122.8 mt, of which 60% was albacore tuna. These vessels fish under a charter arrangement and land their fish to the new government joint-venture fish-processing facility, Niue Fish Processors Ltd (Tafatu 2006). During 2006 and 2007, the number of vessels fishing in Niuean waters and landing their catch to the processing facility fluctuated, resulting in the closing of the facility due to the limited amount of fish available for processing, which made the operation uneconomical.

Small-scale tuna fishery around FADs

Niuean fishers have a long history of fishing outside the reef for coastal pelagics, tunas and bottom fish from lightweight, one-man or three-man outrigger paddling canoes, which are carried down cliff paths for launching (Devambez 1962). In 1962, fishing trials were undertaken using one of the Niue Administration's 24-foot (7.5 m) launches. The methods used during the trials were trolling and pelagic longlining to target tunas and other large coastal pelagics, such as *wahoo* (*Acanthocybium solandri*) and *mahi mahi* (*Coryphaena hippurus*). The aim of the trials was to see if the catch of fish for sale on the island could be increased by using motorised vessels rather than traditional canoes (Devambez 1962).

Further fishing trials for tunas and large coastal pelagics were undertaken in mid-1977, with New Zealand providing a 28-foot (9 m) 'Karitane' boat, one male fisher and a range of suitable fishing gear under bilateral aid to Niue (Dryden 1978; Crossland 1979). The boat was used to train local fishers in a range of fishing methods, including trolling, longlining, handlining and various bait-catching methods. Unfortunately, the vessel, a wide range of gear and the shore freezers were lost in 1979 as a result of Cyclone Ofa (Anon. 1981). However, in February 1980, the first of three *alia* catamarans was delivered from Samoa, which allowed fishing operations to continue. The fish caught were sold to local retailers (Anon. 1981). An important aspect of fishing in Niue is the need to have small vessels that can be removed from the water, as there is no safe anchorage anywhere on the island.

Fish aggregating devices (FADs) were first introduced to Niue in the early 1980s, with materials funded under the United Nations Development Project, and SPC providing a masterfisher to rig and deploy the FADs while training local fisheries staff in these techniques (Mead 1997). Four FADs were deployed in 1982 along the west coast in 220–780 m depths and at a distance of 1–3.75 km from the island. Fishing trials around the FADs were conducted using trolling, vertical longlining and bait-trapping. Vertical longlining produced the most catch (86 fish weighing 920.5 kg), although good catches of baitfish were also reported from the trap, which was suspended beneath the FAD buoy-system by rope (Mead 1997; Anon. 1983).

With the successful development of an FAD programme in Niue, the fisheries department regularly maintained the FADs. Several FADs were deployed in the mid-1980s, followed by another six in 1989/90 (Chapman 2004). The fisheries staff continued to maintain and replace FADs during the 1990s, with seven FADs on station in 1991 and 8 FADs on station in 1999. Local fishers continued fishing around the FADs, mainly trolling, with a few fishers using vertical longlines. In 1997, the fisheries department had licensed 40 outboard-powered dinghies for fishing, and at least 50 canoes were also estimated to be in operation (Anon. 1997). By 2001, the number of licensed boats had increased to 62 and the number of canoes was estimated to be around 200 (Gillett 2002).

In 2001, a joint project was initiated between SPC and the fisheries departments of Niue and Cook Islands. The project was to develop a more cost-effective FAD mooring design, collect catch and effort data from fishers (with a focus on FAD fishing), conduct a cost–benefit analysis of the FADs, and produce a manual on the most effective FAD mooring designs (Anon. 2005). Over a three-year period, 11 FADs were deployed off Niue and a data-collection system initiated. The results clearly showed the value of FADs to the small-scale tuna and coastal pelagic fishery off Niue, and the fisheries department has continued its FAD programme, although at a reduced rate given funding constraints and the limited access to a suitable boat to deploy the FADs.

Several attempts have been made by local fishers to set up a small charter-fishing or sport-fishing operation on Niue. In the early 2000s there were two main companies with small charter vessels (Whitelaw 2001). However, these companies struggled when tourism slowed as a result of reduced air access to Niue.

Deep-water snapper fishery

Traditionally, canoe fishers in Niue have fished down to depths of 200 m using handlines, although most fishing was conducted in much shallower depths. New deep-water snapper fishing techniques were introduced to Niuean male fishers in 1978, when the SPC Deep Sea Fisheries Development Project (DSFDP) conducted the first training sessions and fishing trials in the country (Fusimalohi 1978; Dalzell and Preston 1992). This was followed by two more visits of the DSFDP in 1979 (Mead 1980) and 1982/83 (Mead 1997; Chapman 2004). Catch rates varied during the different trips and ranged from 2.8 kg/line-hour on the first trip to 7.0 kg/line-hour on the second trip. Fishing was also conducted at Beveridge Reef (125 nm southeast of Niue Island) in 1979 under a joint Niue Government and FAO/UNDP project using a Tongan vessel, with a catch rate of 5.6 kg/line-hour recorded (Mead 1980; Dalzell and Preston 1992).

Following the survey work and looking at the limited bathymetry data available for Niue, several areas were thought to have ridges or seamounts to develop a deep-water snapper fishery. In 1987, the Townsend Cromwell conducted a survey using echo sounding equipment and a global positioning system to chart the areas (Polovina *et al*. 1987). The results showed several small ridges and seamounts, but these were limited in size.

Dalzell and Preston (1992) analysed the data from the three separate DSFDP visits to Niue (1978, 1979 and 1982/83), including the trip to Beveridge Reef, and estimated the maximum sustainable yield from this resource to be 3.6–10.8 t/year for around Niue and 3.4–10.0 t/year for Beveridge Reef. Given the limited size of the resource and the small size of the skiffs and canoes used by Niuean fishers, deep-water snapper fishing is conducted on an *ad-hoc* basis (Chapman 2004).

Scoop-netting of flying fish

One of the traditional fishing methods still being used today is scoop-netting flying fish, which are attracted or spotted by light at night (Hinds 1970). Traditionally, coconut fronds were bound and set alight to provide light; however, in the early 1970s, pressure lamps were used and aluminium poles were being considered for making up the nets (Hinds 1970). Today, car batteries and spotlights are mainly used, although the shape of the scoop-net has not changed much at all, with some nets made from wood and others from aluminium pipe. Flying fish are a prized commodity, considered a fine food fish (mainly eaten raw), as well as very good bait when trolling for larger tunas and coastal pelagic fish.

Aquaculture

There are no aquaculture projects on Niue, although this has been considered in the past for species such as trochus, giant clams and pearl oysters (Anon. 1999, Gillett 2002). One feasibility study on aquaculture was carried out in 1994 by FFA and ICLARM, looking at the farming of freshwater prawns and crayfish, and the setting up of a giant clam hatchery. Results of this study concluded that this would be costly and not economically viable (Gillett 2002).

Reef fisheries (finfish and invertebrates)

Niue has no lagoon, so there are only two types of reef fisheries. The first is the use of canoes to fish outside the reef for reef-associated species, such as *ulihega* (*Decapterus macarellus*) using shallow-water handlining and traditional methods. The second is shore-based fisheries, including hook and line, occasional gillnetting, reef gleaning, diving and spearfishing (Anon. 1999).

The ulihega *fishery*

Niueans have traditionally fished for *ulihega* from outrigger canoes using a special forked ‘rod’, which has a short line with a small hook attached to the end of each fork. The hooks are baited with green coconut flesh, with the fisher chewing up some of the coconut flesh and spitting it into the water to 'burley' or 'chum' the fish close to the canoe. The fisher twists the forked rod to create a jigging action to encourage the fish to take the bait. Quite often, fishers form groups in specific locations (called 'holes') and fish together to concentrate the fish in this area for all to catch. Fishing is usually done at first and last light, with the *ulihega* a prized food fish, eaten raw, although they are also excellent bait.

As part of the technical assistance given to Niue in 1982/83, fish traps were trialled in association with FADs. A trap was suspended below the buoy system of the FAD and no bait used. The baitfish, mainly *ulihega* and some *atule* (*Selar crumenophthalmus*) freely entered the trap. It was impossible to record the catches of baitfish because many fishers hauled the trap at different times (Mead 1997). The traps were successful, but were discontinued after the fishing trials.

Gillett (1987) estimated that, although the catch of *ulihega* was much less than five tonnes per year, these fish accounted for a higher proportion of the total fish catch in Niue than in any other Pacific Island country. Gillett (1987) also conducted fishing trials for *ulihega* using a Hawaiian-style hoop net in 1987. The net was cone shaped: around 4 m in diameter at the mouth and tapering to the end. Over the month-long fishing trials, 75 hauls were made of the hoop net, yielding a catch of 2579 *ulihega* weighing 516 kg. The trials were successful; however, the catch rates were much lower than in the Hawaii fishery (Gillett 1987). The technique did not catch on, and Niuean fishers continue to catch *ulihega* in the traditional manner.

Reef fishing activities

There is basically no data on the catch of inshore resources. Dalzell *et al*. (1990) reported that reef gleaning activities, such as collecting shellfish and other invertebrates, are commonly practised, while catch rates for different fishing activities on coral reefs were not known. Dalzell *et al*. (1990) also estimated the total fisheries production to be 115 t/year, half of which was from reef fisheries and equated to 9.3 t/year/km^2 of reef area. If this was true, then Niue's reef resources are reasonably heavily exploited.

This was further highlighted in a 2002 study where, during departmental consultation, a key issue that emerged was the unsustainable use of inshore fish resources, coupled with the lack of baseline information on these (Butler 2002). Other issues highlighted in Butler (2002) included the incidence of ciguatera in some species and at some locations around Niue Island; and the fact that the two offshore reefs were poorly known and could potentially provide fishery resources if they were sustainably managed.

Females are involved in a range of reef fishing activities. During the day when the tide is low, females collect a range of invertebrates, including octopus, *Turbo* spp. snails, tube worms, sea urchins, clams, seaweed and other shellfish (Tuara 2000). Most of these are collected by hand, although metal implements are sometimes used to dislodge some shellfish from the rocks. Females also use poles with a piece of monofilament line and a hook to fish for reef fish in rock pools at the reef edge. Seasonally, females and males fish for the small yellow-striped goatfish (*kaloama*) when they occur in shallow water close to shore (Tuara 2000).

Coconut crabs

Although not a marine resource, the coconut crab (*Birgus latro*), which is a land crab, is a delicacy on Niue and is harvested year round. It is also a popular commodity with Niueans living in New Zealand, with estimates of 2 t/year being exported during the 1980s (Dalzell *et al*. 1993). Schiller (1992) estimated the density of coconut crabs on Niue at 1 crab per 217 m^2, a quarter of the density of unharvested stocks (1 crab per 50–70 m^2). Anecdotal information indicates that the export of coconut crabs to New Zealand continued during the 1990s when direct flights were running; however neither the numbers nor the volumes were known (Friedman and Pakoa 2007).

Friedman and Pakoa (2007) conducted a desk review on the coconut crab in Niue at the request of the Niue fisheries department. The review noted that, in the early 1990s, stocks of coconut crab were already depleted and stock abundance had continued to fall. Management measures, which had previously been recommended to halt declines, had only been partially adopted and had proved insufficient to stem declines in the populations. However, even highly depleted fisheries have managed to recover, as long as spawning stock (the number of females of spawning size) is not decimated. The review recommended that only strong controls on harvest can protect the remaining stock of coconut crabs on Niue.

Inshore fisheries research and marine protected areas

Little is known about the coastal resources around Niue. In 1990, a fisheries resources survey was undertaken by the SPC Inshore Fisheries Research Project and the FAO South Pacific Aquaculture Development Programme (Dalzell *et al*. 1990; Dalzell *et al*. 1993), with three specific objectives:

1. to review all information on the fisheries of Niue and incorporate observations on catch, catch rates, species composition and fishing methods into the final report;
2. to conduct a comprehensive resource questionnaire survey among the population of Niue covering fishing methods, the catch from reef and deep sea and the commonest species caught by gear type; and
3. to make an assessment of giant clams and other commercially important invertebrate species, assess the socio-cultural importance of clams in the diet of Niueans, and assess the potential for clam aquaculture in Niue.

In addition, the survey team was asked to look at the feasibility of introducing the commercial topshell (*Trochus niloticus*).

The in-water survey revealed that there were two species of clams, *Tridacna maxima* and *T. derasa*, with *T. maxima* the more common species at 89 clams/ha. Estimates of total coral cover were also assessed, as Niue had been hit by a cyclone in January 1990. Only nine adult crown-of-thorns starfish were recorded. The commonest sea cucumber species were *Holothuria atra* (low value) on the intertidal reef, with *H. atra* co-dominant with *Thelenota ananas* (commercial species) on the sub-tidal reef, but still in low densities. Three species of spiny lobster or crayfish were recorded during night dives on the reef (*Panulirus penicillatus, P. longipes* and *P. versicolor*). A range of other crustaceans was also recorded (Dalzell *et al*. 1990).

Assessment of the data indicated that there was little potential for culturing clams in Niue due to the absence of a lagoon and suitable habitat for juveniles. However, the potential for trochus was much better, with suitable reef-shelf environment if they were to be introduced. The stocks of sea cucumbers were practically non-existent, so very little potential was found for these species (Dalzell *et al*. 1990; Dalzell *et al*. 1993).

Butler (2002) summarised the work that was done up until 2001; however, most of this comprised statements in reports concerning the lack of baseline data, the need for management, and the fact that inshore resources were overfished and that pollution was becoming a problem. This led to the establishing of a pilot project under the International Waters Programme in the area of 'sustainable coastal fisheries' (Anon. 2002).

Coral cover

Several assessments of coral cover and species have been undertaken at different locations around Niue. Dalzell *et al*. (1993) recorded during survey work in 1990 that total coral cover was 5–50% (mean cover 14.1%) and live-coral cover was 5–35% (mean cover 8.9%) off the west and north coasts (between Tepa Point in the southwest and Liha Point in the northeast), mainly as a result of a cyclone that had recently hit this part of the island. From Liha Point to Vaigata along the northeast cost, coral cover was much higher: total coral cover was 60–80% (mean 73.3%) and live-coral cover was 40–70% (mean 57.5%).

During the assessment of ciguatera in 2002 (Yeeting 2003), coral cover was also assessed in the survey areas around the Alofi wharf on the west coast of the island. The corals in the area were not very healthy with less than 30% live-coral cover in most cases (Yeeting 2003). The coral damage from the previous cyclone that had hit Niue in 1990 was still evident. In addition, signs of coral bleaching were observed, which would have been related to the 1997–98 global coral bleaching event. The dead, branching corals and the bleached corals were already colonised by algae.

As part of the International Waters Programme, baseline surveys were conducted at the pilot-site coastal villages of Alofi North and Makefu, as well as selected sites on the west coast of Niue (Fisk 2007). Surveys were conducted in December 2003 and March 2004, with Cyclone Heta hitting Niue in January 2004. The results of the surveys indicated that cyclone damage varied greatly from virtually no damage to complete removal of the living-coral reef veneer, though damage overall in the pilot village coastal areas was high to severe (Fisk 2007). Major reduction in coral cover was recorded on the reef slope in the most exposed locations, including the more northerly and southerly portions of the pilot village areas. Also recorded were the proliferation and dominance of a single macro-algal species (*Liagora* sp.) in most slope and reef-flat pools, as well as extensive expansion of turf algae and blue-green algae mats in both reef-flat and slope habitats (Fisk 2007).

Trochus introduction

The commercial topshell, *Trochus niloticus*, does not naturally occur in Niue; however, suitable habitat was identified around Niue during a 1990 survey (Dalzell *et al*. 1990). In 1992, the transhipment and introduction of trochus to Niue were arranged with the assistance of the FAO/UNDP Regional Fishery Support Programme and the US Embassy (using a US military aircraft) (Gillett 1993). The trochus were collected from Lakeba Island in Fiji's Lau Group. In August 1992, 213 live trochus were successfully introduced to Niue, with

99 placed at a reef at Uani near Hakupu Village, 77 at Matalave and Makatutaha near Namukulu Village, and 47 at Patuoto near Tamakautoga Village (Gillett 1993).

Several surveys were conducted between the introduction of the trochus and 1995 to monitor progress. It appeared that trochus could survive in the Niuean habitat, but the low numbers introduced may have been a limiting factor (Pasisi 1995). Another survey in 1996 concluded that 3–4 years after the introduction of trochus, some animals were still alive; however, there were no obvious signs of breeding and no new recruits to the fringing reef around the island (Anon. 1996). A further 311 live trochus were introduced to Niue from Tonga in 1996, with these placed on the reefs at Namukulu and Tamakautoga (Gillett 2002).

Namoui fisheries reserve

In late 1998, SPC was requested to undertake a resource assessment at the recently declared 'Namoui fisheries reserve' in Niue. This covered a total surface area of 27.67 ha, out to the 50 m isobath (Labrosse *et al*. 1999). The assessment was to set a baseline by making an inventory and reporting on the status of the species (fish and invertebrate) and the habitat, and to formulate a programme to monitor the reserve's progress. A total of 103 fish species were recorded, although the biomass values were low compared to the second survey site at Avatele. Eight species or groups of species were considered for invertebrates, with the densities of giant clams (only one species recorded) and sea cucumbers at much lower levels that recorded in 1990 by Dalzell *et al*. (1993).

Ciguatera fish poison

Ciguatera fish poisoning is reported from many countries around the Pacific, including Niue. From 1973 to 2000 there were 101 reported cases of ciguatera fish poisoning on Niue (Yeeting 2003). In late 2001, there was an outbreak on Niue; 20 cases were reported within a 3–4 month period. SPC was able to draw up an algal sampling programme for the Niue fisheries department at the time, and provided equipment for the collection and processing of the samples with a detailed description of the algae collection procedures, processing of samples and preservation techniques. The results from the samples showed a very high presence of *Gambierdiscus* spp., which suggests that the fish poisoning cases are related to ciguatera. These findings were further strongly supported by the details of the symptoms recorded from the 20 cases of fish poisoning admitted into the local hospital, which were very typical of ciguatera fish poisoning (Yeeting 2001).

In early 2002, the ciguatera problem in Niue was considered very serious by the Government. SPC was again asked for assistance, and this was provided in mid-2002. Three sites around the Alofi wharf area were studied, as this was the main area reported by locals for toxic fish. The results of the algae samples confirmed the presence of *G. toxicus* in high numbers, especially in the wharf area, strongly suggesting that the wharf area is a highly ciguatoxic area and therefore fish from this area and nearby reefs should be avoided (Yeeting 2003).

1.3.3 Fisheries management

In 1995, a review of the Niuean domestic fisheries legislation led to the combining of the Niue Island Fish-Protection Act 1991, the Sunday Fishing Prohibition Act 1980, the Niue Island Fish-Protection Ordinances 1965 No. 32, and the Safety at Sea Act 1980, into the Domestic Fishing Act 1995 (Anon. 1999). Other pieces of fisheries legislation include the

Domestic Fishing Regulations 1996, and the Territorial Sea and Exclusive Economic Zone Act 1996 (Anon. 1999). Conservation regulations also include the Niue Whale Sanctuary Regulations 2003, which protect any cetacean from any impact.

The Domestic Fishing Act 1995 (Government of Niue 1997) and Domestic Fishing Regulations 1996 (Government of Niue 1996) include: the prohibition of fish export (sea cucumbers, live sea shells, all species of crayfish, all species of egg-carrying or soft-shelled crustaceans, and others), size limits for coconut crabs, lobsters, giant clams and slipper lobsters, fish quota limits (10 giant clams and lobsters per day and fisher respectively), and protection for selected fish species. The use of illegal fishing means is prohibited, including any kind of explosives, natural or chemical poisoning, firearms, nets with a mesh size less than 75 mm diagonal measurement except for use as flying fish net, and SCUBA dive gear.

A range of other regulations are also in place under this legislation, including:

- A Sunday ban is enforced for all fishing activities within Niue's fishery waters (territorial zone);
- All boats need to be licensed on an annual basis and to provide information on their weight and purpose of use;
- Concerning the bait fishing of *ulihega*: The local village custom will establish the date and time when all fishing groups of the community proceed at the same time to the designated areas. No net, fish substance, ground or line bait other than coconut is permitted when fishing for *ulihega*; and
- With the concurrence of the village council, Cabinet may from time to time by public notice declare a marine reserve or a *fono* for fishing (However, such exemptions are of short duration and usually represent a one-day event.).

In addition to the governmental fisheries regulations, each village has the opportunity to establish by-laws within the given framework of customary tenure (Vunisea 2005). For example, villages ban the use of nets and swimming in close proximity when *kaloama* (*Mulloidichthys flavolineatus*) is schooling, to increase opportunities to catch this fish, which is considered a special delicacy. The period for any such protective measures is variable and its implementation depends on the likelihood of *kaloama* schooling, i.e. particularly in the sheltered coastal areas between Avatele in the south and Hikutavake in the north of the country's west coast.

There are also several activities (previous and ongoing) implemented by the Niue Fisheries Division in cooperation with regional agencies, which aim(ed) to contribute to or improve fisheries management; these include:

- the Community-Based Fisheries Management Programme assisted by SPC (Vunisea 2005) focusing on the co-management of fisheries resources and the marine environment by villages and the Fisheries Division (These include the development of fisheries management plans for each participating village. Management plans have been developed by three villages: Liko, Alofi South and Toi, and a marine protected area has been officially approved for Alofi South (Figure 1.5).);
- the establishment of the Niue Marine Life Species Database, a project that is still in its infancy;

- The FAD project, assisted by SPC and funded by NZAID (Anon. 2005) to provide alternative fishing locations in order to reduce fishing pressure on reef resources and to collect data on fishing strategies and catches provided by participating fishers; and
- The International Waters Programme, assisted by SPREP (Anon. 2003) with sustainable coastal fisheries as a focal area for Niue.

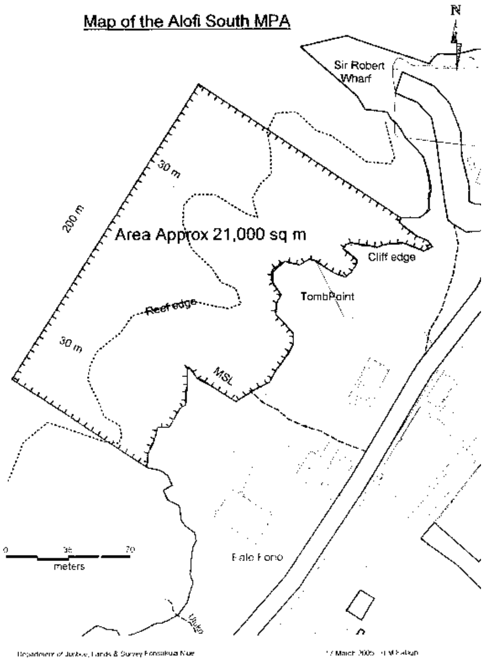

Figure 1.5: Map of the Alofi South Marine Protected Area - Niue.

A draft national management plan, or pilot plan, for coastal fisheries around Niue was developed in 2003 (DAFF 2003) with assistance from SPC. This draft pilot plan was developed to produce baseline information; to promote existing and introduce appropriate new management and co-management mechanisms; to assess the effectiveness of these mechanisms with respect to fishery production and social systems; and to implement a fully operational Coastal Fishery Management and Development Plan before December 2006 (DAFF 2003). Some parts of this plan have been implemented or progressed; however, there was still no specific, fully operational coastal fisheries management and development plan in place in mid-2008.

1.4 Selection of sites in Niue

Under normal operations, the PROCFish/C and CoFish programmes select four representative sites for work in each country or territory. However, in the case of Niue (Figure 1.4), it was possible to survey the whole country due to the small size of the island and the limited reef area. Therefore, Niue was considered as a single site, and that is how the results are presented in this report.

2. PROFILE AND RESULTS FOR NIUE

2.1 Site characteristics

Niue is a single uplifted coral island located in the central east Pacific, distant from the centre of biodiversity, with a land area of 259 km^2 and an exclusive economic zone (EEZ) area of 390,000 km^2. The island of Niue has a coastline of ~70 km in perimeter, and is surrounded by a narrow wave-cut platform (rather than a fringing reef), which rises with undercut limestone cliffs to a height of 20–30 m above sea level (Cartwright *et al*. 2003). Waters adjacent to the wave-cut platform drop off steeply, reaching depths of around 2000 m within 3–5 km of the shore. Much of the south and east sides of the island are entirely devoid of reef flats (Dalzell *et al*. 1993).

Niue's reef fishing grounds are limited (Figure 2.1), with 10.07 km^2 of outer-reef slope immediately outside the breakers and a coastal reef-flat area of 4.98 km^2; however, only 1.9 km^2 of the reef-flat area is accessible to fishers. The reef around Niue is composed of mainly coral slab, strongly dominated by hard bottom, with limited live-coral cover. Limited coral cover is the result of cyclone damage, with the last being Cyclone Heta in January 2004. However, many young coral recruits were observed during the surveys (May/June 2005), indicating coral recovery has started.

Figure 2.1: Main reefal structure adjoining Niue.

Niue has basically no coastal waters, no lagoon and no harbour, so access to the coast or reef is limited. Sea tracks have been put in at each village to allow fishers access to the reef adjacent to their villages. Fishers use locally made, lightweight outrigger canoes to fish around the island, outside the reef. The canoes are lifted in and out of the water and stored in caves or on platforms well above the high-tide level, or at the top of the cliffs. Outboard-powered skiffs, mainly 3.4–5 m in length, are used to fish for coastal pelagics. These skiffs are lifted in and out of the water by crane at one of two locations: Avatele on the southwest corner of the island and Alofi, the capital, on the west coast. The skiffs are on trailers, so they can be towed away from the crane to higher ground or taken home.

2.2 Socioeconomic surveys

Socioeconomic fieldwork was carried out in all 14 villages of Niue from 20 May to 10 June, 2005. Household interviews focused on the collection of community demographic and socioeconomic data. Data to characterise fishing strategies and to assess current fishing pressure are sourced from individual interviews with male and female fishers. All 14 villages were surveyed.

The survey covered 218 out of 468 households (47%). All village surveys were done by the survey team with the exception of Alofi North. The latter survey was implemented by staff from the International Waters Programme in cooperation with the trained CoFish local attachment team member. In addition, a total of 139 individual interviews with finfish fishers (101 males, 38 females) and 140 individual interviews with invertebrate fishers (63 males, 77 females) were conducted. In some cases the same person was interviewed for both finfish and invertebrate harvesting.

2.2.1 The role of fisheries in Niue: fishery demographics, income and seafood consumption patterns

Coastal fishing in Niue does not necessarily require boat transport. Walkways, though mostly steep, allow access to the coastal reef from each village. Fishing from the coastal reeftop during favourable weather, sea and tidal conditions is very common. However, the use of paddling canoes for coastal and pelagic fishing as well as motorised boats for mainly pelagic fishing is not uncommon. About 40% of all households surveyed own a boat. Locally built wooden canoes propelled with paddles are more common (78%) than motorised boats (22%).

The survey results indicate an average of 1.3 fishers per household. If we extrapolate this average figure to the total population of Niue, there is an estimated total of 597 fishers (346 males, 251 females). Of these, 170 persons fish only for finfish (155 males, 15 females), 75 only harvest invertebrates (13 males, 62 females), and 352 fish for both finfish and invertebrates (178 males, 174 females) though not necessarily during one single fishing trip.

Table 2.1: Fishery demography, income and seafood consumption patterns in Niue

Survey coverage	Niue (n = 218 HH)
Demography	
HH involved in reef fisheries (%)	75
Number of fishers per HH	1.3 (±0.07)
Male finfish fishers per HH (%)	25.9
Female finfish fishers per HH (%)	2.5
Male invertebrate fishers per HH (%)	2.2
Female invertebrate fishers per HH (%)	10.4
Male finfish and invertebrate fishers per HH (%)	29.9
Female finfish and invertebrate fishers per HH (%)	29.1
Income	
HH with fisheries as 1st income (%)	1.4
HH with fisheries as 2nd income (%)	8.7
HH with agriculture as 1st income (%)	5.0
HH with agriculture as 2nd income (%)	12.8
HH with salary as 1st income (%)	61.0
HH with salary as 2nd income (%)	10.1
HH with other source as 1st income (%)	34.4
HH with other source as 2nd income (%)	22.5
Expenditure (USD/year/HH)	6495 (±234.1)
Remittance (USD/year/HH) [(1)]	1234 (±248.5)
Consumption	
Quantity fresh fish consumed (kg/capita/year)	31.1 (±2.28)
Frequency fresh fish consumed (times/week)	2.00 (±0.09)
Quantity fresh invertebrates consumed (kg/capita/year)	n/a
Frequency fresh invertebrates consumed (times/week)	0.50 (±0.05)
Quantity canned fish consumed (kg/capita/year)	18.2 (±2.04)
Frequency canned fish consumed (times/week)	2.0 (±0.11)
HH eat fresh fish (%)	99
HH eat invertebrates (%)	84
HH eat canned fish (%)	92
HH eat fresh fish they catch (%)	67
HH eat fresh fish they buy (%)	61
HH eat fresh fish they are given (%)	53
HH eat fresh invertebrates they catch (%)	62
HH eat fresh invertebrates they buy (%)	22
HH eat fresh invertebrates they are given (%)	34

HH = household; n/a = no information available; [(1)] average sum for households that receive remittances; numbers in brackets are standard error.

The survey data also show that Niue's population does not depend on the primary sector for income generation (Figure 2.2) but on salaries and private business, which are the major source of revenue for >60% and >30% of all households respectively. Only 10% of all households surveyed reported that fisheries provide a complementary income (and another 18% gain a secondary income from selling agricultural produce).

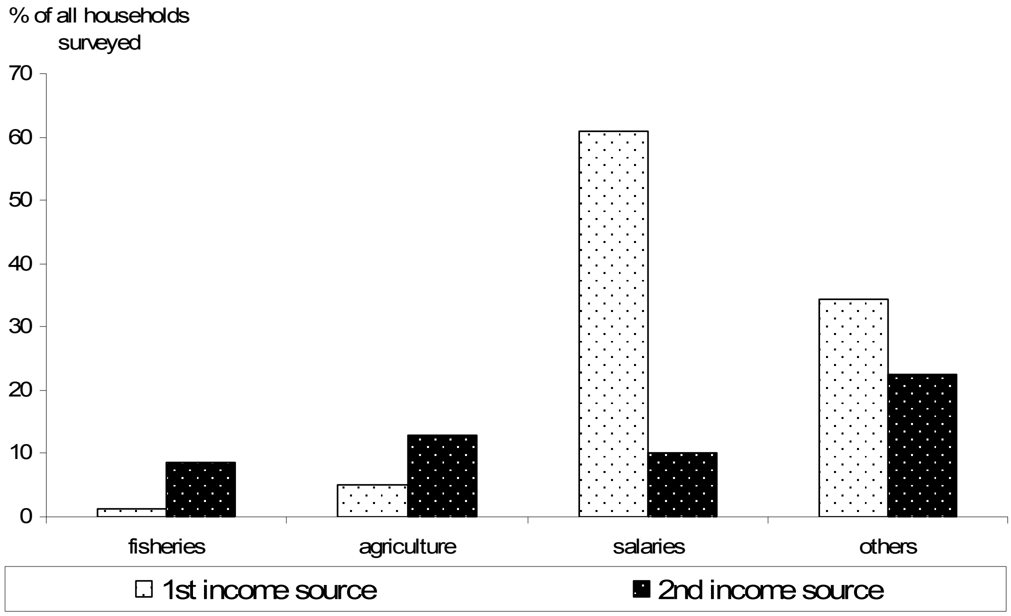

Figure 2.2: Ranked sources of income (%) in Niue.
Total number of households = 218 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly retirement payments, handicrafts and private businesses.

This survey also revealed interesting results concerning the nature, frequency and quantity of seafood consumption. Taking into account all households interviewed, the per capita consumption of fresh fish was found to be 31.1 kg/year on average. This figure is below the regional average estimated at 35 kg/ year and also lower than previous estimates, which range from 40.8 to 49 kg/year (Dalzell *et al.* 1993) to 118.9 kg/year (SPC 2000).

However, it should be noted that the data we collected only cover the average household consumption and do not include finfish consumed at frequent feasts and celebrations, such as haircutting ceremonies, or in meals purchased from snacks and restaurants, which is likely to be a substantial amount. An estimation of this increment is made by adding pelagic and mid-water catch data reported in the framework of the SPC project on FADs to our reef and canoe fishing data (See section 2.2.4.).

Variation in finfish consumption among villages, however, is significant. As shown in Figure 2.3, consumption ranges from 7.8 kg/year (Namakulu) to 49 kg/year (Alofi North). Comparing the geographic location of villages where fresh fish consumption is high, such as Avatele, Tamakautoga and Alofi, with those where consumption is much lower, higher consumption appears to coincide with easier access to less exposed fishing grounds.

The average per capita canned fish consumption of 18.2 kg/year is relatively high but not surprising given the high dependency on imported goods and the fact that fish constitutes a traditional and integral component of the Niuean diet (Figures 2.3 and 2.4). Also not surprisingly, the quantity of canned fish consumed varies considerably (13.4 kg/year in Tuapa and 28.3 kg/year in Namakulu) and is generally inversely related to the level of fresh fish consumption, i.e. communities that eat more fresh fish, eat less canned fish and communities that eat less fresh fish, eat more canned fish.

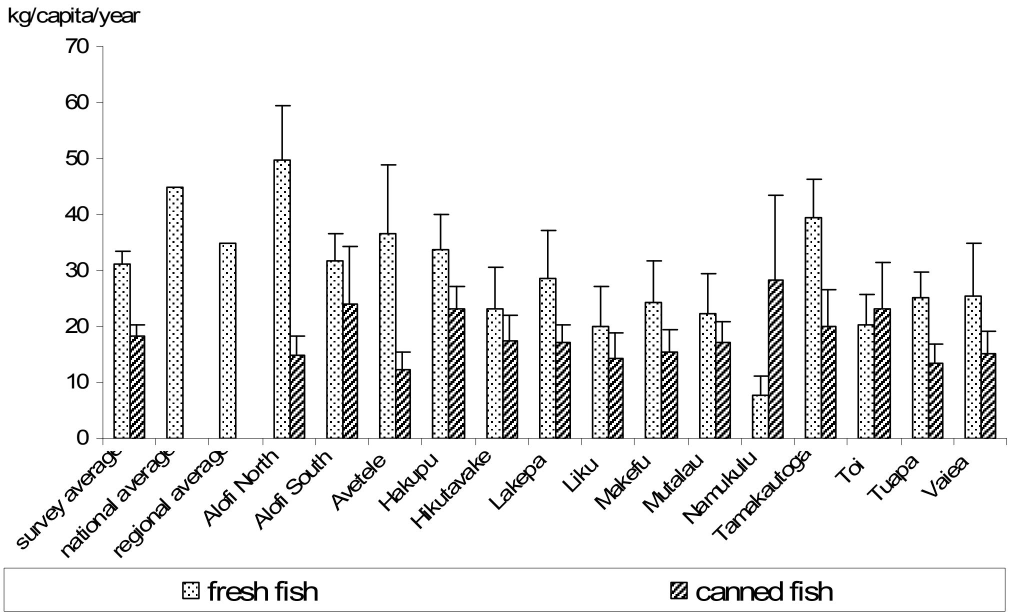

Figure 2.3: Per capita consumption (kg/year) of fresh fish and canned fish in Niue (n = 218).
Bars represent standard error (+SE).

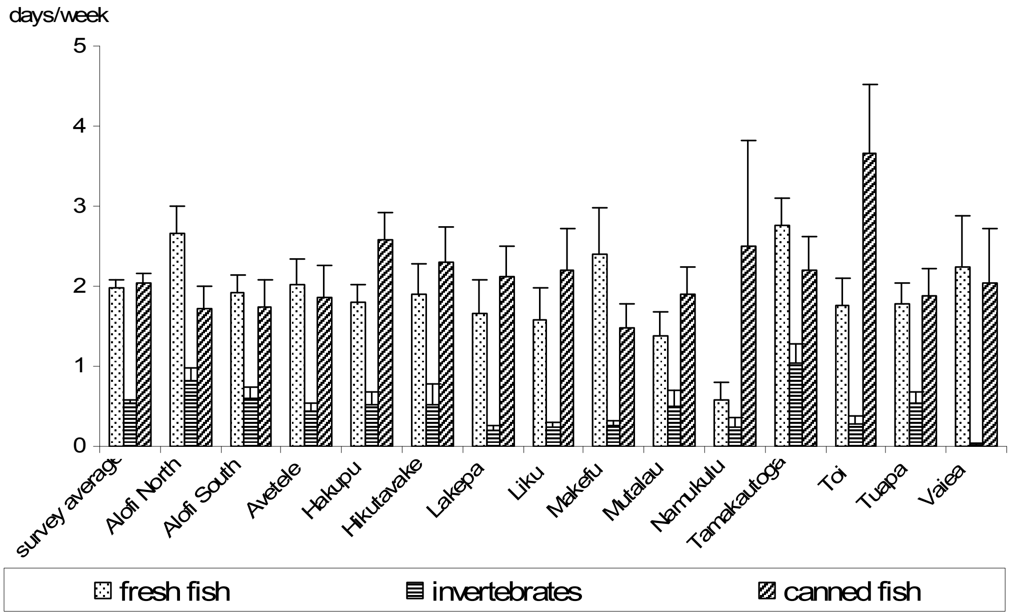

Figure 2.4: Frequency of seafood consumption in Niue.
Bars represent standard error (+SE).

At the national level, both fresh fish and canned fish are eaten about twice a week (Figure 2.4). As expected, fresh fish or canned fish are more frequently consumed in villages with higher per capita consumption while the consumption frequencies fall below the national average in villages with lowest consumption figures. Invertebrates are the least frequently eaten seafood. At the national average, invertebrates are eaten once a fortnight, i.e. four times less often than fresh and canned fish.

The survey also highlighted that Niuean seafood consumers are selective in terms of preferred fish and invertebrate species. However, preferred species include reef, deep-bottom and pelagic fish. Thus it must be taken into account that the consumption figures presented here are not exclusive to reef fish species. This observation is further supported if comparing the importance of the different sources of seafood (Figure 2.5). The high percentage of households that consume fish or invertebrates that have been caught by a household member agrees with the earlier observation that, on average, there is at least one fisher in every household. The fact that, also, at least half of all households surveyed reported receiving fish on a non-monetary basis underlines the persistence of traditional values and a closely knit social network among the island's population. However, the high proportion of households that also buy fresh fish suggests that the fishing activities of an average household are insufficient to satisfy home consumption. Information collected from respondents and market visits also suggests that it is mostly pelagic fish species that are marketed. Reef fish appear only occasionally on the local market and in small quantities. To some extent, seasonal fish, in particular the much favoured *kaloama* (*Mulloidichthys flavolineatus*), may be an exception to this observation.

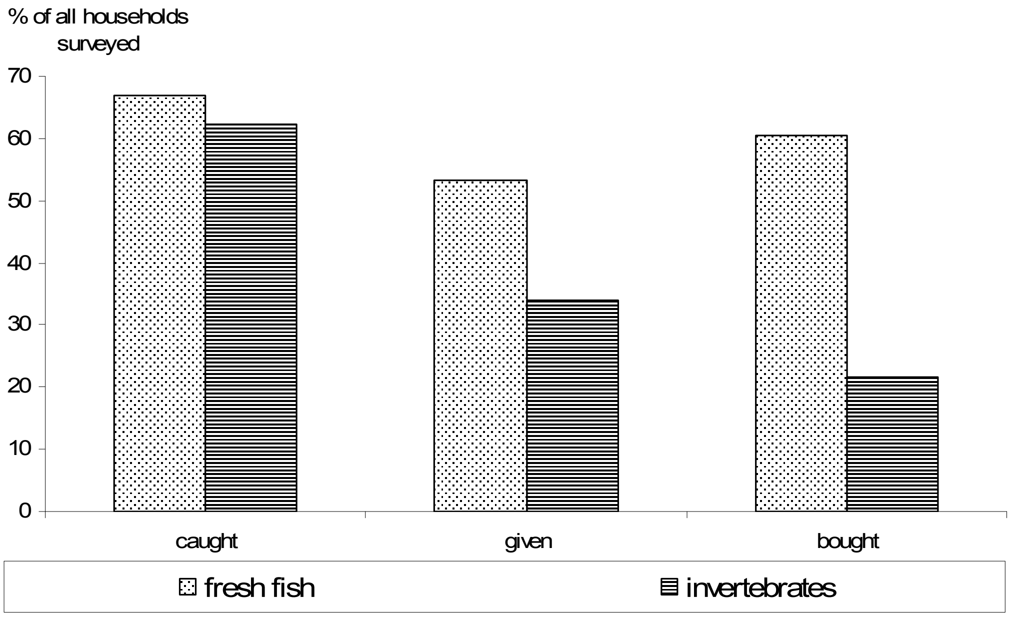

Figure 2.5: Origin of fresh fish and invertebrates consumed in Niue.

2.2.2 Resource user profile

Male and female participation in fisheries is comparatively high. Most fishers fish for both finfish and invertebrates, although not necessarily during one single fishing trip (Figure 2.6). There are more males than females who only fish for finfish, and slightly more females than males who only target invertebrates. Coastal reef flats are the main habitat for invertebrate collection. Only very few males dive for giant clams, octopus, etc. (Table 2.2).

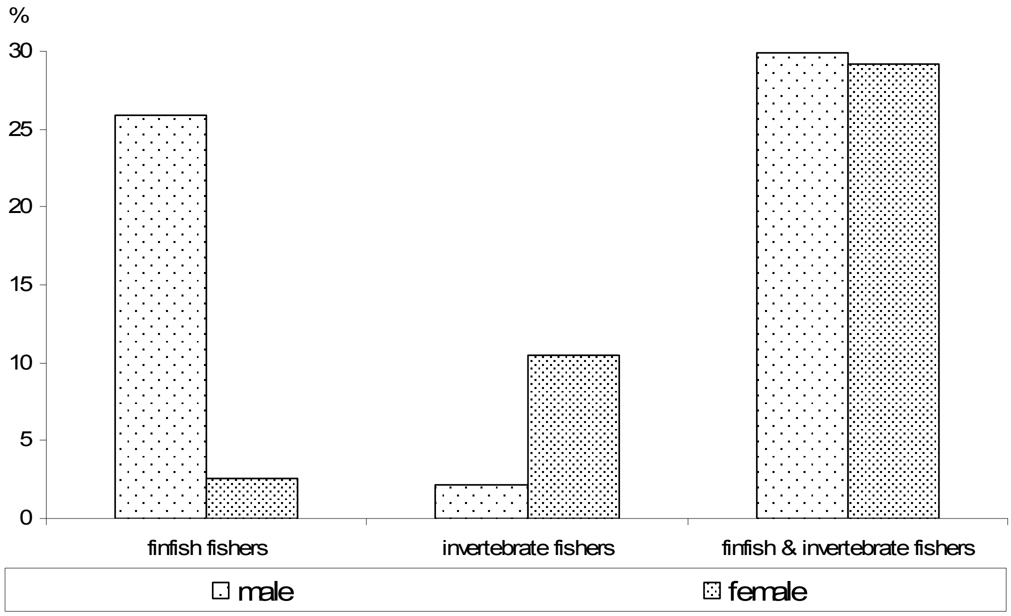

Figure 2.6: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Niue.
All fishers = 100%.

Table 2.2: Proportion (%) of male and female fishers harvesting finfish and invertebrate stocks across a range of habitats (reported catch) in Niue

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Coastal reef slope	100	100
Invertebrates	Coastal reef flat (reeftop)	98.4	100
	Other	1.6	0

'Other' refers to the lobster and giant clam fishery.
Finfish fisher interviews, males: n = 101; females: n = 38. Invertebrate fisher interviews, males: n = 63; females, n = 77.

2.2.3 Fishing strategies and gear

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip is used to estimate the fishing pressure imposed on Niue's coastal reef area.

In our survey we focused on coastal reef fisheries, i.e. one habitat targeted. However, due to its narrowness and its steep slope, it is sometimes difficult to distinguish between reef, deep-bottom and pelagic fishing activities. For instance, pelagic fish and deep-bottom species can both be easily caught from the reeftop.

On average Niueans go fishing about once a week. However, it should be noted that fishing activities are not performed as regularly as this figure may suggest. Due to the very variable sea conditions, local fishers can fish only when sea conditions are favourable, which is hard to predict. Survey data support this observation, as only 27% of all respondents reported fishing continuously throughout the year. Some examples showing the variability of suitable periods when sea, weather and other conditions allow particular fish species to be targeted are provided in Figure 2.7, i.e. the seasonal calendars for fishing prepared by participants of community meetings of the Niue Community Based Fisheries Management Programme.

