PACIFIC REGIONAL OCEANIC AND COASTAL FISHERIES DEVELOPMENT PROGRAMME (PROCFish/C/CoFish)

TUVALU COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT FUNAFUTI, NUKUFETAU, VAITUPU AND NIUTAO

(October – November 2004 and March – April 2005)

by

Samasoni Sauni, Mecki Kronen, Silvia Pinca, Lillian Sauni, Kim Friedman, Lindsay Chapman and Franck Magron

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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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[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 coastal component of the EU-funded Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C) conducted fieldwork in four Tuvalu sites between October – November 2004 and March – April 2005. Tuvalu is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by PROCFish/C or its associated programme CoFish (Pacific Regional 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.

Programme outputs include:

- Implementation of the first comprehensive, multi-country comparative assessment of reef fisheries (including resource and human use components), 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 indicate 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 Tuvalu covered three disciplines (finfish, invertebrates and socioeconomics), with the work undertaken in two visits, each by a team of five programme scientists and several local attachments from the Tuvalu government fisheries department. The team also helped to build local capacity by training local counterparts in survey methodologies, data collection, and data entry.

The four PROCFish/C study sites selected in Tuvalu were the atolls of Funafuti and Nukufetau, and the islands of Vaitupu in the central group and Niutao in the northern group. These sites were selected after a visit to Tuvalu by SPC staff, which included meetings and discussions with key government agencies, the Funafuti Island Government and local fish-market owners. The sites were spread over the country, covering different island types and areas both near and far from population centres, so as to gain a broad picture of Tuvalu's marine resources.

The selected sites shared most of the required characteristics for our study: i.e. they

- had active reef fisheries,
- were representative of the country,
- were relatively closed systems,
- were appropriate in size,
- possessed diverse habitats,
- presented no major logistic limitations that would make fieldwork unfeasible,
- had been investigated by previous studies (although not all sites), and
- were of particular interest for Tuvalu's Department of Fisheries.

Results from fieldwork at Funafuti

Funafuti Atoll, the capital of Tuvalu, is the largest atoll in the country, and occupies a total land area of 2.79 km^2, consisting of many separate islets or *motu* around the barrier reef. The barrier reef rim is cut by several deep passages along its western side, and a single, deep passage to the southeast. The atoll has an area of 242.2 km^2, of which 15% is reef platform. The bulk of the reef platform (37 km^2) consists of bare reef flats (92%), vegetated islets (7%) and adjacent beaches (1%). Fishing on the island is semi-commercial, and many people still fish for food after work and at weekends. The local demand for fresh fish is high and often market supply falls short of demand. Trolling for pelagic fish is common, using either wooden or aluminium skiffs that are equipped with an outboard engine. Lagoon fishing is mostly performed using gillnets, handlines, rods and fish traps. Spearfishing, rod fishing and handlining are common methods used for reef fishing. The Funafuti Conservation Area (MCA) is the only legal, localised *tapu* area in the country. Since its establishment in 1997, the 33 km^2 of protected ocean area include six small *motu*, encompassing about 20% of the total coral reef area of Funafuti lagoon. The protection of animals and plants extends from the land to the sea.

Socioeconomics: Funafuti

Socioeconomic surveys on Funafuti covered eight districts, with a total of 30 households interviewed, covering 245 people. This represented around 5% of the island's households (551) and population (4500 people). Fisheries were found to provide the first income for 30% of all households and the second source of income for 23% of households. Salaries were the most important income source (50% 1st income, 13% 2nd income). About 43% of all households interviewed reported receiving remittances, with USD 1830 per year the average amount received, which was substantial as it covered about two-thirds of the average annual household expenditure (USD 3080). Average annual consumption per capita of fresh fish was high at 135 kg, while the consumption of canned fish was low at 2.3 kg/capita/year. Invertebrates were consumed less than once per week.

Fishing on Funafuti was dominated by males (~80%), targeting finfish or a mix of finfish and invertebrate species. Females focused more on invertebrate fishing. Most finfish fishers targeted the lagoon (40%) and sheltered coastal reef (34%). Most invertebrates were caught by gleaning (~70%). Over 60% of the finfish catch was for subsistence needs, with around 30% sold and less than 10% given away. Invertebrates were mainly caught for subsistence and less than 20% of their catch was sold.