Seasonal finfishing calendars (Source: Community Based Fisheries Management Programme)

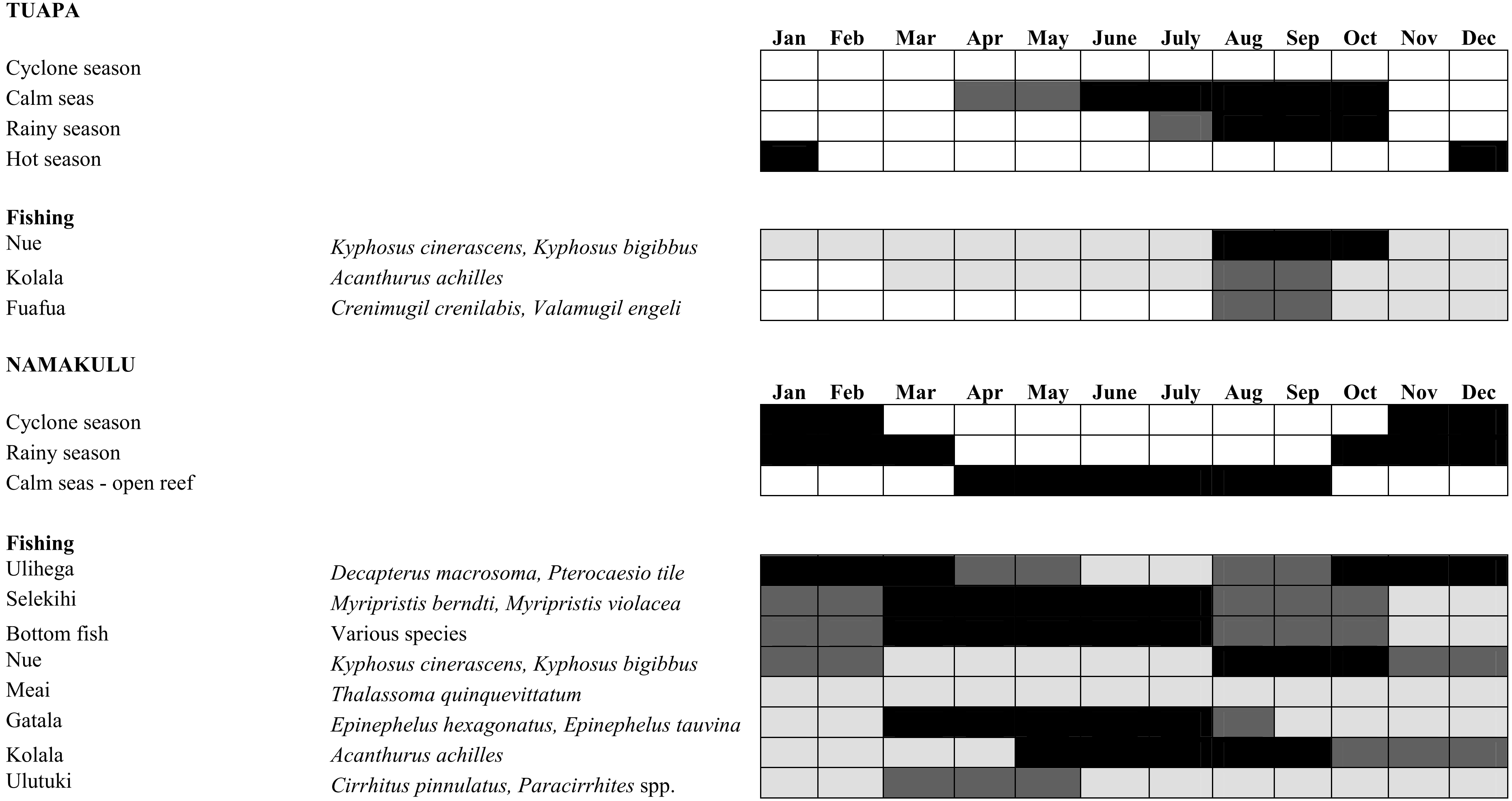

Figure 2.7: Seasonal calendar for selected finfish.
Prepared by participants of village meetings as part of the Niue Community Based Fisheries Management Programme.

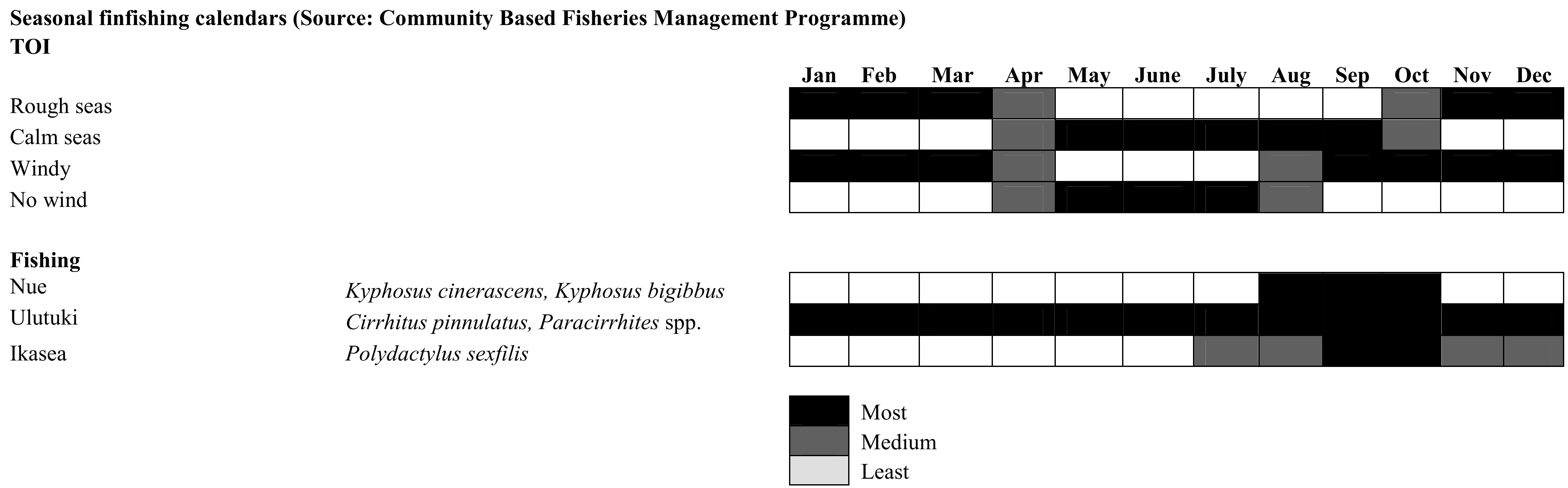

Figure 2.7: Seasonal calendar for selected finfish (continued).
Prepared by participants of village meetings as part of the Niue Community Based Fisheries Management Programme.

Fishing trips are short, lasting on average 1–1.5 hours each (Table 2.3). However, as shown in Figure 2.8, the frequency of fishing trips varies greatly among fishers from different villages. By comparison, fishers from Alofi, Avatele, Tamakautoga, Vaiea, Toi and Makefu tend to go fishing more often when conditions are favourable than do fishers from Hakapu, Lakepa, Liku, Mutalau, Namakulu and Tuapa.

Table 2.3: Average frequency and duration of fishing trips reported by male and female fishers in Niue

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Coastal reef slope	1.17 (±0.10)	1.32 (±0.21)	3.47 (±0.13)	3.38 (±0.16)
Invertebrates	Coastal reef flat (reeftop)	1.02 (±0.14)	1.13 (±0.10)	2.77 (±0.13)	2.90 (±0.12)
	Other	2.50	0	2.00	0

Figures in brackets denote standard error; 'other' refers to the lobster and giant clam fishery.
Finfish fisher interviews, males: n = 101; females: n = 63. Invertebrate fisher interviews, males: n = 38; females: n = 77.

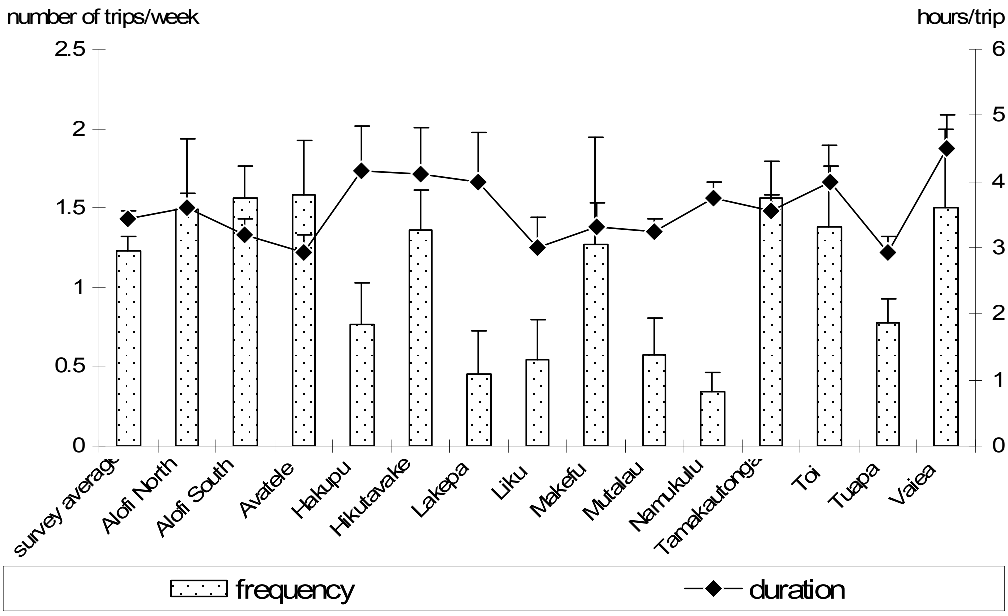

Figure 2.8: Average frequency and duration of fishing trips in each village in Niue.
Frequency = number of trips per week; duration = hours per trip; bars represent standard error (+SE).

Most fishers walk; only ~9% of all respondents reported always or sometimes using canoes or, in rare cases, motorised boats for coastal reef fisheries.

Fishing with rods is the main technique used for coastal reef fisheries, whether done by standing on the reeftop or from the canoe (Figure 2.9). Fishing rods include the 'Niuean rod', a hand-made, single- or two-forked bamboo rod and the 'Palangi rod' the local term for any commercial fishing rod. Most respondents use both types of rods, with no particular preference for either. Spearfishing is not common due to the predominantly rough sea conditions.

The fact that some fishers also use techniques that target non-reef fish (trolling, deep-bottom line) supports the above-mentioned argument that the nature of Niue's coastal reef makes a clear distinction between reef, deep-bottom and pelagic fisheries difficult (Figure 2.10).

Ice is hardly ever used during reef fishing trips. This is not surprising given the short duration of trips and the fact that boat transport is rarely used.

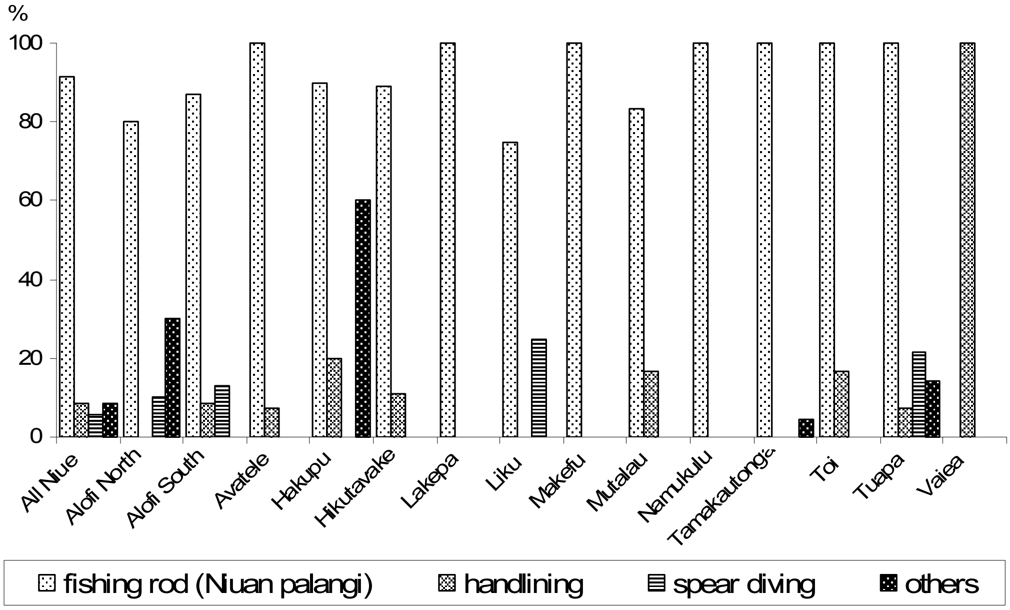

Figure 2.9: Major fishing techniques used in each village interviewed in Niue.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. 'Others' include: scoop net, deep-bottom line, bow & arrow, gillnet, trolling, bush knife, spearing by hand and walking.

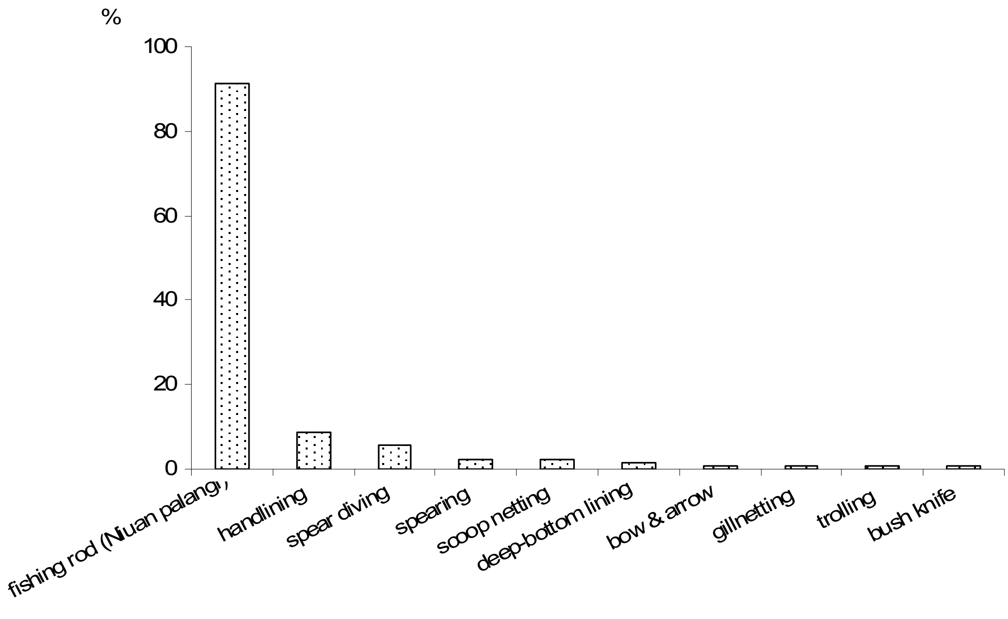

Figure 2.10: Fishing methods commonly used in Niue.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Most fishers fish according to the tides. A quarter of all fishers interviewed only fish during the day, and very few fish exclusively at night.

The Niue invertebrate fishery is limited to one habitat, the narrow and steep-sloped coastal reef, which is only accessible when sea and tidal conditions permit. As a result, reefs are mainly gleaned by males and females (99%), and diving for giant clams and lobsters is rarely performed by a few (1%) male fishers only (Figure 2.11).

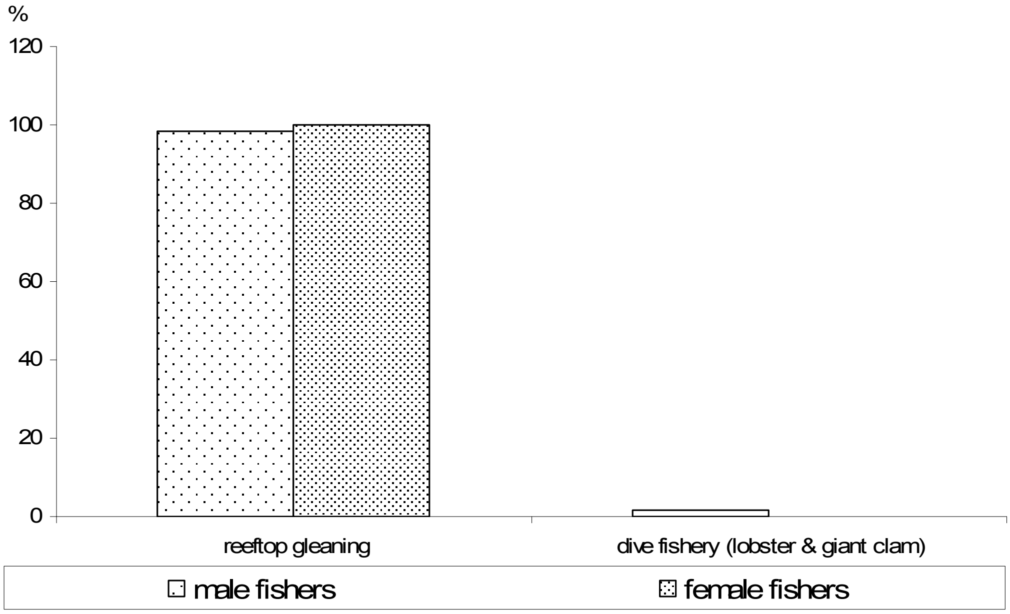

Figure 2.11: Proportion (%) of male and female fishers targeting various invertebrate habitats in Niue.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; figures refer to the proportion of all fishers that target each habitat: n = 38 for males, n = 77 for females; 'other' refers to the lobster and giant clam fishery, targeted by free diving.

Weather, sea and tidal conditions are even more limiting for invertebrate than for finfish fisheries. This explains why, on average, respondents reported that invertebrate collection is only possible during 6–7 months of the year. Diving is possible only for about 4 months per year. Suitable months for gleaning or diving are hard to predict and may vary between years. Village meetings held at Tuapa, Namakulu and Toi as part of the Niue Community Based Fisheries Management Programme developed seasonal calendars for invertebrate fishing (Figure 2.12), which show the variability in the timing of harvesting particular target species. On average, reeftop gleaners go out once a week and divers may go as often as 2.5 times/week. Collection trips are relatively short, lasting on average 2–3 hours.

Invertebrate harvesting, either gleaning or diving, is done without any boat transport. In very rare cases boat transport may be used to reach an otherwise difficult-to-access reeftop, but gleaning is done by walking.

Depending on the target species, invertebrate fishing is done by day or night. *Alili* (*Turbo crassus*, *T. setosus*), one of the most preferred species group, are collected at night.

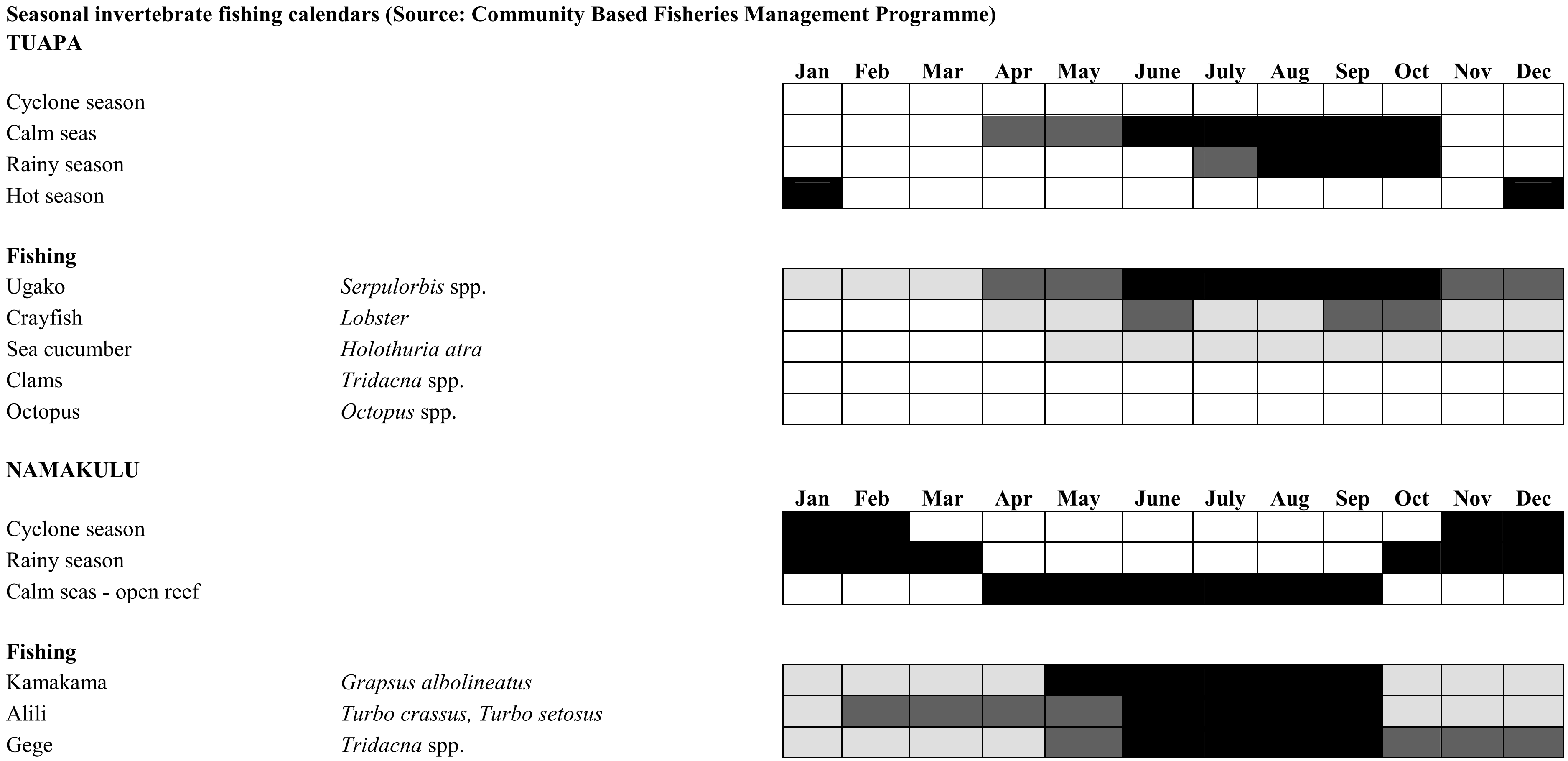

Figure 2.12: Seasonal calendar for selected invertebrates.
Prepared by participants of village meetings as part of the Niue Community Based Fisheries Management Programme.

Seasonal invertebrate fishing calendars (Source: Community Based Fisheries Management Programme)

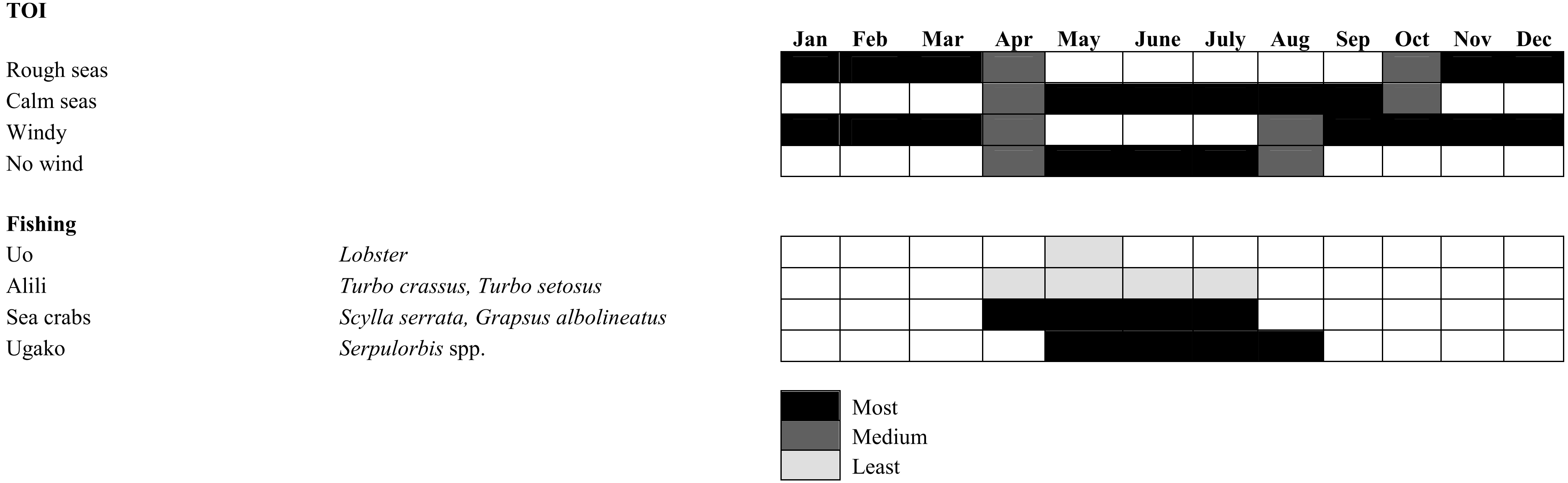

Figure 2.12: Seasonal calendar for selected invertebrates (continued).
Prepared by participants of village meetings as part of the Niue Community Based Fisheries Management Programme.

2.2.4 Catch composition and volume – finfish

The total annual reported catch from the coastal reef fishery amounts to 16 t. Most of this catch (13.2 t = 82%) is accounted for by male fishers, and female fishers contribute 2.8 t/year (18%).

Our figures are based on snapshot survey data that cover the activities of perhaps one-quarter of all Niuean fishers. As mentioned earlier, due to the Niuean coastal geomorphology, it is almost impossible to distinguish exactly among the reef, mid-water, and deep-bottom fishery. Our recorded and total extrapolated figures therefore include all reef fishing and most of canoe fishing, i.e. a mixture of reef, mid-water, and deep-bottom fishing. Our data do not include catches from motorised boats that mainly target pelagic and deep-bottom species. If we extrapolate our recorded catch data to the total number of potential fishers in Niue, the annual catch totals 57.6 t. Males contribute 43.6 t/year and female fishers provide the remaining 14 t/year. Comparing the total annual catch from reef and canoe fishing with the total per capita fish consumption (excluding purchased meals and feasts), we arrive at a difference of about 11 t/year (Figure 2.13).

Before the longline industry began, there was no commercial export of finfish from Niue. During our survey, the commercial longline operations just started and are therefore not taken into account here.

However, taking into account average catch records and annual estimates of local trolling and mid-water fishing from the SPC FAD project (SPC 2004), we can assume a production of ~61–89.8 t/year in addition to our reef and canoe fishing catch data. While both the CoFish and the FAD surveys have very specific objectives, i.e. one focusing on reef and the other on mid-water and pelagic fisheries, some overlap exists concerning those fishers who use paddling canoes. This may explain some (although not significant) double counting of reef and mid-water or pelagic catches as some fishers reported their catches to both surveys. Applying the average of the three years' annual SPC FAD catch estimates (including the year of Cyclone Heta in 2004), we conclude an additional sum of 76.2 t/year from the mid-water and trolling catches (Table 2.4).

Table 2.4: Approximation of total finfish production (t/year) and use in Niue

	Total finfish production (t/year)
Reef and canoe fishery production (CoFish survey)	57.6
Trolling and mid water catch (SPC FAD project)	76.2 (1)
Total annual catch (reef, canoe, trolling and mid-water catches combined)	133.9
Non-commercial export overseas (Gillett and Lightfoot 2001)	5.0
Consumption by expatriates (10%)	12.9
Annual consumption (CoFish survey)	69.6
Balance	46.4

(1) Average figure for recorded and estimated catches between 2002 and 2004; balance = difference between total annual catch and annual consumption.

The total national finfish production thus amounts to 133.9 t/year. Deducting an estimated 5 t/year of non-commercial exports, a 10% consumption by expatriates (12.9 t/year) and a surveyed total annual fish consumption of 69.6 t/year, the balance of 46.4 t/year represents the amount that is consumed via purchased meals (snacks, restaurants) and during public and private feasts and functions. If we apply our correction factors for gender–age and edible fish parts to the total population of Niue, we arrive at a total consumption of 66.1 kg/person/year, which includes the average household consumption and any other purchased (snacks, restaurants) or shared (functions) finfish meals.

Comparison of our recorded and extrapolated survey data with previous estimates (Table 2.5) shows general concordance with several estimates ranging between 100 and 120 t/year (McCoy 1990, Dalzell *et al.* 1993 and 1996, Niue Department of Agriculture, Forestry and Fisheries cited in Gillet and Lightfoot 2001 p. 171). However the household survey estimates (Gillet and Lightfoot 2001) seem to largely overestimate the country's annual fishery production.

Table 2.5: Various sources of estimated total finfish catch (t/year) in Niue

Time period	Total finfish catch (t/year)	Source
May-June 2005	57.6	CoFish socioeconomic survey
1988-1992	20-50	Niuean Fisheries Development Plan
1990	100–150 (50% reef; 50% pelagic)	McCoy
1993	119.9	Dalzell *et al.*
1996	115	Dalzell *et al.*
2001	120	Niue Department of Agriculture, Forestry and Fisheries
2000	194	Household survey covering 3.6% of all households

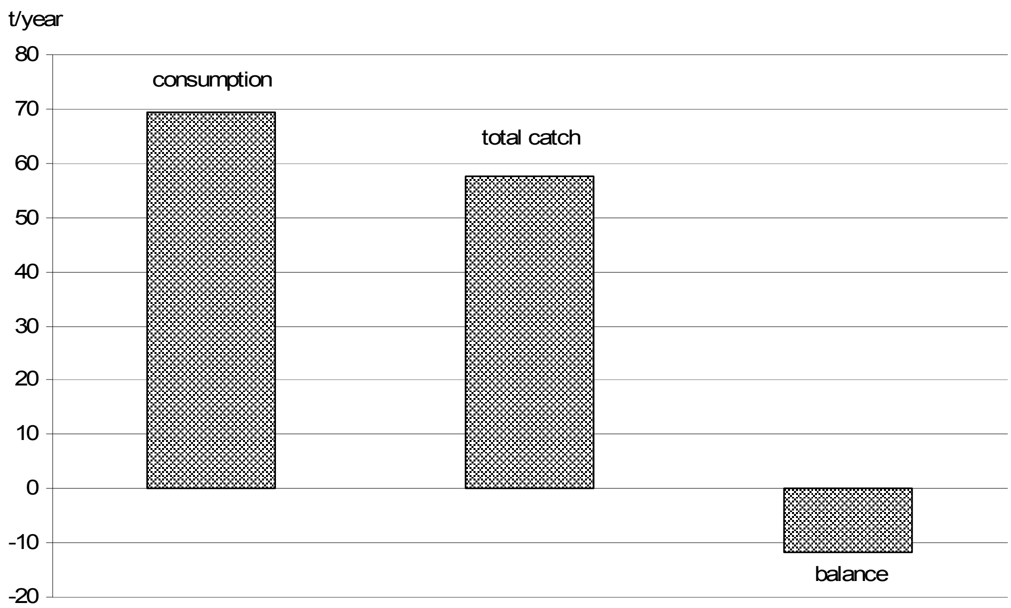

Figure 2.13: The relationship between total annual consumption and total catch of finfish in Niue.

Most reef fish is caught for home consumption, some is distributed among family members, and very little is sold at the local market. A high commercial interest in fishing trips was only expressed by fishers from Namakulu, Avatele and, to a lesser extent, Hikutavake. Highest commercial interest exists among fishers from Tuvalu based at Vaiea. The proportions of catch used for home consumption, non-monetary distribution and local sale are presented for each village in Table 2.6.

Table 2.6: Objectives of fishing trips (home consumption, non-monetary distribution, local sales) as expressed in % of responses by all fishers interviewed (n = 139) in Niue

Village	Home consumption	Non-monetary distribution	Local sales
Alofi North	76	24	0
Alofi South	53	39	8
Avatele	48	11	41
Hakapu	49	51	0
Hikutavake	47	34	20
Lakepa	62	38	0
Liku	68	32	0
Makefu	86	11	3
Mutalau	55	45	0
Namakulu	26	10	64
Tamakautoga	80	20	0
Toi	63	37	0
Tuapa	81	19	0
Vaiea	18	0	82

On average, male fishers catch double the amount of fish (133 kg/fisher/year) caught by female fishers (75 kg/fisher/year). However, Figure 2.14 shows that the annual productivity of both males and females and the relationship between both varies significantly between villages. For instance, there are no female fishers among the Tuvaluan population of Vaiea. Female fishers from Tuapa, Hikutavake and Alofi North catch significantly less than the national average. In contrast, female fishers from Avatele perform extremely well, and have on average slightly higher annual catches than males, as do females in Lakepa, Makefu and Toi. The annual catch rates of Niuean male fishers are highest in Alofi South, Vaiea, Avatele and Tamakautoga, i.e. in the southwest where sea conditions are usually best.

Similarly to the annual catch rates, male fishers' CPUEs are almost double those of female fishers (Figure 2.15). Again, the highest CPUEs largely occur in villages where catch rates were also highest, i.e. Alofi South, Avatele, Vaiea and, in addition, Hakapu. This observation also applies to female fishers. Female fishers from Avatele reach by far the highest CPUE.

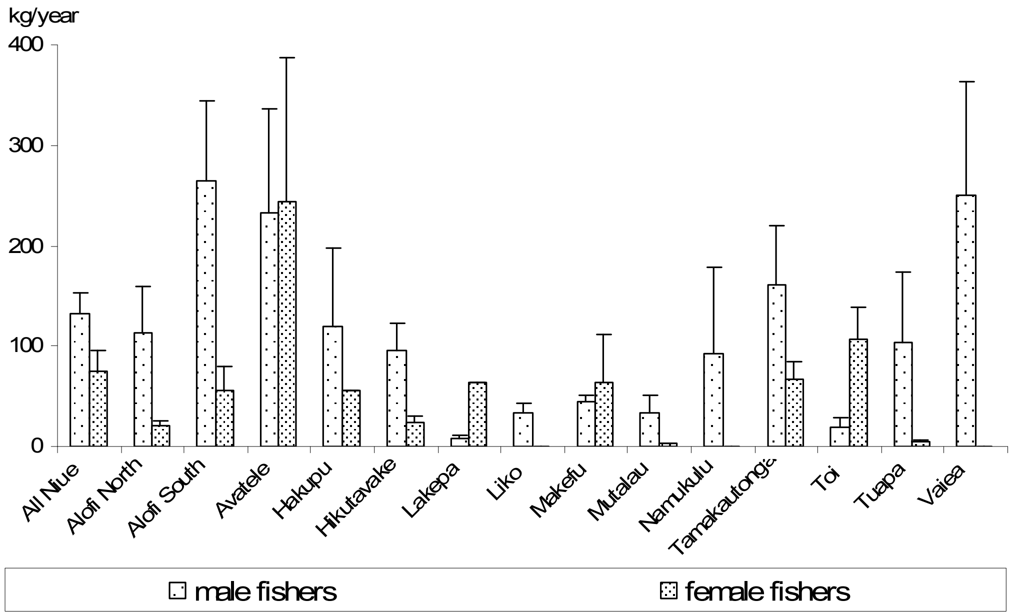

Figure 2.14: Average annual finfish catch (kg/year) of male and female fishers per village in Niue.
Based on reported catch only; bars represent standard error (+SE).

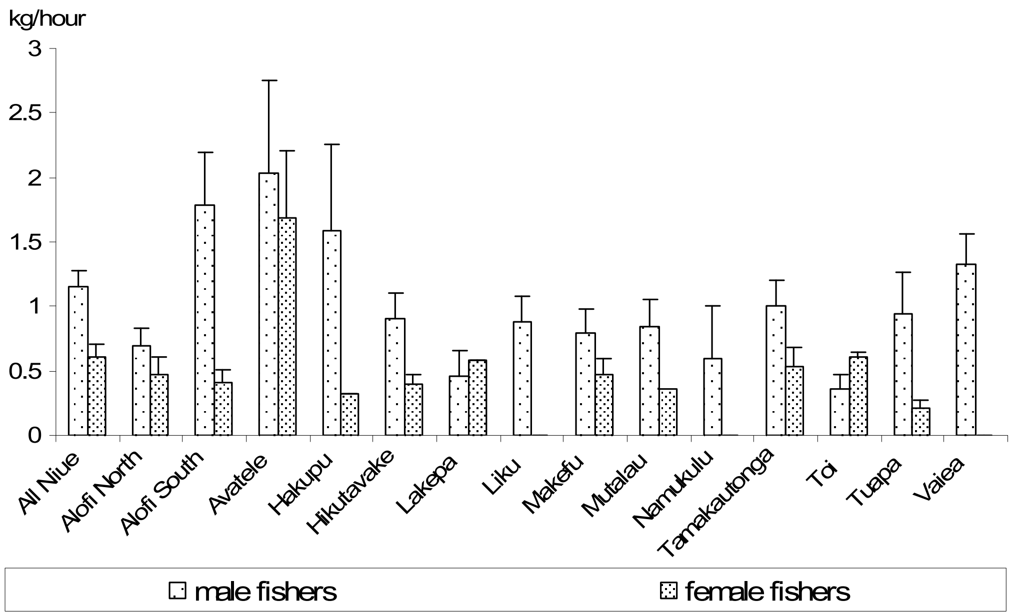

Figure 2.15: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by village in Niue.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Data on fish length by species reported suggest that basically fish of 10–25 cm are caught (Figure 2.16). Only species of Polynemidae and Lethrinidae are usually larger, with an average of about 30 cm length. In contrast, species of Sphyraenidae, Belonidae and Scaridae are smaller (12–18 cm). However, the reported average length of Scaridae, which is particularly small, should be used with care. Scaridae are rarely consumed and are not among the preferred target species. In fact Scaridae catches were only reported by a total of four fishers from two villages. While three fishers from Alofi South reported average catch sizes of about 11 cm, records from the only fisher from Liku are more than double this size (24 cm). The small and highly variable sample is reflected in the high standard error (Figure 2.16).

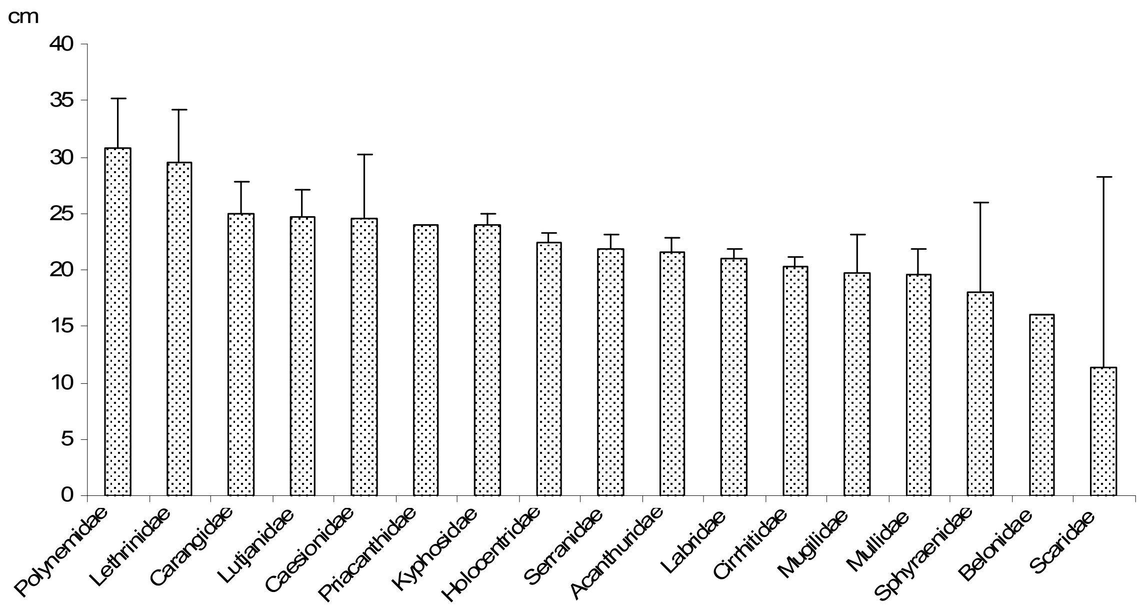

Figure 2.16: Average sizes (cm fork length) of fish caught by family in Niue.
Bars represent standard error (+SE).

2.2.5 Catch composition and volume – invertebrates

The total annual catch of invertebrates reported by fishers interviewed amounts to 11.6 t biomass (wet weight) with an almost equal contribution by male (5.6 t/year) and female (6 t/year) fishers. The Niuean invertebrate fishery is restricted to reef habitats. Most biomass is removed from the reeftop by gleaning (99.6%) while collection by free divers has only a marginal impact (0.4%).

Applying our survey data to the total number of possible invertebrate fishers in Niue, the total annual impact in biomass (wet weight) removed amounts to 35.3 t/year. Males contribute 16.6 t/year (47%; 0.1 t/year from diving for giant clams and lobsters; and 16.5 t/year from reeftop gleaning) and females account for 18.7 t/year (53%) of the total annual catch.

While 20 different vernacular names were reported for gleaning activities, divers target two species only, i.e. giant clams and lobsters (Figure 2.17).

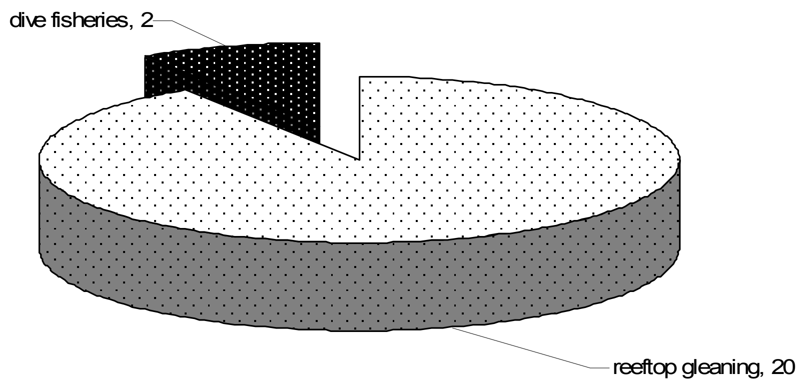

Figure 2.17: Number of vernacular names recorded for each invertebrate fishery in Niue.

Comparing the total annual harvest in biomass (wet weight) by species, it becomes apparent that fishing pressure focuses on one single group of species, *Turbo crassus* and *Turbo setosus* (*alili*) (Figure 2.18). By comparison, the amount of biomass harvested from lobsters, giant clams, crabs (*Scylla serrata*, *Grapsus albolineatus*), several gastropods (*Drupa* spp., *Patella flexuosa*) and the Vermetidae gastropod (*Serpulorbis* spp.) is small, and total reported annual catches of any of the other 12 species are marginal.

Regarding the proportional size distribution of reported *alili* (*Turbo crassus*, *T. setosus*) catches, the average size class of 6 cm accounts for ~60% of the catch (Figure 2.19). Larger specimens are less frequent, i.e. accounting for ~30% in the 8 cm and ~5% in the >8 cm size range, which is the maximum shell length of these species (8–8.5 cm) (Carpenter and Niem 1998). Thus, the reported average size distribution of *alili* catches does not show any negative impact from fishing.

Invertebrates are almost exclusively harvested for consumption. Only 0.5% of the total reported annual biomass collected is sold at the local market (in Alofi South), and another 18% may be either consumed or sold. In other words, the proportion of invertebrate biomass harvested that is used commercially probably does not exceed 10% of the total annual catch (Figure 2.20).

Although both males and females participate in reeftop gleaning, the average annual catch per fisher is higher for males than females. However, as shown in Figure 2.21, annual catches per fisher and the relationship between males' and females' annual catches vary considerably among villages.

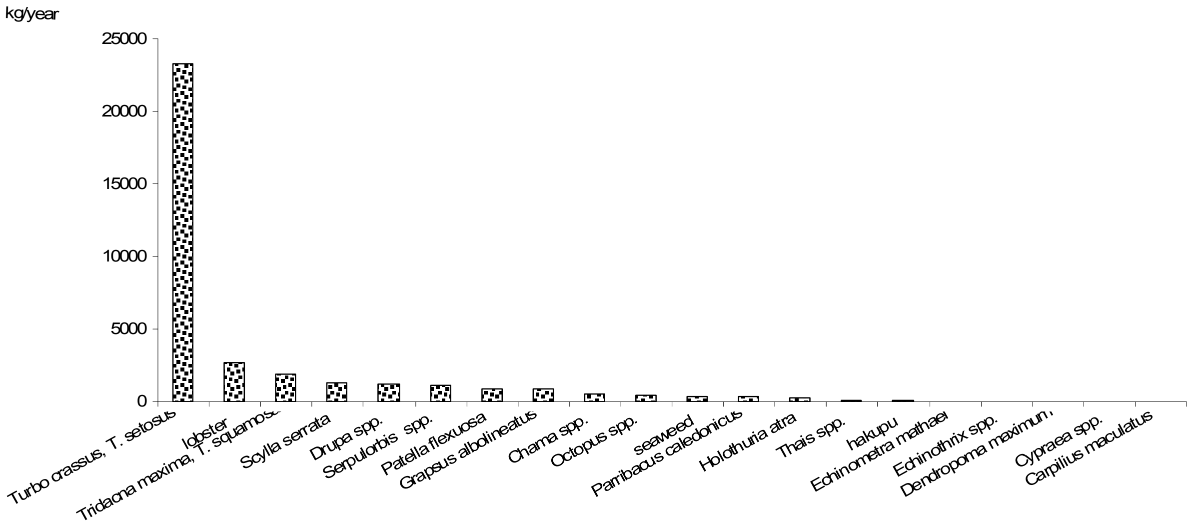

Figure 2.18: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Niue.