Finfish: Funafuti

Finfish resources in Funafuti atoll were showing early signs of impact from fishing and appeared to be in decline. Although species diversity and density estimates were fairly high, estimates of biomass (except at the outer reef) were the lowest found of all four survey sites, and fish sizes were small, a combination that suggests increased fishing pressure. More evidence of impact from fishing was apparent in the low ratio of carnivore fish families compared to herbivores, as carnivores are usually the first fish to be targeted. In Funafuti, the carnivorous fish families of Lutjanidae, Lethrinidae and Serranidae were much lower in all reefs than at the comparable site of Nukufetau, and herbivorous fish families, Acanthuridae and Scaridae, were dominant. Target species of Lutjanidae, Lethrinidae, Serranidae and Siganidae were becoming increasingly over-exploited.

Fish biomass and density increased from coastal fishery to lagoon, back and outer-reef fishery. This correlated well with accessibility to fishing spots, habitat health and the varying level of fishing pressure exerted on these habitats. Coastal reefs were much poorer than the other habitats, possibly resulting from the high population density and high dependence on marine resources for subsistence and semi-commercial purposes. The high population index per unit area of available reefs gave an early warning that close monitoring of the resources was needed in order not to exceed sustainable fishing levels.

Invertebrates: Funafuti

Invertebrate surveys at Funafuti recorded 33 species or species groups from both broad-scale and fine-scale techniques. Giant clams were not consistently recorded across the atoll. The low densities and skewed size ranges for giant clams within Funafuti Atoll suggested that stocks were heavily impacted by fishing. Reproductive success and therefore subsequent recruitment is likely to be impaired at these levels, and giant clam stocks at these low densities are likely to decline further unless action is taken to further protect clams. Commercial mother-of-pearl species, such as trochus, *Trochus niloticus*, have survived in the lagoon following translocation, but were still rare and considered impacted by fishing. Trochus are not endemic to Tuvalu, and although habitats look suitable, much of the lagoon reefs were nutrient poor, and did not afford much potential for developing a trochus fishery. There was a limited number of sea cucumber species available for commercial fishing, and stock densities were generally low. The presence of high-value white teatfish, and prickly redfish was of interest for commercialisation, but this preliminary survey suggests stocks are limited.

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomics, finfish and invertebrate surveys), the following recommendations are made for Funafuti Atoll:

- The Tuvalu Fisheries Department work with the local Falekaupule and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur, as there are signs of this starting to occur with finfish, given the low biomass and small fish size of the main target species.

- A swift transition from reef fishing to oceanic and deep-bottom fishing be encouraged, coupled with the use of multi fishing methods to target a variety of species during any one fishing trip. This would relieve fishing pressure on reef finfish resources, which is likely to continue to gain momentum into the future along with the increase of semi-commercial fishing operations.

- The Tuvalu Fisheries Department work with the local Falekaupule and *Kaupule* to develop management plans or arrangements for the inshore resources of Funafuti atoll to ensure the sustainable harvest of all marine resources, now and in the future.

- The management of the marine conservation area (MCA) at Funafuti be strengthened, possibly with assistance from the local Falekaupule and *Kaupule*, to ensure that no fishing occurs within its boundaries, as this area holds good potential for retaining broodstock of important invertebrate species, such as giant clams and trochus.

- The Tuvalu Fisheries Department move some of the introduced giant clams *Tridacna derasa* from their current location to a more suitable habitat within the lagoon, in areas far from the Fisheries Department's wharf, if the clams can be protected from fishing.

- If a further movement of trochus to Funafuti is undertaken, that firstly transplants be put on reefs inside the lagoon (possibly near the west passages) to enable them to get established. Translocated adults need protection from predators when they are released onto reefs, and need to remain protected until they have become acclimatised to local conditions (that is, a staged release is recommended).

- The Tuvalu Fisheries Department be very cautious with any endeavour to open the sea cucumber fishery on Funafuti for white teatfish and prickly redfish, as stocks are limited. Further work is needed to assess what level of harvest can be allowed. This should all be done through a management plan for this fishery, under the control of the local Falekaupule and *Kaupule*.