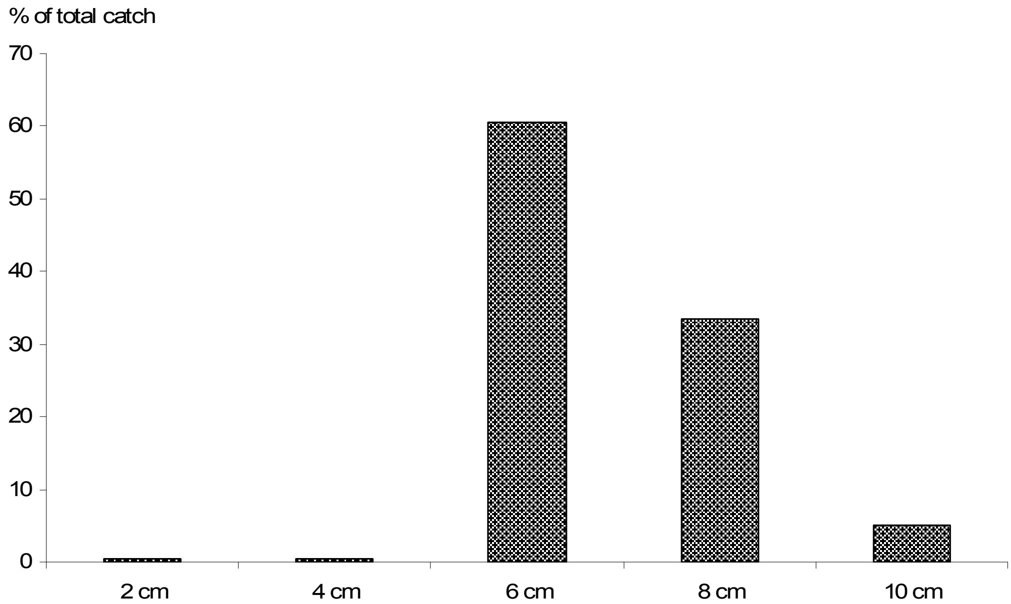

Figure 2.19: Size (cm) distribution of *alili* (*Turbo crassus*, *T. setosus*) from reported catches in Niue.

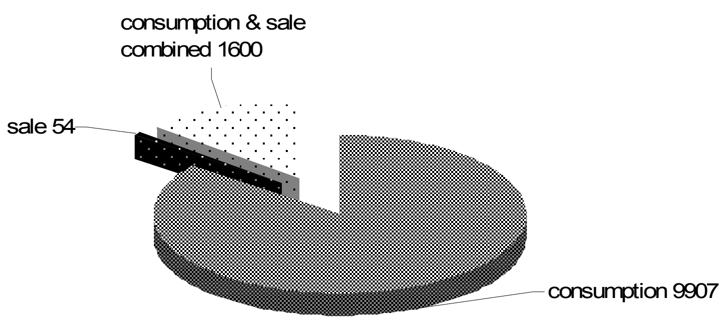

Figure 2.20: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Niue.

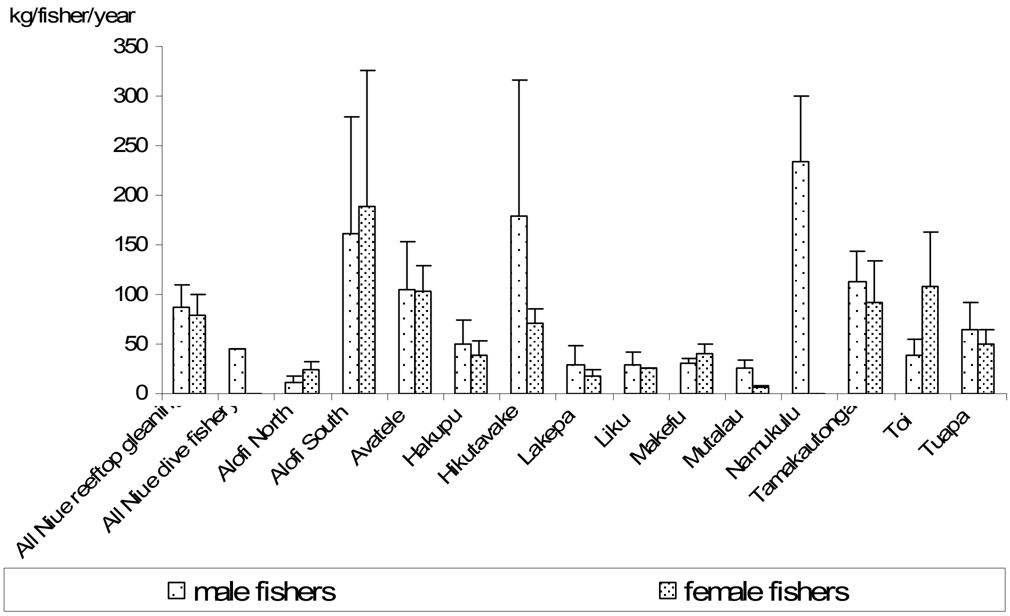

Figure 2.21: Average annual catch of invertebrates in biomass (kg wet weight/fisher/year) by male and female reeftop gleaners per village in Niue.
Bars represent standard error (+SE).

Fishing pressure

The estimation of current pressure that is imposed by reef fishing activities takes into account the total reef area available for finfish fisheries and the accessible reef-flat areas for invertebrate harvesting, i.e:

- Coastal reef slope (total reef area) 10.1 km^2
- Total coastal reef flat 5.0 km^2
- Accessible coastal reef flat 1.9 km^2

Although from a geomorphological point of view the Niuean reef falls into the 'coastal' category, its direct exposure to the open ocean suggests that in practice it should be considered more as an 'outer' reef. Also due to the steepness of the reef slope and the immediate pelagic influence, only the coastal reef flats are considered here as the available fishing ground for invertebrate collection. The survey also revealed that most of the country's coastline is subject to rough wind and sea conditions and therefore mostly not accessible to local fishers. By using the occurrence of the seasonally schooling *kaloama* (*Mulloidichthys flavolineatus*) as an indicator to distinguish between the heavily exposed and more sheltered coastline, the accessible coastal reef flat for invertebrate collection, which extends from Hikutavake in the northwest to Avatele in the southwest, only comprises 1.9 km^2.

The above argument to focus only on the accessible part of the coastal reef flat, as compared to the total coastal reef flat, applies only to invertebrate collection. In the case of finfish fisheries the total coastal reef-slope area applies, as finfish fishers can access more areas by using canoes propelled by paddles or motorised boats.

Recorded data from about 25% of all Niuean fishers suggest an annual finfish catch of 16 t. Extrapolating the recorded fishing patterns and productivity, the total annual impact of reef finfish fisheries is estimated at 57.6 t.

In the case of invertebrate harvesting, the recorded survey data from approximately 30% of all invertebrate fishers interviewed revealed a total annual catch of 11.6 t biomass (wet weight). Applying the recorded fishing patterns and catch rates to all invertebrate fishers, the total annual production is estimated at 35.3 t (biomass wet weight).

Comparison of finfish and invertebrate data shows a substantial difference in the number of target species that determine the catch composition. Finfish catches and thus impact are distributed over at least 10 species groups. Three fish groups including the vernacular names *nue*, *telekihi* and *ulihega* determine ~58% of the catch, and another 28% are accounted for by an additional eight fish groups (*ulutuki*, *meai*, *palu tikava*, *aheu*, *gatala*, *malau pokoahu*, *tafauli*, *fuafua*). The remaining 14% include 32 additional species groups.

In the case of invertebrates, 66% of the catch is determined by *alili* (*Turbo* spp.) only. In addition, seven other species (lobsters, *gege*, *paka*, *fofouli*, *ugako*, *matapihu*, *kamakama*) account for another 28%. The remaining 6% comprises 12 further species.

Table 2.7: Parameters used in assessing fishing pressure in Niue

Parameters	Habitat			
	Coastal reef-slope area	Coastal reef-flat area	Accessible coastal reef-flat area	Total fishing ground
Fishing ground area (km^2)	10.07	4.98	1.9	15.05
Total population				1780
Total number of finfish fishers	522	522		522
Total number of invertebrate fishers		425	425	425
Population density (people/km^2)				118
Density of finfish fishers (fishers/km^2)	52	105		35
Density of invertebrate fishers (fishers/km^2)		85	224	
Average annual finfish catch (kg/fisher/year)	115.2 (±16.5)	115.2 (±16.5)		
Average annual invertebrate catch (kg/fisher/year)		82.9 (±15.2)	82.9 (±15.2)	
Total subsistence finfish catch (t/year)				53.40
Total subsistence invertebrate catch (t/year)		35.27	35.27	
Total fishing pressure of subsistence finfish catches (t/km^2)				4
Total fishing pressure of subsistence invertebrate catches (t/km^2)		7.1	18.3	

Figures in brackets denote standard error.

Based on the assumptions made, the calculated finfish fishers' density of 52 per km² total reef area and invertebrate fisher densities of 85 per km² coastal reef-flat area and 224 per km^2 accessible reef-flat area are relatively high (Table 2.7). The average catches per fisher for finfish and for invertebrates correspond to the fact that fishers mainly fish for home consumption. Consequently these figures are relatively low. However, the relation between the total annual catch by all finfish fishers and the total coastal reef-slope area suggests a moderate finfish pressure of 4 t/km^2/year. In case of invertebrates, the available and the accessible coastal reef-flat areas are much smaller, and hence the current fishing pressure is even higher, reaching ~7 and 18 t/km^2/year respectively (Table 2.7).

In addition, the calculated invertebrate impact strongly focuses on one species group, i.e. *alili* (*Turbo* spp.), which accounts for about 66% of the total annual biomass removed (wet weight). Therefore, the fishing pressure imposed on Niue's total coastal reef flat by *alili* alone amounts to about 4.7 t/year/km^2 and on the accessible reef-flat area is 11.9 t/year/km^2.

2.2.5 Costs and revenues: finfish

Undoubtedly, a short-term assessment such as the CoFish socioeconomic survey cannot reveal all details; nevertheless it gives some insight into the nature and extent of Niue's reef fishery. Compared to other countries in the region, the question arises as to what extent fisheries in Niue are for subsistence purposes. Interviews revealed that a number of Niuean households do depend on fishing to supplement their family meals. However, the impression also emerged that taking the time to go fishing is valued as providing lifestyle quality and well-being. The recent establishment of a longline fishery and plant triggered serious concern about the capacity to compete and thus the future of local commercially oriented fishers. Although neither longlining nor the few local commercial fishers focus on reef resources, the opportunity was used to estimate the financial viability of local fisheries operations. A comparison was made among motorised boat fishing, fishing from canoes propelled by paddles and fishing done by walking on the reef flat, in order to find out whether Niuean fishers fish more for subsistence purposes or for leisure.

Data were collected from several fishers regarding investment costs (transport, fishing gear), operation costs (fuel, oil, etc.) and revenues (average catch, retail prices). A minimum wage of NZD 5.50 per hour was applied taking into account the average duration of a fishing trip. Costs per kg of fish caught averaged over a period of one year and determination of profit margins were calculated using the 'present value' approach[5]. An interest rate of 15% was applied.

The case studies (Appendix 2.6) show that fishing with motorised boat transport is not profitable due to fuel costs and the investment costs for boats and outboard engines. Depending on the frequency of the fishing trips and the annual productivity, the costs of an average kg of catch were found to range between NZD 5.44–12.12. Given an average retail price of NZD 8 per kg fish, the profit margin is hardly ever reached.

Fishing from canoes involves much lower investment costs, but at the same time also provides smaller catches per trip. The costs of an average kg of catch range from NZD 1.42–4.75. In the case of canoe fishing, labour is the most decisive cost factor.

Given the almost marginal investment cost if fishing with a rod by walking on the reeftop, labour becomes a crucial factor, in particular regarding the low productivity of this type of fishing. In fact, if we apply the minimum wage, production costs were found to be extremely high, ranging between NZD 7.05–11.22 per kg of catch, and hardly meeting the profit margin.

These results allow the following conclusions:

- Motorised boat fishers hardly cover their costs and hence pursue fishing for lifestyle reasons rather than profit.

[5] Determines the present value of an investment over a period of time in the future.

- Fishers who cast their rods by walking on the reeftop are inefficient from a productivity point of view, which suggests that fishing is a lifestyle and leisure occupation rather than a necessity. This also applies regardless of the fact that local people may not consider that time spent fishing has a monetary cost.

- Canoe fishers are the most efficient and, in economic terms, pursue the most viable operation. However, if we consider the restrictions imposed by sea and weather conditions that often do not permit canoe fishing, and the relatively low average catch that can be landed with a single-handed canoe, most canoe fishing is conducted for lifestyle and leisure values rather than as a reliable source of food or income.

These results and conclusions must also be seen in the light of the particular Niuean situation, as costs and prices are controlled and determined on political or social grounds rather than in response to a free-market economy. Consequently, production costs and profit margins are highly susceptible to planned changes and may be used to manipulate the supply and demand of seafood. However, even manipulated cost and price mechanisms cannot alter the fact that the maximum market potential for seafood is limited by the country's small population and the lack of export opportunities.

At present, by-catch from the newly established longline fishing operation and plant has started to enter and is likely to continue supplying the local market. By-catch is a cost factor for the longline industry and also poses a disposal problem. Thus, prices for by-catch at the local market are much below the generally established and accepted price of NZD 8 per kg pelagic fish. Respondents from the household survey appreciated the opportunity to purchase much cheaper pelagic fish and reported that they have eaten more fresh fish lately as a result. Local male fishers, particularly those who fish with motorised boats, fear the competition, as they cannot meet production at the lower market price given their comparatively small scale of production and fuel cost.

2.2.6 Discussion and conclusions: socioeconomics

- The potential of the Niuean reef fisheries is limited due to the narrowness of the coastline, the exposure to strong winds and rough seas, particularly on the eastern side of the island, the lack of reef flats in most of the south and eastern side, and detrimental cyclone impacts.

- The small size and population of Niue makes economic development difficult and explains the county's external dependency, particularly on New Zealand. The high orientation to a western lifestyle that includes high living costs, frequent travel, and a high education level, suggests the existence of alternative income opportunities and thus a low dependency on reef fisheries for income and nutrition.

- Nevertheless, reef fishing is part of the Niuean lifestyle, underpinning the strong bond between the native Polynesian people and the sea. People in Niue go fishing not to catch as many fish as possible, nor to make money, but for pleasure and well being. The frequent exchange of seafood on a non-monetary basis further supports the argument that reef fishing in Niue has a traditional value.

- There is no official export of reef fish, although a certain amount of seafood is exported as gifts for relatives and friends overseas (estimated at ~5 t/year). Hence the catch volume of reef fisheries is limited to the country's own demand and needs. The average fresh fish consumption of 31.1 kg/person/year (of both reef and pelagic fish) reported by the households is relatively low given a regional average of 35 kg/person/year, and much lower than previously estimated (Dalzell *et al.* 1993, SPC 2000). However, it is relatively high when taking into account the possible amount of finfish (pelagic) that is consumed via restaurants, snacks and functions. If we add this, the average consumption may increase to 66.1 kg/person/year and thus exceed the regional and most of the previous estimates. Nevertheless, it appears that the previous figure of 118.9 kg/person/year (SPC 2000) substantially overestimates the Niuean fish consumption.

- Our survey data suggest a total annual reef (and canoe) finfish catch of 53.4 t. According to the consumption figures of our survey, this catch meets about 77% of the consumption needs of Niue's total island population (69.3 t/year, excluding the pelagic fish consumption associated with restaurants, snacks, feasts and ceremonies). In addition, there is an estimated annual production of 76.2 t from mid-water and trolling fishing (SPC 2005), bringing the total annual finfish catch to 129.6 t. An estimated 5 t/year of fish and reef resources is shipped as presents for relatives and friends living overseas (Gillet and Lightfoot 2001).

- Comparisons of fishing costs for motorised, canoe and walking fishing operations showed that fishing operations that use motorised boats are not economically viable. Canoe fishers are the most efficient in economic terms but these boats cannot always access the fishing grounds and thus their productivity is irregular. Fishers who walk on the reef are very inefficient in economic terms because of the long time spent fishing and the low average catch per trip. These results further support the conclusion that reef fishing in Niue is performed for lifestyle and quality of life rather than as a necessity to provide nutrition and/or income.

- The potential for invertebrate fisheries is limited to one fishery, i.e. reef exploitation, and is restricted by the available, exploitable and accessible reef area. These limiting circumstances explain why most of the annual biomass is removed by gleaning the reeftop rather than diving for giant clams and lobsters.

- About 20 different vernacular names were reported for invertebrate species frequently targeted by reef gleaners. Total biomass removed annually was estimated at 35.3 t and most of this biomass (23.3 t/year wet weight) is accounted for by *alili* (*Turbo crassus* and *T. setosus*). Species such as lobsters, giant clams, crabs and selected gastropods contribute another 9.9 t/year.

- Although consumption patterns suggest that higher fresh fish consumption is related to accessible fishing grounds, our survey results do not show a clear pattern of high fishing and consumption in the western part and low fishing and consumption in the eastern part of the country. This may be explained by the fact that customary tenure rights are overruled by the tight social network among all Niueans and thus allow a *de facto* 'free choice' of fishing grounds.

- However, customary tenure and the traditional Sunday ban were the main reasons for the reported disputes between the Niueans and the Tuvaluan immigrants. Tuvaluan people have no access to reef flats for gleaning. The few Tuvaluan families that remain on the island have adapted to these restrictions by using motorised boats to focus on mid- and open-water fishing. Except for the fact that Tuvaluan females do not engage in any fishing and that fishing is almost exclusively done from motorised boats, Tuvaluan fishing activities were not found to vary significantly from Niuean.

- Fishing pressure was determined by applying two different approaches. In the case of finfish fisheries the impact was estimated over the total available coastal reef-slope area (~10.1 km^2); for invertebrates, the impact was estimated over the total coastal reef-flat area (~5 km^2) as compared to the accessible reef-flat area (~1.9 km^2). The accessible reef-flat area was determined by using the locations where seasonal schooling of *kaloama* occurs as an indicator of sheltered areas. Generally, finfish fisher and invertebrate fisher densities are relatively high. The impact of finfish fisheries is moderate with ~4 t/km^2/year on the total reef area or fishing ground. Also the invertebrate fishing pressure imposed on the total coastal reef-flat area and the 1.9 km^2 of accessible reef flats only is surprisingly high: ~7 and 18.3 t/km^2/year respectively.

- Survey results found that, although reef fisheries may not play an important role in terms of food and income, they do have a significant cultural value. CPUE and annual productivity are rather low; however, due to the limited accessible reef area, finfish fishers and invertebrate fishers may cause severe problems in some areas and for certain species that are susceptible to degradation. Target species that determine the bulk of annual catches and that may therefore be detrimentally affected by current and future fishing pressure include: *nue, telekihi* and *ulihega* for finfish fisheries and *alili* for invertebrate fisheries. Monitoring of these species is recommended in the most accessible and thus most targeted areas, i.e. the western coastline between Hikutavake in the north and Avatele in the south.

- The newly established longline fishery may have several impacts on coastal fisheries. If substantial by-catch from longline operations enters the local market, the local motorised-boat fishers, who may already operate uneconomically, will no longer be able to compete with the significantly lower market prices. The Niuean population is likely to continue to prefer certain deep-bottom and reef fish species and may only accept or buy selected by-catch species, so the demand for deep-bottom and reef fish will not necessarily decrease. At the time of the survey, by-catch from the longline fishery was being sold for cheaper prices on the local market. This involves the risk that motorised-boat (and to some extent also canoe) fishers are likely to switch to deep-bottom fishing. This development may impose detrimental pressure on a fragile resource. An investigation is therefore required to determine the sustainable exploitation level of Niue's deep-bottom fish resources. From the consumer point of view, it is recommended that local fish prices are lowered to avoid this problem. This may also trigger an increase in the local fish consumption rate, and decrease dependency on other, imported protein sources. If we compare present prices levels (Figure 2.22), reef fish is by far the most expensive protein source, while even pelagic fish is more expensive than fresh pig and frozen chicken.

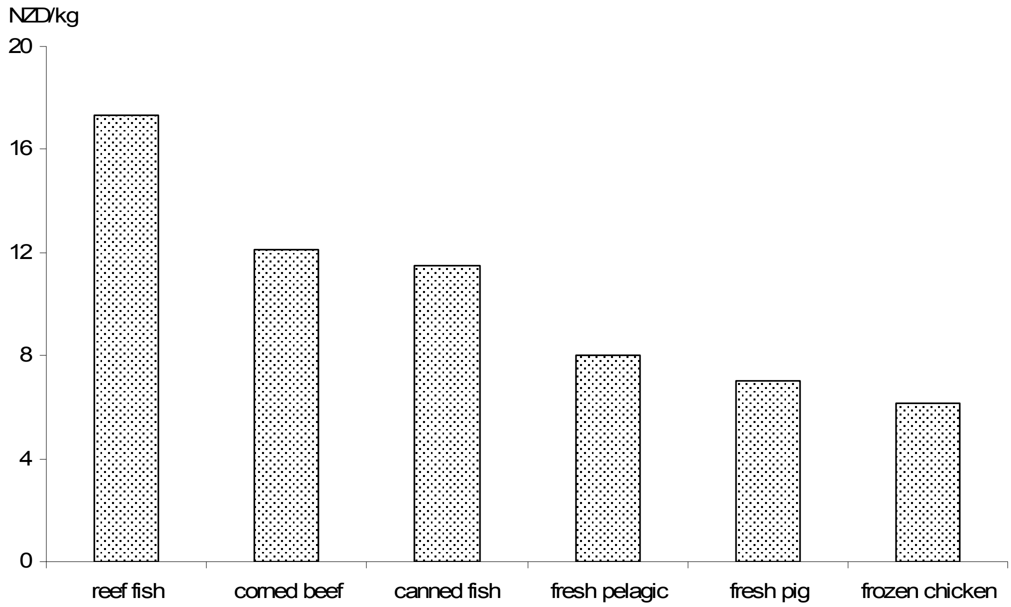

Figure 2.22: Local prices in NZD per kg for selected protein sources in comparison to reef and pelagic fish (average prices applied) in Niue.

2.3 Finfish resource surveys

Finfish resources and associated habitats were assessed between 21 May and 10 June 2005 from a total of 50 transects, effectively covering 75% of Niue's shore (Figure 2.23 and Appendix 3.1 for transect locations and coordinates). Survey design consisted of six transects per site (Avatele, Alofi South, Tamakautoga, Tuapa, Namakulu and Hikutavake), including the MPA at Makefu and the fish plant at Alofi South. Additional transects were conducted in Alofi North (two transects), Makefu (four transects), Mutalau (three transects), Lakepa (three transects) and Liku (two transects). The southeast coast of the island could not be surveyed due to unfavourable weather conditions (Figure 2.24).

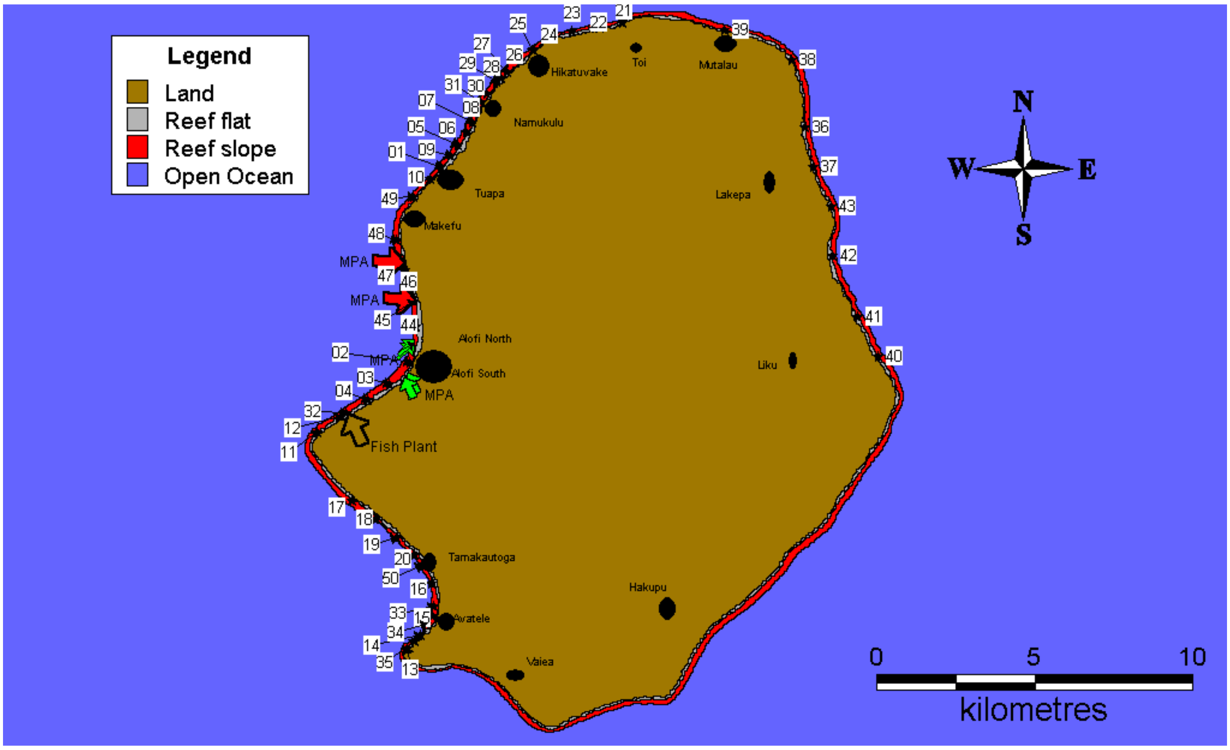

Figure 2.23: Habitat types and transect locations for finfish assessment in Niue.

2.3.1 Finfish assessment results

The reef around Niue was composed of coral slab in most parts (Figure 2.25). It was strongly dominated by hard bottom (88% average cover) while live coral only represented 8% of total substrate (Table 2.8). This type of environment generally favours herbivorous fish that can graze on small algae growing on bare rocks.

Table 2.8: Primary finfish habitat and resource parameters recorded in Niue (average values ±SE)

Parameters	Niue
Number of transects	50
Total habitat area (km^2)	6 (3-20)
Depth (m)	0.7±0.1
Soft bottom (% cover)	2.4 ±1.0
Rubble & boulders (% cover)	88.1 ±1.3
Hard bottom (% cover)	8.1 ±0.8
Live coral (% cover)	0.6 ±0.2
Soft coral (% cover)	38
Biodiversity (species/transect)	0.45 ±0.03
Density (fish/m^2)	15.78 ±0.3
Size (cm FL)	51.1 ±0.8
Size ratio (%)	61.1 ±5.6

A total of 23 families, 59 genera, 141 species and 29,101 fish were recorded in the 50 transects (See Appendix 3.2 for list of species.). Only data on the 15 regionally most dominant commercial families are presented below, representing 13 families, 43 genera, 119 species and 27,034 individuals for Niue (The remaining two dominant families Nemipteridae and Siganidae were not sighted in Niue.).

Figure 2.24: Strong swell is common in Niue.

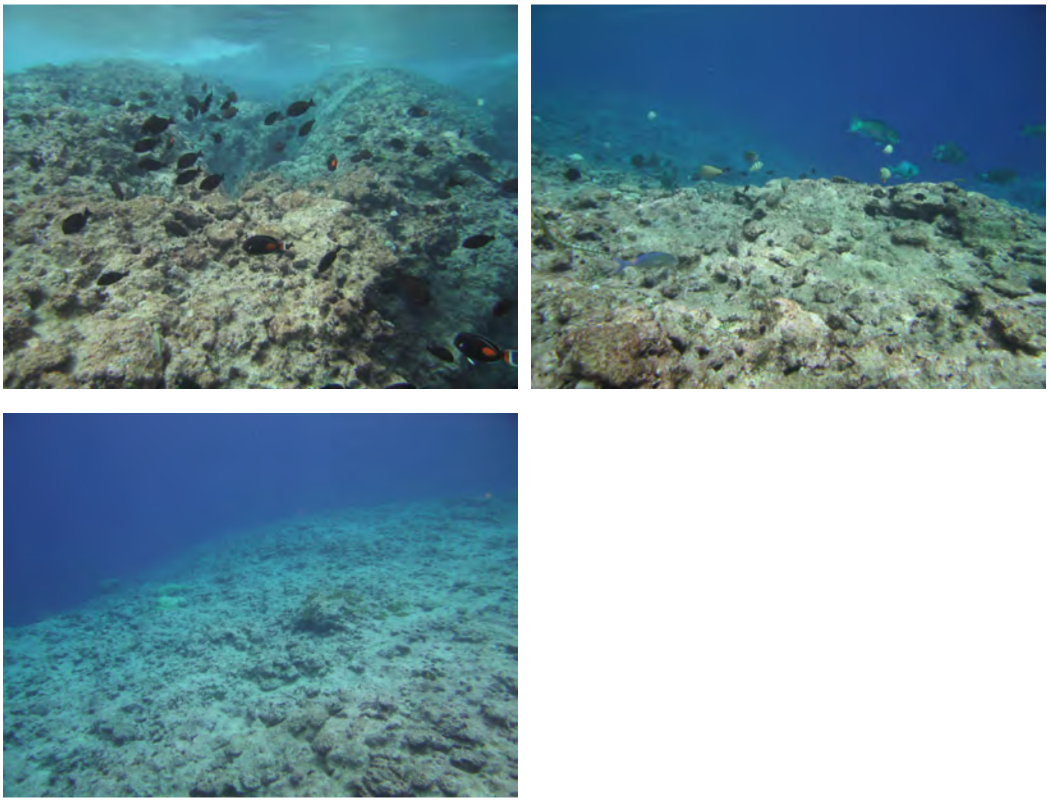

Figure 2.25: Reef around Niue was mostly represented by coral slab, which favours the development of small, herbivorous surgeonfish and parrotfish, which can graze small algae growing on bare rock substrate.

Outer-reef environment

The reef fish assemblage was strongly numerically dominated by herbivorous fish, mostly Acanthuridae (surgeonfish) and Balistidae (triggerfish) and, to a lesser extent, Scaridae (parrotfish) (Figure 2.27). Biomass was dominated by Acanthuridae and Scaridae. These two families of herbivores were represented by the following species that were most important in terms of density and biomass (Table 2.9): *Ctenochaetus striatus, Acanthurus blochii, A. nigricans, A. achilles, A. lineatus, Scarus forsteni*, and *Chlorurus frontalis.* Some species, such as the steephead parrotfish (*Chlorurus microrhinos*), transited between flat and slope habitats, extending their range to feed on the reef flat at high tide (Figure 2.26).

Table 2.9: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Niue

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.13	11.6
	Acanthurus blochii	Ringtail surgeonfish	0.07	4.6
	Acanthurus nigricans	Whitecheek surgeonfish	0.04	4.0
	Acanthurus lineatus	Striped surgeonfish	0.02	5.0
	Acanthurus achilles	Achille's tang	0.02	3.5
	Naso lituratus	Orangespine unicornfish	0.01	2.8
	Acanthurus olivaceus	Orangeband surgeonfish	0.01	0.9
Balistidae	*Melichthys vidua*	Pinktail triggerfish	0.02	1.7
	Melichthys niger	Black triggerfish	0.01	1.7
Scaridae	*Scarus forsteni*	Rainbow parrotfish	0.008	3.1
	Chlorurus frontalis	Tan-faced parrotfish	0.007	2.8

Figure 2.26: Large groups of steephead parrotfish (*Chlorurus microrhinos*) are frequently seen grazing reef flats at high tide in very shallow water. Such a spectacle can only be observed in areas where fishing pressure is very low – Niue.

The dominant herbivorous surgeonfish show their typical association with hard substrate areas of clear and seaward reefs from the lower surge zone. These fish occur in fact over coral, rock, pavement or rubble substrates, where they feed on filamentous algae, blue-green algae and diatoms, as well as on various small invertebrates. Similarly, triggerfish were observed in large numbers in seaward reefs. Unlike surgeonfish, triggerfish diets consist mainly of detritus with addition of crustaceans. The outer-reef environment provides suitable conditions and habitat characteristics for the dominance of both large groups of surgeonfish and triggerfish around the island.

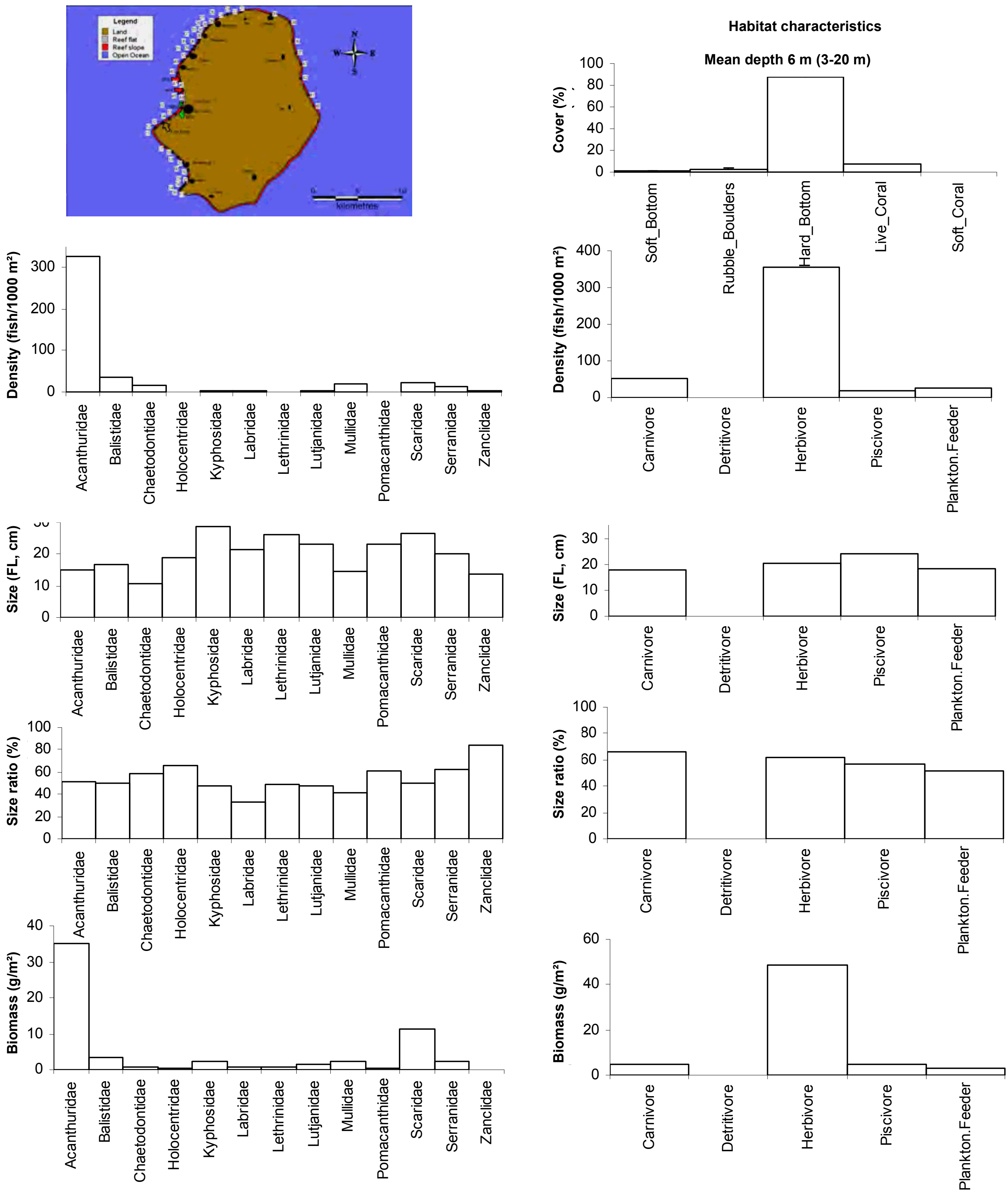

Figure 2.27: Profile of finfish resources in the outer-reef environment of Niue.
FL = fork length.

Spatial variability – Locating biodiversity refuges

Analysis of spatial patterns revealed extremely low live-coral cover (<2 %) on most parts of the north and west coasts of Niue (Figure 2.28), reflecting the path of Cyclone Heta that hit the island in January 2004 from a north/northwest direction. Only the east coast with up to 29% live-coral cover, the sheltered bay of Tamakautoga with up to 40% cover, and a tiny reef sheltered behind a rocky point near Tuapa with 10% cover escaped severe impact from the cyclone. However, the coral habitat was very different in these three coral-rich zones: encrusting corals dominated the reefs on the east coast creating a habitat of low complexity, while mostly tabular and branching corals dominated the reefs in Tamakautoga and near Tuapa creating high complexity (Figure 2.28).

Statistical analysis of fish densities at species level revealed two types of fish communities around Niue (Figure 2.28). The first type was localised in Tamakautoga and Tuapa, where habitat was characterised by highly complex, tabular and branching coral reefs. The second type of fish community was found in low-complexity habitats all around the island, suggesting that the encrusting coral reefs of the east coast provide no better habitat for finfish than the bare rock substrate of the cyclone-impacted west coast reefs. Apart from Tamakautoga and Tuapa, the analysis indicated also that the finfish resources were similarly poor on the east, north and cyclone-impacted west coasts of Niue, suggesting that the exposed and supposedly less fished east coast cannot constitute a fish reservoir that could guarantee the replenishment of the finfish resources of the sheltered, supposedly more fished west coast.

While the east coast is unlikely to act as a refuge for finfish, further analysis of the spatial structure of fish assemblage in Niue revealed that both the bay of Avatele/Tamakautoga and the reef near Tuapa could be considered fish reservoirs. In fact, not only did they display greater biodiversity, density and biomass compared to the other sites, but a clear trend of decreasing biodiversity, density and biomass could be observed when moving away from Avatele/Tamakautoga bay (Figure 2.28). This large and coral-rich area may act as a source from which resources of other reefs can reconstitute and recover after major environmental stresses such as cyclones. The reef of Tuapa also displayed a rich resource but the area was probably too small to act as a source for the replenishment of adjacent reefs. However, reefs such as Tuapa may also play an important role of habitat relay during the recovery of Niuean reef fish resources from Cyclone Heta. Finally, it is worth noting than even the best and most preserved sites in Niue displayed a much poorer resource than the regional average, suggesting that the poor quality of the finfish resource in Niue may largely be structural rather than solely induced by the cyclone impact.

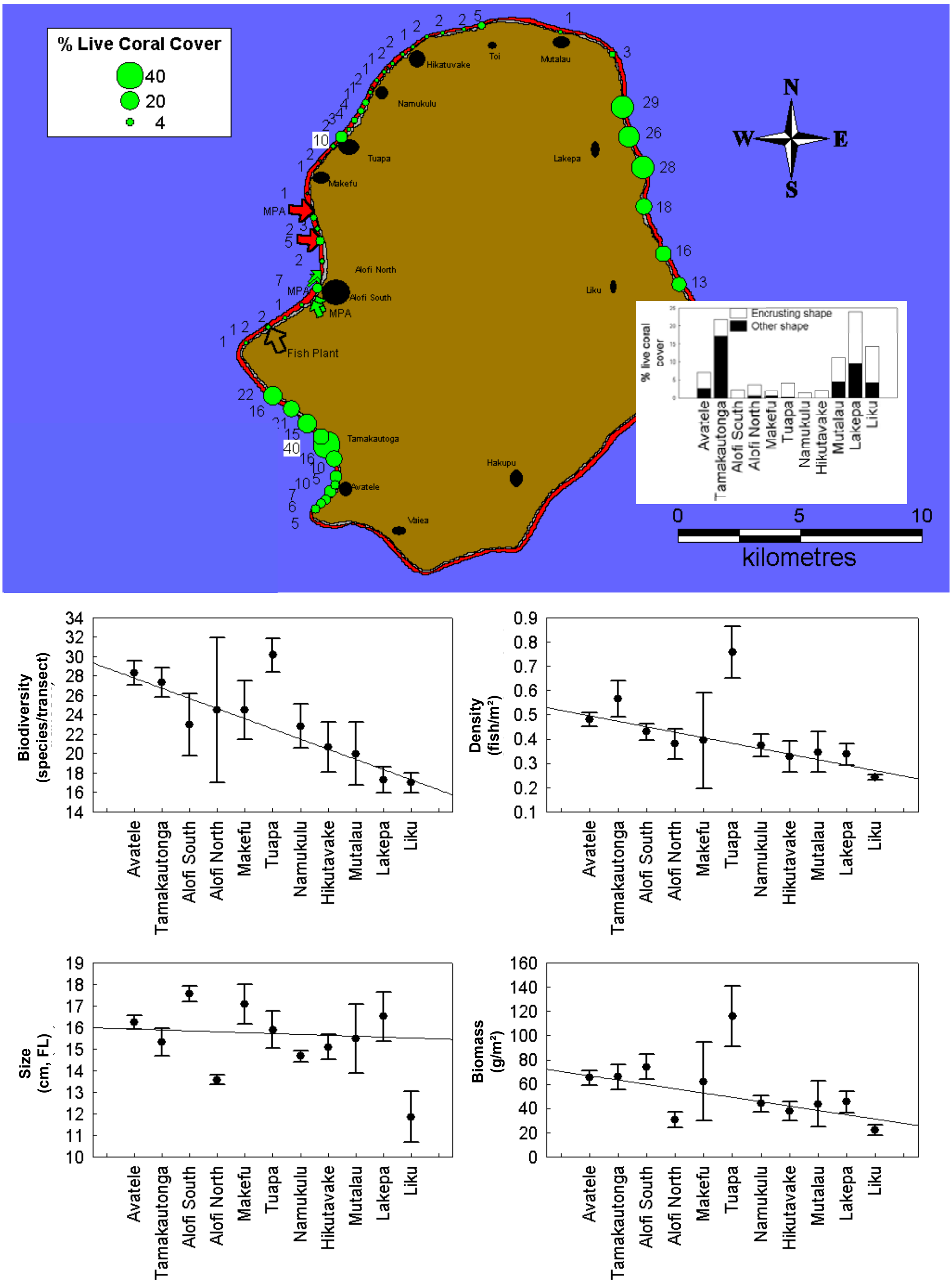

Figure 2.28: Spatial variability of finfish resource and live coral cover in Niue.
The southeast coast was not included in the survey.

Temporal variability – monitoring Namoui MPA

The Namoui marine protected area near Makefu and a control site, Avatele, were surveyed by UVC in November 1998 (Protection status was already enforced.), in February 2004 (immediately post Cyclone Heta), and in May – June 2005 (this present study – over one year after the cyclone). Sampling design did not specifically aim at evaluating the effect of protection, resulting in unbalanced, poorly replicated data collected at different seasons (Table 2.10). For instance, only two transects were conducted in the MPA during the current survey. This is understandable as our study aimed at evaluating the reef fish resource of the entire surface of Niue, and satellite information indicated that the MPA only represented 2% (~1.3 km) of the total coastline of Niue (~67 km). Consequently, the information given below should be viewed with caution.

Table 2.10: Monitoring of the marine protected area of Makefu and Avatele control site by underwater visual census (UVC)

Year	Site	Number of UVC transects
November 1998	MPA - Namoui	16
	Control - Avatele	8
February 2004	MPA - Namoui	6
	Control - Avatele	3
May-June 2005	MPA - Namoui	2
	Control - Avatele	6

Live-coral cover dramatically dropped at both sites from 40–50% in 1998 to less than 5% in 2004 (Figure 2.29), which clearly quantifies the strong impact of Cyclone Heta on the coral reefs of Niue. In 2005, more than one year after the impact, coral cover remained very low, with, however, signs of slight recovery in Avatele, where coral cover increased from 2 to 7% in one year. Furthermore, the presence of recently recruited coral colonies was recorded all around the island, indicating that a general recovery of the reef was underway.

In contrast to the observations on live-coral, fish biodiversity, density and biomass were similar or smaller before the cyclone in 1998, when the coral was healthy, to values in 2004 and 2005, after the destruction of habitat by Cyclone Heta, further suggesting that the poor quality of Niuean reef fish resources was largely structural, with only little negative effects from Cyclone Heta. Furthermore, over the three years of comparisons, fish biodiversity, density and biomass were systematically higher in the control site, with absolutely no obvious net effect of protection on the status of the finfish resource in Namoui over a period of seven years (Figure 2.29). This suggests that: 1) the cyclone erased the benefits, if any, of the protection status, and/or 2) protection was not fully enforced, and/or 3) fishing pressure was so low on Niuean reef fish that protection had no effect on the resource and/or 4) the Namoui MPA is too small to generate any measurable effect on the resource.

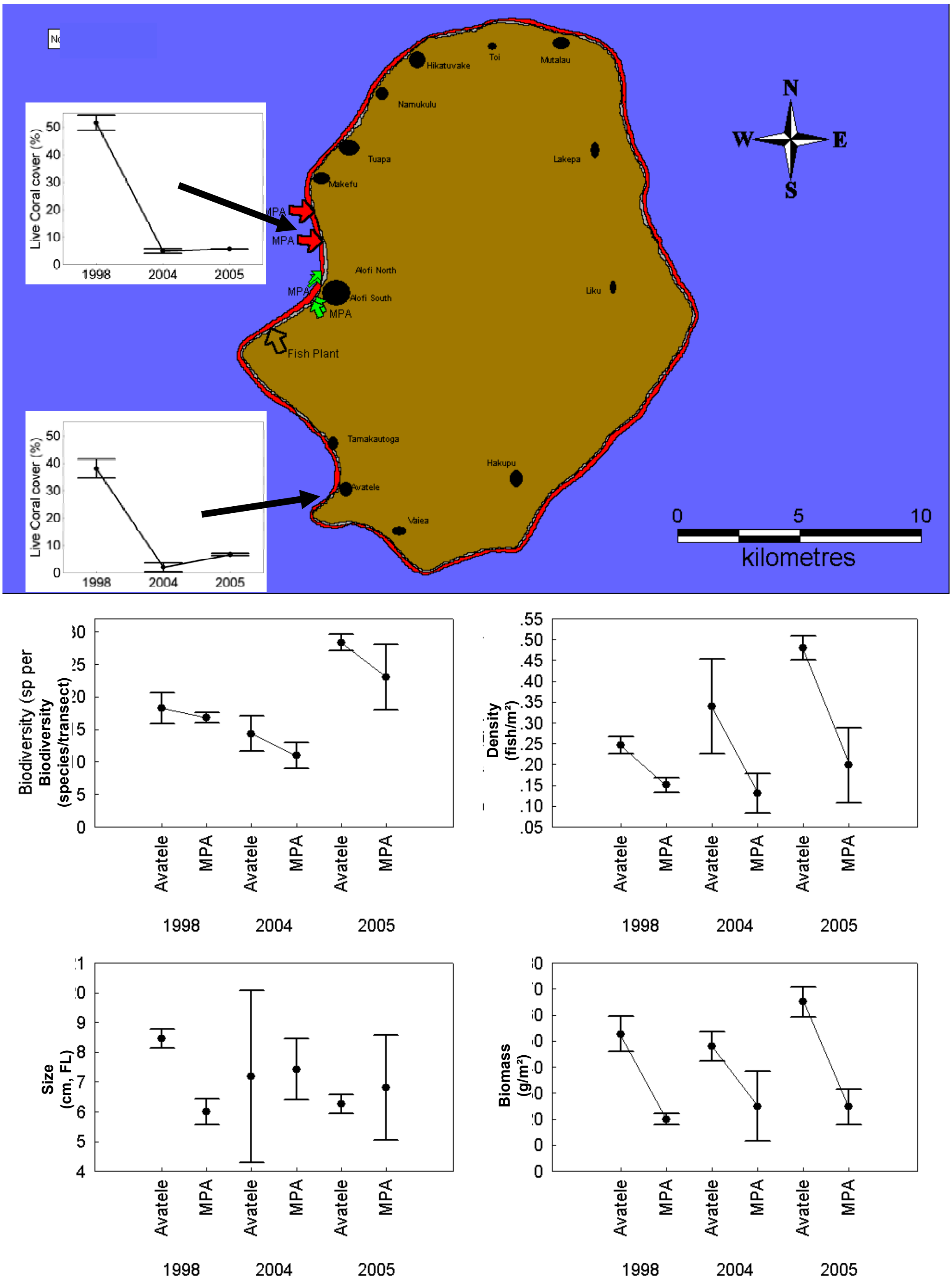

Figure 2.29: Temporal variability of finfish resources and live-coral cover in Niue.

Impact at the fish processing plant

At the request of the Fisheries Department, an assessment was conducted in front of the fish processing plant. The zone of possible impact is a little cove (50–100 m coastline) with a small (~15 cm diameter) pipe by which effluents were evacuated from the plant (Figure 2.30). Due to the small size of the area, only one transect was conducted at the impact site.

The reef and finfish assemblage in front of the fish processing plant contrasted with the rest of the island. There was an unusually large amount of turf and herbivorous species in front of the plant (Figure 2.30). The site seemed to be under a strong nutrient influence, apparent as a large biomass of finfish. This may be an impact of the effluent of the fish plant or a natural characteristic of the site (Two underground springs are flowing right there.). In fact, other transects around Niue also displayed a high amount of turf. Without further information on the effluent itself (biochemical analyses of effluent and seawater) and without any information on how the site was before the plant started, no strong conclusion can be drawn. In any case, if there is an impact, this is very localised and unlikely to spread elsewhere (cliff, steep slope directly leading to open-deep ocean). In that regard, the fish processing plant should not pose a major threat to the reef environment of Niue. However, a major health risk for swimmers or divers is always possible near industrial waste effluents. Biochemical analyses are required to assess this risk. It would be a good idea to set up a 'no swimming area' around the plant as a preventive action until water analyses can be done.

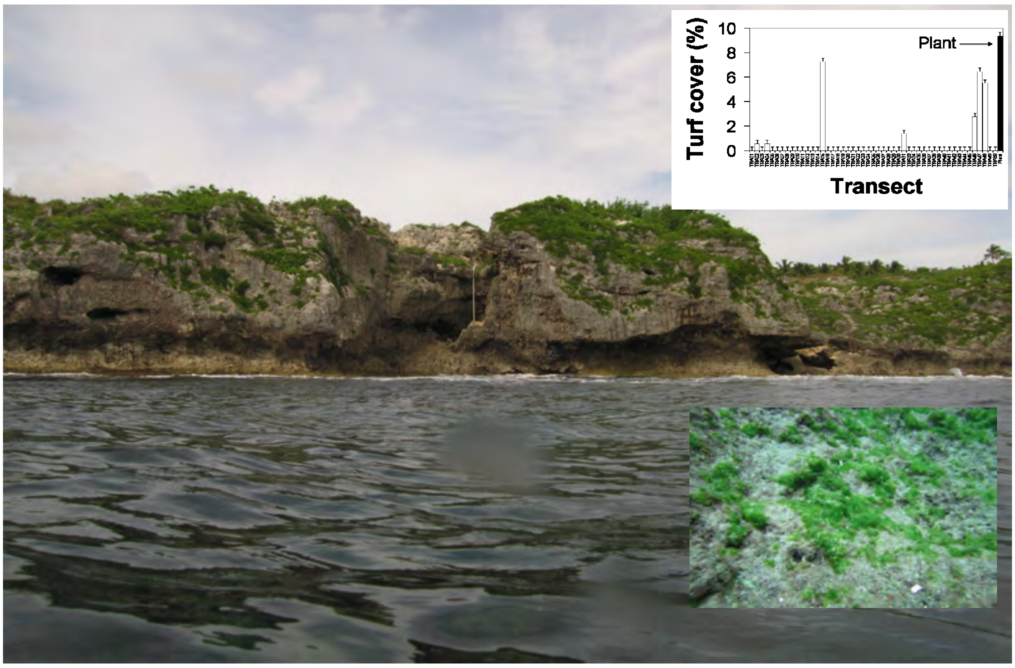

Figure 2.30: Underwater habitat in front of the fish processing plant in Niue displays an unusual amount of turf; further studies are, however, needed to determine whether the cause is natural or industrial.

2.3.2 Discussion and conclusions: finfish resources

The finfish resource assessment indicates that the quality of finfish resources in Niue is quite poor. Preliminary results suggest that this scarcity of finfish may be natural rather than induced by fishing, possibly due to the lack of lagoon and the remoteness and small size of the island, as well as the frequency of cyclones. Both temporal and spatial patterns indicated that Cyclone Heta had a strong negative impact on the coral habitat but impact was not yet apparent on the reef finfish resources, perhaps due to a time lag in the response of the finfish community. While Cyclone Heta destroyed most of the coral habitat in Niue, there was evidence of a biodiversity refuge in the bay of Tamakautoga.

At the time of the survey, fish assemblage at the Namoui MPA was as poor as anywhere else around the island. Finally, the reef near the fish processing plant seemed under a strong nutrient influence with an unusual amount of turf. Unfortunately, our data were too limited to conclude whether the cause was natural or industrial, or what were the effects and the risks posed by this apparent pollution.

2.4 Invertebrate resource surveys

The diversity and abundance of invertebrate species at Niue were independently determined using a range of survey techniques (Table 2.11): broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 2.31) and finer-scale assessment of specific reef and benthic habitats (Figure 2.32).

The main objective of the broad-scale assessment was to describe the distribution pattern of invertebrates (rareness/commonness, patchiness) at large scale and, importantly, to identify target areas for further, fine-scale assessment. Then fine-scale assessment was conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

Table 2.11: Number of stations and replicates completed at Niue

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	9	54 transects
Reef-benthos transects (RBt)	3	18 (2 m width) transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	10 RFs 9 RFs_w	110 search periods
Sea cucumber day searches (Ds)	0	0 search period
Sea cucumber night searches (Ns)	0	0 search period

RFs_w = reef-front search by walking.

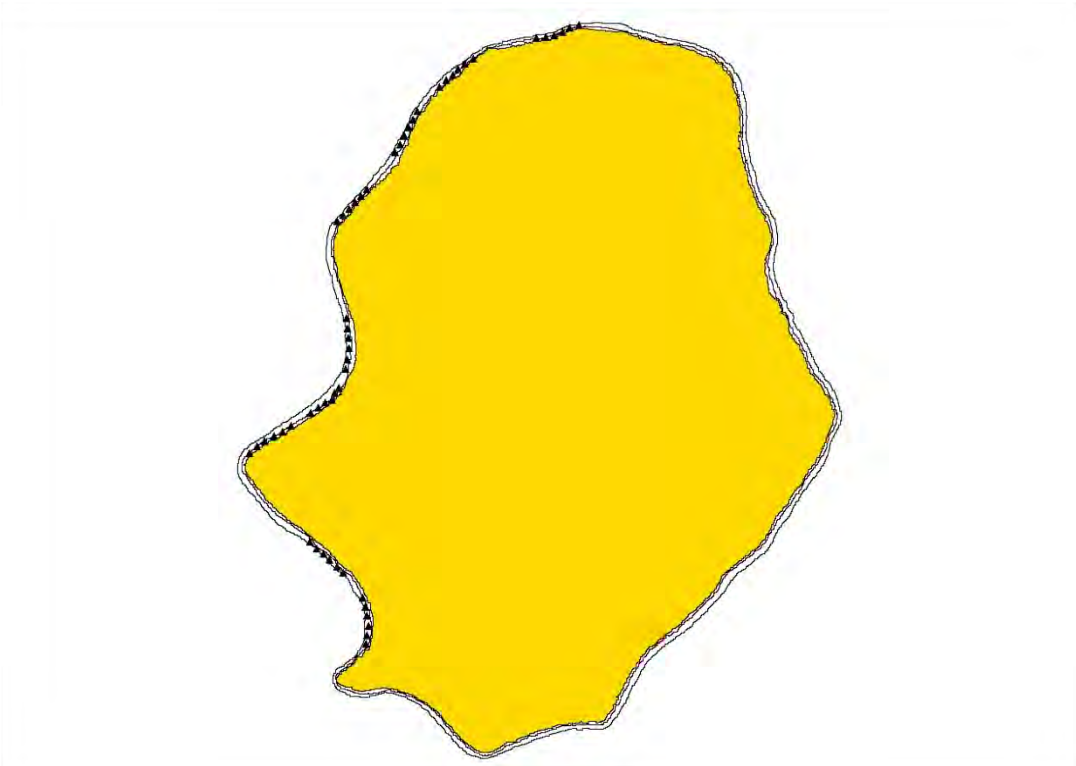

Figure 2.31: Broad-scale survey stations for invertebrates in Niue.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

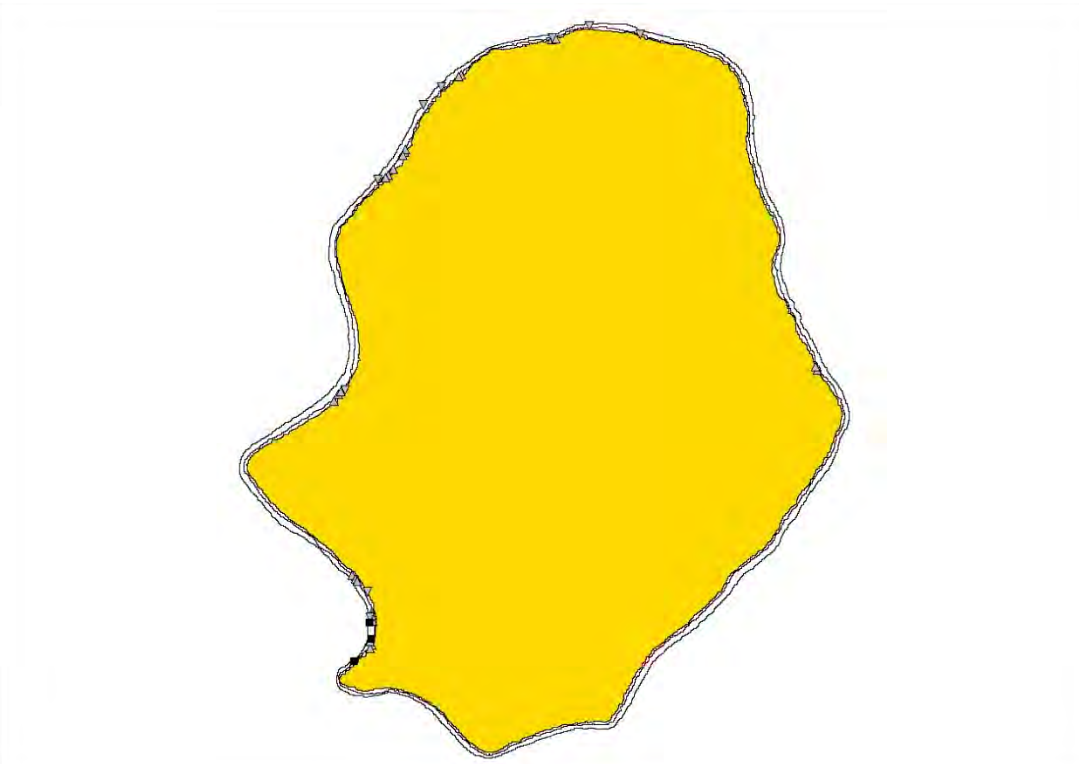

Figure 2.32: Fine-scale reef-benthos transect survey stations for invertebrates in Niue.
Grey triangles: reef-front search stations (RFs);
inverted grey triangles: reef-front search by walking stations (RFs_w).

Nineteen species or species groupings (groups of species within a genus) were recorded in the Niue invertebrate surveys; among these were 1 bivalve, 5 gastropods, 7 sea cucumbers, and 5 urchins (Appendix 4.1). Information on key families and species is detailed below.

2.4.1 Giant clams

Shallow reef habitat and reeftop (platform) that is suitable for giant clams was widespread in Niue (15 km^2). Approximately 0.27 km^2 of this is protected from fishing, although there is also the possibility of *fono*, a temporary restriction (usually for a year as respect for a deceased family member) or *tapu* (permanent village restriction mostly used for land) that can exclude fishing from some sectors. Most of the coastal habitat is narrow fringing reef, which extends along the perimeter of the exposed coastline (lineal distance 67 km); much of the reeftop dries for extended periods during low tide. The reef slope was either exposed or very exposed as it was unprotected from oceanic swell. At its worst, reef had been swept clean of benthic growth; reef facing the northeast had been largely affected by the recent Cyclone Heta (January 2004), a severe cyclone which clearly had a strong influence on the habitat and the presence and density of giant clams found in survey. Another area that was generally inaccessible to fishers due to the prevailing rough conditions is the southeast, and this area was not accessible during the survey for similar reasons.

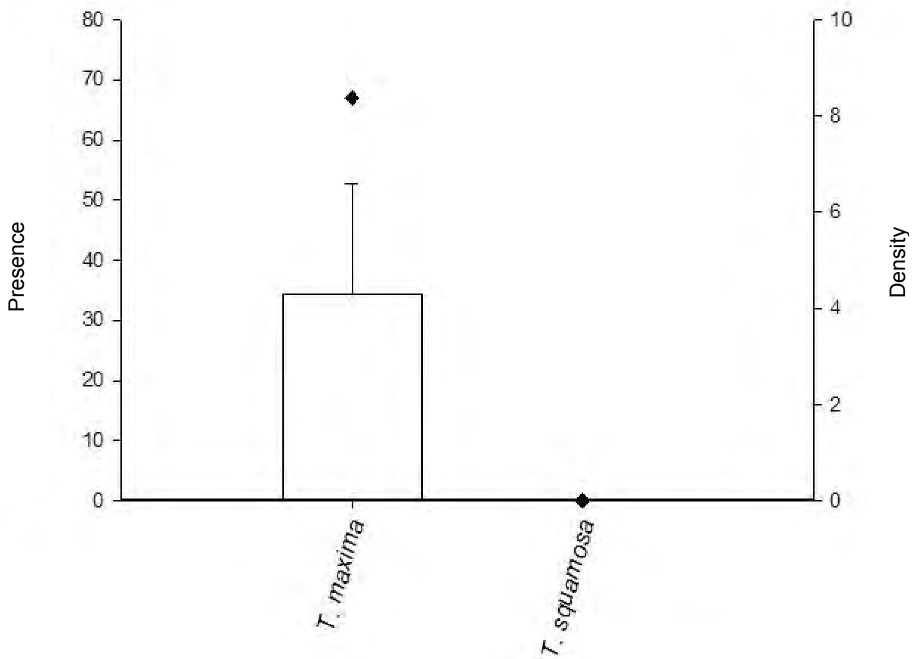

Figure 2.33: Presence and mean density of giant clam species at Niue based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Broad-scale sampling provided an overview of giant clam distribution across the submerged reefs of Niue. The rugose giant clam, *Tridacna maxima*, was the only clam species observed during the survey. *T. maxima* stocks are widely dispersed and were recorded at low density in most locations surveyed (recorded in six of nine stations, Figure 2.33). Another species of clam, *Tridacna squamosa*, which has been recorded in past surveys of Niue (Dalzell *et al.*

1993, Labrosse *et al.* 1999), appears now to be 'commercially' extinct[6] over most of its former range.

The highest densities of *T. maxima* were located on slope habitats between Tamakautoga and Avatele, and on the northern end of Alofi North (near the Namoui Marine Reserve). An apparent high density of clams from broad-scale surveys at Hikutavake is misleading, as this consisted of a single cluster of eight clams that were present on a large boulder in relatively deep water (approximately 15 m deep).

Based on the findings of the broad-scale survey, fine-scale searches were conducted using reef-front search swims (RFs) at 10 stations, and reef-benthos transects (RBt) at three stations. These surveys targeted specific areas of clam habitat in an area largely protected from the cyclone and highlighted the potential of reefs in Niue. In reef-benthos assessments (modified technique, as width of transect was extended to 2 m and the depth averaged 8.7 m), *T. maxima* was present within all stations, while clams were recorded in 80% of reef-front search stations (Figure 2.34).

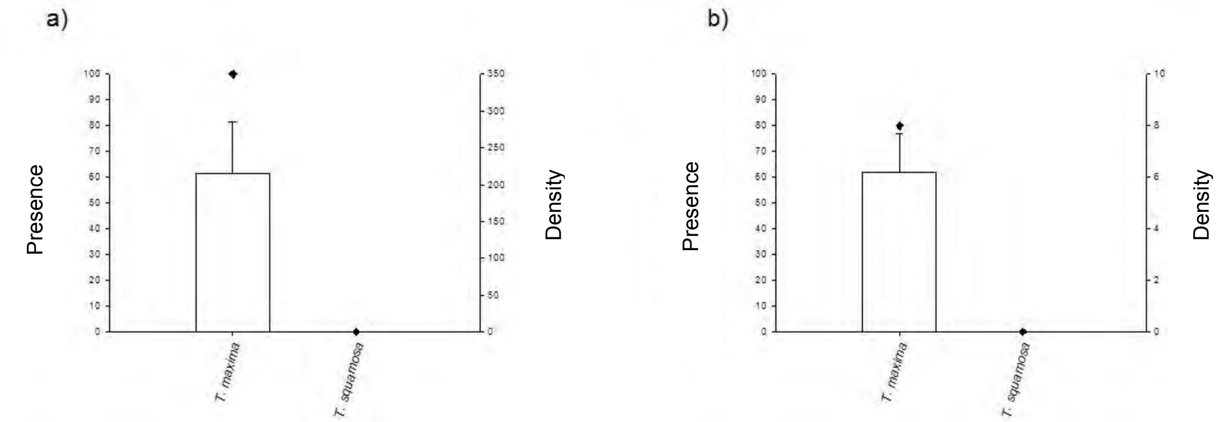

Figure 2.34: Presence and mean density of giant clam species at Niue based on a) fine-scale reef-benthos survey and b) reef-front search survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

As can be seen from Figures 2.34 a) and b), clams were rare in the more extensive reef-front searches of accessible areas of the west coast. Reef-front search stations returned a range of 4–13 clams/ha, which equates to no station having >3 clams recorded for 30 min of searching (six 5-min search periods). On the other hand, *T. maxima* from reef-benthos transects at one southwest location of Niue highlighted the potential for higher clam density. The three stations accessed on SCUBA at this location held clams at 215.3 per ha ±69.4, which equates to an average of 1.7 clams per 80 m^2 replicate.

T. maxima from reef-benthos transects had an average length of 14.8 cm ±1.2. When clams from all survey methods were included (from deeper water and more exposed locations), the mean size varied a little, to 13.5 cm ±1.1. *T. maxima* of this size are over six years old. As can be seen from the length-frequency graph (Figure 2.35), there was a range of size classes, including small clams, which represent new recruitment. Few large clams were recorded.

[6] Probably present at very low density but 'commercially extinct', in that there are too few individuals – a scarcity such that collection is not possible to service commercial or subsistence fishing.

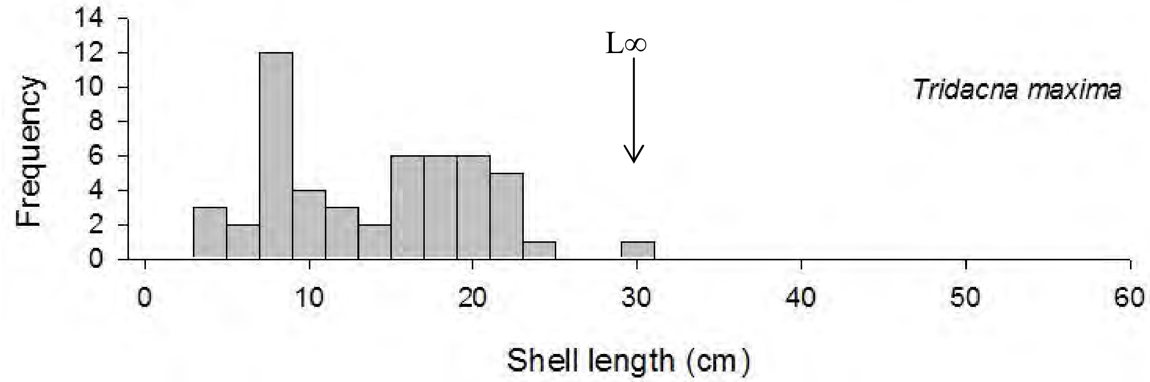

Figure 2.35: Size frequency histograms of giant clam *Tridacna maxima* shell length (cm) for Niue.

A survey of Niue in 1990 (Dalzell *et al.* 1993) concluded that overall clam densities were considered to be low compared to other areas in the Pacific. This was attributed to the unsuitability of habitat, local fishing pressure, and possibly the immediate effects of Cyclone Ofa (early that year). Clams on subtidal slopes of Niue were estimated to have overall densities of 117 clams/ha in the west and 44 clams/ha in the east (In these studies, Tepa Point to the north of Vaihaka is defined as the west coast area, and Vaihaka to Vaigata is defined as the east coast.). The results of the 1990 clam survey also allowed for an estimate of the ratio of *T. maxima* to *T. squamosa*; the west coast survey area showed a relative abundance ratio of 11:1, compared to the east coast ratio of 2:1.

A giant clam survey (species not specified) in 1998 at Namoui MPA and Avatele (Labrosse *et al.* 1999) recorded lower clam densities in the MPA (combined slope and reef-flat mean of 15 per ha) compared to Avatele (slope and reef-flat mean of 54 per ha).

From these studies we can see that clam densities appear to have fallen dramatically since the early and late 1990s. As with more recent surveys (Fisk 2004a, b), this study showed that *T. squamosa* is absent from assessment records since 1998. Labrosse *et al.* (1999) used different methods compared to the earlier survey (Dalzell *et al.* 1993), so it is difficult to directly compare the two survey results. However, they suggested that fishing pressure may have caused the decline in clam densities over the eight-year period (1990–1998). In contrast to these results, surveys from another part of Niue report that Beveridge reef (a submerged atoll with shallow-water lagoon 300 km southeast of Niue) is still rich in *T. maxima* (Pasisi pers. comm.).

2.4.2 Mother-of-pearl species (MOP): trochus and pearl oysters

Niue is not within the natural distribution of the commercial topshell *Trochus niloticus*; however, the reefs around Niue constitute a suitable benthos for adults (67 km lineal distance of reef front). Niue is an uplifted coralline island with little back-reef or shallow-water rubble areas for juvenile trochus. However, specimens were translocated from Fiji in 1992 and introduced to the shallow subtidal habitat by dropping them from boats (Gillett 2002; Leolahi pers. comm.). Introductions in August 1992 were near Makapu (recorded as Hakapu, 99 shells), Patuoto near Tamakautoga (47 shells), and at Matalave and Makatutaha near Namakulu (77 shells). A second introduction of 311 shells was carried out in August 1996 at Tamakautoga and Namakulu.

It is not known how successful these introductions have been. 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 Namoui MPA including Makapu, and Avatele towards the south of Tamakautoga.). Small, dead trochus shells have also been observed on small sand and rubble accumulations at the base of the shoreline cliffs in recent years (Leolahi pers. comm.). The current study included survey methods designed to detect trochus in the areas where introductions were made, but no trochus were observed and diving was made difficult by weather conditions during the survey.

A species with a similar life history to trochus, the green topshell, *T. pyramis*, (of low commercial value) and the blacklip pearl oyster, *Pinctada margaritifera*, were also not recorded in Niue assessments and no dead shells of either of these species was found.

2.4.3 Infaunal species and groups

The reef systems in Niue do not hold shell beds of in-ground resource species such as arc shells, *Anadara* spp. or venus shells, *Gafrarium* spp. Therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made.

2.4.4 Other gastropods and bivalves

Seba's spider conch, *Lambis truncata*, was detected in broad-scale and reef-benthos surveys, although it was rare (2% of transects in broad-scale survey). Unusually, *Astralium, Cerithium, Conus* and *Turbo* spp. *(T. argyrostomus, T. setosus*), were not recorded in surveys on shallow reef-benthos, reef front (snorkel) or reef-front walks during low tide. Results from other resource species targeted by fishers (e.g. *Cypraea, Serpulorbis, Siphonaria* and *Thais*) were recorded during independent surveys (Appendices 4.1 to 4.7).

The large vermetid species *Dendropoma maximum* (*matatue*) was observed to be abundant in a wide range of locations except Tamakautoga, but was not recorded in survey records. *D. maximum* was particularly common on the shallow-to-mid depth slope and less common on reef-platform locations. Another common vermetid species on Niue reef flats is the smaller *Serpulorbis colubrinus* (*ugako*), which was frequently observed on reef platforms and in some locations occurred at high density. This species is not adequately surveyed using timed searches because of its high density and small size. Belt transects or quadrat surveys would be more appropriate survey tools for this species, but unfortunately there was not time to undertake such surveys during the visit. The International Waters Project (IWP) recorded densities of *ugako* of up to 15 individuals/m^2 in small, dense patches on relatively inaccessible reef platforms in Makefu (Fisk 2004b).

Data on other bivalves, such as *Chama isostoma,* which is a locally common rock/jewelbox oyster prized by gleaners, was not collected during timed searches (not suitable for estimates of the abundance of this species). Its presence was also observed on all reef-flat surveys. Many uncommon species of invertebrates (occurring at low density) are also used for food, but are only opportunistically harvested when gleaners are searching for more abundant target species (Lambeth and Fay-Sauni 2001). These species are not easily included in general survey.

2.4.5 Lobsters

Dalzell *et al.* (1993) conducted a limited 'presence/absence' evaluation of tropical spiny lobsters (*Panulirus penicillatus*, *P. longipes*, *P. versicolor*), slipper lobsters (*Parribacus caledonicus*), and large reef crabs, such as the red reef crab (*Etisus splendidus*), and the three-spot crab (*Carpilius maculatus*). Collections of these crustaceans from three night dives on the west coast resulted in 37 pronghorn or double-spined rock lobsters (*P. penicillatus*), 13 longlegged spiny lobsters (*P. longipes*) and 12 painted rock lobsters (*P. versicolor*).

There was no dedicated night reef-front searches for lobsters in this assessment (See Methods.), no night searches for sea cucumbers and no daytime observations of lobsters. However, there were anecdotal reports from fishers that concentrations of lobsters can still be found in the numerous subtidal caves around the coastline.

2.4.6 Sea cucumbers[7]

The 260 km^2 landmass of Niue was bordered by approximately 15 km^2 of reef front and reef slope. The high degree of exposure to oceanic conditions and general dynamic water movement across reefs at Niue do not provide an ideal habitat for most deposit-feeding sea cucumbers (which eat organic matter in the upper few mm of bottom substrates). Even the reef platforms that are partially protected from swell were generally narrow, exposed and prone to dry at low tide.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.13, Appendix 4, also see Methods.). Deep dives on SCUBA (25–35 m), which would provide a preliminary assessment of deep-water stocks, such as the high-value white teatfish (*Holothuria fuscogilva*) and the lower-value amberfish (*Thelenota anax*) were not conducted in Niue. During in-water assessments, six commercial species of sea cucumber were recorded (Table 2.13). In a 1990 study, five species of holothurians were observed (Dalzell *et al.* 1993).

The range and densities of commercial species of sea cucumber in Niue were generally poor. Within the group of species generally associated with reef, only the black teatfish (*H. nobilis*), leopardfish (*Bohadschia argus*), and prickly redfish (*T. ananas*) were recorded. *B. argus* is a large commercial species that was only observed on the shallow slope at Alofi North. This species was more common on reef flats prior to Cyclone Heta in January 2004 (Dave Fisk, pers. comm.). Although leopardfish and black teatfish were rare in this survey, there was some indication that prickly redfish, *T. ananas*, had relatively broad coverage and relatively high densities at some locations. In addition, Fisk (pers. comm.) noted *T. ananas* on reef flats before the cyclone, although in this survey none were seen above the tide line.

Surf redfish, *Actinopyga mauritiana*, which is found in the dynamic conditions of the reef front, was generally rare in subtidal locations but found more commonly on exposed reef platforms (recorded in 16% of RFs_w periods). In earlier surveys, *A. mauritiana* was recorded at low density on the reef flat in Makefu and Alofi North (Fisk 2004a, b, 2005, Dalzell *et al.* 1993). Considering the suitable nature and extent of the reef and surge zone at

[7] There has been a recent change to sea cucumber taxonomy that has changed the name of the black teatfish in the Pacific from *Holothuria* (*Microthele*) *nobilis* to *H. whitmaei*. It is possible that the scientific name for white teatfish may also change in the future. This should be noted when comparing texts, as in this report the 'original' taxonomic names are used.

Niue, the current presence and density of surf redfish are not sufficiently high to suggest commercial fishing should be commenced at this time.

Limited subtidal surveys in recent years (Fisk 2004a, b, 2005) did not record the other species mentioned in Dalzell *et al*. (1993), i.e. *Holothuria nobilis*, *Stichopus chloronotus*, and an unidentified *Bohadschia* species. In contrast, a filter-feeding species (*Neothyonidium* sp.) was observed on the reef flat in the 2003 study (Fisk 2004a, b), but not in 2005 (Fisk 2005). On this survey, leopardfish and black teatfish were noted at low density, but *S. chloronotus* was not recorded. This indicates a significant reduction in the number of *S. chloronotus* in recent times and, as *S. chloronotus* is not commonly targeted by fishers, its decrease in abundance is probably due to natural causes (e.g. cyclone activity).

More protected areas of reef and soft benthos were not available at Niue, although the back sector of exposed reeftops held lollyfish (*H. atra*) at moderate density. An additional reef platform species detected in IWP surveys, *H. leucospilota*, was not mentioned in earlier studies by Dalzell *et al.* (1993) or Labrosse *et al.* (1999). It is possible that former surveys did not distinguish between *H. atra* and *H. leucospilota*, as both are superficially similar. Also, a significant decrease in the abundance of this species was noted following Cyclone Heta (Fisk 2004a, 2005). In this survey, *H. leucospilota* was observed, but only outside of survey assessments.

An unidentified *Holothuria* spp. (*sepulupulu*) was observed on the Tamakautoga reef flat in scattered dense patches. This is a very small species and it is occasionally harvested for food. This could also be a juvenile form of another species but it has been observed in the same location in high-density patches for approximately two years (Dave Fisk pers. comm.) and all individuals have not significantly increased in size during this time.

From a descriptive comparison of results, it is clear that holothurian densities have significantly reduced since Cyclone Heta, as well as since earlier surveys in the 1990s, and that some species have been affected more than others. Surveys of species such as *Neothyonidium* spp., *Holothuria leucospilota*, *Stichopus chloronotus* and probably *Actinopyga mauritiana* have recorded reductions in overall abundance, particularly in the north/northwest sectors of Niue.

2.4.7 Other echinoderms

A single edible slate urchin *Heterocentrotus mammillatus* was recorded subtidally in Niue. None were found on the reeftop. *H. mammillatus* is seasonally harvested for its egg mass in Niue (Fisk pers. comm.). *Echinothrix* spp. (*E. diadema* and *E. calamaris*) were relatively common (in 89% of broad-scale stations at a mean density of 183.3 per ha ±131.2, see Table 2.12 and Appendices 4.1 to 4.7).

Table 2.12: Total number of sea urchins at Niue based on various assessment techniques

Stations	*Echinothrix* spp.	*Heterocentrotus mammillatus*	*Echinometra mathaei*	*Echinometra oblonga*	*Echinostrephus* spp.
B-S	594	1	6		common
RBt					27
RFs	94		21	559	2572
RFs_w	65		39	832	2

B-S = broad-scale; RBt = reef-benthos transect; RFs = reef-front search; RFs_w = reef-front search by walking.

The current status of urchins (Fisk 2004a, b, 2005) on Niue indicates that a significant shift in the relative abundance of species has occurred in recent years, though it is possible that the numerically abundant burrowing species were not specifically noted in some of the previous surveys. Nonetheless, the very low occurrences in the most recent surveys of *Diadema setosum* and *Echinometra mathaei* are significant recent changes. The absence of any reference to the presence of *Echinothrix diadema* in previous surveys compared to this survey is also a significant difference.

Starfish, such as *Linckia laevigata* the blue starfish, and coralivore starfish such as the pincushion star *Culcita novaeguineae* and crown of thorns (COTS, *Acanthaster planci*) were not observed during this survey. COTS were rare in previous surveys of Niue. Dalzell *et al.* (1993) reported 0.98 individuals/ha and Fisk (2004a, b, 2005) reported none.

Table 2.12: Sea cucumber species records for Niue

Species	Common name	Commercial value [5]	B-S transects n = 70			Reef benthos stations n = 3			Other stations RFs = 10			Other stations RFs_w = 9		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	2.2	23.3	9				0.4	4.4	10	2.8	5.1	56
Actinopyga miliaris	Blackfish	M/H							0.4	4.4	10			
Bohadschia argus	Leopardfish	M	0.3	16.7	2									
Holothuria atra	Lollyfish	L										69.8	69.8	100
Holothuria leucospilota	-	L										Recorded out of assessment		
Holothuria nobilis [4]	Black teatfish	H	0.3	16.7	2				0.4	4.4	10			
Stichopus horrens	Peanutfish	M										Recorded out of assessment		
Thelenota ananas	Prickly redfish	H	4.9	38.1	13	90.3	270.8	33	8.9	22.2	40			

[1] D = mean density (numbers/ha); [2] DwP = mean density (numbers/ha) for transects or stations where the species was present; [3] PP = percentage presence (units where the species was found); [4] the scientific name of the black teatfish has recently changed from *Holothuria* (*Microthele*) *nobilis* to *H. whitmaei* and the white teatfish (*H. fuscogilva*) may have also changed name before this report is published. [5] L = low value; M = medium value; H= high value; B-S transects= broad-scale transects; RFs = reef-front search; RFs_w = reef-front search by walking.

2.4.8 Discussion and conclusions: invertebrate resources

The key issues for Niue with respect to management of coastal fisheries resources are that the island:

- is geographically isolated from other Pacific reef systems that could be a source of replenishment / recruitment;
- is small in overall size and in the area of intertidal and reef habitats; and
- has low diversity of coral reef habitats compared to what is normally present in Pacific island systems.

A summary of environmental, stock status and management factors for the main fisheries is given below. Please note that information on other, smaller fisheries and the status of less prominent species groups can be found within the body of the invertebrate chapter.

- The significant conclusion from these surveys is that there has been a steady decline in the number of giant clams on Niue reefs since 1990. *Tridacna squamosa* has been seen to dramatically decline in the last decade to a point where it is now commercially extinct[8], and unlikely to recover without assistance.

- The rugose clam, *T. maxima* (a more common and robust giant clam species) is also showing a significant decline in recorded density. The density and size range of *T. maxima* at Niue indicate that the impacts of Cyclone Heta have compounded a decline in stocks that was attributed to fishing pressure and the earlier effects of Cyclone Ofa (1990). As the reefs are very exposed on Niue, the effects of both cyclones and fishing pressure are jointly degrading the resource to a point where densities are now low.

- Data collected on this mission suggest that trochus, *T. niloticus* have not become established in Niue following their introductions in 1992 and 1996. Clearly, the severity of the impact of Cyclone Heta on shallow slope communities is a contributing factor; however, this cannot explain the lack of individuals in the Tamakautoga area where cyclone impacts were minimal.

- Based on the information collected on sea cucumber stocks, there are a very limited number of species available for commercial fishing on Niue. The exposed environment of Niue plays a large part in defining the fishery.

2.5 Overall recommendations for Niue

Based on the survey work undertaken and the assessments made, the following recommendations are made for Niue:

- The quality and quantity of reef finfish resources in Niue will only allow limited subsistence use; expansion of the fishery is not possible without causing overfishing.

- Any additional survey work on finfish and invertebrates should focus on the species that are of most concern for Niuean people and which are the main focus of current harvest activity, especially in the most targeted areas, i.e. the western coastline between

[8] Referring to a scarcity such that collection is not possible to service commercial or subsistence fishing, but species may still be present at very low densities.

Hikutavake in the north and Avatele in the south. This would include an assessment of the status and population dynamics of: *nue, telekihi* and *ulihega* for finfish fisheries and, for invertebrates, *alili* or *Turbo* spp., *matatue* (the vermetid mollusc *Dendropoma maximum*) as well as *papahua* (the oyster *Chama isostoma*). Though not a major focus for Niueans, the status of nocturnal crustacean species (especially crayfish and crabs) should also be targeted for study.

- Biochemical analyses of the reef in front of the fish processing plant be conducted as this area seemed to be under strong nutrient influence.

- The protection status of the Namoui MPA be continued and all resources within it monitored for future changes. Consideration of enlarging the size of this MPA may be beneficial to strengthen protection. Serious consideration should be given to afford special protection to the currently most productive and diverse coastal marine communities in Tamakautoga (and possibly parts of Avatele), which would significantly enhance the potential recovery of other sections of the west coast marine communities.

- Any future releases of trochus should consider first placing the transplanted shells in protective cages within well-circulated pools and releasing them to the reef in stages. Staged release acclimatises the shells to local conditions: carefully placing them in areas where there is epiphytic growth and potential food sources will ensure the transplanted shells have the best chance of survival.

- Careful low-level harvests of prickly redfish, *Thelenota ananas*, may be considered only after there is some recovery to reefs. However, careful spatial monitoring of this resource will need to be in place to ensure the fishery is stopped before catches and sizes indicate 'growth' (size) or recruitment overfishing.

- There can be no harvesting of black teatfish (*Holothuria nobilis*), white teatfish (*H. fuscogilva*), or surf redfish, *Actinopyga mauritiana*, with the current low stock levels. However, these stocks need to be monitored as, in future years, good recruitment could offer opportunities for periodic harvests when conditions allow.

- A total ban needs to be placed on the collection of clams for a minimum period of 3–5 years as an exercise in enhancing the recovery of severely depleted stocks. The ban should at least include the north and northwest slope and reef-flat habitats (e.g. between Makefu and Mutalau), where cyclone damage was greatest. If this is not possible, a closure of more areas to preserve localised areas of adults at densities that promote successful spawning events and cross-fertilisation could be considered.

- The adoption of specific management systems is essential to achieve the long-term viability of invertebrate stocks; these management regimes will have to be controlled by the community at scales larger than the current village boundaries.

- Present densities of coralivore starfish (such as COTS) are not a concern to Niue; however, following the recent disturbance (cyclone), increased monitoring to forewarn of an outbreak is needed.

- Coral re-growth will need to be monitored following Cyclone Heta.

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APPENDIX 1: SURVEY METHODS

1.1 Socioeconomic surveys, questionnaires and average invertebrate wet weights

1.1.1 Socioeconomic survey methods

Preparation

The PROCFish/C socioeconomic survey is planned in close cooperation with local counterparts from national fisheries authorities. It makes use of information gathered during the selection process for the four sites chosen for each of the PROCFish/C participating countries and territories, as well as any information obtained by resource assessments, if these precede the survey.

Information is gathered regarding the target communities, with preparatory work for a particular socioeconomic field survey carried out by the local fisheries counterparts, the project's attachment, or another person charged with facilitating and/or participating in the socioeconomic survey. In the process of carrying out the surveys, training opportunities are provided for local fisheries staff in the PROCFish/C socioeconomic field survey methodology.

Staff are careful to respect local cultural and traditional practices, and follow any local protocols while implementing the field surveys. The aim is to cause minimal disturbance to community life, and surveys have consequently been modified to suit local habits, with both the time interviews are held and the length of the interviews adjusted in various communities. In addition, an effort is made to hold community meetings to inform and brief community members in conjunction with each socioeconomic field survey.

Approach

The design of the socioeconomic survey stems from the project focus, which is on rural coastal communities in which traditional social structures are to some degree intact. Consequently, survey questions assume that the primary sectors (and fisheries in particular) are of importance to communities, and that communities currently depend on coastal marine resources for their subsistence needs. As urbanisation increases, other factors gain in importance, such as migration, as well as external influences that work in opposition to a subsistence-based socioeconomic system in the Pacific (e.g. the drive to maximise income, changes in lifestyle and diet, and increased dependence on imported foods). The latter are not considered in this survey.

The project utilises a 'snapshot approach' that provides 5–7 working days per site (with four sites per country). This timeframe generally allows about 25 households (and a corresponding number of associated finfish and invertebrate fishers) to be covered by the survey. The total number of finfish and invertebrate fishers interviewed also depends on the complexity of the fisheries practised by a particular community, the degree to which both sexes are engaged in finfish and invertebrate fisheries, and the size of the total target population. Data from finfish and invertebrate fisher interviews are grouped by habitat and fishery, respectively. Thus, the project's time and budget and the complexity of a particular site's fisheries are what determine the level of data representation: the larger the population and the number of fishers, and the more diversified the finfish and invertebrate fisheries, the lower the level of representation that can be achieved. It is crucial that this limitation be taken into consideration, because the data gathered through each survey and the emerging distribution patterns are extrapolated to estimate the total annual impact of all fishing activity reported for the entire community at each site.

If possible, people involved in marketing (at local, regional or international scale) who operate in targeted communities are also surveyed (e.g. agents, middlemen, shop owners).

Key informants are targeted in each community to collect general information on the nature of local fisheries and to learn about the major players in each of the fisheries that is of concern, and about fishing rights and local problems. The number of key informants interviewed depends on the complexity and heterogeneity of the community's socioeconomic system and its fisheries.

At each site the extent of the community to be covered by the socioeconomic survey is determined by the size, nature and use of the fishing grounds. This selection process is highly dependent on local marine tenure rights. For example, in the case of community-owned fishing rights, a fishing community includes all villages that have access to a particular fishing ground. If the fisheries of all the villages concerned are comparable, one or two villages may be selected as representative samples, and consequently surveyed. Results will then be extrapolated to include all villages accessing the same fishing grounds under the same marine tenure system.

In an open access system, geographical distance may be used to determine which fishing communities realistically have access to a certain area. Alternatively, in the case of smaller islands, the entire island and its adjacent fishing grounds may be considered as one site. In this case a large number of villages may have access to the fishing ground, and representative villages, or a cross-section of the population of all villages, are selected to be included in the survey.

In addition, fishers (particularly invertebrate fishers) are regularly asked how many people external to the surveyed community also harvest from the same fishing grounds and/or are engaged in the same fisheries. If responses provide a concise pattern, the magnitude of additional impact possibly imposed by these external fishers is determined and discussed.

Sampling

Most of the households included in the survey are chosen by simple random selection, as are the finfish and invertebrate fishers associated with any of these households. In addition, important participants in one or several particular fisheries may be selected for complementary surveying. Random sampling is used to provide an average and representative picture of the fishery situation in each community, including those who do not fish, those engaged in finfish and/or invertebrate fishing for subsistence, and those engaged in fishing activities on a small-scale artisanal basis. This assumption applies provided that selected communities are mostly traditional, relatively small (~100–300 households) and (from a socioeconomic point of view) largely homogenous. Similarly, gender and participation patterns (types of fishers by gender and fishery) revealed through the surveys are assumed to be representative of the entire community. Accordingly, harvest figures reported by male and female fishers participating in a community's various fisheries may be extrapolated to assess the impacts resulting from the entire community, sample size permitting (at least 25–30% of all households).

Data collection and analysis

Data collection is performed using a standard set of questionnaires developed by PROCFish/C's socioeconomic component, which include a household survey (key socioeconomic parameters and consumption patterns), finfish fisheries survey, invertebrate fisheries survey, marketing of finfish survey, marketing of invertebrates survey, and general information questionnaire (for key informants). In addition, further observations and relevant details are noted and recorded in a non-standardised format. The complete set of questionnaires used is attached as Appendix 1.1.2.

Most of the data are collected in the context of face-to-face interviews. Names of people interviewed are recorded on each questionnaire to facilitate cross-identification of fishers and households during data collection and to ensure that each fisher interview is complemented by a household interview. Linking data from household and fishery surveys is essential to permit joint data analysis. However, all names are suppressed once the data entry has been finalised, and thus the information provided by respondents remains anonymous.

Questionnaires are fully structured and closed, although open questions may be added on a case-to-case situation. If translation is required, each interview is conducted jointly by the leader of the project's socioeconomic team and the local counterpart. In cases where no translation is needed, the project's socioeconomist may work individually. Selected interviews may be conducted by trainees receiving advanced field training, but trainees are monitored by project staff in case clarification or support is needed.

The questionnaires are designed to allow a minimum dataset to be developed for each site, one that allows:
- the community's dependency on marine resources to be characterised;
- assessment of the community's engagement in and the possible impact of finfish and invertebrate harvesting; and
- comparison of socioeconomic information with data collected through PROCFish/C resource surveys.

Household survey

The major objectives of the household survey are to:

- **collect recent demographic information** (needed to calculate seafood consumption);
- **determine the number of fishers per household, by gender and type of fishing activity** (needed to assess a community's total fishing impact); and
- **assess the community's relative dependency on marine resources** (in terms of ranked source(s) of income, household expenditure level, agricultural alternatives for subsistence and income (e.g. land, livestock), external financial input (i.e. remittances), assets related to fishing (number and type of boat(s)), and seafood consumption patterns by frequency, quantity and type).

The demographic assessment focuses only on permanent residents, and excludes any family members who are absent more often than they are present, who do not normally share the household's meals or who only join on a short-term visitor basis (for example, students during school holidays, or emigrant workers returning for home leave).

The number of fishers per household distinguishes three categories of adult (≥ 15 years) fishers for each gender: (1) exclusive finfish fishers, (2) exclusive invertebrate fishers, and (3) fishers who pursue both finfish and invertebrate fisheries. This question also establishes the percentage of households that do not fish at all. We use this pattern (i.e. the total number of fishers by type and gender) to determine the number of female and male fishers, and the percentage of these who practise either finfish or invertebrate fisheries exclusively, or who practise both. The share of adult men and women pursuing each of the three fishery categories is presented as a percentage of all fishers. Figures for the total number of people in each fishery category, by gender, are also used to calculate total fishing impact (see below).

The role of fisheries as a source of income in a community is established by a ranking system. Generally, rural coastal communities represent a combined system of traditional (subsistence) and cash-generating activities. The latter are often diversified, mostly involving the primary sector, and are closely associated with traditional subsistence activities. Cash flow is often irregular, tailored to meet seasonal or occasional needs (school and church fees, funerals, weddings, etc.). Ranking of different sources of income by order of importance is therefore a better way to render useful information than trying to quantify total cash income over a certain time period. Depending on the degree of diversification, multiple entries are common. It is also possible for one household to record two different activities (such as fisheries and agriculture) as equally important (i.e. both are ranked as a first source of income, as they equally and importantly contribute to acquisition of cash within the household). In order to demonstrate the degree of diversification and allow for multiple entries, the role that each sector plays is presented as a percentage of the total number of households surveyed. Consequently, the sum of all figures may exceed 100%. Income sources include fisheries, agriculture, salaries, and 'others', with the latter including primarily handicrafts, but sometimes also small private businesses such as shops or kava bars.

Cash income is often generated in parallel by various members of one household and may also be administered by many, making it difficult to establish the overall expenditure level. On the other hand, the head of the household and/or the woman in charge of managing and organising the household are typically aware and in control of a certain amount of money that is needed to ensure basic and common household needs are met. We therefore ask for the level of average household expenditure only, on a weekly, bi-weekly or monthly basis, depending on the payment interval common in a particular community. Expenditures quoted in local currency are converted into US dollars (USD) to enable regional comparison. Conversion factors used are indicated.

Geomorphologic differences between low and high islands influence the role that agriculture plays in a community, but differences in land tenure systems and the particulars of each site are also important, and the latter factors are used in determining the percentage of households that have access to gardens and agricultural land, the average size of these areas, and the type (and if possible number) of livestock that are at the disposal of an average household. A community whose members are equally engaged in agriculture and fisheries will either show distinct groups of fishers and farmers/gardeners, or reveal active and non-active fishing seasons in response to the agricultural calendar.

We can use the frequency and amount of remittances received from family members working elsewhere in the country or overseas to assess the degree to which principles of the MIRAB economy apply. MIRAB was coined to characterise an economy dependent on migration, remittances, foreign aid and government bureaucracy as its major sources of revenue (Small and Dixon 2004; Bertram 1999; Bertram and Watters 1985). A high influx of foreign financing, and in particular remittances, is considered to yield flexible yet stable economic conditions at the community level (Evans 2001), and may also substitute for or reduce the need for local income-generating activities, such as fishing.

The number of boats per household is indicative of the level of isolation, and is generally higher for communities that are located on small islands and far from the nearest regional centre and market. The nature of the boats (e.g. non-motorised, handmade dugout canoes, dugouts equipped with sails, and the number and size of any motorised boats) provides insights into the level of investment, and usually relates to the household expenditure level. Having access to boats that are less sensitive to sea conditions and equipped with outboard engines provides greater choice of which fishing grounds to target, decreases isolation and increases independence in terms of transport, and hence provides fishing and marketing advantages. Larger and more powerful boats may also have a multiplication factor, as they accommodate bigger fishing parties. In this context it should be noted that information on boats is usually complemented by a separate boat inventory performed by interviewing key informants and senior members of the community. If possible, we prefer to use the information from the complementary boat inventory surveys rather than extrapolating data from household surveys, in order to minimise extrapolation errors.

A variety of data are collected to characterise the seafood consumption of each community. We distinguish between fresh fish (with an emphasis on reef and lagoon fish species), invertebrates and canned fish. Because meals are usually prepared for and shared by all household members, and certain dishes may be prepared in the morning but consumed throughout the day, we ask for the average quantity prepared for one day's consumption. In the case of fresh fish we ask for the number of fish per size class, or the total weight, usually consumed. However, the weight is rarely known, as most communities are largely self-sufficient in fresh fish supply and local, non-metric units are used for marketing of fish (heap, string, bag, etc.). Information on the number of size classes consumed allows calculation of weight using length–weight relationships, which are known for most finfish species (FishBase 2000, refer to Letourneur *et al.* 1998; Kulbicki pers. com.). Size classes (using fork length) are identified using size charts (Figure A1.1.1).

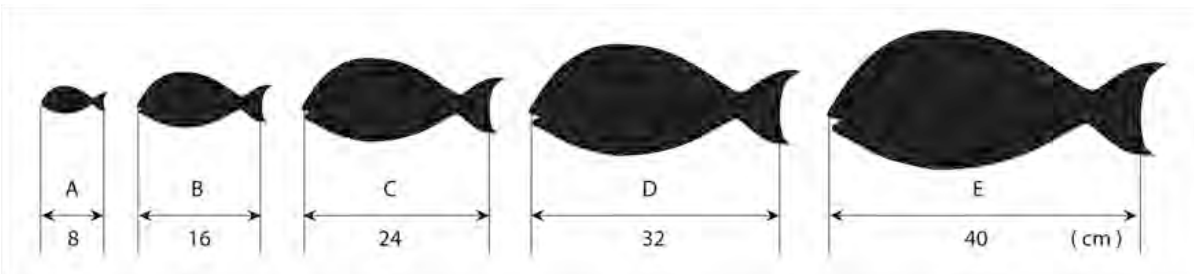

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

The frequency of all consumption data is adjusted downwards by 17% (a factor of 0.83 determined on the basis that about two months of the year are not used for fishing due to festivities, funerals and bad weather conditions) to take into account exceptional periods throughout the year when the supply of fresh fish is limited or when usual fish eating patterns are interrupted.

Equation for fresh finfish:

$$F_{wj} = \sum_{i=1}^{n}(N_{ij} \bullet W_i) \bullet 0.8 \bullet F_{dj} \bullet 52 \bullet 0.83$$

F_{wj} = finfish net weight consumption (kg edible meat/household/year) for household$_j$
n = number of size classes
N_{ij} = number of fish of size class$_i$ for household$_j$
W_i = weight (kg) of size class$_i$
0.8 = correction factor for non-edible fish parts
F_{dj} = frequency of finfish consumption (days/week) of household$_j$
52 = total number of weeks/year
0.83 = correction factor for frequency of consumption

For invertebrates, respondents provide numbers and sizes or weight (kg) per species or species groups usually consumed. Our calculation automatically transfers these data entries per species/species group into wet weight using an index of average wet weight per unit and species/species group (Appendix 1.1.3).[1] The total wet weight is then automatically further broken down into edible and non-edible proportions. Because edible and non-edible proportions may vary considerably, this calculation is done for each species/species group individually (e.g. compare an octopus that consists almost entirely of edible parts with a giant clam that has most of its wet weight captured in its non-edible shell).

Equation for invertebrates:

$$Inv_{wj} = \sum_{i=1}^{n} E_{p_i} \bullet (N_{ij} \bullet W_{wi}) \bullet F_{dj} \bullet 52 \bullet 0.83$$

Inv_{wj} = invertebrate weight consumption (kg edible meat/household/year) of household$_j$
E_{pi} = percentage edible (1 = 100%) for species/species group$_i$ (Appendix 1.1.3)
N_{ij} = number of invertebrates for species/species group$_i$ for household$_j$
n = number of species/species group consumed by household$_j$
W_{wi} = wet weight (kg) of unit (piece) for invertebrate species/species group$_i$
1000 = to convert g invertebrate weight into kg
F_{dj} = frequency of invertebrate consumption (days/week) for household$_j$
52 = total number of weeks/year
0.83 = correction factor for consumption frequency

[1] The index used here mainly consists of estimated average wet weights and ratios of edible and non-edible parts per species/species group. At present, SPC's Reef Fishery Observatory is making efforts to improve this index so as to allow further specification of wet weight and edible proportion as a function of size per species/species group. The software will be updated and users informed about changes once input data are available.

Appendix 1: Survey methods
Socioeconomics

Equation for canned fish:

Canned fish data are entered as total number of cans per can size consumed by the household at a daily meal, i.e.:

$$CF_{wj} = \sum_{i=1}^{n} (N_{cij} \bullet W_{ci}) \bullet F_{dcj} \bullet 52$$

CF_{wj} = canned fish net weight consumption (kg meat/household/year) of household$_j$
N_{cij} = number of cans of can size$_i$ for household$_j$
n = number and size of cans consumed by household$_j$
W_{ci} = average net weight (kg)/can size$_i$
F_{dcj} = frequency of canned fish consumption (days/week) for household$_j$
52 = total number of weeks/year

Age-gender correction factors are used because simply dividing total household consumption by the number of people in the household will result in underestimating per head consumption. For example, imagine the difference in consumption levels between a 40-year-old man as compared to a five-year-old child. We use simplified gender-age correction factors following the system established and used by the World Health Organization (WHO; Becker and Helsing 1991), i.e. (Kronen *et al.* 2006):

Age (years)	Gender	Factor
≤5	All	0.3
6–11	All	0.6
12–13	Male	0.8
≥12	Female	0.8
14–59	Male	1.0
≥60	Male	0.8

The per capita finfish, invertebrate and canned fish consumptions are then calculated by selecting the relevant formula from the three provided below:

Finfish per capita consumption:

$$F_{pcj} = \frac{F_{wj}}{\sum_{i=1}^{n} AC_{ij} \bullet C_i}$$

F_{pcj} = Finfish net weight consumption (kg/capita/year) for household$_j$
F_{wj} = Finfish net weight consumption (kg/household/year) for household$_j$
n = number of age-gender classes
AC_{ij} = number of people for age class i and household j
C_i = correction factor of age-gender class$_i$

Appendix 1: Survey methods
Socioeconomics

Invertebrate per capita consumption:

$$Inv_{pcj} = \frac{Inv_{wj}}{\sum_{i=1}^{n} AC_{ij} \bullet C_i}$$

Inv_{pcj} = Invertebrate weight consumption (kg edible meat/capita/year) for household$_j$
Inv_{wj} = Invertebrate weight consumption (kg edible meat/household/year) for household$_j$
n = number of age-gender classes
AC_{ij} = number of people for age class i and household j
C_i = correction factor of age-gender class$_i$

Canned fish per capita consumption:

$$CF_{pcj} = \frac{CF_{wj}}{\sum_{i=1}^{n} AC_{ij} \bullet C_i}$$

CF_{pcj} = canned fish net weight consumption (kg/capita/year) for household$_j$
CF_{wj} = canned fish net weight consumption (kg/household/year) for household$_j$
n = number of age-gender classes
AC_{ij} = number of people for age class$_i$ and household$_j$
C_i = correction factor of age-gender class$_i$

The total finfish, invertebrate and canned fish consumption of a known population is calculated by extrapolating the average per capita consumption for finfish, invertebrates and canned fish of the sample size to the entire population.

Total finfish consumption:

$$F_{tot} = \frac{\sum_{j=1}^{n} F_{pcj}}{n_{ss}} \bullet n_{pop}$$

F_{pcj} = finfish net weight consumption (kg/capita/year) for household$_j$
n_{ss} = number of people in sample size
n_{pop} = number of people in total population

Total invertebrate consumption:

$$Inv_{tot} = \frac{\sum_{j=1}^{n} Inv_{pcj}}{n_{ss}} \bullet n_{pop}$$

Inv_{pcj} = invertebrate weight consumption (kg edible meat/capita/year) for household$_j$
n_{ss} = number of people in sample size
n_{pop} = number of people in total population

Total canned fish consumption:

$$CF_{tot} = \frac{\sum_{j=1}^{n} CF_{pcj}}{n_{ss}} \bullet n_{pop}$$

CF_{pcj} = canned fish net weight consumption (kg/capita/year) of household$_j$
n_{ss} = number of people in sample size
n_{pop} = number of people in total population

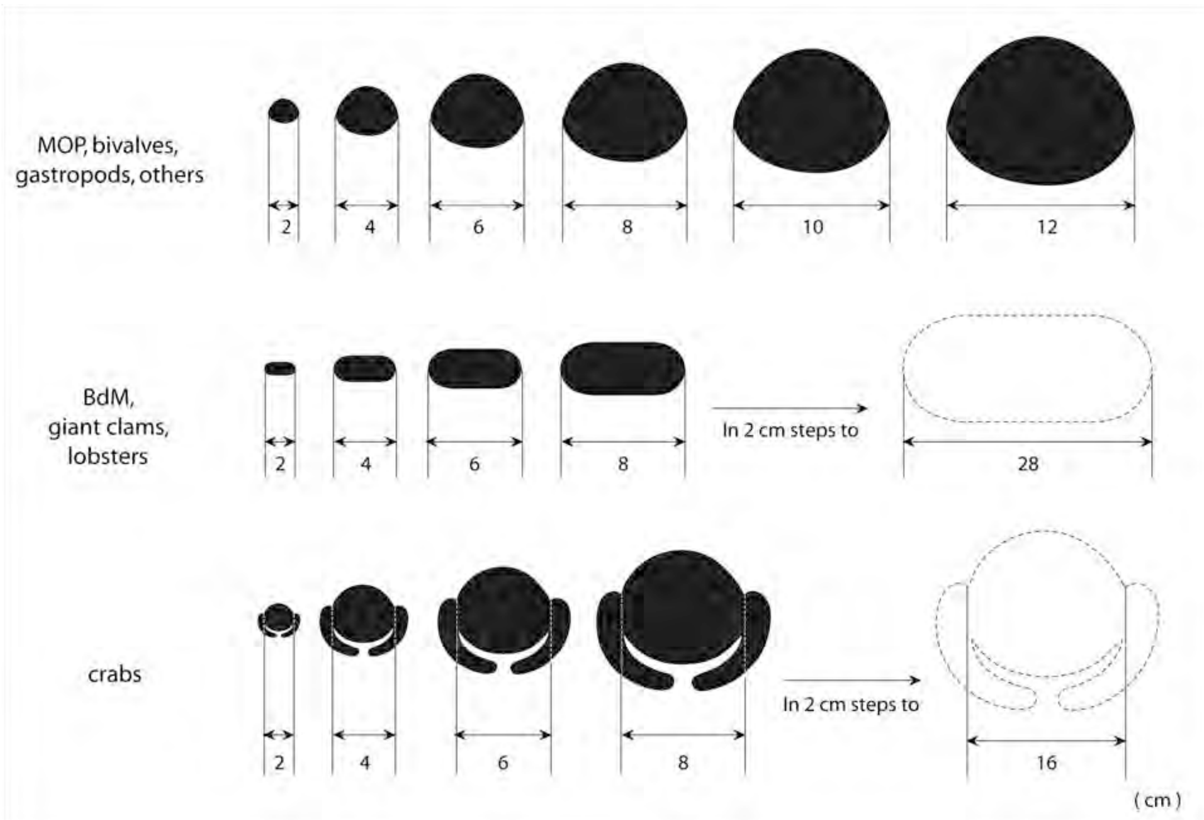

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

Appendix 1: Survey methods
Socioeconomics

Finfish fisher survey

The finfish fisher survey primarily aims to collect the data needed to understand finfish fisheries strategies, patterns and dimensions, and thus possible impacts on the resource. Data collection faces the challenge of retrieving information from local people that needs to match resource survey parameters, in order to make joint data analysis possible. This challenge is highlighted by the following three major issues:

(i) Fishing grounds are classified by habitat, with the latter defined using geomorphologic characteristics. Local people's perceptions of and hence distinctions between fishing grounds often differ substantially from the classifications developed by the project. Also, fishers do not target particular areas according to their geomorphologic characteristics, but instead due to a combination of different factors including time and transport availability, testing of preferred fishing spots, and preferences of members of the fishing party. As a result, fishers may shift between various habitats during one fishing trip. Fishers also target lagoon and mangrove areas, as well as passages if these are available, all of which cannot be included in the resource surveys. It should be noted that a different terminology for reef and other areas fished is needed to communicate with fishers.

These problems are dealt with by asking fishers to indicate the areas they refer to as coastal reef, lagoon, outer-reef and pelagic fishing on hydrologic charts, maps or aerial photographs. In this way we can often further refine the commonly used terms of coastal or outer reef to better match the geomorphologic classification. The proportion of fishers targeting each habitat is provided as a percentage of all fishers surveyed; the socioeconomic analysis refers to habitats by the commonly used descriptive terms for these habitats, rather than the ecological or geomorphologic classifications.

Fishers may travel between various habitats during a single fishing trip, with differing amounts of time spent in each of the combined habitats; the catch that is retrieved from each combined habitat may potentially vary from one trip to the next. If targeting combined habitats is a common strategy practised by most fishers, the resource data for individual geomorphologic habitats need to be lumped to enable comparison of results.

(ii) People usually provide information on fish by vernacular or common names, which are far less specific than (and thus not compatible with) scientific nomenclature. Vernacular name systems are often very localised, changing with local languages, and thus may differ significantly between the sites surveyed in one country alone. As a result, one fish species may be associated with a number of vernacular names, but each vernacular name may also apply to more than one species.

This issue is addressed, as much as possible, through indexing the vernacular names recorded during a survey to the scientific names for those species. However, this is not always possible due to inconsistencies between informants. The use of photographic indices is helpful but can also trigger misleading information, due to the variety of photos presented and the limitations of species recognition using photos alone. In this respect, collaboration with local counterparts from fisheries departments is crucial.

(iii) The assessment of possible fishing impacts is based on the collection of average data. Accordingly, fishers are requested to provide information on a catch that is neither exceptionally good nor exceptionally bad. They are also requested to provide this information concerning the most commonly caught species. This average information suffers from two major shortcomings. Firstly, some fish species are seasonal and may be dominant during a short period of the year but do not necessarily appear frequently in the average catch. Depending on the time of survey implementation this may result in over- or under-representation of these species. Secondly, fishers usually employ more than one technique. Average catches may vary substantially by quantity and quality depending on which technique they use.

We address these problems by recording any fish that plays a seasonal role. This information may be added and helpful for joint interpretation of resource and socioeconomic data. Average catch records are complemented by information on the technique used, and fishers are encouraged to provide the average catch information for the technique that they employ most often.

The design of the finfish fisher survey allows the collection of details on fishing strategies, and quantitative and qualitative data on average catches for each habitat. Targeting men and women fishers allows differences between genders to be established.

Determination of fishing strategies includes:

- frequency of fishing trips
- mode and frequency of transport used for fishing
- size of fishing parties
- duration of the fishing trip
- time of fishing
- months fished
- techniques used
- ice used
- use of catch
- additional involvement in invertebrate fisheries.

The frequency of fishing trips is determined by the number of weekly (or monthly) trips that are regularly made. The average figure resulting from data for all fishers surveyed, per habitat targeted, provides a first impression of the community's engagement in finfish fisheries and shows whether or not different habitats are fished with the same frequency.

Information on the utilisation of non-motorised or motorised boat transport for fishing helps to assess accessibility, availability and choice of fishing grounds. Motorised boats may also represent a multiplication factor as they may accommodate larger fishing parties.

We ask about the size of the fishing party that the interviewee usually joins to learn whether there are particularly active or regular fisher groups, whether these are linked to fishing in certain habitats, and whether there is an association between the size of a fishing party and fishing for subsistence or sale. We also use this information to determine whether information regarding an average catch applies to one or to several fishers.

The duration of a fishing trip is defined as the time spent from any preparatory work through the landing of the catch. This definition takes into account the fact that fishing in a Pacific Island context does not follow a western economic approach of benefit maximisation, but is a more integral component of people's lifestyles. Preparatory time may include up to several hours spent reaching the targeted fishing ground. Fishing time may also include any time spent on the water, regardless of whether there was active fishing going on. The average trip duration is calculated for each habitat fished, and is usually compared to the average frequency of trips to these habitats (see discussion above).

Temporal fishing patterns – the times when most people go fishing – may reveal whether the timing of fishing activities depends primarily on individual time preferences or on the tides. There are often distinct differences between different fisher groups (e.g. those that fish mostly for food or mostly for sale, men and women, and fishers using different techniques). Results are provided in percentage of fishers interviewed for each habitat fished.

To calculate total annual fishing impact, we determine the total number of months that each interviewee fishes. As mentioned earlier, the seasonality of complementary activities (e.g. agriculture), seasonal closing of fishing areas, etc. may result in distinct fishing patterns. To take into account exceptional periods throughout the year when fishing is not possible or not pursued, we apply a correction factor of 0.83 to the total provided by people interviewed (this factor is determined on the basis that about two months of every year – specifically, 304/365 days – are not used for fishing due to festivals, funerals and bad weather conditions).

Knowing the range of techniques used and learning which technique(s) is/are predominantly used helps to identify the possible causes of detrimental impacts on the resource. For example, the predominant use of gillnets, combined with particular mesh sizes, may help to assess the impact on a certain number of possible target species, and on the size classes that would be caught. Similarly, spearfishing targets particular species, and the impacts of spearfishing on the abundance of these species in the habitats concerned may become evident. To reveal the degree to which fishers use a variety of different techniques, the percentage of techniques used refers to the proportion of all fishers who use that technique. Percentages show which techniques are used by most or even all fishers, and which are used by smaller groups. In addition, the data are presented by habitat (what percentage of fishers targeting a habitat use a particular technique, where n = the total number of fishers interviewed by habitat).

The use of ice (whether it is used at all, used infrequently or used regularly) hints at the degree of commercialisation, available infrastructure and investment level. Usually, communities targeted by our project are remote and rather isolated, and infrastructure is rudimentary. Thus, ice needs to be purchased and is often obtained from distant sources, with attendant costs in terms of transport and time. On the other hand, ice may be the decisive input that allows marketing at a regional or urban centre. The availability of ice may also be a decisive factor in determining the frequency of fishing trips.

Determining the use of the catch or shares thereof for various purposes (subsistence, non-monetary exchange and sale) is a necessary prerequisite to providing fishery management advice. Fishing pressure is relatively stable if determined predominantly by the community's subsistence demand. Fishing is limited by the quantity that the community can consume, and changes occur in response to population growth and/or changes in eating habits. In contrast, if fishing is performed mainly for external sale, fishing pressure varies according to outside market demand (which may be dynamic) and the cost-benefit (to fishers) of fishing. Fishing strategies may vary accordingly and significantly. The recorded purposes of fishing are presented as the percentage of all fishers interviewed per habitat fished. We distinguish these figures by habitat so as to allow for the fact that one fisher may fish several habitats but do so for different purposes.

Information on the additional involvement of interviewed fishers in invertebrate fisheries, for either subsistence or commercial purposes, helps us to understand the subsistence and/or commercial importance of various coastal resources. The percentage of finfish fishers who also harvest invertebrates is calculated, with the share of these who do so for subsistence and/or for commercial purposes presented in percentage (the sum of the latter percentages may exceed 100, because fishers may harvest invertebrates for both subsistence and sale).

The average catch per habitat (technique and transport used) is recorded, including:

- a list of species, usually by vernacular names; and
- the kg or number per size class for each species.

These data are used to calculate total weight per species and size class, using a weight–length conversion factor (FishBase 2000, refer to Letourneur *et al.* 1998; Kulbicki pers. com.). This requires using the vernacular/scientific name index to relate (as far as possible) local names to their scientific counterparts. Fish length is reported by using size charts that comprise five major size classes in 8 cm intervals, i.e. 8 cm, 16 cm, 24 cm, 32 cm and 40 cm. The length of any fish that exceeds the largest size class (40 cm) presented in the chart is individually estimated using a tape measure. The length–weight relationship is calculated for each site using a regression on catch records from finfish fishers' interviews weighted by the annual catch. Data used from the catch records consist of scientific names correlated to the vernacular names given by fishers, number of fish, size class (or measured size) and/or weight. In other words, we use the known length–weight relationship for the corresponding species to vernacular names recorded.

Once we have established the average and total weight per species and size class recorded, we provide an overview of the average size for each family. The resulting pattern allows analysis of the degree to which average and relative sizes of species within the various families present at a particular site are homogeneous. The same average distribution pattern is calculated for all families, per habitat, in order to reveal major differences due to the locations where the fish were caught. Finally, we combine all fish records caught, per habitat and site, to determine what proportion of the extrapolated total annual catch is composed of each of the various size classes. This comparison helps to establish the most dominant size class caught overall, and also reveals major differences between the habitats present at a site.

Catch data are further used to calculate the total weight for each family (includes all species reported) and habitat. We then convert these figures into the percentage distribution of the total annual catch, by family and habitat. Comparison of relative catch composition helps to identify commonalities and major differences, by habitat and between those fish families that are most frequently caught.

A number of parameters from the household and fisher surveys are used to calculate the total annual catch volume per site, habitat, gender, and use of the catch (for subsistence and/or commercial purposes).

Appendix 1: Survey methods
Socioeconomics

Data from the household survey regarding the number of fishers (by gender and type of fishery) in each household interviewed are extrapolated to determine the total number of men and women that target finfish, invertebrates, or both.

Data from the fisher survey are used to determine what proportion of men and women fishers target various habitats or combinations of habitats. These figures are assumed to be representative of the community as a whole, and hence are applied to the total number of fishers (as determined by the household survey). The total number of finfish fishers is the sum of all fishers who solely target finfish, and those who target both finfish and invertebrates; the same system is applied for invertebrate fishers (i.e. it includes those who collect only invertebrates and those who target both invertebrates and finfish. These numbers are also disaggregated by gender.

The total annual catch per fisher interviewed is calculated, and the average total annual catch reported for each type of fishing activity/fishery (including finfish and invertebrates) by gender is then multiplied by the total number of fishers (calculated as detailed above, for each type of fishing activity/fishery and both genders). More details on the calculation applied to invertebrate fisheries are provided below.

<u>Total annual catch (t/year):</u>

$$\text{TAC} = \sum_{h=1}^{N_h} \frac{Fif_h \bullet Acf_h + Fim_h \bullet Acm_h}{1000}$$

TAC = total annual catch t/year
Fif_h = total number of female fishers for habitat_h
Acf_h = average annual catch of female fishers (kg/year) for habitat_h
Fim_h = total number of male fishers for habitat_h
Acm_h = average annual catch of male fishers (kg/year) for habitat_h
N_h = number of habitats

Where:

$$\text{Acf}_h = \frac{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cfi}{If_h} \bullet \frac{\sum_{k=1}^{Rf_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{If_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

If_h = number of interviews of female fishers for habitat_h (total number of interviews where female fishers provided detailed information for habitat_h)
f_i = frequency of fishing trips (trips/week) as reported on interview_i
Fm_i = number of months fished (reported in interview_i)
Cf_i = average catch reported in interview_i (all species)
Rf_h = number of targeted habitats as reported by female fishers for habitat_h (total numbers of interviews where female fishers reported targeting habitat_h but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for habitat_k
Fm_k = number of months fished for reported habitat_k (fishers = sum of finfish fishers and mixed fishers, i.e. people pursuing both finfish and invertebrate fishing)

Thus, we obtain the total annual catch by habitat and gender group. The sum of all catches from all habitats and both genders equals the total annual impact of the community on its fishing ground.

The accuracy of this calculation is determined by reliability of the data provided by interviewees, and the extrapolation procedure. The variability of the data obtained through fisher surveys is illuminated by providing standard errors for the calculated average total annual catches. The size of any error stemming from our extrapolation procedure will vary according to the total population at each site. As mentioned above, this approach is best suited to assess small and predominantly traditional coastal communities. Thus, the risk of over- or underestimating fishing impact increases in larger communities, and those with greater urban influences. We provide both the total annual catch by interviewees (as determined from fisher records) and the extrapolated total impact of the community, so as to allow comparison between recorded and extrapolated data.

The total annual finfish consumption of the surveyed community is used to determine the share of the total annual catch that is used for subsistence, with the remainder being the proportion of the catch that is exported (sold externally).

Total annual finfish export:

$$E = TAC - \left(\frac{F_{tot}}{1000} \bullet \frac{1}{0.8}\right)$$

Where:

E = total annual export (t)
TAC = total annual catch (t)
F_{tot} = total annual finfish consumption (net weight kg)
$\frac{1}{0.8}$ = to calculate total biomass/weight, i.e. compensate for the earlier deduction by 0.8 to determine edible weight parts only

In order to establish fishing pressure, we use the habitat areas as determined by satellite interpretation. However, as already mentioned, resource surveys and satellite interpretation do not include lagoon areas. Thus, we determine the missing areas by calculating the smallest possible polygon (Figure A1.1.3) that encompasses the total fishing ground determined with fishers and local people during the fieldwork. In cases where fishing grounds are gazetted, owned and managed by the community surveyed, the missing areas are determined using the community's fishing ground limits.

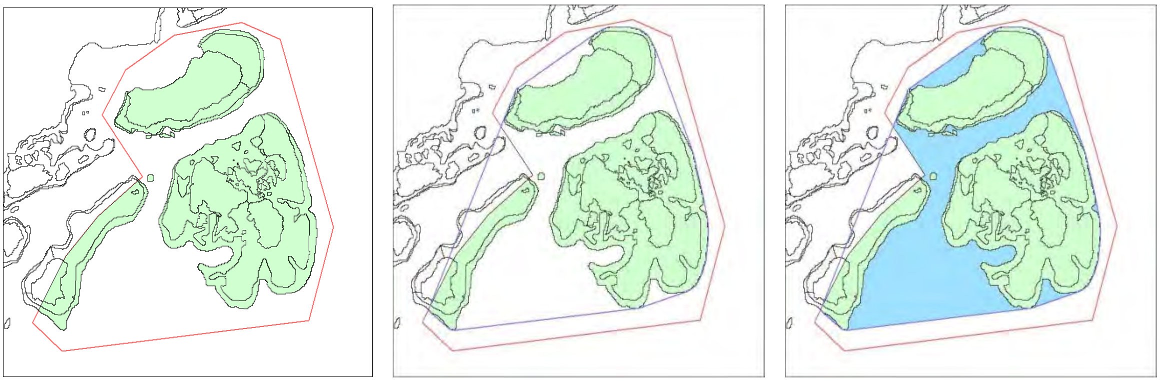

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as lagoon (in blue) (Developed using MapInfo).

We use the calculated total annual impact and fishing ground areas to determine relative fishing pressure. Fishing pressure indicators include the following:

- annual catch per habitat
- annual catch per total reef area
- annual catch per total fishing ground area.

Fisher density includes the total number of fishers per km^2 of reef and total fishing ground area, and productivity is the annual catch per fisher. Due to the lack of baseline data, we compare selected indicators, such as fisher density, productivity (catch per fisher and year) and total annual catch (per reef and total fishing ground area), across all sites for each country surveyed. This comparison may also be done at the regional level in the future.

The catch per unit effort (CPUE) is generally acknowledged as an indicator of the status of a resource. If an increasing amount of time is required to obtain a certain catch, degradation of the resource is assumed. However, taking into account that our project is based on a snapshot approach, CPUE is used on a comparative basis between sites within a country, and will be employed later on a regional scale. Its application and interpretation must also take into account the fact that fishing in the Pacific Islands does not necessarily follow efficiency or productivity maximisation strategies, but is often an integral component of people's lifestyles. As a result, CPUE has limited applicability.

In order to capture comparative data, in calculating CPUE we use the entire time spent on a fishing trip, including travel, fishing and landing. Thus, we divide the total average catch per fisher by the total average time spent per fishing trip. CPUE is determined as an overall average figure, by gender and habitat fished.

Invertebrate fisher survey

The objective, purpose and design of the invertebrate fisher survey largely follow those of the finfish fisher survey. Thus, the primary aim of the invertebrate fisher survey is to collect data needed to understand the strategies, patterns and dimensions of invertebrate fisheries, and hence the possible impacts on invertebrate resources. Invertebrate data collection faces several challenges, as retrieval of information from local people needs to match the resource survey parameters in order to enable joint data analysis. Some of the major issues are:

Appendix 1: Survey methods
Socioeconomics

(i) The invertebrate resource survey defines invertebrate fisheries using differing parameters (several are primarily determined by habitat, others by target species). However, these fisheries classifications do not necessarily coincide with the perceptions and fishing strategies of local people. In general, there are two major types of invertebrate fishers: those who walk and collect with simple tools, and those who free-dive using masks, fins, snorkel, hands, simple tools or spears. The latter group is often more commercially oriented, targeting species that are exploited for export (trochus, BdM, lobster, etc.). However, some of the divers may harvest invertebrates as a by-product of spearfishing for finfish. Fishers who primarily walk (some may or may not use non-motorised or even motorised transport to reach fishing grounds) are mainly gleaners targeting available habitats (or a combination of habitats, if convenient). While gleaning is often performed for subsistence needs, it may also be used as a source of income, albeit mostly serving national rather than export markets. While gleaning is an activity that may be performed by both genders, diving is usually men's domain.

We have addressed the problem of collecting information according to fisheries as defined by the resource survey by asking people to report according to the major habitats they target and/or species-specific dive fisheries they engage in. Very often this results in the grouping of various fisheries, as they are jointly targeted or performed on one fishing trip. Where possible, we have disaggregated data for these groups and allocated individuals to specific fisheries. Examples of such data disaggregation are the proportion of all fishers and fishers by gender targeting each of the possible fisheries at one site.

We have also disaggregated some of the catch data, because certain species are always or mostly associated with a particular fishery. However, the disagreement between people's perception and the resource classification becomes visible when comparing species composition per fishery (or combination of fisheries) as reported by interviewed fishers, and the species and total annual wet weight harvested allocated individually by fishery, as defined by the resource survey.

(ii) As is true for finfish, people usually provide information on invertebrate species by vernacular or common names, which are far less specific and thus not directly compatible with scientific nomenclature. Vernacular name systems are often very localised, changing with local languages, and thus may differ significantly between the sites surveyed in one country. Differing from finfish, vernacular names for invertebrates usually combine a group (often a family) of species, and are rarely species specific.

Similar to finfish, the issue of vernacular versus scientific names is addressed by trying to index as many scientific names as possible for any vernacular name recorded during the ongoing survey. Inconsistencies between informants are a limiting factor. The use of photographic indices is very useful, but may trigger misleading information; in addition, some reported species may not be depicted. Again, collaboration with local counterparts from fisheries departments is crucial.

The lack of specificity in the vernacular names used for invertebrates is an issue that cannot be resolved, and specific information regarding particular species that are included with others under one vernacular name cannot be accurately provided.

(iii) The assessment of possible fishing impacts is based on the collection of average data. This means that fishers are requested to provide information on a catch that is neither exceptionally good nor exceptionally bad. They are also requested to provide this information concerning the most commonly caught species. In the case of invertebrate fisheries this results in underestimation of the total number of species caught, and often greater attention is given to commercial species than to rare species that are used mainly for consumption. Seasonality of invertebrate species appears to be a less important issue than when compared to finfish.

We address these problems by encouraging people to also share with us the names of species they may only rarely catch.

(iv) Assessment of possible fishing impact requires knowledge of the size–weight relationship of (at least) the major species groups harvested. Unfortunately, a comparative tool (such as FishBase and others that are used for finfish) is not available for invertebrates. In addition, the proportion of edible and non-edible parts varies considerably among different groups of invertebrates. Further, non-edible parts may still be of value, as for instance in the case of trochus. However, these ratios are also not readily available and hence limit current data analysis.

We have dealt with this limitation by applying average weights (drawn from the literature or field measurements) for certain invertebrate groups. The applied wet weights are listed in Appendix 1.1.3. We used this approach to estimate total biomass (wet weight) removed; we have also listed approximations of the ratio between edible and non-edible biomass for each species.

Information on invertebrate fishing strategies by fishery and gender includes:

- frequency of fishing trips
- duration of an average fishing trip
- time when fishing
- total number of months fished per year
- mode of transport used
- size of fishing parties
- fishing external to the community's fishing grounds
- purpose of the fisheries
- whether or not the fisher also targets finfish.

In addition, for each fishery (or combination of fisheries) the species composition of an average catch is listed, and the average catch for each fishery is specified by number, size and/or total weight. If local units such as bags (plastic bags, flour bags), cups, bottles or buckets are used, the approximate weight of each unit is estimated and/or weighed during the field survey and average weight applied accordingly. For size classes, size charts for different species groups are used (Figure A1.1.2).

The proportion of fishers targeting each fishery (as defined by the resource survey) is presented as a percentage of all fishers. Records of fisheries that are combined in one trip are disaggregated by counting each fishery as a single data entry. The same process is applied to determine the share of women and men fishers per fishery (as defined by the resource survey).

Appendix 1: Survey methods
Socioeconomics

The number of different vernacular names recorded for each fishery is useful to distinguish between opportunistic and specialised harvesting strategies. This distribution is particularly interesting when comparing gleaning fisheries, while commercial dive fisheries are species specific by definition.

The calculation of catch volumes is based on the determination of the total number of invertebrate fishers and fishers targeting both finfish and invertebrates, by gender group and by fishery, as described above.

The average invertebrate catch composition by number, size and species (with vernacular names transferred to scientific nomenclature), and by fishery and gender group, is extrapolated to include all fishers concerned. Conversion of numbers and species by average weight factors (Appendix 1.1.3) results in a determination of total biomass (wet weight) removed, by fishery and by gender. The sum of all weights determines the total annual impact, in terms of biomass removed.

To calculate total annual impact, we determine the total numbers of months fished by each interviewee. As mentioned above, seasonality of complementary activities, seasonal closing of fishing areas, etc. may result in distinct fishing patterns. Based on data provided by interviewees, we apply – as for finfish – a correction factor of 0.83 to take into account exceptional periods throughout the year when fishing is not possible or not pursued (this is determined on the basis that about two months (304/365 days) of each year are not used for fishing due to festivals, funerals and bad weather conditions).

Total annual catch:

$$\mathrm{TACj} = \sum_{h=1}^{N_h} \frac{F_{inv} f_h \bullet Ac_{inv} f_{hj} + F_{inv} m_h \bullet Ac_{inv} m_{hj}}{1000}$$

TACj = total annual catch t/year for species$_j$

$F_{inv}f_h$ = total number of female invertebrate fishers for habitat$_h$

$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for habitat$_h$ and species$_j$

$F_{inv}m_h$ = total number of male invertebrate fishers for habitat$_h$

$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for habitat$_h$ and species$_j$

N_h = number of habitats

Where:

$$\mathrm{Ac_{inv}f_{hj}} = \frac{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cf_{ij}}{I_{inv} f_h} \bullet \frac{\sum_{k=1}^{R_{inv}f_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

$I_{inv}f_h$ = number of interviews of female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for habitat$_h$)

f_i = frequency of fishing trips (trips/week) as reported in interview$_i$

Fm_i = number of months fished as reported in interview$_i$
Cf_{ij} = average catch reported for species$_j$ as reported in interview$_i$
$R_{inv}f_h$ = number of targeted habitats reported by female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers reported targeting habitat$_h$ but did not necessarily provide detailed information)
f_k = frequency of fishing trips (trips/week) as reported for habitat$_k$
Fm_k = number of months fished for reported habitat$_k$

The total annual biomass (t/year) removed is also calculated and presented by species after transferring vernacular names to scientific nomenclature. Size frequency distributions are provided for the most important species, by total annual weight removed, expressed in percentage of each size group of the total annual weight harvested. The size frequency distribution may reveal the impact of fishing pressure for species that are represented by a wide size range (from juvenile to adult state). It may also be a useful parameter to compare the status of a particular species or species group across various sites at the national or even regional level.

To further determine fishing strategies, we also inquire about the purpose of harvesting each species (as recorded by vernacular name). Results are depicted as the proportion (in kg/year) of the total annual biomass (net weight) removed for each purpose: consumption, sale or both. We also provide an index of all species recorded through fisher interviews and their use (in percentage of total annual weight) for any of the three categories.

In order to gain an idea of the productivity of and differences between the fisheries practices used in each site we calculate the average annual catch per fisher, by gender and fishery. This calculation is based on the total biomass (net weight) removed from each fishery and the total number of fishers by gender group.

For invertebrate species that are marketed, detailed information is collected on total numbers (weight and/or combination of number and size), processing level, location of sale or client, frequency of sales and price received per unit sold. At this stage of our project we do not fully analyse this marketing information. However, prices received for major commercial species, as well as an approximation of sale volumes by fishery and fisher, help to assess what role invertebrate fisheries (or a particular fishery) play(s) in terms of income generation for the surveyed community, and in comparison to the possible earnings from finfish fisheries.

We use the calculated total annual impact in combination with the fishing ground area to determine relative fishing pressure. Fishing pressure indicators are calculated as the annual catch per km^2 for each area that is considered to support any of the fisheries present at each study site. In some instances (e.g. intertidal fisheries), areas are replaced by linear km; accordingly, fishing pressure is then related to the length (in km) of the supporting habitat. Due to the lack of baseline data, we compare selected indicators, such as the fisher density (number of fishers per km^2 – or linear km – of fishing ground, for each fishery), productivity (catch per fisher and year) and total annual catch per fishery, across all sites for each country surveyed. This comparison may also be done at the regional level in the future.

The differing nature of invertebrate species that may be caught during one fishing trip, and hence the great variability between edible and non-edible, useful and non-useful parts of species caught, make the determination of CPUE difficult. Substantial differences in the economic value of species add another challenge. We have therefore refrained from calculating CPUE values at this stage of the project.

Data entry and analysis

Data from all questionnaire forms are entered in the Reef Fisheries Integrated Database (RFID) system. All data entered are first verified and 'cleaned' prior to analysis. In the process of data entry, a comprehensive list of vernacular and corresponding scientific names for finfish and invertebrate species is developed.

Database queries have been defined and established that allow automatic retrieval of the descriptive statistics used when summarising results at the site and national levels.

1.1.2 Socioeconomic survey questionnaires

- Household census and consumption survey
- Finfish fishing and marketing survey (for fishers)
- Invertebrate fishing and marketing survey (for fishers)
- Fisheries (finfish and invertebrate and socioeconomics) general information survey

HOUSEHOLD CENSUS AND CONSUMPTION SURVEY

HH NO. ☐

Name of head of household: ________________ Village: _________________

Name of person asked: _____________________ Date: __________________

Surveyor's ID: __________________

1. Who is the head of your household? *(must be living there; tick box)* — male ☐ female ☐

2. How old is the head of household? *(enter year of birth)* ☐

3. How many people ALWAYS live in your household? *(enter number)* ☐

4. How many are male and how many are female? (*tick box and enter age in years or year of birth)*

male	age	female	age
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐

5. Does this household have any agricultural land?

yes ☐ no ☐

6. How much (*for this household only*)?

for permanent/regular cultivation ☐ (unit)

for permanent/regular livestock ☐ (unit)
type of animals__________ no. ☐

7. How many fishers live in your household? ☐
(*enter number of people who go fishing/collecting regularly*)

invertebrate fishers		finfish fishers		invertebrate & finfish fishers	
M	F	M	F	M	F
☐	☐	☐	☐	☐	☐

8. Does this household own a boat? yes ☐ no ☐

9a. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9b. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9c. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP

10. Where does the CASH money in this household come from? (*rank options, 1 = most money, 2 = second important income source, 3 = 3rd important income source, 4 = 4th important income source*)

Fishing/seafood collection ☐

Agriculture (crops & livestock) ☐

Salary ☐

Others (handicrafts, etc.) ☐ specify: ____________________

11. Do you get remittances? yes ☐ no ☐

12. How often?

1 per month	1 per 3 months	1 per 6 months	other *(specify)*
☐	☐	☐	☐

13. How much? *(enter amount)* Every time? (currency) ☐

14. How much CASH money do you use on average for household expenditures (food, fuel for cooking, school bus, etc.)?

(currency) ☐ per week/2-weekly/month (or? specify_______)

15. What is the educational level of your household members?

no. of people	having achieved:
☐	elementary/primary education
☐	secondary education
☐	tertiary education (college, university, special schools, etc.)

CONSUMPTION SURVEY

16. During an average/normal week, on how many days do you prepare fish, other seafood and canned fish for your family? *(tick box)*

	7 days	6 days	5 days	4 days	3 days	2 days	1 day	other, specify
Fresh fish	☐	☐	☐	☐	☐	☐	☐	☐
Other seafood	☐	☐	☐	☐	☐	☐	☐	☐
Canned fish	☐	☐	☐	☐	☐	☐	☐	☐

17. Mainly at	breakfast	lunch	supper
Fresh fish	☐	☐	☐
Other seafood	☐	☐	☐
Canned fish	☐	☐	☐

18. How much do you cook on average per day for your household? *(tick box)*

	number	kg	size: A	B	C	D	E	>E (cm)
Fresh fish	☐	☐	☐	☐	☐	☐	☐	☐

Other seafood

name:	no.	size	kg	plastic bag ¼	½	¾	1
____________	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐
____________	☐	☐	☐	☐	☐	☐	☐

19. Canned fish No. of cans: ☐ Size of can: ☐ small

☐ medium

☐ big

20. Where do you normally get your fish and seafood from?

Fish:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ____________________________

Which is the most important source? ☐ caught ☐ given ☐ bought

Invertebrates:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ____________________________

Which is the most important source? ☐ caught ☐ given ☐ bought

21. Which is the last day you had fish? ______________________________

22. Which is the last day you had other seafood? ______________________________

–THANK YOU–

FISHING (FINFISH) AND MARKETING SURVEY

Name: ____________________ F ☐ M ☐ **HH NO.** ☐

Name of head of household: ______________________ Village: ______________

Surveyor's name: ____________________ Date: ______________

1. Which areas do you fish?

coastal reef ☐ lagoon ☐ outer reef ☐ mangrove ☐ pelagic ☐

2. Do you go to only one habitat per trip?

Yes ☐ no ☐

3. If no, how many and which habitats do you visit during an average trip?

total no. ☐ habitats: coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

4. How often (days/week) do you fish in each of the habitats visited?

coastal reef	lagoon	mangrove	outer reef	
☐	☐	☐	☐	__________/times per week/month
☐	☐	☐	☐	__________/times per week/month
☐	☐	☐	☐	__________/times per week/month

5. Do you use a boat for fishing?

	Always	sometimes	never
coastal reef	☐	☐	☐
lagoon	☐	☐	☐
mangrove	☐	☐	☐
outer reef	☐	☐	☐

6. If you use a boat, which one?

1 canoe (paddle) ☐ sailing ☐
motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

2	canoe (paddle)	☐				sailing	☐
	motorised	☐		HP outboard	☐	4-stroke engine	☐
	coastal reef	☐	lagoon ☐	outer reef	☐		
3	canoe (paddle)	☐				sailing	☐
	motorised	☐		HP outboard	☐	4-stroke engine	☐
	coastal reef	☐	lagoon ☐	outer reef	☐		

7. How many fishers ALWAYS go fishing with you?

Names:____
____
____
____

Appendix 1: Survey methods
Socioeconomics

INFORMATION BY FISHERY **Name of fisher: _____________** **HH NO.** ☐

coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

1. HOW OFTEN do you normally go out FISHING for this habitat? *(tick box)*

Every Day	5 days/ week	4 days/ week	3 days/ week	2 days/ week	1 day/ week	other, specify:
☐	☐	☐	☐	☐	☐	___________________

2. What time do you spend fishing this habitat per average trip? ___________________
(if the fisher can't specify, tick a box)

<2 hrs	2–6 hrs	6–12 hrs	>12 hrs
☐	☐	☐	☐

3. WHEN do you go fishing? *(tick box)* day ☐ night ☐ day & night ☐

4. Do you go all year?

Yes ☐ no ☐

5. If no, which months don't you fish?

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Which fishing techniques do you use (*in the habitat referred to here*)?

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep bottom line ☐ poison: which one? _____________

☐ other, specify: ____

7. Do you use more than one technique per trip for this habitat? If yes, which ones usually?

☐ one technique/trip ☐ more than one technique/trip:

____

8. Do you use ice on your fishing trips?

☐ always ☐ sometimes ☐ never

☐ is it homemade? ☐ or bought?

9. What is your average catch (kg) per trip? ☐ Kg OR:

size class:	A	B	C	D	E	>E (cm)
number:	☐	☐	☐	☐	☐	☐

10. Do you sell fish? yes ☐ no ☐

11. Do you give fish as a gift (for no money)? yes ☐ no ☐

12. Do you use your catch for family consumption? yes ☐ no ☐

13. How much of your usual catch do you keep for family consumption?

kg ☐ OR:

size class	A	B	C	D	E	>E (cm)
no	☐	☐	☐	☐	☐	☐

and the rest you gift? yes ☐

how much? kg ☐ OR:

size class	A	B	C	D	E	>E (cm)
no.	☐	☐	☐	☐	☐	☐

and/or sell? yes ☐

how much? kg ☐ OR:

size class	A	B	C	D	E	>E (cm)
no.	☐	☐	☐	☐	☐	☐

14. What sizes of fish do you use for your family consumption, what for sale and what do you give away without getting any money?

size classes:	all	A	B	C	D	E	and larger (no. and cm)
consumption	☐	☐	☐	☐	☐	☐	☐
sale	☐	☐	☐	☐	☐	☐	☐
give away	☐	☐	☐	☐	☐	☐	☐

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

market ☐ agents/middlemen ☐ shop owners ☐ others ☐ ___________

16. In an average catch what fish do you catch, and how much of each species? *(write down the species in the table)*

technique usually used:_____________________ boat type usually used:________________
habitat usually fished: ____

Specify the number by size

Name of fish	kg	A	B	C	D	E	>E cm

20. Do you also fish invertebrates?

Yes ☐ no ☐ if yes for consumption? ☐ sale? ☐

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ____________________________________

Gender: ☐ female ☐ male Age: ☐

Village: ____________________________________

Date: _______________ Surveyor's name: __________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

☐ bêche-de mer diving ☐ mother-of-pearl diving trochus, pearl shell, etc.

☐ lobster diving ☐ other, such as clams, octopus

2. *(if more than one fishery in question 1):* Do you usually go fishing at only one of the fisheries or do you visit several during one fishing trip?

☐ one only ☐ several

If several fisheries at a time, which ones do you combine?

----

3. How often do you go gleaning/diving (*tick as from questions 1 and 2 above and watch for combinations*) and for how long, and do you also finfish at the same time?

	times/week	duration in hours (*if the fisher can't specify, tick the box*)	<2	2–4	4–6	>6	glean/dive at D	N	D&N	fish no. of months/year
☐ seagrass gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mangrove & mud gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ sand & beach gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ reeftop gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ bêche-de-mer diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ lobster diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mother-of-pearl diving trochus, pearl shell, etc.	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ other diving (clams, octopus)	☐	____	☐	☐	☐	☐	☐	☐	☐	________

D = day, N = night, D&N = day and night (no preference but fish with tide)

4. Do you sometimes go gleaning/fishing for invertebrates outside your village fishing grounds?

   yes ☐ no ☐

   If yes, where? ____

5. Do you finfish? yes ☐ no ☐

   for: ☐ consumption? ☐ sale?

   at the same time? yes ☐ no ☐

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

GLEANING: seagrass ☐ mangrove & mud ☐ sand & beach ☐ reeftop ☐

DIVING: bêche-de-mer ☐ lobster ☐ mother-of-pearl, trochus, pearl shell, etc. ☐ other (clams, octopus) ☐

SHEET 1: EACH FISHERY PER FISHER INTERVIEWED: ☐ **HH NO. __Name of fisher: ______________** **gender: F** ☐ **M** ☐

What transport do you mainly use? ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

How many fishers are usually on a trip? (total no.) ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

Species vernacular/common name and scientific code if possible	**Average quantity/trip**							**Used for** (specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given) gift = giving away for no money		
	total number/ trip	weight/trip					average size cm	cons.	gift	sale
		total kg	plastic bag unit							
			1	3/4	1/2	1/4				

Appendix 1: Survey methods
Socioeconomics

<table>
<tr><td>Species
vernacular/common name and scientific code if possible</td><td colspan="7">Average quantity/trip</td><td colspan="3">Used for
(specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given)
gift = giving away for no money</td></tr>
<tr><td rowspan="3"></td><td rowspan="3">total number/ trip</td><td colspan="5">weight/trip</td><td rowspan="3">average size cm</td><td rowspan="3">cons.</td><td rowspan="3">gift</td><td rowspan="3">sale</td></tr>
<tr><td rowspan="2">total kg</td><td colspan="4">plastic bag unit</td></tr>
<tr><td>1</td><td>3/4</td><td>1/2</td><td>1/4</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

Appendix 1: Survey methods
Socioeconomics

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

GLEANING: seagrass ☐ mangrove & mud ☐ sand & beach ☐ reeftop ☐

DIVING: bêche-de-mer ☐ lobster ☐ mother-of-pearl, trochus, pearl shell, etc. ☐ other (clams, octopus) ☐

SHEET 2: SPECIES SOLD PER FISHER INTERVIEWED: **HH NO**. ☐ **Name of fisher:** ________________________

Copy all species that have been named for 'SALE' in previous sheet

Who markets your products? ☐ you ☐ your wife ☐ your husband ☐ a group of fishers ☐ other __________________

Species for sale – copy from sheet 2 (for each fishery per fisher) above	Processing level of product sold (see list)	Where do you sell? (see list)	How often? Days/week?	How much each time? Quantity/unit	Price

FISHERIES (FINFISH AND INVERTEBRATE AND SOCIOECONOMICS) GENERAL INFORMATION SURVEY

Target group: key people, groups of fishers, fisheries officers, etc.

1. Are there management rules that apply to your fisheries? Do they specifically target finfish or invertebrates, or do they target both sectors?

a) legal/Ministry of Fisheries

b) traditional/community/village determined:

2. What do you think – do people obey:

traditional/village management rules?

mostly ☐ sometimes ☐ hardly ☐

legal/Ministry of Fisheries management rules?

mostly ☐ sometimes ☐ hardly ☐

3. Are there any particular rules that you know people do not respect or follow at all? And do you know why?

4. What are the main techniques used by the community for:

a) finfishing

gillnets – most-used mesh sizes:

What is usually used for bait? And is it bought or caught?

b) invertebrate fishing → ***see end!***

5. Please give a quick inventory and characteristics of boats used in the community (length, material, motors, etc.).

Seasonality of species

What are the **FINFISH** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

Seasonality of species

What are the **INVERTEBRATE** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

How many people carry out the invertebrate fisheries below, from inside and from outside the community?

GLEANING	**no. from this village**	**no.**	**from village**	**no.**	**from village**
☐ seagrass gleaning	☐	☐	______	☐	______
☐ mangrove & mud gleaning	☐	☐	______	☐	______
☐ sand & beach gleaning	☐	☐	______	☐	______
☐ reeftop gleaning	☐	☐	______	☐	______
DIVING					
☐ bêche-de-mer diving	☐	☐	______	☐	______
☐ lobster diving	☐	☐	______	☐	______
☐ mother-of-pearl diving trochus, pearl shell, etc.	☐	☐	______	☐	______
☐ other (clams, octopus)	☐	☐	______	☐	______

What gear do invertebrate fishers use? *(tick box of technique per fishery)*

GLEANING (soft bottom = seagrass)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

GLEANING (soft bottom = mangrove & mud)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

GLEANING (soft bottom = sand & beach)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

GLEANING (hard bottom = reeftop)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

DIVING (bêche-de-mer)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

DIVING (lobster)

☐ spoon	☐ wooden stick	☐ knife	☐ iron rod	☐ spade
☐ hand net	☐ net	☐ trap	☐ goggles	☐ dive mask
☐ snorkel	☐ fins	☐ weight belt		
☐ air tanks	☐ hookah	☐ other __________		

DIVING (mother-of-pearl, trochus, pearl shell, etc.)

☐ spoon ☐ wooden stick ☐ knife ☐ iron rod ☐ spade

☐ hand net ☐ net ☐ trap ☐ goggles ☐ dive mask

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

DIVING (other, such as clams, octopus)

☐ spoon ☐ wooden stick ☐ knife ☐ iron rod ☐ spade

☐ hand net ☐ net ☐ trap ☐ goggles ☐ dive mask

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

Any traditional/customary/village fisheries?

Name:

Season/occasion:

Frequency:

Quantification of marine resources caught:

Species name	Size	Quantity (unit?)

1.1.3 Average wet weight applied for selected invertebrate species groups

Unit weights used in conversions for invertebrates.

Scientific names	g/piece	% edible part	% non-edible part	Edible part (g/piece)	Group
Acanthopleura gemmata	29	35	65	10.15	Chiton
Actinopyga lecanora	300	10	90	30	BdM (1)
Actinopyga mauritiana	350	10	90	35	BdM (1)
Actinopyga miliaris	300	10	90	30	BdM (1)
Anadara sp.	21	35	65	7.35	Bivalves
Asaphis violascens	15	35	65	5.25	Bivalves
Astralium sp.	20	25	75	5	Gastropods
Atactodea striata, *Donax cuneatus,* *Donax cuneatus*	2.75	35	65	0.96	Bivalves
Atrina vexillum, *Pinctada margaritifera*	225	35	65	78.75	Bivalves
Birgus latro	1000	35	65	350	Crustacean
Bohadschia argus	462.5	10	90	46.25	BdM (1)
Bohadschia sp.	462.5	10	90	46.25	BdM (1)
Bohadschia vitiensis	462.5	10	90	46.25	BdM (1)
Cardisoma carnifex	227.8	35	65	79.74	Crustacean
Carpilius maculatus	350	35	65	122.5	Crustacean
Cassis cornuta, *Thais aculeata,* *Thais aculeata*	20	25	75	5	Gastropods
Cerithium nodulosum, *Cerithium nodulosum*	240	25	75	60	Gastropods
Chama sp.	25	35	65	8.75	Bivalves
Codakia punctata	20	35	65	7	Bivalves
Coenobita sp.	50	35	65	17.5	Crustacean
Conus miles, *Strombus gibberulus gibbosus*	240	25	75	60	Gastropods
Conus sp.	240	25	75	60	Gastropods
Cypraea annulus, *Cypraea moneta*	10	25	75	2.5	Gastropods
Cypraea caputserpensis	15	25	75	3.75	Gastropods
Cypraea mauritiana	20	25	75	5	Gastropods
Cypraea sp.	95	25	75	23.75	Gastropods
Cypraea tigris	95	25	75	23.75	Gastropods
Dardanus sp.	10	35	65	3.5	Crustacean
Dendropoma maximum	15	25	75	3.75	Gastropods
Diadema sp.	50	48	52	24	Echinoderm
Dolabella auricularia	35	50	50	17.5	Others
Donax cuneatus	15	35	65	5.25	Bivalves
Drupa sp.	20	25	75	5	Gastropods
Echinometra mathaei	50	48	52	24	Echinoderm
Echinothrix sp.	100	48	52	48	Echinoderm
Eriphia sebana	35	35	65	12.25	Crustacean
Gafrarium pectinatum	21	35	65	7.35	Bivalves
Gafrarium tumidum	21	35	65	7.35	Bivalves
Grapsus albolineatus	35	35	65	12.25	Crustacean
Hippopus hippopus	500	19	81	95	Giant clams
Holothuria atra	100	10	90	10	BdM (1)
Holothuria coluber	100	10	90	10	BdM (1)

1.1.3 Average wet weight applied for selected invertebrate species groups (continued)

Unit weights used in conversions for invertebrates.

Scientific names	g/piece	% edible part	% non-edible part	Edible part (g/piece)	Group
Holothuria fuscogilva	2000	10	90	200	BdM (1)
Holothuria fuscopunctata	1800	10	90	180	BdM (1)
Holothuria nobilis	2000	10	90	200	BdM (1)
Holothuria scabra	2000	10	90	200	BdM (1)
Holothuria sp.	2000	10	90	200	BdM (1)
Lambis lambis	25	25	75	6.25	Gastropods
Lambis sp.	25	25	75	6.25	Gastropods
Lambis truncata	500	25	75	125	Gastropods
Mammilla melanostoma, *Polinices mammilla*	10	25	75	2.5	Gastropods
Modiolus auriculatus	21	35	65	7.35	Bivalves
Nerita albicilla, *Nerita polita*	5	25	75	1.25	Gastropods
Nerita plicata	5	25	75	1.25	Gastropods
Nerita polita	5	25	75	1.25	Gastropods
Octopus sp.	550	90	10	495	Octopus
Panulirus ornatus	1000	35	65	350	Crustacean
Panulirus penicillatus	1000	35	65	350	Crustacean
Panulirus sp.	1000	35	65	350	Crustacean
Panulirus versicolor	1000	35	65	350	Crustacean
Parribacus antarcticus	750	35	65	262.5	Crustacean
Parribacus caledonicus	750	35	65	262.5	Crustacean
Patella flexuosa	15	35	65	5.25	Limpet
Periglypta puerpera, *Periglypta reticulate*	15	35	65	5.25	Bivalves
Periglypta sp., *Periglypta* sp., *Spondylus* sp., *Spondylus* sp.,	15	35	65	5.25	Bivalves
Pinctada margaritifera	200	35	65	70	Bivalves
Pitar proha	15	35	65	5.25	Bivalves
Planaxis sulcatus	15	25	75	3.75	Gastropods
Pleuroploca filamentosa	150	25	75	37.5	Gastropods
Pleuroploca trapezium	150	25	75	37.5	Gastropods
Portunus pelagicus	227.83	35	65	79.74	Crustacean
Saccostrea cucullata	35	35	65	12.25	Bivalves
Saccostrea sp.	35	35	65	12.25	Bivalves
Scylla serrata	700	35	65	245	Crustacean
Serpulorbis sp.	5	25	75	1.25	Gastropods
Sipunculus indicus	50	10	90	5	Seaworm
Spondylus squamosus	40	35	65	14	Bivalves
Stichopus chloronotus	100	10	90	10	BdM (1)
Stichopus sp.	543	10	90	54.3	BdM (1)
Strombus gibberulus gibbosus	25	25	75	6.25	Gastropods
Strombus luhuanus	25	25	75	6.25	Gastropods
Tapes literatus	20	35	65	7	Bivalves
Tectus pyramis, *Trochus niloticus*	300	25	75	75	Gastropods
Tellina palatum	21	35	65	7.35	Bivalves

1.1.3 Average wet weight applied for selected invertebrate species groups (continued)

Unit weights used in conversions for invertebrates.

Scientific names	g/piece	% edible part	% non-edible part	Edible part (g/piece)	Group
Tellina sp.	20	35	65	7	Bivalves
Terebra sp.	37.5	25	75	9.39	Gastropods
Thais armigera	20	25	75	5	Gastropods
Thais sp.	20	25	75	5	Gastropods
Thelenota ananas	2500	10	90	250	BdM (1)
Thelenota anax	2000	10	90	200	BdM (1)
Tridacna maxima	500	19	81	95	Giant clams
Tridacna sp.	500	19	81	95	Giant clams
Trochus niloticus	200	25	75	50	Gastropods
Turbo crassus	80	25	75	20	Gastropods
Turbo marmoratus	20	25	75	5	Gastropods
Turbo setosus	20	25	75	5	Gastropods
Turbo sp.	20	25	75	5	Gastropods

BdM = Bêche-de-mer; (1) edible part of dried Bêche-de-mer, i.e. drying process consumes about 90% of total wet weight; hence 10% are considered as the edible part only.

1.2 Methods used to assess the status of finfish resources

Fish counts

In order to count and size fish in selected sites, we use the **distance-sampling underwater visual census (D-UVC)** method (Kulbicki and Sarramegna 1999, Kulbicki *et al.* 2000), fully described in Labrosse *et al.* (2002). Briefly, the method consists of recording the species name, abundance, body length and the distance to the transect line for each fish or group of fish observed; the transect consists of a 50 m line, represented on the seafloor by an underwater tape (Figure A1.2.1). For security reasons, two divers are required to conduct a survey, each diver counting fish on a different side of the transect. Mathematical models are then used to estimate fish density (number of fish per unit area) and biomass (weight of fish per unit area) from the counts.

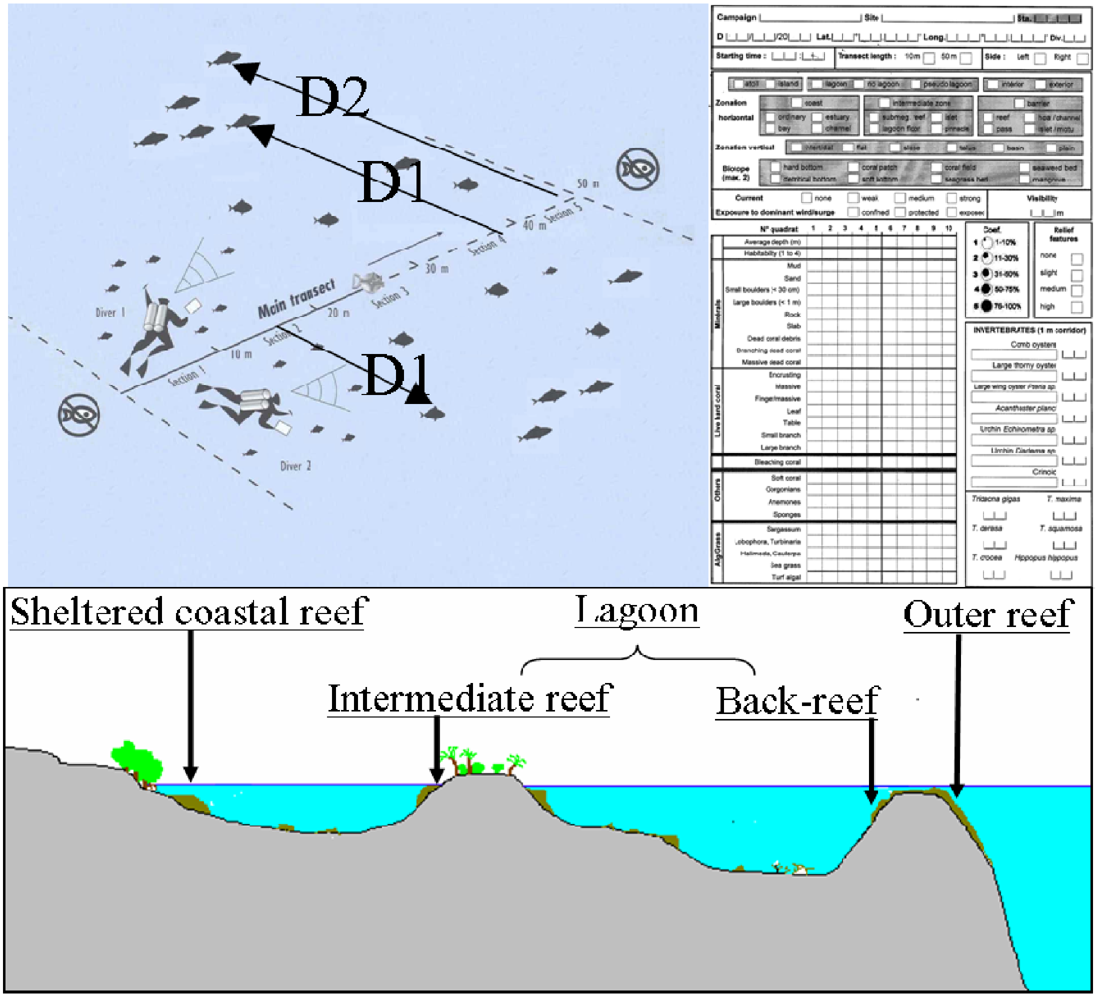


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys are conducted along 24 transects, with six transects in each of the four main geomorphologic coral reef structures: sheltered coastal reefs, intermediate reefs and back-reefs (lumped into the 'lagoon reef' category of socioeconomic assessment), and outer reefs. D1 is the distance of an observed fish from the transect line. If a school of fish is observed, D1 is the distance from the transect line to the closest fish; D2 the distance to the furthest fish.

Appendix 1: Survey methods
Finfish

Species selection

Only reef fish of interest for consumption or sale and species that could potentially serve as indicators of coral reef health are surveyed (see Table A1.2.1; Appendix 3.2 provides a full list of counted species and abundance for each site surveyed).

Table A1.2.1: List of finfish species surveyed by distance sampling underwater visual census (D-UVC)
Most frequently observed families on which reports are based are highlighted in yellow.

Family	Selected species
Acanthuridae	All species
Aulostomidae	*Aulostomus chinensis*
Balistidae	All species
Belonidae	All species
Caesionidae	All species
Carangidae	All species
Carcharhinidae	All species
Chaetodontidae	All species
Chanidae	All species
Dasyatidae	All species
Diodontidae	All species
Echeneidae	All species
Ephippidae	All species
Fistulariidae	All species
Gerreidae	*Gerres* spp.
Haemulidae	All species
Holocentridae	All species
Kyphosidae	All species
Labridae	*Bodianus axillaris, Bodianus loxozonus, Bodianus perditio, Bodianus* spp., *Cheilinus:* all species, *Choerodon:* all species, *Coris aygula, Coris gaimard, Epibulus insidiator, Hemigymnus:* all species, *Oxycheilinus diagrammus, Oxycheilinus* spp.
Lethrinidae	All species
Lutjanidae	All species
Monacanthidae	*Aluterus scriptus*
Mugilidae	All species
Mullidae	All species
Muraenidae	All species
Myliobatidae	All species
Nemipteridae	All species
Pomacanthidae	*Pomacanthus semicirculatus, Pygoplites diacanthus*
Priacanthidae	All species
Scaridae	All species
Scombridae	All species
Serranidae	Epinephelinae: all species
Siganidae	All species
Sphyraenidae	All species
Tetraodontidae	*Arothron*: all species
Zanclidae	All species

Analysis of percentage occurrence in surveys at both regional and national levels indicates that of the initial 36 surveyed families, only 15 families are frequently seen in country counts.

Appendix 1: Survey methods
Finfish

Since low percentage occurrence could either be due to rarity (which is of interest) or low detectability (representing a methodological bias), we decided to restrict our analysis to the 15 most frequently observed families, for which we can guarantee that D-UVC is an efficient resource assessment method.

These are:

- Acanthuridae (surgeonfish)
- Balistidae (triggerfish)
- Chaetodontidae (butterflyfish)
- Holocentridae (squirrelfish)
- Kyphosidae (drummer and seachubs)
- Labridae (wrasse)
- Lethrinidae (sea bream and emperor)
- Lutjanidae (snapper and seaperch)
- Mullidae (goatfish)
- Nemipteridae (coral bream and butterfish)
- Pomacanthidae (angelfish)
- Scaridae (parrotfish)
- Serranidae (grouper, rockcod, seabass)
- Siganidae (rabbitfish)
- Zanclidae (moorish idol).

Substrate

We used the **medium-scale approach** (MSA) to record substrate characteristics along transects where finfish were counted by D-UVC. MSA has been developed by Clua *et al.* (2006) to specifically complement D-UVC surveys. Briefly, the method consists of recording depth, habitat complexity, and 23 substrate parameters within ten 5 m x 5 m quadrats located on each side of a 50 m transect, for a total of 20 quadrats per transect (Figure A1.2.1). The transect's habitat characteristics are then calculated by averaging substrate records over the 20 quadrats.

Parameters of interest

In this report, the status of finfish resources has been characterised using the following seven parameters:

- **biodiversity** – the number of families, genera and species counted in D-UVC transects;
- **density** (fish/m^2) – estimated from fish abundance in D-UVC;
- **size** (cm fork length) – direct record of fish size by D-UVC;
- **size ratio** (%) – the ratio between fish size and maximum reported size of the species. This ratio can range from nearly zero when fish are very small to nearly 100 when a given fish has reached the greatest size reported for the species. Maximum reported size (and source of reference) for each species are stored in our database;
- **biomass** (g/m^2) – obtained by combining densities, size, and weight–size ratios (Weight–size ratio coefficients are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit);
- **community structure** – density, size and biomass compared among families; and

- **trophic structure –** density, size and biomass compared among trophic groups. Trophic groups are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit. Each species was classified into one of five broad trophic groups: 1) carnivore (feed predominantly on zoobenthos), 2) detritivore (feed predominantly on detritus), 3) herbivore (feed predominantly on plants), 4) piscivore (feed predominantly on nekton, other fish and cephalopods) and 5) plankton feeder (feed predominantly on zooplankton). More details on fish diet can be found online at: http://www.fishbase.org/manual/english/FishbaseThe_FOOD_ITEMS_Table.htm.

The relationship between environment quality and resource status has not been fully explored at this stage of the project, as this task requires complex statistical analyses on the regional dataset. Rather, the living resources assessed at all sites in each country are placed in an environmental context via the description of several crucial habitat parameters. These are obtained by grouping the original 23 substrate parameters recorded by divers into the following six parameters:

- **depth** (m)
- **soft bottom** (% cover) – sum of substrate components:
  (1) mud (sediment particles <0.1 mm), and
  (2) sand and gravel (0.1 mm <hard particles <30 mm)
- **rubble and boulders** (% cover) – sum of substrate components:
  (3) dead coral debris (carbonated structures of heterogeneous size, broken and removed from their original locations),
  (4) small boulders (diameter <30 cm), and
  (5) large boulders (diameter <1 m)
- **hard bottom** (% cover) – sum of substrate components:
  (6) slab and pavement (flat hard substratum with no relief), rock (massive minerals) and eroded dead coral (carbonated edifices that have lost their coral colony shape),
  (7) dead coral (dead carbonated edifices that are still in place and retain a general coral shape), and
  (8) bleaching coral
- **live coral** (% cover) – sum of substrate components:
  (9) encrusting live coral,
  (10) massive and sub-massive live corals,
  (11) digitate live coral,
  (12) branching live coral,
  (13) foliose live coral,
  (14) tabulate live coral, and
  (15) *Millepora* spp.
- **soft coral** (% cover) – substrate component:
  (16) soft coral.

Sampling design

Coral reef ecosystems are complex and diverse. The NASA Millennium Coral Reef Mapping Project (MCRMP) has identified and classified coral reefs of the world in about 1000 categories. These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the needs of the finfish resource assessment, MCRMP reef types were grouped into the four main coralline geomorphologic structures found in the Pacific (Figure A1.2.2):

- **sheltered coastal reef**: reef that fringes the land but is located inside a lagoon or a pseudo-lagoon
- **lagoon reef**:
  - **intermediate reef** – patch reef that is located inside a lagoon or a pseudo-lagoon, and
  - **back-reef** – inner/lagoon side of outer reef
- **outer reef**: ocean side of fringing or barrier reefs.

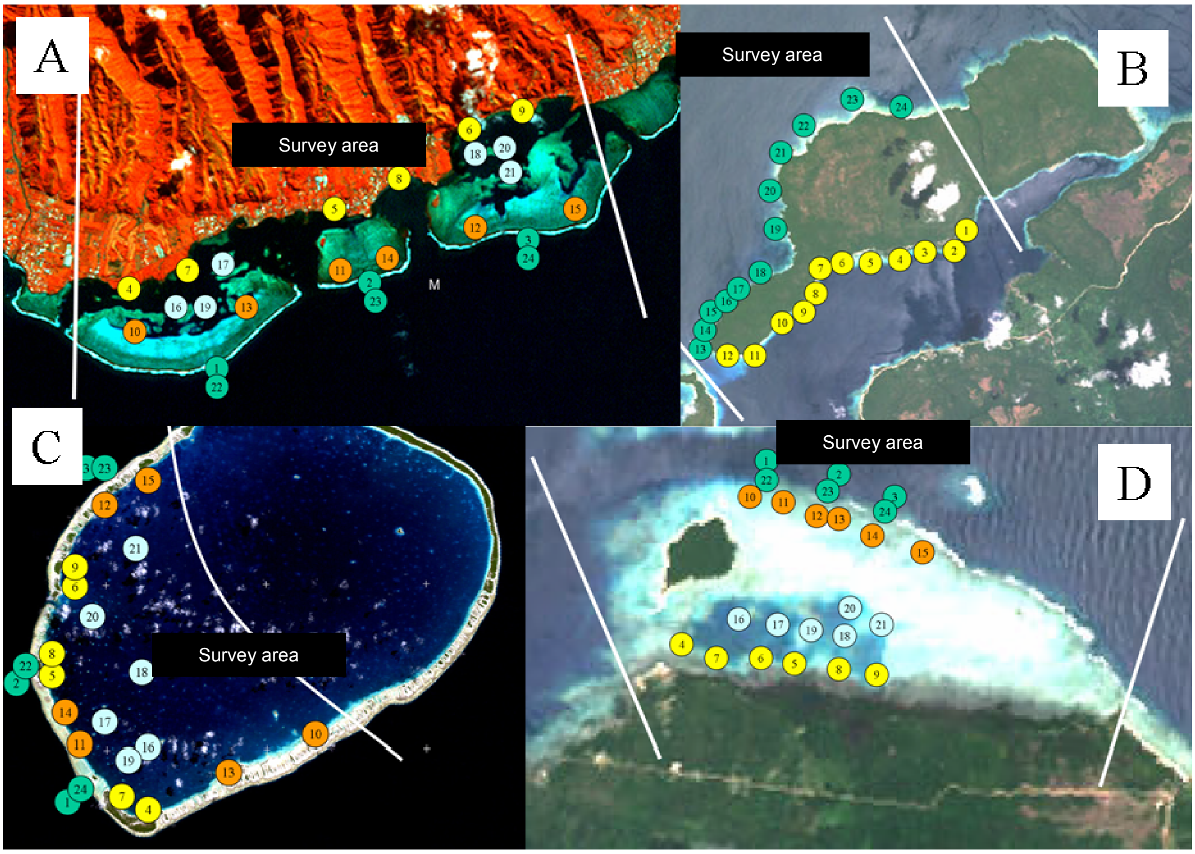


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon back-reef transects in orange and outer-reef transects in green. Transect locations are determined using satellite imagery prior to going into the field, which greatly enhances fieldwork efficiency. The white lines delimit the borders of the survey area.

Fish and associated habitat parameters are recorded along 24 transects per site, with a balanced design among the main geomorphologic structures present at a given site (Figure A1.2.2). For example, our design results in at least six transects in each of the sheltered coastal, lagoon intermediate, lagoon back-reef, and outer reefs of islands with lagoons (Figure A1.2.2A) or 12 transects in each of the sheltered coastal and outer reefs of islands with pseudo-lagoons (Figure A1.2.2B). This balanced, stratified and yet flexible sampling design was chosen to optimise the quality of the assessment, given the logistical and time constraints that stem from the number and diversity of sites that have to be covered over the life of the project. The exact position of transects is determined in advance using satellite imagery, to assist in locating the exact positions in the field; this maximises accuracy and allows replication for monitoring purposes (Figure A1.2.2).

Scaling

Maps from the Millennium Project allow the calculation of reef areas in each studied site, and those areas can be used to scale (using weighted averages) the resource assessment at any spatial level. For example, the average biomass (or density) of finfish at site (i.e. village) level would be calculated by relating the biomass (or density) recorded in each of the habitats sampled at the site ('the data') to the proportion of surface of each type of reef over the total reef present in the site ('the weights'), by using a weighted average formula. The result is a village-level figure for finfish biomass that is representative of both the intrinsic characteristics of the resource and its spatial distribution. Technically, the weight given to the average biomass (or density) of each habitat corresponds to the ratio between the total area of that reef habitat (e.g. the area of sheltered coastal reef) and the total area of reef present (e.g. the area of sheltered coastal reef + the area of intermediate reef, etc.). Thus the calculated weighted biomass value for the site would be:

$$B_{Vk} = \sum j_l \, [B_{Hj} \bullet S_{Hj}] \, / \sum_j S_{Hj}$$

Where:

B_{Vk} = computed biomass or fish stock for village k
B_{Hj} = average biomass in habitat H_j
S_{Hj} = surface of that habitat H_j

A comparative approach only

Density and biomass estimated by D-UVC for each species recorded in the country are given in Appendix 3.2. However, it should be stressed that, since estimates of fish density and biomass (and other parameters) are largely dependent upon the assessment method used (this is true for any assessment), the resource assessment provided in this report can only be used for management in a comparative manner. Densities, biomass and other figures given in this report provide only estimates of the available resource; it would be a great mistake (possibly leading to mismanagement) to consider these as true indicators of the actual available resource.

Campaign |______| Site |______| Diver |_|_| Transect |_|_|_|

D |_|_|/|_|_|/20|_|_| Lat.|_|_|°|_|_|.|_|_|_|' Long.|_|_|_|°|_|_|.|_|_|_|' WT |_|_|_|

Starting time : |_|_|:|_|_|	Visibility |_|_| m	Side : Left ☐ Right ☐

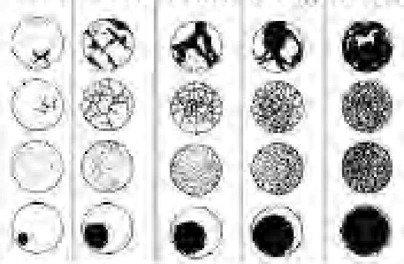
☐ coast		☐ intermediate zone		☐ barrier	
☐ linear	☐ cape	☐ submerg. reef	☐ pinnacle	☐ outer slope	☐ pass
☐ bay mouth	☐ back of bay	☐ near surf. reef	☐ islet lagoon	☐ reef crest	☐ hoa/channel
☐ estuary	☐ channel	☐ lagoon floor	☐ islet fringing reef	☐ back reef	☐ motu

☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

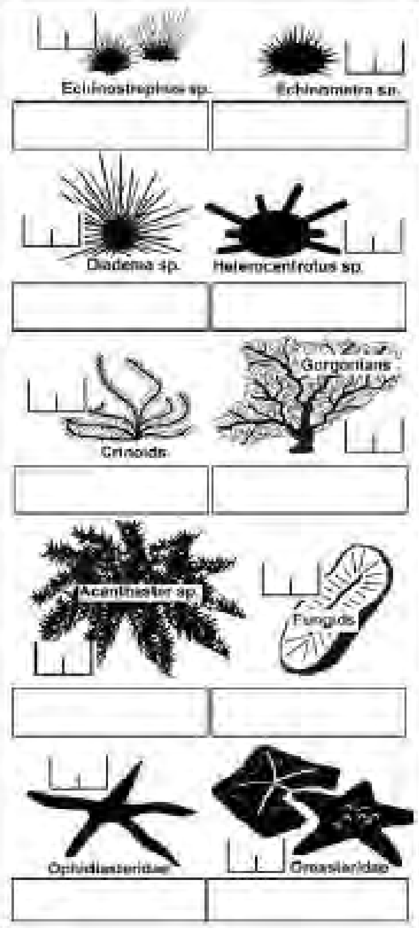
☐ hard bottom	☐ large coral patches	☐ small coral patches	☐ coral field	☐ seaweed bed
☐ detritical bottom	☐ soft bottom		☐ seagrass bed	☐ mangrove

	current	relief features	exposure to dominant wind	oceanic influence	terrigenous influence
none	☐	☐	☐	☐	☐
medium	☐	☐	☐	☐	☐
strong	☐	☐	☐	☐	☐

1	2	3	4	5
1-10%	11-30%	31-50%	51-75%	76-100%



Quadrat limits	0	5	10	15	20	25	30	35	40	45	50
Average depth (m)											
Habitability (1 to 4)											
General coverage											
Mud											
Sand											
Dead coral debris											
Small boulders (< 30 cm)											
Large boulders (< 1 m)											
Eroded dead coral, rock											
Old dead coral in place											
Bleaching coral											
(1) Live corals											
(2) Soft invertebrates											
(1) Live corals											
Encrusting											
Massive											
Digitate											
Branch											
Foliose											
Tabulate											
Millepora sp.											
(2)											
Soft corals											
Sponges											
Grass/alg											
Cyanophyceae											
Sea grass											
Encrusting algae											
Small macro-algae											
Large macro-algae											
Drifting algae											
Micro-algae, Turf											
Others :											



Appendix 1: Survey methods
Finfish

Campaign |__________________| Site |____________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|__|' Long.|__|__|__|°|__|__|,|__|__|__|__|' Left ☐ Right ☐

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1.3 Invertebrate resource survey methods

1.3.1 Methods used to assess the status of invertebrate resources

Introduction

Coastal communities in the Pacific access a range of invertebrate resources. Within the PROCFish/C study, a range of survey methods were used to provide information on key invertebrate species commonly targeted. These provide information on the status of resources at scales relevant to species (or species groups) and the fishing grounds being studied that can be compared across sites, countries and the region, in order to assess relative status.

Species data resulting from the resource survey are combined with results from the socioeconomic survey of fishing activity to describe invertebrate fishing activity within specific 'fisheries'. Whereas descriptions of commercially orientated fisheries are generally recognisable in the literature (e.g. the sea cucumber fishery), results from non-commercial stocks and subsistence-orientated fishing activities (e.g. general reef gleaning) will also be presented as part of the results, so as to give managers a general picture of invertebrate fishery status at study sites.

Field methods

We examined invertebrate stocks (and fisheries) for approximately seven days at each site, with at least two research officers (SPC Invertebrate Biologist and Fisheries Officer) plus officers from the local fisheries department. The work completed at each site was determined by the availability of local habitats and access to fishing activity.

Two types of survey were conducted: fishery-dependent surveys and fishery independent surveys.

- Fishery-dependent surveys rely on information from those engaged in the fishery, e.g. catch data;
- Fishery-independent surveys are conducted by the researchers independently of the activity of the fisheries sector.

Fishery-dependent surveys were completed whenever the opportunity arose. This involved accompanying fishers to target areas for the collection of invertebrate resources (e.g. reef-benthos, soft-benthos, trochus habitat). The location of the fishing activity was marked (using a GPS) and the catch composition and catch per unit effort (CPUE) recorded (kg/hour).

This record was useful in helping to determine the species complement targeted by fishers, particularly in less well-defined 'gleaning' fisheries. A CPUE record, with related information on individual animal sizes and weights, provided an additional dataset to expand records from reported catches (as recorded by the socioeconomic survey). In addition, size and weight measures collected through fishery-dependent surveys were compared with records from fishery-independent surveys, in order to assess which sizes fishers were targeting.

For a number of reasons, not all fisheries lend themselves to independent snapshot assessments: density measures may be difficult to obtain (e.g. crab fisheries in mangrove systems) or searches may be greatly influenced by conditions (e.g. weather, tide and lunar conditions influence lobster fishing). In the case of crab or shoreline fisheries, searches are very subjective and weather and tidal conditions affect the outcome. In such cases, observed and reported catch records were used to determine the status of species and fisheries.

A further reason for accompanying groups of fishers was to gain a first-hand insight into local fishing activities and facilitate the informal exchange of ideas and information. By talking to fishers in the fishing grounds, information useful for guiding independent resource assessment was generally more forthcoming than when trying to gather information using maps and aerial photographs while in the village. Fishery-independent surveys were not conducted randomly over a defined site 'study' area. Therefore assistance from knowledgeable fishers in locating areas where fishing was common was helpful in selecting areas for fishery-independent surveys.

A series of fishery-independent surveys (direct, in-water resource assessments) were conducted to determine the status of targeted invertebrate stocks. These surveys needed to be wide ranging within sites to overcome the fact that distribution patterns of target invertebrate species can be strongly influenced by habitat, and well replicated as invertebrates are often highly aggregated (even within a single habitat type).

PROCFish/C assessments do not aim to determine the size of invertebrate populations at study sites. Instead, these assessments aim to determine the status of invertebrates within the main fishing grounds or areas of naturally higher abundance. The implications of this approach are important, as the haphazard measures taken in main fishing grounds are indicative of stock health in these locations only and should not be extrapolated across all habitats within a study site to gain population estimates.

This approach was adopted due to the limited time allocated for surveys and the study's goal of 'assessing the status of invertebrate resources' (as opposed to estimating the standing stock). Making judgements on the status of stocks from such data relies on the assumption that the state of these estimates of 'unit stock'[2] reflects the health of the fishery. For example, an overexploited trochus fishery would be unlikely to have high-density 'patches' of trochus, just as a depleted shallow-reef gleaning fishery would not hold high densities of large clams. Conversely, a fishery under no stress would be unlikely to be depleted or show skewed size ratios that reflected losses of the adult component of the stock.

In addition to examining the density of species, information on spatial distribution and size/weight was collected, to add confidence to the study's inferences.

The basic assumption that looking at a unit stock will give a reliable picture of the status of that stock is not without weaknesses. Resource stocks may appear healthy within a much-restricted range following stress from fishing or environmental disturbance (e.g. a cyclone), and historical information on stock status is not usually available for such remote locations. The lack of historical datasets also precludes speculation on 'missing' species, which may be 'fished-out' or still remain in remnant populations at isolated locations within study sites.

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[2] As used here, 'unit stock' refers to the biomass and cohorts of adults of a species in a given area that is subject to a well-defined fishery, and is believed to be distinct and have limited interchange of adults from biomasses or cohorts of the same species in adjacent areas (Gulland 1983).

As mentioned, specific independent assessments were not conducted for mud crab and shore crabs (mangrove fishery), lobster or shoreline stocks (e.g. nerites, surf clams and crabs), as limited access or the variability of snapshot assessments would have limited relevance for comparative assessments.

Generic terminology used for surveys: site, station and replicates

Various methods were used to conduct fishery-independent assessments. At each site, surveys were generally made within specific areas (termed 'stations'). At least six replicate measures were made at each station (termed 'transects', 'searches' or 'quadrats', depending on the resource and method) (Figure A1.3.1).

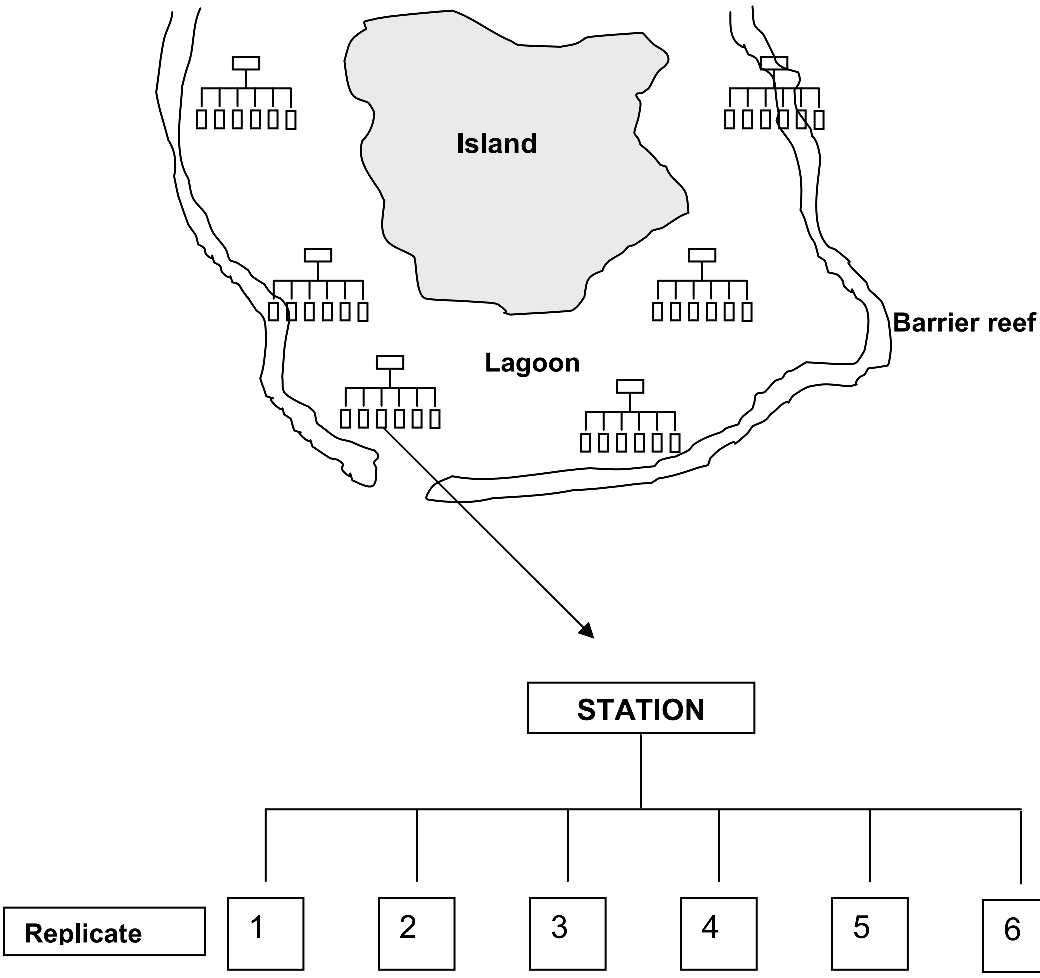


Figure A1.3.1: Stations and replicate measures at a given site.
A replicate measure could be a transect, search period or quadrat group.

Invertebrate species diversity, spatial distribution and abundance were determined using fishery-independent surveys at stations over broad-scale and more targeted surveys. Broad-scale surveys aimed to record a range of macro invertebrates across sites, whereas more targeted surveys concentrated on specific habitats and groups of important resource species.

Recordings of habitat are generally taken for all replicates within stations (see Appendix 1.3.3). Comparison of species complements and densities among stations and sites does not factor in fundamental differences in macro and micro habitat, as there is presently no established method that can be used to make allowances for these variations. The complete dataset from PROCFish/C will be a valuable resource to assess such habitat effects, and by identifying salient habitat factors that reliably affect resource abundance, we may be able to account for these habitat differences when inferring 'status' of important species groups. This will be examined once the full Pacific dataset has been collected.

More detailed explanations of the various survey methods are given below.

Broad-scale survey

Manta 'tow-board' transect surveys

A general assessment of large sedentary invertebrates and habitat was conducted using a tow-board technique adapted from English *et al.* (1997), with a snorkeller towed at low speed (<2.5 km/hour). This is a slower speed than is generally used for manta transects, and is less than half the normal walking pace of a pedestrian.

Where possible, manta surveys were completed at 12 stations per site. Stations were positioned near land masses on fringing reefs (inner stations), within the lagoon system (middle stations) and in areas most influenced by oceanic conditions (outer stations). Replicate measures within stations (called transects) were conducted at depths between 1 m and <10 m of water (mostly 1.5–6 m), covering broken ground (coral stone and sand) and at the edges of reefs. Transects were not conducted in areas that were too shallow for an outboard-powered boat (<1 m) or adjacent to wave-impacted reef.

Each transect covered a distance of ~300 m (thus the total of six transects covered a linear distance of ~2 km). This distance was calibrated using the odometer function within the trip computer option of a Garmin 76Map® GPS. Waypoints were recorded at the start and end of each transect to an accuracy of ≤ 10 m. The abundance and size estimations for large sedentary invertebrates were taken within a 2 m swathe of benthos for each transect. Broad-based assessments at each station took approximately one hour to complete (7–8 minutes per transect × 6, plus recording and moving time between transects). Hand tally counters and board-mounted bank counters (three tally units) were used to assist with enumerating common species.

The tow-board surveys differed from traditional manta surveys by utilising a lower speed and concentrating on a smaller swathe on the benthos. The slower speed, reduced swathe and greater length of tows used within PROCFish/C protocols were adopted to maximise efficiency when spotting and identifying cryptic invertebrates, while covering areas that were large enough to make representative measures.

Targeted surveys

Reef- and soft-benthos transect surveys (RBt and SBt), and soft-benthos quadrats (SBq)

To assess the range, abundance, size and condition of invertebrate species and their habitat with greater accuracy at smaller scales, reef- and soft-benthos assessments were conducted within fishing areas and suitable habitat. Reef benthos and soft benthos are not mutually exclusive, in that coral reefs generally have patches of sand, while soft-benthos seagrass areas can be strewn with rubble or contain patches of coral. However, these survey stations (each covering approximately 5000 m^2) were selected in areas representative of the habitat (those generally accessed by fishers, although MPAs were examined on occasion). Six 40 m transects (1 m swathe) were examined per station to record most epi-benthic invertebrate resources and some sea stars and urchin species (as potential indicators of habitat condition). Transects were randomly positioned but laid across environmental gradients where possible (e.g. across reefs and not along reef edges). A single waypoint was recorded for each station (to an accuracy of ≤ 10 m) and habitat recordings were made for each transect (see Figure A1.3.2 and Appendix 1.3.2).

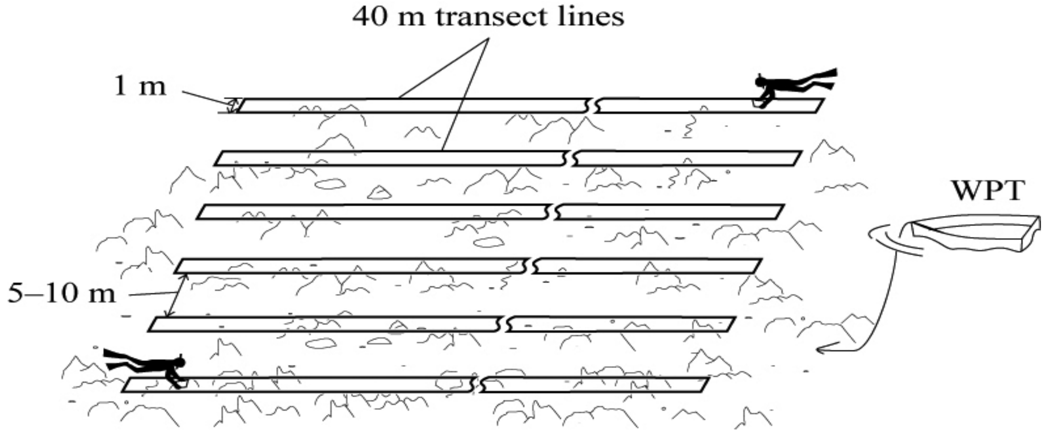


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

To record infaunal resources, quadrats (SBq) were used within a 40 m × 2 m strip transect to measure densities of molluscs (mainly bivalves) in soft-benthos 'shell bed' areas. Four 25 cm x 25 cm quadrats (one quadrat group) were dug to approximately 5–8 cm to retrieve and measure infaunal target species and potential indicator species. Eight randomly spaced quadrat groups were sampled along the 40 m transect line (Figure A1.3.3). A single waypoint and habitat recording was taken for each infaunal station.

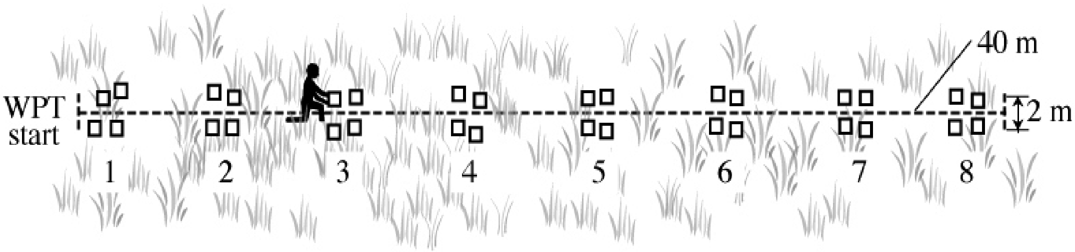


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<u>Mother-of-pearl (MOP) or sea cucumber (BdM) fisheries</u>

To assess fisheries such as those for trochus or sea cucumbers, results from broad-scale, reef- and soft-benthos assessments were used. However, other specific surveys were incorporated into the work programme, to more closely target species or species groups not well represented in the primary assessments.

<u>Reef-front searches (RFs and RFs_w)</u>

If swell conditions allowed, three 5-min search periods (conducted by two snorkellers, i.e. 30 min total) were conducted along exposed reef edges (RFs) where trochus (*Trochus niloticus*) and surf redfish (*Actinopyga mauritiana*) generally aggregate (Figure A1.3.4). Due to the dynamic conditions of the reef front, it was not generally possible to lay transects, but the start and end waypoints of reef-front searches were recorded, and two snorkellers recorded the abundance (generally not size measures) of large sedentary species (concentrating on trochus, surf redfish, gastropods and clams).

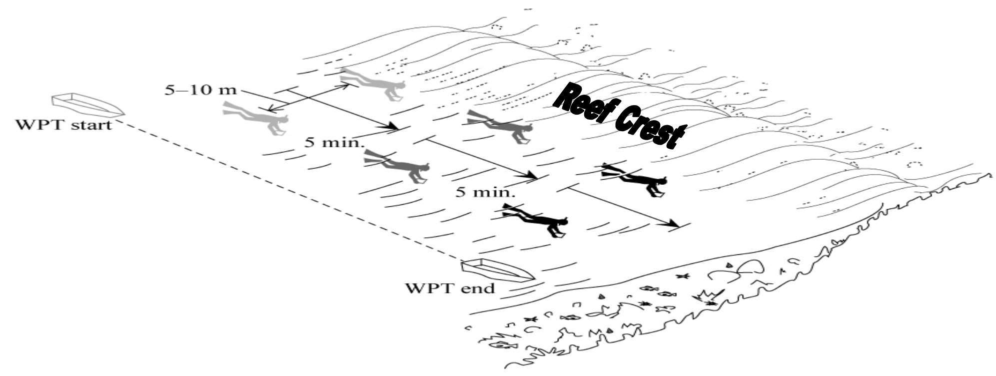


Figure A1.3.4: Reef-front search (RFs) station.

On occasions when it was too dangerous to conduct in-water reef-front searches (due to swell conditions or limited access) and the reeftop was accessible, searches were conducted on foot along the top of the reef front (RFs_w). In this case, two officers walked side by side (5–10 m apart) in the pools and cuts parallel to the reef front. This search was conducted at low tide, as close as was safe to the wave zone. In this style of assessment, reef-front counts of sea cucumbers, gastropod shells, urchins and clams were made during three 5-min search periods (total of 30 minutes search per station).

In the case of *Trochus niloticus*, reef-benthos transects, reef-front searches and local advice (trochus areas identified by local fishers) led us to reef-slope and shoal areas that were surveyed using SCUBA. Initially, searches were undertaken using SCUBA, although SCUBA transects (greater recording accuracy for density) were adopted if trochus were shown to be present at reasonable densities.

Mother-of-pearl search (MOPs)

Initially, two divers (using SCUBA) actively searched for trochus for three 5-min search periods (30 min total). Distance searched was estimated from marked GPS start and end waypoints. If more than three individual shells were found on these searches, the stock was considered dense enough to proceed with the more defined area assessment technique (MOPt).

Mother-of-pearl transects (MOPt)

Also on SCUBA, this method used six 40-m transects (2 m swathe) run perpendicular to the reef edge and not exceeding 15 m in depth (Figure A1.3.5). In most cases the depth ranged between 2 and 6 m, although dives could reach 12 m at some sites where more shallow-water habitat or stocks could not be found. In cases where the reef dropped off steeply, more oblique transect lines were followed. On MOP transect stations, a hip-mounted (or handheld) Chainman® measurement system (thread release) was used to measure out the 40 m. This allowed a hands-free mode of survey and saved time and energy in the often dynamic conditions where *Trochus niloticus* are found.

Appendix 1: Survey methods
Invertebrates

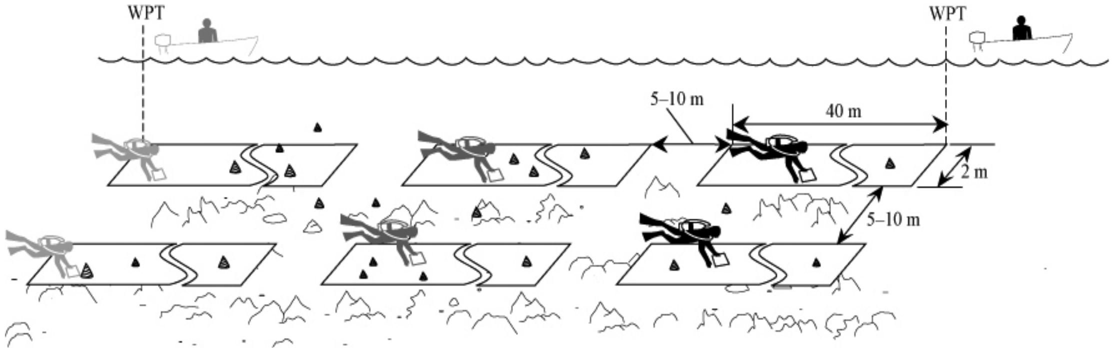


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

Sea cucumber day search (Ds)

When possible, dives to 25–35 m were made to establish if white teatfish (*Holothuria (Microthele) fuscogilva*) populations were present and give an indication of abundance. In these searches two divers recorded the number and sizes of valuable deep-water sea cucumber species within three 5-min search periods (30 min total). This assessment from deep water does not yield sufficient presence/absence data for a very reliable inference on the status (i.e. 'health') of this and other deeper-water species.

Sea cucumber night search (Ns)

In the case of sea cucumber fisheries, dedicated night searches (Ns) for sea cucumbers and other echinoderms were conducted using snorkel for predominantly nocturnal species (blackfish *Actinopyga miliaris*, *A. lecanora*, and *Stichopus horrens*). Sea cucumbers were collected for three 5-min search periods by two snorkellers (30 min total), and if possible weighed (length and width measures for *A. miliaris* and *A. lecanora* are more dependent on the condition than the age of an individual).

Reporting style

For country site reports, results highlight the presence and distribution of species of interest, and their density at scales that yield a representative picture. Generally speaking, mean densities (average of all records) are presented, although on occasion mean densities for areas of aggregation ('patches') are also given. The later density figure is taken from records (stations or transects, as stated) where the species of interest is present (with an abundance >zero). Presentation of the relative occurrence and densities (without the inclusion of zero records) can be useful when assessing the status of aggregations within some invertebrate stocks.

An example and explanation of the reporting style adopted for invertebrate results follows.

1. The mean density range of *Tridacna* spp. on broad-scale stations (n = 8) was 10–120 per ha.

Density range includes results from all stations. In this case, replicates in each station are added and divided by the number of replicates for that station to give a mean. The lowest and highest station averages (here 10 and 120) are presented for the range. The number in brackets (n = 8) highlights the number of stations examined.

2. The mean density (per ha, ±SE) of all *Tridacna* clam species observed in broad-scale transects (n = 48) was 127.8 ±21.8 (occurrence in 29% of transects).

Mean density is the arithmetic mean, or average of measures across all replicates taken (in this case broad-scale transects). On occasion mean densities are reported for stations or transects where the species of interest is found at an abundance greater than zero. In this case the arithmetic mean would only include stations (or replicates) where the species of interest was found (excluding zero replicates). If this was presented for stations, even stations with a single clam from six transects would be included. (Note: a full breakdown of data is presented in the appendices.)

Written after the mean density figure is a descriptor that highlights variability in the figures used to calculate the mean. Standard error[3] (SE) is used in this example to highlight variability in the records that generated the mean density (SE = (standard deviation of records)/√n). This figure provides an indication of the dispersion of the data when trying to estimate a population mean (the larger the standard error, the greater variation of data points around the mean presented).

Following the variability descriptor is a presence/absence indicator for the total dataset of measures. The presence/absence figure describes the percentage of stations or replicates with a recording >0 in the total dataset; in this case 29% of all transects held *Tridacna* spp., which equated to 14 of a possible 48 transects (14/48*100 = 29%).

3. The mean length (cm, ±SE) of *T. maxima* was 12.4 ±1.1 (n = 114).

The number of units used in the calculation is indicated by *n*. In the last case, 114 clams were measured.

[3] In order to derive confidence limits around the mean, a transformation (usually y = log (x+1)) needs to be applied to data, as samples are generally non-normally distributed. Confidence limits of 95% can be generated through other methods (bootstrapping methods) and will be presented in the final report where appropriate.

1.3.2 General fauna invertebrate recording sheet with instructions to users

DATE		RECORDER		Pg No	

STATION NAME																		
WPT - WIDTH																		
RELIEF / COMPLEXITY **1–5**																		
OCEAN INFLUENCE **1–5**																		
DEPTH (M)																		
% SOFT SED (M – S – CS)																		
% RUBBLE / BOULDERS																		
% CONSOL RUBBLE / PAVE																		
% CORAL *LIVE*																		
% CORAL *DEAD*																		
SOFT / SPONGE / FUNGIDS																		
ALGAE *CCA*																		
CORALLINE																		
OTHER																		
GRASS																		
EPIPHYTES **1–5** / SILT **1–5**																		
bleaching: % of																		
entered /	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

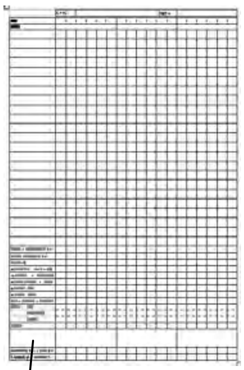
Figure A1.3.6: Sample of the invertebrate fauna survey sheet.

The sheet above (Figure A1.3.6) has been modified to fit on this page (the original has more line space (rows) for entering species data). When recording abundance or length data against species names, columns are used for individual transects or 5-min search replicates. If more space is needed, more than a single column can be used for a single replicate.

A separate sheet is used by a recorder in the boat to note information from handheld GPS equipment. In addition to the positional information, this boat sheet has space for manta transect distance (from GPS odometer function) and for sketches and comments.

1.3.3 Habitat section of invertebrate recording sheet with instructions to users

Figure A1.3.7 depicts the habitat part of the form used during invertebrate surveys; it is split into seven broad categories.



RELIEF / COMPLEXITY **1–5**							1
OCEAN INFLUENCE **1–5**							2
DEPTH (M)							3
% SOFT SED (M– S – CS)							4
% RUBBLE / BOULDERS							4
% CONS RUBBLE / PAVE							4
% CORAL *LIVE*							4
% CORAL *DEAD*							4
SOFT / SPONGE / FUNGIDS							5
ALGAE *CCA*							5
CORALLINE							5
OTHER							5
GRASS							5
							5
EPIPHYTES **1–5** / SILT **1–5**							6
BLEACHING: % OF BENTHOS							7

Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

Relief and complexity (section 1 of form)

Each is on a scale of 1 to 5. If a record is written as 1/5, relief is 1 and complexity is 5, with the following explanation.

Relief describes average height variation for hard (and soft) benthos transects:

1 = flat (to ankle height)
2 = ankle up to knee height
3 = knee to hip height
4 = hip to shoulder/head height
5 = over head height

Complexity describes average surface variation for substrates (relative to places for animals to find shelter) for hard (and soft) benthos transects:

1 = smooth – no holes or irregularities in substrate
2 = some complexity to the surfaces but generally little

3 = generally complex surface structure
4 = strong complexity in surface structure, with cracks, spaces, holes, etc.
5 = very complex surfaces with lots of spaces, nooks, crannies, under-hangs and caves

Ocean influence (section 2 of form)

1 = riverine, or land-influenced seawater with lots of allochthonous input
2 = seawater with some land influence
3 = ocean and land-influenced seawater
4 = water mostly influenced by oceanic water
5 = oceanic water without land influence

Depth (section 3 of form)

Average depth in metres

Substrate – bird's-eye view of what's there (section 4 of form)

All of section 4 must make up 100%. Percentage substrate is estimated in units of 5% so, e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Soft substrate	Soft sediment – mud
Soft substrate	Soft sediment – mud and sand
Soft substrate	Soft sediment – sand
Soft substrate	Soft sediment – coarse sand
Hard substrate	Rubble
Hard substrate	Boulders
Hard substrate	Consolidated rubble
Hard substrate	Pavement
Hard substrate	Coral live
Hard substrate	Coral dead

Mud, sand, coarse sand: The sand is not sieved – it is estimated visually and manually. Surveyors can use the 'drop test', where sand drops through the water column and mud stays in suspension. Patchy settled areas of silt/clay/mud in very thin layers on top of coral, pavement, etc. are not listed as soft substrate unless the layer is significant (>a couple of cm).

Rubble is small (<25–30 cm) fragments of coral (reef), pieces of coral stone and limestone debris. AIMS' definition is very similar to that for Reefcheck (found on the 'C-nav' interactive CD): 'pieces of coral (reef) between 0.5 and 15 cm. If smaller, it is sand; if larger, then rock or whatever organism is growing upon it'.

Boulders are detached, big pieces (>30 cm) of stone, coral stone and limestone debris.

Consolidated rubble is attached, cemented pieces of coral stone and limestone debris. We tend to use 'rubble' for pieces or piles loose in the sediment of seagrass, etc., and 'consolidated rubble' for areas that are not flat pavement but concreted rubble on reeftops and cemented talus slopes.

Appendix 1: Survey methods
Invertebrates

Pavement is solid, substantial, fixed, flat stone (generally limestone) benthos.

Coral live is any live hard coral.

Coral dead is coral that is recognisable as coral even if it is long dead. Note that long-dead and *eroded* coral that is found in flat pavements is called 'pavement' and when it is found in loose pieces or blocks it is termed 'rubble' or 'boulders' (depending on size).

Cover – what is on top of the substrate (section 5 of form)

This cannot exceed 100%, but can be anything from 0 to 100%. Surveyors give scores in blocks of 5%, so e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Cover	Soft coral
Cover	Sponge
Cover	Fungids
Cover	Crustose-nongeniculate coralline algae
Cover	Coralline algae
Cover	Other (algae like *Sargassum*, *Caulerpa* and *Padina* spp.)
Cover	Seagrass

Soft coral is all soft corals but not Zoanthids or anemones.

Sponge includes half-buried sponges in seagrass beds – only sections seen on the surface are noted.

Fungids are fungids.

Crustose – nongeniculate coralline algae are pink rock. Crustose or nongeniculate coralline algae (NCA) are red algae that deposit calcium carbonate in their cell walls. Generally they are members of the division Rhodophyta.

Coralline algae – halimeda are red coralline algae (often seen in balls – *Galaxaura*). (Note: AIMS lists *halimeda* and other coralline algae as macro algae along with fleshy algae not having $CaCo_3$ deposits.)

Other algae include fleshy algae such as *Turbinaria*, *Padina* and *Dictyota*. Surveyors describe coverage by taking a bird's-eye view of what is covered, not by delineating the spatial area of the algae colony within the transect (i.e. differences in very low or high density are accounted for). The large space on the form is used to write species information if known.

Seagrass includes seagrass spp. such as *Halodule*, *Thalassia*, *Halophila* and *Syringodium*. Surveyors note types by species if possible or by structure (i.e. flat versus reed grass), and describe coverage by taking a bird's-eye view of what benthos is covered, not by delineating the spatial area of the grass meadow within the transect (i.e. differences in very low or high density are accounted for).

Cover continued – epiphytes and silt (section 6 of form)

Epiphytes 1–5 grade are mainly turf algae – turf that grows on hard and soft substrates, but also on algae and grasses. The growth is usually fine-stranded filamentous algae that have few noticeable distinguishing features (more like fuzz).

1 = none
2 = small areas or light coverage
3 = patchy, medium coverage
4 = large areas or heavier coverage
5 = very strong coverage, long and thick almost choking epiphytes – normally including strands of blue-green algae as well

Silt 1–5 grade (or a similar fine-structured material sometimes termed 'marine snow') consists of fine particles that slowly settle out from the water but are easily re-suspended. When re-suspended, silt tends to make the water murky and does not settle quickly like sand does. Sand particles are not silt and should not be included here when seen on outer-reef platforms that are wave affected.

1 = clear surfaces
2 = little silt seen
3 = medium amount of silt-covered surfaces
4 = large areas covered in silt
5 = surfaces heavily covered in silt

Bleaching (section 7 of form)

The percentage of bleached live coral is recorded in numbers from 1 to 100% (Not 5% blocks). This is the percentage of benthos that is dying hard coral (just-bleached) or very recently dead hard coral showing obvious signs of recent bleaching.

APPENDIX 2: SOCIOECONOMIC SURVEY DATA

2.1 Total annual catch (kg) of finfish species groups per village and all Niue

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
All Niue			
Aheu	Carangidae	*Caranx melampygus*	517
Aku	Belonidae	*Platybelone* spp.	12
Fangamea	Lutjanidae	*Lutjanus bohar*	115
Fotuo	Lethrinidae	*Monotaxis grandoculis*	47
Fuafua	Mugilidae	*Crenimugil crenilabis*	321
Gatala	Serranidae	*Epinephelus metta*	462
Hafulu	Mullidae	*Parupeneus multifasciatus*	190
Hahave	Polynemidae	*Cheilopogon unicolor*	3
Haku	Xiphiidae	*Xiphias gladius*	45
Hapi	Acanthuridae	*Acanthurus guttatus*	120
Humu	Acanthuridae	*Rhinecanthus rectangulus*	207
Ikatea	Holocentridae	*Sargocentron cornutum*	114
Ilaila	-	-	30
Kaene	Priacanthidae	*Priacanthus hamrur*	149
Kaloama	Mullidae	*Mulloidichthys flavolineatus*	17
Koho utu	Sphyraenidae	*Sphyraena picudilla*	15
Kokio	Polymixiidae	*Polymixia japonica*	88
Kolala	Acanthuridae	*Acanthurus achilles*	62
Loa	Carangidae	*Scomberoides lysan*	24
Malau	Serranidae	*Variola louti*	32
Malau pokoahu	Serranidae	*Cephalopholis miniata*	423
Malau tea	Carangidae	*Caranx melampygus*	19
Manini	Cirrhitidae	*Paracirrhites* spp.	45
Mataele	Serranidae	*Cephalopholis urodeta*	42
Meai	Labridae	*Thalassoma quinquevittatum*	586
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	221
Monega	Scaridae	*Chlorurus microrhinos*	135
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	3968
Paholo	Scaridae	*Scarus* spp.	246
Palu gu	Lutjanidae	*Aphareus rutilans*	116
Palu tikava	Carangidae	*Seriola rivoliana*	539
Pelepele	Serranidae	*Cephalopholis aurantia Cephalopholis sonnerati*	48
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	3356
Ta gutoloa	Holocentridae	*Sargocentron spiniferum*	7
Tafauli	Carangidae	*Caranx lugubris*	390
Talaao	Serranidae	*Epinephelus fasciatus*	114
Tufu	Labridae	*Thalassoma purpureum*	195
Tukutea	Acanthuridae	*Acanthurus triostegus*	11
Ulihega	Carangidae	*Decapterus macarellus*	2184
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	1370

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
Total of Niue (continued)			
Utu	Sphyraenidae	*Sphyraena forsteri, Sphyraena genie Sphyraena barracuda*	17
Vahakula	Scombridae	*Thunnus albacares*	13
ALOFI NORTH			
Fuafua	Mugilidae	*Crenimugil crenilabis*	13
Gatala	Serranidae	*Epinephelus merra*	18
Hahave	Polynemidae	*Cheilopogon unicolor*	3
Hapi	Acanthuridae	*Acanthurus guttatus*	13
Humu	Acanthuridae	*Rhinecanthus rectangulus*	3
Kaene	Priacanthidae	*Priacanthus hamrur*	124
Koho utu	Sphyraenidae	*Sphyraena picudilla*	15
Loa	Carangidae	*Scomberoides lysan*	13
Malau	Serranidae	*Variola louti*	15
Mataele	Serranidae	*Cephalopholis urodeta*	10
Meai	Labridae	*Thalassoma quinquevittatum*	83
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	91
Palu gu	Lutjanidae	*Aphareus rutilans*	34
Pelepele	Serranidae	*Cephalopholis aurantia Cephalopholis sonnerati*	9
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	231
Tafauli	Carangidae	*Caranx lugubris*	38
Tufu	Labridae	*Thalassoma purpureum*	40
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	138
ALOFI SOUTH			
Aheu	Carangidae	*Caranx melampygus*	311
Aku	Belonidae	*Platybelone* spp.	4
Fotuo	Lethrinidae	*Monotaxis grandoculis*	41
Fuafua	Mugilidae	*Crenimugil crenilabis*	21
Gatala	Serranidae	*Epinephelus merra*	84
Hafulu	Mullidae	*Parupeneus multifasciatus*	96
Hapi	Acanthuridae	*Acanthurus guttatus*	64
Humu	Acanthuridae	*Rhinecanthus rectangulus*	22
Ikatea	Holocentridae	*Sargocentron cornutum*	81
Kokio	Polymixiidae	*Polymixia japonica*	87
Kolala	Acanthuridae	*Acanthurus achilles*	31
Malau pokoahu	Serranidae	*Cephalopholis miniata*	58
Meai	Labridae	*Thalassoma quinquevittatum*	41
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	164
Monega	Scaridae	*Chlorurus microrhinos*	90
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus bigibbus*	1437
Paholo	Scaridae	*Scarus* spp.	236

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
ALOFI SOUTH (continued)			
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	767
Ulihega	Carangidae, Caesionidae	*Decapterus macrosoma, Pterocaesio tile*	695
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	209
AVATELE			
Fangamea	Lutjanidae	*Lutjanus bohar*	11
Fotuo	Lethrinidae	*Monotaxis grandoculis*	4
Fuafua	Mugilidae	*Crenimugil crenilabis*	168
Gatala	Serranidae	*Epinephelus merra*	71
Hafulu	Mullidae	*Parupeneus multifasciatus*	8
Ilaila	-	-	10
Kaene	Priacanthidae	*Priacanthus hamrur*	25
Malau pokoahu	Serranidae	*Cephalopholis miniata*	17
Mataele	Serranidae	*Cephalopholis urodeta*	32
Meai	Labridae	*Thalassoma quinquevittatum*	47
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	905
Palu tikava	Carangidae	*Seriola rivoliana*	232
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	976
Tafauli	Carangidae	*Caranx lugubris*	251
Tufu	Labridae	*Thalassoma purpureum*	14
Ulihega	Carangidae	*Decapterus macarellus*	447
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	173
Utu	Sphyraenidae	*Sphyraena forsteri, Sphyraena genie Sphyraena barracuda*	17
HAKUPU			
Aheu	Carangidae	*Caranx melampygus*	29
Fangamea	Lutjanidae	*Lutjanus bohar*	8
Fuafua	Mugilidae	*Crenimugil crenilabis*	18
Hapi	Acanthuridae	*Acanthurus guttatus*	25
Ikatea	Holocentridae	*Sargocentron cornutum*	3
Ilaila	-	-	19
Malau tea	Carangidae	*Caranx melampygus*	2
Meai	Labridae	*Thalassoma quinquevittatum*	44
Monega	Scaridae	*Chlorurus microrhinos*	19
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	145
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	67
Tufu	Labridae	*Thalassoma purpureum*	27
Tukutea	Acanthuridae	*Acanthurus triostegus*	11
Ulihega	Carangidae	*Decapterus macarellus*	774
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	13

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
HIKUTAVAKE			
Aku	Belonidae	*Platybelone* spp.	9
Fuafua	Mugilidae	*Crenimugil crenilabis, Valamugil engeli*	6
Gatala	Serranidae	*Epinephelus merra*	43
Hafulu	Mullidae	*Parupeneus multifasciatus*	10
Humu	Acanthuridae	*Rhinecanthus rectangulus*	7
Ikatea	Holocentridae	*Sargocentron cornutum*	21
Kokio	Polymixiidae	*Polymixia japonica*	1
Malau tea	Carangidae	*Caranx melampygus*	17
Meai	Labridae	*Thalassoma quinquevittatum*	45
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	129
Palu tikava	Carangidae	*Seriola rivoliana*	108
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	190
Tufu	Labridae	*Thalassoma purpureum*	46
Ulihega	Carangidae	*Decapterus macarellus*	53
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	103
LAKEPA			
Fuafua	Mugilidae	*Crenimugil crenilabis*	9
Hapi	Acanthuridae	*Acanthurus guttatus*	4
Ikatea	Holocentridae	*Sargocentron cornutum*	15
Meai	Labridae	*Thalassoma quinquevittatum*	1
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	9
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	47
Tufu	Labridae	*Thalassoma purpureum*	2
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	7
LIKU			
Fangamea	Lutjanidae	*Lutjanus bohar*	6
Gatala	Serranidae	*Epinephelus merra*	4
Humu	Acanthuridae	*Rhinecanthus rectangulus*	7
Ikatea	Holocentridae	*Sargocentron cornutum*	13
Kolala	Acanthuridae	*Acanthurus achilles*	8
Meai	Labridae	*Thalassoma quinquevittatum*	14
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	5
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	61
Paholo	Scaridae	*Scarus* spp.	10
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	13

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
MAKEFU			
Fangamea	Lutjanidae	*Lutjanus bohar*	7
Fotuo	Lethrinidae	*Monotaxis grandoculis*	2
Gatala	Serranidae	*Epinephelus merra*	7
Hafulu	Mullidae	*Parupeneus multifasciatus*	6
Haku	Xiphiidae	*Xiphias gladius*	28
Hapi	Acanthuridae	*Acanthurus guttatus*	4
Meai	Labridae	*Thalassoma quinquevittatum*	14
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	9
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	213
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	87
Ta gutoloa	Holocentridae	*Sargocentron spiniferum*	7
Tafauli	Carangidae	*Caranx lugubris*	6
Tufu	Labridae	*Thalassoma purpureum*	21
Ulihega	Carangidae	*Decapterus macarellus*	9
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	30
MUTALAU			
Fangamea	Lutjanidae	*Lutjanus bohar*	3
Fotuo	Lethrinidae	*Monotaxis grandoculis*	1
Fuafua	Mugilidae	*Crenimugil crenilabis*	0
Gatala	Serranidae	*Epinephelus merra*	2
Hafulu	Mullidae	*Parupeneus multifasciatus*	69
Humu	Acanthuridae	*Rhinecanthus rectangulus*	6
Ikatea	Holocentridae	*Sargocentron cornutum*	8
Ilaila	Polynemidae	-	1
Kokio	Polymixiidae	*Polymixia japonica*	0
Loa	Carangidae	*Scomberoides lysan*	0
Malau	Serranidae	*Variola louti*	14
Meai	Labridae	*Thalassoma quinquevittatum*	7
Monega	Scaridae	*Chlorurus microrhinos*	3
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	37
Pelepele	Serranidae	*Cephalopholis aurantia Cephalopholis sonnerati*	39
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	31
Tafauli	Carangidae	*Caranx lugubris*	21
Talaao	Serranidae	*Epinephelus fasciatus*	114
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	27
Vahakula	Scombridae	*Thunnus albacares*	13

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
NAMUKULU			
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	12
Ulihega	Carangidae	*Decapterus macarellus*	37
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	1
TAMAKAUTONGA			
Fuafua	Mugilidae	*Crenimugil crenilabis*	66
Gatala	Serranidae	*Epinephelus merra*	194
Hapi	Acanthuridae	*Acanthurus guttatus*	5
Ikatea	Holocentridae	*Sargocentron cornutum*	56
Kaloama	Mullidae	*Mulloidichthys flavolineatus*	15
Loa	Carangidae	*Scomberoides lysan*	11
Malau pokoahu	Serranidae	*Cephalopholis miniata*	348
Manini	Cirrhitidae	-	45
Meai	Labridae	*Thalassoma quinquevittatum*	277
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	33
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	557
Palu tikava	Carangidae	*Seriola rivoliana*	25
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	690
Tufu	Labridae	*Thalassoma purpureum*	25
Ulihega	Carangidae	*Decapterus macarellus*	16
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	370
TOI			
Gatala	Serranidae	*Epinephelus merra*	7
Humu	Acanthuridae	*Rhinecanthus rectangulus*	0
Ikatea	Holocentridae	*Sargocentron cornutum*	12
Malau	Serranidae	*Variola louti*	1
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	185
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	7
Tufu	Labridae	*Thalassoma purpureum*	9
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	63
TUAPA			
Aheu	Carangidae	*Caranx melampygus*	176
Fangamea	Lutjanidae	*Lutjanus bohar*	81
Fuafua	Mugilidae	*Crenimugil crenilabis*	21
Gatala	Serranidae	*Epinephelus merra*	34
Hafulu	Mullidae	*Parupeneus multifasciatus*	1
Haku	Xiphiidae	*Xiphias gladius*	17
Hapi	Acanthuridae	*Acanthurus guttatus*	4
Kaloama	Mullidae	*Mulloidichthys flavolineatus*	2
Kokio	Polymixiidae	*Polymixia japonica*	1

2.1 Total annual catch (kg) of finfish species groups per village and all Niue (continued)

(catch data reported by finfish fishers interviewed)

Vernacular name	Family	Scientific name	Total weight (kg)
TUAPA (continued)			
Kolala	Acanthuridae	*Acanthurus achilles*	23
Malau	Serranidae	*Variola louti*	1
Meai	Labridae	*Thalassoma quinquevittatum*	13
Monega	Scaridae	*Chlorurus microrhinos*	23
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	101
Palu gu	Lutjanidae	*Aphareus rutilans*	82
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	262
Tafauli	Carangidae	*Caranx lugubris*	74
Tufu	Labridae	*Thalassoma purpureum*	12
Ulihega	Carangidae	*Decapterus macarellus*	154
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	23
VAIEA			
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	61
Palu tikava	Carangidae	*Seriola rivoliana*	174
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	36
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	201

2.2 Annual-catch composition (% of total weight) of reef finfish in Niue

(based on recorded catch data, n = 139)

Vernacular name	Family	Scientific name	% of total catch
Nue	Kyphosidae	*Kyphosus cinerascens, Kyphosus vaigiensis Kyphosus bigibbus*	23.98
Telekihi	Holocentridae	*Myripristis berndti, Myripristis violacea*	20.28
Ulihega	Carangidae	*Decapterus macarellus*	13.20
Ulutuki	Cirrhitidae	*Cirrhitus pinnulatus, Paracirrhites hemistictus*	8.28
Meai	Labridae	*Thalassoma quinquevittatum*	3.54
Palu tikava	Carangidae	*Seriola rivoliana*	3.26
Aheu	Carangidae	*Caranx melampygus*	3.12
Gatala	Serranidae	*Epinephelus merra*	2.79
Malau pokoahu	Serranidae	*Cephalopholis miniata*	2.56
Tafauli	Carangidae	*Caranx lugubris*	2.35
Fuafua	Mugilidae	*Crenimugil crenilabis*	1.94
Paholo	Scaridae	*Scarus* spp.	1.48
Meito	Acanthuridae	*Acanthurus xanthopterus, Acanthurus nigroris*	1.34
Tufu	Labridae	*Thalassoma purpureum*	1.18
Hafulu	Mullidae	*Parupeneus multifasciatus*	1.15
Kaene	Priacanthidae	*Priacanthus hamrur*	0.90
Monega	Scaridae	*Chlorurus microrhinos*	0.81
Hapi	Acanthuridae	*Acanthurus guttatus*	0.72
Palu gu	Lutjanidae	*Aphareus rutilans*	0.70
Fangamea	Lutjanidae	*Etelis carbunculus, Lutjanus bohar*	0.70
Ikatea	Holocentridae	*Sargocentron cornutum*	1.25
Talaao	Serranidae	*Epinephelus fasciatus*	0.69
Kokio	Polymixiidae	*Polymixia japonica*	0.53
Kolala	Acanthuridae	*Acanthurus achilles*	0.38
Pelepele	Serranidae	*Cephalopholis aurantia Cephalopholis sonnerati*	0.29
Fotuo	Lethrinidae	*Monotaxis grandoculis*	0.29
Manini	Cirrhitidae	*Paracirrhites* spp.	0.27
Haku	Xiphiidae	*Xiphias gladius*	0.27
Humu	Acanthuridae	*Rhinecanthus rectangulus*	0.27
Mataele	Serranidae	*Cephalopholis urodeta*	0.26
Malau	Serranidae	*Variola louti*	0.19
Ilaila		-	0.18
Loa	Carangidae	*Scomberoides lysan*	0.15
Malau tea	Carangidae	*Caranx melampygus*	0.11
Utu	Sphyraenidae	*Sphyraena forsteri, Sphyraena genie Sphyraena barracuda*	0.10
Kaloama	Mullidae	*Mulloidichthys flavolineatus*	0.10
Koho utu	Sphyraenidae	*Sphyraena picudilla*	0.09
Vahakula	Scombridae	*Thunnus albacares*	0.08
Aku	Belonidae	*Platybelone* spp.	0.08
Tukutea	Acanthuridae	*Acanthurus triostegus*	0.07
Ta gutoloa	Holocentridae	*Sargocentron spiniferum*	0.04
Hahave	Polynemidae	*Cheilopogon unicolor*	0.02

2.3 Invertebrate species caught on reefs in Niue by type and weight
(% of total annual wet weight caught)

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Dive fishery	Lobster	-	8
	Gege	*Tridacna maxima, Tridacna squamosa*	5
Reeftop gleaning	Alili	*Turbo crassus, Turbo setosus*	66
	Paka	*Scylla serrata*	4
	Ugako	*Serpulorbis* spp.	3
	Fofouli	*Drupa* spp.	3
	Kamakama	*Grapsus albolineatus*	2
	Matapihu	*Patella flexuosa*	2
	Loli	*Holothuria atra*	1
	Tapatapa	*Parribacus caledonicus*	1
	Limu	-	1
	Feke	*Octopus* spp.	1
	Papahoha	*Chama* spp.	1
	Fuapule	*Cypraea* spp.	<1
	Hakupu	-	<1
	Kina	*Echinometra mathaei*	<1
	Matatue	*Dendropoma maximum*	<1
	Patupatu	*Thais* spp.	<1
	Tutu	*Carpilius maculatus*	<1
	Vana	*Echinothrix* spp.	<1
Total:			**100**

2.4 Average invertebrate length-frequency distribution in Niue
(% of total annual catch weight)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Alili	*Turbo crassus, Turbo setosus*	2 cm	<1
		4 cm	1
		6 cm	61
		8 cm	34
		10 cm	5
Feke	*Octopus* spp.	5 cm	67
		6 cm	25
		10 cm	8
Fofouli	*Drupa* spp.	2 cm	25
		3 cm	12
		4 cm	32
		5 cm	16
		6 cm	15
		7 cm	<1
		8 cm	<1
Fuapule	*Cypraea* spp.	6 cm	100
Gege	*Tridacna maxima, Tridacna squamosa*	5 cm	11
		11 cm	1
		14 cm	3
		18 cm	3
		20 cm	2
		32 cm	80
Hakupu	-	6 cm	74
		16 cm	26
Kamakama	*Grapsus albolineatus*	2 cm	6
		4 cm	1
		5 cm	2
		6 cm	16
		7 cm	9
		8 cm	4
		9 cm	23
		10 cm	17
		12 cm	9
		13 cm	7
		14 cm	4
		18 cm	3
Kina	*Echinometra mathaei*	12 cm	56
		16 cm	44
Lobster	-	12 cm	<1
		16 cm	4
		17 cm	5
		18 cm	1
		19 cm	3
		20 cm	3
		22 cm	2
		26 cm	82
Loli	*Holothuria atra*	16 cm	36
		20 cm	64

2.4 Average invertebrate length-frequency distribution in Niue (continued)

(% of total annual catch weight)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Matapihu	*Patella flexuosa*	2 cm	2
		3 cm	21
		4 cm	29
		5 cm	22
		6 cm	21
		7 cm	7
Matatue	*Dendropoma maximum*	n/a	42
		4 cm	25
		8 cm	32
Paka	*Scylla serrata*	7 cm	13
		8 cm	4
		9 cm	36
		10 cm	31
		11 cm	1
		14 cm	5
		15 cm	8
		16 cm	1
Papahoha	*Chama* spp.	2 cm	12
		4 cm	1
		5 cm	57
		6 cm	6
		7 cm	7
		8 cm	14
		9 cm	2
Patupatu	*Thais* spp.	4 cm	28
		5 cm	12
		6 cm	19
		7 cm	9
		8 cm	20
		10 cm	11
Tapatapa	*Parribacus caledonicus*	9 cm	100
Tutu	*Carpilius maculatus*	10 cm	72
		16 cm	28
Ugako	*Serpulorbis* spp.	n/a	34
		2 cm	43
		3 cm	22
		7 cm	1
Vana	*Echinothrix* spp.	n/a	15
		8 cm	33
		10 cm	51

2.5 Total annual biomass (kg wet weight/year) by species and category of use in Niue
(recorded catch data only, n = 139)

Vernacular name	Scientific name	Total biomass (kg wet weight/year)		
		Consumption	Sale	Consumption & sale combined
Alili	*Turbo crassus, Turbo setosus*	6111	18	1505
Feke	*Octopus* spp.	143	0	0
Fofouli	*Drupa* spp.	386	9	8
Fuapule	*Cypraea* spp.	0	4	0
Gege	*Tridacna maxima, Tridacna squamosa*	613	0	0
Hakupu	-	19	0	0
Kamakama	*Grapsus albolineatus*	277	0	0
Kina	*Echinometra mathaei*	12	0	0
Limu	-	120	0	0
Lobster	-	891	0	0
Loli	*Holothuria atra*	73	0	0
Matapihu	*Patella flexuosa*	251	16	11
Matatue	*Dendropoma maximum*	6	0	0
Paka	*Scylla serrata*	419	0	0
Papahoha	*Chama* spp.	146	2	8
Patupatu	*Thais* spp.	26	0	0
Tapatapa	*Parribacus caledonicus*	105	0	0
Tutu	*Carpilius maculatus*	4	0	0
Ugako	*Serpulorbis* spp.	296	5	69
Vana	*Echinothrix* spp.	10	0	0
Total:		**9907**	**54**	**1600**
%		**86**	**0**	**14**

2.6 Case studies to compare viability and cost factors of various finfish operations in Niue

FISHING FROM MOTORISED BOAT – Case MI

Niue modelling NPV for selected fishery operations (using 'present value' method)
NPV = Net present value of an investment over a period of time in the future, PMT payment made each period, here one year

TRANSPORT COSTS *INVESTMENT COST:*		*Total cost (NZD)*	*Lifespan (year)*	*Annual cost (NZD)*
Boat:				
Type:	Aluminium hull	10,000	10	-1070.03
Length:	15 ft			
Outboard engine:				
HP:	45	8000	6	-1392.27
Gear:				
Reels x 2:	800.00 each	1600	10	-171.20
Lines x 2:	250.00 each	500	5	-103.78
Skirts x 5:	17.50 each	87.50	1	-354.38
Safety equipment:				
Two lifejackets x 100:		200	5	-41.51
Radio:		400	5	-83.02
			Sub-total:	**-3216.20**
ANNUAL MAINTENANCE COSTS (BOAT & ENGINE):		300	1	-303.75
INTEREST RATE:	15%			

OPERATIONAL COST:

Fuel/trip:	*Litres fuel*	*Cost of fuel/ litre (NZD)*	*Cost/trip (NZD)*
	40	2.00	-80.00

Oil/trip:	*Litres oil*	*Cost of oil/ litre (NZD)*	*Cost/trip (NZD)*
	0.8	9.00	-7.20
Fuel & oil cost/trip:			-87.20

Transport costs:	*Number of trips/year*	*Cost of fuel & oil (NZD)*	*Annual cost (NZD)*
	32	87.20	-2790.40
	96	87.20	-8371.20
	128	87.20	-11,161.60

LABOUR COST:

Hours/trip	*Salary/hour (NZD)*	*Labour cost/trip (NZD)*
6	5.50	6 x 5.50 = 33.00

Trips/week	*Number of months fished*	*Trips/year*	*Labour cost/ trip (NZD)*	*Annual cost (NZD)*
1	8	32		-1056.00
3	8	96		-3168.00
4	8	128		-4224.00

REVENUES:

	Catch/trip (kg)	*Trips/year*	*Annual catch (kg)*
	19	32	608
		96	1824
		128	2432

COST OF CATCHING FISH (NZD/kg):

	1 trip/week	*3 trips/week*	*4 trips/week*
ANNUAL COSTS:			
Investment:	-3216.20	-3216.20	-3216.20
Operation:	-3094.15	-8674.95	-11,465.35
Labour:	-1056.00	-3168.00	-4224.00
Total annual costs:	**-7366.35**	**-15,059.15**	**-18,905.55**
Annual catch (kg):	608	1824	2432
Retail price kg/fish:	8.00		
Cost (NZD) of catching one kg fish:	-12.12	-8.26	-7.77
Profit margin kg/fish caught:	-4.12	-0.26	0.23

FISHING FROM MOTORISED BOAT – Case MII

TRANSPORT COSTS *INVESTMENT COST:*		***Total cost (NZD)***	***Lifespan (year)***	***Annual cost (NZD)***
Boat:				
Type:	Aluminium hull	12,000	10	-1284.04
Length:	14.6 ft			
Outboard engine:				
HP:	40	6000	6	-1044.20
Gear:				
Reels x 3:	1000; 700; 500	2200	10	-235.41
Lines x 3:	250.00 each	750	5	-155.67
Skirts x 100:	17.50 each	1750	1	-1771.88
Hooks:		500	1	-506.25
Safety equipment:				
Two lifejackets x 100:		200	5	-41.51
Radio:		400	5	-83.02
			Sub-total:	**-5121.98**
ANNUAL MAINTENANCE COSTS (BOAT & ENGINE):		300	1	-303.75
INTEREST RATE:	15%			

OPERATIONAL COST:

Fuel/trip:	***Litres fuel***	***Cost of fuel/ litre (NZD)***	***Cost/trip (NZD)***
	22	2.00	-44.00
Oil/trip:	***Litres oil***	***Cost of oil/ litre (NZD)***	***Cost/trip (NZD)***
	0.25	9.00	-2.25
Fuel & oil cost/trip:			-46.25

Transport costs:	***Number of trips/year***	***Cost of fuel & oil (NZD)***	***Annual cost (NZD)***
	32	46.25	-1480.00
	96	46.25	-4440.00
	128	46.25	-5920.00

Appendix 2: Socioeconomic survey data

Labour cost:

Hours/trip	*Salary/hour (NZD)*	*Labour cost/trip (NZD)*
6	5.50	6 x 5.50 = 33.00

Trips/week	*Number of months fished*	*Trips/year*	*Labour cost/ trip (NZD)*	*Annual cost (NZD)*
3	11	32		-1056.00
4	11	96		-3168.00
5	11	128		-4224.00

Revenues:

	Catch/trip (kg)	*Trips/year*	*Annual catch (kg)*
	20	32	640.00
		96	1920.00
		128	2560.00

COST OF CATCHING FISH (NZD/kg):

With the new boat:

	1 trip/week	*3 trips/week*	*4 trips/week*
Annual costs:			
Investment:	-5121.98	-5121.98	-5121.98
Operation:	-1783.75	-4743.75	-6223.75
Labour:	-1056.00	-3168.00	-4224.00
Total annual costs:	**-7961.73**	**-13,033.73**	**-15,569.73**
Annual catch (kg):	640.00	1920.00	2560.00
Cost (NZD) of catching one kg of fish:	-12.44	-6.79	-6.08
Retail price kg/fish:	8.00		
Profit margin kg/fish caught:	-4.44	1.21	1.92

With the 11-year old boat, there are no boat costs, only the cost of the new engine:

	1 trip/week	*3 trips/week*	*4 trips/week*
Annual costs:			
Investment:	-3489.88	-3489.88	-3489.88
Operation:	-1783.75	-4743.75	-6223.75
Labour:	-1056.00	-3168.00	-4224.00
Total annual costs:	**-6329.63**	**-11,401.63**	**-13,937.63**
Annual catch (kg):	640.00	1920.00	2560.00
Retail price kg/fish:	8.00		
Cost (NZD) of catching one kg of fish:	-9.89	-5.94	-5.44
Profit margin kg/fish caught:	-1.89	2.06	2.56

Has another 12 ft boat to catch flying fish for bait

FISHING FROM CANOE – Case CI

Niue modelling NPV for selected fishery operations (using present value method)
Present value of an investment over a period of time in the future, PMT payment made each period, here one year

TRANSPORT COSTS *INVESTMENT COST:*		*Total cost (NZD)*	*Lifespan (year)*	*Annual cost (NZD)*
Boat:				
Type:	Wooden canoe	1000.00	10	-107.00
Length:	3.20 m			
Outboard engine:				
HP:	0	0	0	
Gear:				
Handline:	25	25	5	-5.19
Hooks and bait:	5 per month	60	1	-60.75
Sinker bottom:	$25/year	25	1	-25.31
Lamp:	15	15	1	-15.19
Safety equipment:				
Two lifejackets x 100:		0	0	
Radio:		0	0	
			Sub-total:	**-213.44**

ANNUAL MAINTENANCE COSTS (BOAT & ENGINE):

	Cost (NZD)	*No.*			
Fibreglass:	35.00/l	2 litres	70	1	-70.88
Labour costs:	5.50/h	7 hours	38.5	1	-38.50
					-109.38

INTEREST RATE: 15%

OPERATIONAL COST:

Fuel for lamp:	*Litres fuel*	*Cost of fuel/ litre (NZD)*	*Cost/trip (NZD)*
	1	2.00	-2.00
Fuel cost/trip:			-2.00

Transport costs:	*Number of trips/year*	*Cost of fuel for lamp (NZD)*	*Annual cost (NZD)*
	32	2.00	-64.00
	96	2.00	-128.00
	128	2.00	-192.00

LABOUR COST:

Hours/trip	*Salary/hour (NZD)*	*Labour cost/trip (NZD)*
4	5.50	4 x 5.50 = 22.00

Trips/week	*Number of months fished*	*Trips/year*	*Labour cost/ trip (NZD)*	*Annual cost (NZD)*
1	8	32	22.00	-704.00
2	8	64	22.00	-1408.00
3	8	96	22.00	-2112.00

REVENUES:

Catch/trip (kg)	*Trips/year*	*Annual catch (kg)*
10.72 (+35 kg)	32	623.04
	96	1309.12
	128	1652.16

(includes occasional tuna catch, 35 kg/trip and 8 trips/year = 280 kg/year)

	Number	*Size*	*Average weight/fish/kg*	*Total weight (kg)*
Average catch:	30	C	0.27	8.1
	2	D	0.66	1.32
	1	E	1.3	1.3
				10.72
Occasional catch	2 (e.g. tuna)		17.50	35

COST OF CATCHING FISH (NZD/kg):

	1 trip/week	*3 trips/week*	*4 trips/week*
ANNUAL COSTS:			
Investment:	-213.44	-213.44	-213.44
Operation:	-173.38	-237.38	-301.38
Labour:	-704.00	-1408.00	-2112.00
Total annual costs:	**-1090.82**	**-1858.82**	**-2626.82**
Annual catch (kg):	623.04	1309.12	1652.16
Retail price kg/fish:	8.00		
Cost (NZD) of catching one kg of fish:	-1.75	-1.42	-1.59
Profit margin kg/fish caught:	6.25	6.58	6.41

FISHING FROM CANOE – Case CII

TRANSPORT COSTS *INVESTMENT COST:*		*Total cost (NZD)*	*Lifespan (year)*	*Annual cost (NZD)*
Boat:				
Type:	Wooden canoe	1000	10	-107.00
Length:	3.20 m			
Outboard engine:				
HP:	0	0	0	
Gear:				
Handline:	25	25	5	-5.19
Hooks and bait:	5 per month	60	1	-60.75
Sinker bottom:	$25/year	25	1	-25.31
Lamp:	15	15	1	-15.19
Safety equipment:				
Two lifejackets x 100:		0	0	
Radio:		0	0	
			Sub-total:	**-213.44**

ANNUAL MAINTENANCE COSTS (BOAT & ENGINE):

	Cost (NZD)	*No.*			
Fibreglass:	35.00	2 litres	70	1	-70.88
Labour costs:	5.50	7 hours	38.5	1	-38.50
					-109.38

INTEREST RATE: 15%

OPERATIONAL COST:

Fuel for lamp:	*Litres fuel*	*Cost of fuel/ litre (NZD)*	*Cost/trip (NZD)*
	1	2.00	-2.00
Fuel cost/trip:			-2.00

Transport costs:	*Number of trips/year*	*Cost of fuel for lamp (NZD)*	*Annual cost (NZD)*
	80	96.00	-192.00

LABOUR COST:

Hours/trip	*Salary/hour (NZD)*	*Labour cost/trip (NZD)*	
5.5	5.50	30.25	
Trips/week	*Number of months fished*	*Trips/year*	*Annual cost (NZD)*
5	4	96	-2904.00

Revenues:

	Catch/trip (kg)	Trips/year	Annual catch (kg)
	7.5	96	720.00

COST OF CATCHING FISH (NZD/kg):

	5 trips/week
Annual costs:	
Investment:	-213.44
Operation:	-301.38
Labour:	-2904.00
Total annual costs:	**-3418.82**
Annual catch (kg):	720.00
Retail price kg/fish:	8.00
Cost (NZD) of catching one kg of fish:	-4.75
Profit margin kg/fish caught:	3.25

FISHING BY WALKING ON THE REEFTOP – WI

Niue modelling NPV for selected fishery operations (using present value method)
Present value of an investment over a period of time in the future, PMT payment made each period, here one year

TRANSPORT COSTS *INVESTMENT COST:*		*Total cost (NZD)*	*Lifespan (year)*	*Annual cost (NZD)*
Boat:				
Type:	None	0	0	
Length:				
Outboard engine:				
HP:	0	0	0	
Gear:				
Handline:	25	25	5	-5.19
Hooks and bait:	5 per month	60	1	-60.75
Sinker bottom:	$25/year	0	0	
Torch:		35	1	-35.44
Batteries:	10 x 4	40	1	-40.50
Safety equipment:				
Two lifejackets x 100:		0	0	
Radio:		0	0	
			Sub-total:	**-141.88**

ANNUAL MAINTENANCE COSTS (BOAT & ENGINE):

	Cost (NZD)	*No.*			
Fibreglass:	35.00	2 litres	0	0	
Labour costs:	5.50	7 hours	0	0	
					0.00

INTEREST RATE: 15%

OPERATIONAL COST:

Fuel for lamp:	*Litres fuel*	*Cost of fuel/ litre (NZD)*	*Cost/trip (NZD)*
	0	2.00	-0.00
Fuel cost/trip:			-0.00

Transport costs:	*Number of trips/year*	*Cost of fuel for lamp (NZD)*	*Annual cost (NZD)*
	32	32.00	0.00
	64	64.00	0.00
	96	96.00	0.00

Labour cost:

Hours/trip	*Salary/hour (NZD)*	*Labour cost/trip (NZD)*	
2.5	5.50	13.75	
Trips/week	*Number of months fished*	*Trips/year*	*Annual cost (NZD)*
1	8	32	-440.00
2	8	64	-880.00
3	8	96	-1320.00

Revenues:

	Catch/trip (kg)	*Trips/year*	*Annual catch (kg)*
	1.621	32	51.87
Catch/trip (kg)		96	155.62
		128	207.49

	Number	*Size*	*Average weight/fish/kg*	*Total weight*
Average catch:	3	C	0.27	0.81
	3	B	0.077	0.231
	1	D	0.58	0.58
				1.621

COST OF CATCHING FISH (NZD/kg):

	1 trip/week	*3 trips/week*	*4 trips/week*
Annual costs:			
Investment:	-141.88	-141.88	-141.88
Operation:	0.00	0.00	0.00
Labour:	-440.00	-880.00	-1320.00
Total annual costs:	**-581.88**	**-1021.88**	**-1461.88**
Annual catch (kg):	51.87	155.62	207.49
Retail price kg/fish:	8.00		
Cost (NZD) of catching one kg of fish:	-11.22	-6.57	-7.05
Profit margin kg/fish caught:	-3.22	1.43	0.95

APPENDIX 3: FINFISH SURVEY DATA

3.1 Coordinates (WGS84) of the 50 D-UVC transects used to assess finfish resource status in Niue

Station	Latitude	Longitude	Station	Latitude	Longitude
TRA01	18°59'43.44" S	169°54'39.3012" W	TRA26	18°57'54.2412" S	169°53'13.3188" W
TRA02	19°03'04.32" S	169°55'13.6812" W	TRA27	18°58'06.5388" S	169°53'28.3812" W
TRA03	19°03'26.2188" S	169°55'35.6988" W	TRA28	18°58'12.9612" S	169°53'35.16" W
TRA04	19°03'42.5988" S	169°55'59.16" W	TRA29	18°58'16.7988" S	169°53'39.9588" W
TRA05	18°59'21.48" S	169°54'20.9988" W	TRA30	18°58'28.6212" S	169°53'49.8012" W
TRA06	18°59'08.7" S	169°54'11.88" W	TRA31	18°58'38.1" S	169°53'56.3388" W
TRA07	18°58'58.44" S	169°54'05.94" W	TRA32	19°03'55.5588" S	169°56'22.4988" W
TRA08	18°58'44.22" S	169°53'58.8588" W	TRA33	19°07'13.5012" S	169°54'47.5812" W
TRA09	18°59'33.36" S	169°54'28.8612" W	TRA34	19°07'33.06" S	169°54'54.8388" W
TRA10	18°59'55.9788" S	169°54'51.5412" W	TRA35	19°07'49.3212" S	169°55'07.86" W
TRA11	19°04'16.0788" S	169°56'53.4012" W	TRA36	18°59'03.5988" S	169°48'05.04" W
TRA12	19°03'59.6412" S	169°56'28.2012" W	TRA37	18°59'43.5588" S	169°47'55.9788" W
TRA13	19°07'56.5788" S	169°55'16.7988" W	TRA38	18°57'54.1188" S	169°48'19.5588" W
TRA14	19°07'43.5612" S	169°55'01.6788" W	TRA39	18°57'23.8788" S	169°49'32.2788" W
TRA15	19°07'23.9412" S	169°54'48.3588" W	TRA40	19°02'58.74" S	169°46'46.8012" W
TRA16	19°06'50.4" S	169°54'49.5612" W	TRA41	19°02'17.9412" S	169°47'08.9988" W
TRA17	19°05'25.98" S	169°56'16.62" W	TRA42	19°01'15.06" S	169°47'36.06" W
TRA18	19°05'44.0412" S	169°55'49.8" W	TRA43	19°00'24.4188" S	169°47'36.8988" W
TRA19	19°06'03.7188" S	169°55'27.9012" W	TRA44	19°02'27.5388" S	169°55'06.8412" W
TRA20	19°06'21.1212" S	169°55'08.8212" W	TRA45	19°02'01.5612" S	169°55'09.7788" W
TRA21	18°57'15.84" S	169°51'23.04" W	TRA46	19°01'44.58" S	169°55'13.3788" W
TRA22	18°57'20.8188" S	169°51'48.42" W	TRA47	19°01'29.7588" S	169°55'18.84" W
TRA23	18°57'25.4988" S	169°52'17.5188" W	TRA48	19°00'58.5612" S	169°55'27.4188" W
TRA24	18°57'31.0212" S	169°52'39.4788" W	TRA49	19°00'15.3" S	169°55'10.0812" W
TRA25	18°57'44.64" S	169°53'00.24" W	TRA50	19°06'31.9788" S	169°55'00.0012" W

3.2 Weighted average density and biomass of all finfish species recorded in Niue
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	0.1268	11.583
Acanthuridae	*Acanthurus blochii*	0.0753	4.587
Acanthuridae	*Acanthurus nigricans*	0.0392	4.044
Acanthuridae	*Acanthurus achilles*	0.0234	3.534
Acanthuridae	*Acanthurus lineatus*	0.0218	4.975
Balistidae	*Melichthys vidua*	0.0163	1.168
Mullidae	*Parupeneus multifasciatus*	0.0126	0.531
Acanthuridae	*Naso lituratus*	0.0102	2.795
Balistidae	*Melichthys niger*	0.0089	1.683
Serranidae	*Cephalopholis urodeta*	0.0079	0.658
Scaridae	*Scarus forsteni*	0.0079	3.096
Scaridae	*Chlorurus frontalis*	0.0068	2.790
Acanthuridae	*Acanthurus nigrofuscus*	0.0059	0.108
Acanthuridae	*Acanthurus olivaceus*	0.0057	0.894
Balistidae	*Sufflamen bursa*	0.0055	0.338
Kyphosidae	*Kyphosus vaigiensis*	0.0043	2.364
Mullidae	*Parupeneus cyclostomus*	0.0041	0.950
Mullidae	*Parupeneus trifasciatus*	0.0037	0.910
Caesionidae	*Pterocaesio tile*	0.0032	0.282
Chaetodontidae	*Forcipiger longirostris*	0.0032	0.144
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0031	0.092
Serranidae	*Cephalopholis argus*	0.0031	1.281
Sphyraenidae	*Sphyraena qenie*	0.0030	7.784
Chaetodontidae	*Chaetodon reticulatus*	0.0029	0.114
Acanthuridae	*Acanthurus guttatus*	0.0028	0.395
Acanthuridae	*Ctenochaetus binotatus*	0.0024	0.039
Lutjanidae	*Aphareus furca*	0.0023	0.497
Labridae	*Coris aygula*	0.0022	0.432
Balistidae	*Balistapus undulatus*	0.0022	0.154
Chaetodontidae	*Chaetodon lunula*	0.0020	0.104
Acanthuridae	*Naso unicornis*	0.0020	0.891
Zanclidae	*Zanclus cornutus*	0.0019	0.178
Scaridae	*Chlorurus microrhinos*	0.0018	3.305
Acanthuridae	*Zebrasoma scopas*	0.0018	0.171
Chaetodontidae	*Chaetodon pelewensis*	0.0018	0.012
Scaridae	*Chlorurus sordidus*	0.0017	0.430
Balistidae	*Rhinecanthus rectangulus*	0.0016	0.048
Scaridae	*Calotomus carolinus*	0.0015	0.389
Scaridae	*Scarus rubroviolaceus*	0.0013	0.645
Lethrinidae	*Monotaxis grandoculis*	0.0012	0.722
Chaetodontidae	*Chaetodon ornatissimus*	0.0012	0.077
Acanthuridae	*Zebrasoma veliferum*	0.0012	0.139
Scaridae	*Scarus altipinnis*	0.0011	0.237
Lutjanidae	*Lutjanus bohar*	0.0011	0.805
Labridae	*Hemigymnus fasciatus*	0.0010	0.137
Chaetodontidae	*Chaetodon auriga*	0.0009	0.050

3.2 Weighted average density and biomass of all finfish species recorded in Niue (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus strigosus*	0.0009	0.043
Acanthuridae	*Acanthurus triostegus*	0.0009	0.048
Carangidae	*Caranx melampygus*	0.0009	0.743
Carangidae	*Carangoides orthogrammus*	0.0007	0.230
Acanthuridae	*Acanthurus* spp.	0.0007	0.004
Chaetodontidae	*Chaetodon ephippium*	0.0007	0.052
Pomacanthidae	*Pomacanthus imperator*	0.0007	0.238
Labridae	*Coris gaimard*	0.0005	0.036
Holocentridae	*Myripristis kuntee*	0.0004	0.119
Chaetodontidae	*Chaetodon trifascialis*	0.0004	0.006
Acanthuridae	*Acanthurus pyroferus*	0.0004	0.032
Scaridae	*Scarus chameleon*	0.0004	0.050
Scaridae	*Scarus frenatus*	0.0003	0.148
Labridae	*Bodianus loxozonus*	0.0003	0.080
Lethrinidae	*Gnathodentex aureolineatus*	0.0003	0.037
Muraenidae	*Gymnothorax* spp.	0.0003	0.003
Holocentridae	*Sargocentron tiere*	0.0003	0.043
Carangidae	*Scomberoides lysan*	0.0003	0.122
Serranidae	*Variola louti*	0.0003	0.109
Chaetodontidae	*Chaetodon mertensii*	0.0003	0.002
Serranidae	*Epinephelus hexagonatus*	0.0003	0.028
Lutjanidae	*Lutjanus monostigma*	0.0003	0.110
Chaetodontidae	*Chaetodon vagabundus*	0.0002	0.011
Acanthuridae	*Ctenochaetus hawaiiensis*	0.0002	0.039
Labridae	*Cheilinus chlorourus*	0.0002	0.048
Monacanthidae	*Cantherhines dumerilii*	0.0002	0.067
Chaetodontidae	*Chaetodon unimaculatus*	0.0002	0.009
Holocentridae	*Myripristis murdjan*	0.0002	0.039
Holocentridae	*Myripristis* spp.	0.0002	0.020
Acanthuridae	*Acanthurus thompsoni*	0.0001	0.007
Monacanthidae	*Cantherhines pardalis*	0.0001	0.007
Chaetodontidae	*Chaetodon ulietensis*	0.0001	0.006
Serranidae	*Gracila albomarginata*	0.0001	0.031
Lutjanidae	*Macolor niger*	0.0001	0.144
Holocentridae	*Sargocentron spiniferum*	0.0001	0.042
Scaridae	*Scarus psittacus*	0.0001	0.041
Lutjanidae	*Lutjanus fulviflamma*	0.0001	0.035
Acanthuridae	*Acanthurus albipectoralis*	0.0001	0.042
Carangidae	*Carangoides ferdau*	0.0001	0.020
Chaetodontidae	*Chaetodon citrinellus*	0.0001	0.000
Serranidae	*Epinephelus fasciatus*	0.0001	0.017
Serranidae	*Epinephelus merra*	0.0001	0.009
Serranidae	*Epinephelus* spp.	0.0001	0.006
Chaetodontidae	*Heniochus monoceros*	0.0001	0.010
Acanthuridae	*Naso annulatus*	0.0001	0.035
Labridae	*Oxycheilinus unifasciatus*	0.0001	0.024

3.2 Weighted average density and biomass of all finfish species recorded in Niue (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Mullidae	*Parupeneus barberinoides*	0.0001	0.006
Mullidae	*Parupeneus pleurostigma*	0.0001	0.003
Scaridae	*Scarus* spp.	0.0001	0.013
Balistidae	*Sufflamen fraenatum*	0.0001	0.005
Acanthuridae	*Acanthurus dussumieri*	0.00004	0.029
Acanthuridae	*Acanthurus xanthopterus*	0.00004	0.043
Balistidae	*Balistes* spp.	0.00004	0.001
Carangidae	*Caranx ignobilis*	0.00004	0.622
Scaridae	*Cetoscarus bicolor*	0.00004	0.016
Chaetodontidae	*Chaetodon lineolatus*	0.00004	0.002
Chaetodontidae	*Coradion altivelis*	0.00004	0.004
Diodontidae	*Diodon hystrix*	0.00004	0.013
Muraenidae	*Gymnothorax javanicus*	0.00004	0.826
Chaetodontidae	*Heniochus singularius*	0.00004	0.003
Kyphosidae	*Kyphosus cinerascens*	0.00004	0.057
Acanthuridae	*Naso tuberosus*	0.00004	0.080
Holocentridae	*Neoniphon sammara*	0.00004	0.004
Balistidae	*Odonus niger*	0.00004	0.008
Mullidae	*Parupeneus barberinus*	0.00004	0.017
Balistidae	*Rhinecanthus aculeatus*	0.00004	0.001
Scaridae	*Scarus ghobban*	0.00004	0.006
Scaridae	*Scarus globiceps*	0.00004	0.010
Scaridae	*Scarus niger*	0.00004	0.016
Scaridae	*Scarus schlegeli*	0.00004	0.035
Balistidae	*Sufflamen chrysopterum*	0.00004	0.004
Carcharhinidae	*Triaenodon obesus*	0.00004	0.843

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Invertebrate species recorded in different assessments in Niue

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+		+
	Actinopyga palauensis			+
	Bohadschia argus	+		
	Holothuria atra			+
	Holothuria nobilis	+		+
	Thelenota ananas	+	+	+
Bivalve	*Tridacna maxima*	+	+	+
Gastropod	*Cypraea caputserpensis*			+
	Cypraea talpa			+
	Lambis lambis	+		
	Lambis spp.		+	
	Serpulorbis colubrinus	+		+
	Siphonaria sirius			+
	Thais armigera			+
Octopus	*Octopus* spp.	+		+
Urchin	*Echinometra mathaei*	+		+
	Echinometra oblonga			+
	Echinostrephus spp.	+	+	+
	Echinothrix calamaris	+		
	Echinothrix diadema	+		+
	Heterocentrotus mammillatus	+		

+ = presence of the species.

4.2 List of macroinvertebrates observed in Niue from previous surveys and the current CoFish survey

Group	Species	CoFish (2005)	IWP (2004) and Fisk (2004b)
Bêche-de-mer	*Actinopyga mauritiana*	P	P
	Actinopyga palauensis	P	
	Holothuria atra	P	P
	Holothuria leucospilota	P	P
	Holothuria spp. 'sepulupulu'	P	P
	Holothuria whitmaei	P	P
	Neothyonidium spp.		P
	Stichopus horrens	P	
	Thelenota ananas	P	P
Bivalve	*Tridacna maxima*	P	P
	Chama isostoma	P	P
	Lithophaga spp.	P	P
Brittle Starfish	*Ophiocoma* spp.	P	P
Gastropod	*Astralium calcar*		P
	Conus capitaneus		P
	Conus cf eburneus		P
	Conus frigidus		P
	Conus virgo		P
	Cypraea caputserpensis	P	P
	Cypraea mauritiana		P
	Cypraea talpa	P	P
	Dendropoma maximum	P	P
	Drupa clathrata	P	P
	Drupa morum		P
	Drupa ricinus	P	P
	Drupella spp	P	P
	Latirus cf polygonius		P
	Morula uva	P	P
	Nassarius cf horridus		P
	Oliva spp.		P
	Oliva vidua		P
	Serpulorbis colubrinus	P	P
	Siphonaria sirius	P	P
	Thais armiger	P	P
	Thais tuberosa		P
	Thais buffo	P	
	Turbo argyrostomus		P
	Turbo petholatus	P	
	Turbo setosus	P	P
	Vasum cf turbinellum		P
Crustacean	*Dardanus guttatus*	P	P
	Stenopus hispidus		P

P = presence of the species.

4.2 List of macroinvertebrates observed in Niue from previous surveys and the current PROCFish survey (continued)

Group	Species	PROCFish (2005)	IWP (2004) and Fish (2004b)
Urchin	*Diadema setosum*	P	P
	Echinometra mathaei	P	P
	Echinometra oblonga	P	P
	Echinostrephus spp.1	P	P
	Echinostrephus spp.2	P	
	Echinothrix calamaris	P	
	Echinothrix diadema	P	P
	Heterocentrotus mammillatus	P	
	Heterocentrotus cf trigonarius		P

P = presence of the species.

4.3 Niue broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	2.2	1.0	54	23.3	4.1	5	2.2	1.1	9	6.5	0.9	3
Bohadschia argus	0.3	0.3	54	16.7		1	0.3	0.3	9	2.8		1
Echinometra mathaei	1.9	1.0	54	25.0	8.3	4	1.9	1.3	9	8.3	2.8	2
Echinothrix calamaris	136.4	113.0	54	1473.3	1154.9	5	136.4	136.1	9	613.9	611.1	2
Echinothrix diadema	46.9	13.8	54	120.6	29.2	21	46.9	17.2	9	60.3	19.3	7
Heterocentrotus mammillatus	0.3	0.3	54	16.7		1	0.3	0.3	9	2.8		1
Holothuria nobilis	0.3	0.3	54	16.7		1	0.3	0.3	9	2.8		1
Lambis lambis	0.3	0.3	54	16.7		1	0.3	0.3	9	2.8		1
Octopus spp.	0.3	0.3	54	16.7		1	0.3	0.3	9	2.8		1
Thelenota ananas	4.9	2.3	54	38.1	12.4	7	4.9	3.6	9	11.1	7.4	4
Tridacna maxima	5.6	2.6	54	33.3	12.7	9	5.6	2.4	9	7.1	2.8	7

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4 Niue reef-benthos transect (RBt) assessment data review

Station: Six 2 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Lambis truncata	13.9	9.5	18	125.0	0.0	2	13.9	13.9	3	41.7		1
Thelenota ananas	90.3	38.9	18	325.0	63.7	5	90.3	90.3	3	270.8		1
Tridacna maxima	215.3	50.3	18	298.1	54.0	13	215.3	69.4	3	215.3	69.4	3

Transect width changed from 1 m to 2 m; mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.5 Niue reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	0.4	0.4	60	26.7		1	0.4	0.4	10	4.4		1
Actinopyga miliaris (palauensis)?	0.4	0.4	60	26.7		1	0.4	0.4	10	4.4		1
Echinometra mathaei	9.3	6.7	60	186.7	101.0	3	9.3	9.3	10	93.3		1
Echinothrix diadema	41.8	10.1	60	104.4	19.3	24	41.8	14.7	10	52.2	16.4	8
Holothuria nobilis	0.4	0.4	60	26.7		1	0.4	0.4	10	4.4		1
Octopus spp.	1.3	0.8	60	26.7	0.0	3	1.3	0.7	10	4.4	0.0	3
Thelenota ananas	8.9	3.4	60	66.7	13.3	8	8.9	4.3	10	22.2	6.5	4
Tridacna maxima	6.2	1.9	60	37.3	4.4	10	6.2	1.5	10	7.8	1.4	8

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.6 Niue reef-front search by walking (RFs_w) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	2.8	1.0	50	17.4	2.3	8	2.8	1.5	9	5.1	2.2	5
Cypraea caputserpensis	0.3	0.3	50	13.9		1	0.3	0.3	9	2.3		1
Cypraea talpa	0.6	0.6	50	27.8		1	0.5	0.5	9	4.6		1
Echinometra mathaei	10.8	6.8	50	77.4	43.3	7	10.0	8.9	9	30.1	25.5	3
Echinothrix diadema	18.1	7.7	50	90.3	30.2	10	16.7	12.8	9	75.2	38.2	2
Holothuria atra	74.7	19.5	50	124.5	29.3	30	69.8	27.7	9	69.8	27.7	9
Thais armigera	0.8	0.5	50	13.9	0.0	3	0.8	0.5	9	3.5	1.2	2
Tridacna maxima	1.7	0.6	50	13.9	0.0	6	1.7	0.4	9	2.5	0.2	6

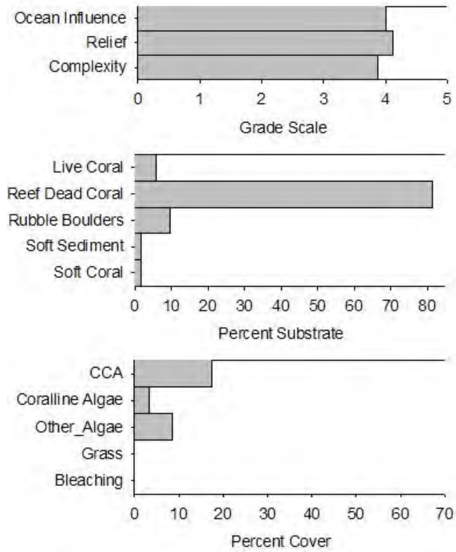
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.7 Niue species size review – all survey methods

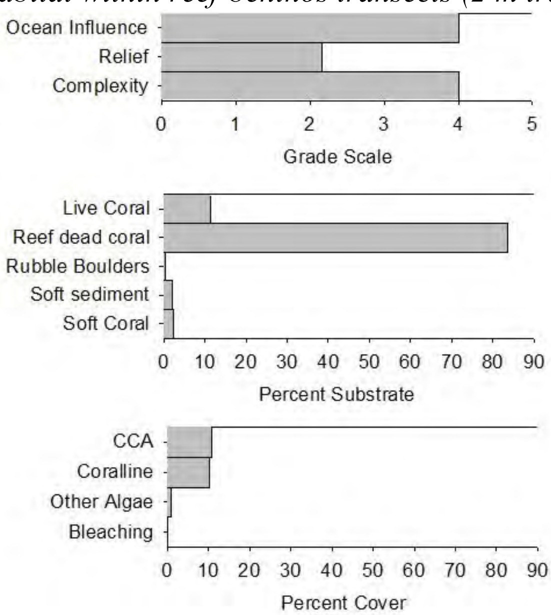
Species	Mean length (cm)	SE	n
Echinostrephus spp.	4.4	0.1	5826
Tridacna maxima	13.4	0.8	69
Echinometra oblonga			1391
Serpulorbis colubrinus			649
Echinothrix calamaris			442
Echinothrix diadema			311
Holothuria atra			269
Echinometra mathaei			66
Thelenota ananas			49
Actinopyga mauritiana			18
Siphonaria sirius			7
Octopus spp.			4
Lambis truncata			3
Thais armigera			3
Cypraea talpa			2
Holothuria nobilis			2
Actinopyga palauensis			1
Bohadschia argus			1
Cypraea caputserpensis			1
Heterocentrotus mammillatus			1

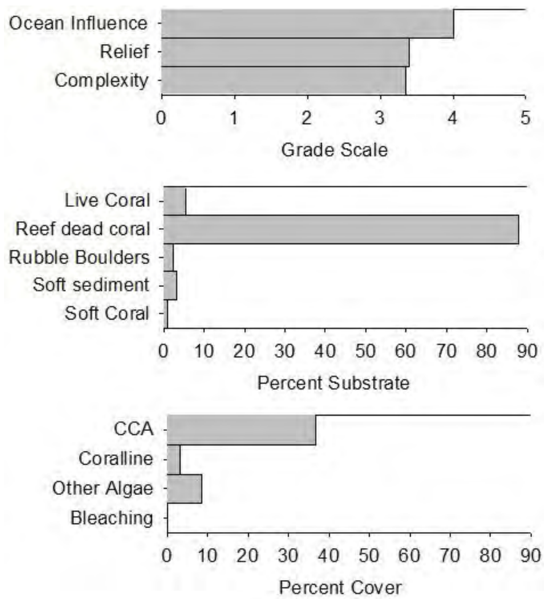
4.8 Habitat descriptors for independent assessments – Niue

Broad-scale assessments of habitat



Habitat within reef-benthos transects (2 m transect width) & reef-front search assessments



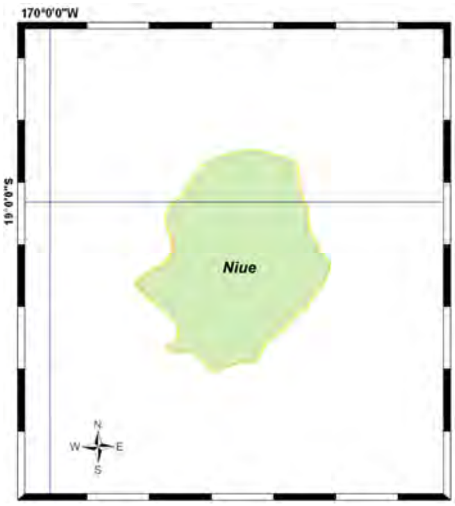


APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – NIUE

Institut de Recherche pour le Développement, UR 128 (France)
Institute for Marine Remote Sensing, University of South Florida (USA)
National Aeronautics and Space Administration (USA)

Millennium Coral Reef Mapping Project
Niue

(October 2008)



The Institute for Marine Remote Sensing (IMaRS) of University of South Florida (USF) was funded in 2002 by the Oceanography Program of the National Aeronautics and Space Administration (NASA) to provide an exhaustive inventory of coral reefs worldwide using high-resolution multispectral satellite imagery (Landsat 7 images acquired between 1999 and 2002 at 30 meters resolution). Since mid-2003, the project is a partnership between Institut de Recherche Pour le Développement (IRD, France) and USF. The goal is to characterize, map and estimate the extent of shallow coral reef ecosystems in the main coral reef provinces (Caribbean-Atlantic, Pacific, Indo-Pacific, Red Sea). The program aims to highlight similarities and differences between reef structures at a scale never considered so far by traditional work based on field studies. We believe the data set generated by this research program will be critical for comparative geochemical, biological and geological studies. It provides a reliable, spatially well constrained data set for biogeochemical budgets, biodiversity assessment, reef structure comparisons, and management. It provides critical information for reef managers in terms of reef location, distribution and extent since this basic information is still of high priority for scientists and managers.

As part of this project, Niue coral reefs are mapped. Reefs are mapped at geomorphological level, the result of a compromise between richness of information and accuracy when no ground-truthing is available.

The PROCFish/Coastal project who is reporting in this document on Niue fishery status has been using Millennium products in the last three years in all targeted countries in order to optimize sampling strategy, access reliable reef maps, and further help in fishery data interpretation. The level of mapping used by PROCFish/C is a thematically simplified version of the Millennium standard. PROCFish/C is using Millennium maps only for the fishery grounds surveyed for the project.

For further inquiries regarding the status of the coral reef mapping of Vanuatu and data availability (satellite images and Geographical Information Systems mapped products), please contact:

Dr Serge Andréfouët
IRD, Research Unit COREUS 128, BP A5, Nouméa Cedex,
98848 New Caledonia;
E-mail: andrefou@noumea.ird.nc

For further information on the project: http://imars.marine.usf.edu/corals.

Reference: Andréfouët S, and 6 authors (2005), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th ICRS, Okinawa 2004, Japan: pp. 1732-1745.