Results from fieldwork at Nukufetau

Nukufetau is the second biggest atoll of Tuvalu, situated about 120 km northwest of Funafuti, almost in the middle of the country. Nukufetau consists of 37 islets with a total land area of 2.99 km^2. The total atoll has an area of 116.5 km^2, of which 22% is reef platform and 78% the enclosed lagoon. The bulk of the reef platform (85%) consists of bare reef flat; vegetated islands and adjacent beaches account for the remainder. The lagoon has two surface channels from the open sea and fills and drains across the reef flat and through subterranean passages. Common fishing practices in the lagoon include handlining and gillnetting, whereas spearfishing and gillnetting are used at the coastal and shallow outer reefs. Semi-commercial trolling for tuna is prevalent. There are by-laws on Nukufetau that place restrictions on gillnet mesh sizes and indiscriminate harvesting of giant clams and sea cucumbers. During the time of surveys on Nukufetau, community leaders were in the process of finalising plans for a marine protected area, with restrictions extended to both sea and land resources within demarcated boundaries.

Socioeconomics: Nukufetau

Socioeconomic fieldwork on Nukufetau covered the two villages of Aulotu and Maneapa, with a total of 28 households interviewed covering 164 people. The survey covered about 24% of the atoll's households (total number 118) and of the total population (~690 people). Survey results suggested an average of two fishers per household. While about 70% of all households in both villages owned a boat, Aulotu had a slightly higher percentage of households with motorised boats (83%) than Maneapa (73%). Salaries were the most important source of income for about 60% of all households. Other sources, such as handicrafts and sale of ice blocks, provided more households (18%) with first income than fisheries (11%). However, fisheries represented a second source of income for about half of all households on Nukufetau. Average annual per capita consumption of fresh fish was high at 185 kg, while the consumption of canned fish was low at 1.5 kg/capita/year. Invertebrates were only eaten around once per month. Fishing was dominated by males (~70%), who mainly targeted finfish or a combination of finfish and invertebrate species. Females focused more on invertebrate fishing. Most of the finfish catch on Nukufetau served subsistence needs, but more than half of all invertebrate catches were sold.

Finfish: Nukufetau

Finfish resources in Nukufetau atoll were in fairly good condition and better than in Funafuti, the only comparable site. Fish density and biomass on the outer-reef habitat, which is common to all four survey sites, were second highest of all four sites. This healthy status was possibly due to: the geographical isolation of Nukufetau; the low population index per unit area of available reefs; the relatively large reef area; and the variety of fishing gear and methods used to target a suite of preferred species. However, the high number and frequent use of motorised boats, as opposed to traditional canoes and sails, have no doubt enhanced the level of fishing pressure.

Average fish sizes were smaller than those recorded at Niutao and Vaitupu but similar to or higher than at Funafuti. Sizes varied among the four habitats and were notably higher in outer reefs for Lethrinidae, Labridae, Mullidae and Scaridae. This may be due to the close proximity and easy accessibility of the sheltered coastal reef, where selective spearfishing and gillnetting were more pronounced. Handlining was more common in the lagoon and outer-reef slope. Fish biomass and density increased from coastal fishery to lagoon, back-reef and outer-reef fishery. This correlated with accessibility to fishing spots, habitat health and the varying level of fishing pressure exerted on these habitats. Certain fish families, especially carnivores Lutjanidae and Lethrinidae, were more dominant compared to the other sites, although fish assemblages differed notably according to habitat type.

Invertebrates: Nukufetau

Invertebrate surveys recorded 29 species or species groups during broad-scale and fine-scale assessment. The density and size range of *Tridacna maxima* giant clams in Nukufetau atoll described a resource that was heavily impacted. The presence of dense aggregations of small-sized *T. maxima* indicated that recruitment was good on reefs in the west of the lagoon. Although the larger species, *T. squamosa*, was generally found at lower density than *T. maxima* in this survey, fishing pressure was the noted cause for the low density records. Assessment results suggested that trochus had not become established at Nukufetau atoll following their introduction in 1988. Presence and recruitment of *Tectus pyramis* was low-to-moderate, although recruitment in the lagoon was occurring. In general, reefs at Nukufetau were predominantly influenced by the open ocean without significant numbers of grazing gastropods. Results showed that *Pinctada margaritifera* populations were low, and considered impacted by fishing. Information collected on sea cucumber stocks revealed a limited number of species available for commercial fishing, and stock densities were generally low for shallow-water reef and lagoon species. The presence of high-value white teatfish and prickly redfish were of interest for commercialisation, but this preliminary survey suggested stocks were limited to two areas in the lagoon.

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomic, finfish and invertebrate surveys), the following recommendations are made for Nukufetau atoll:

- The Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur, especially with invertebrate species of which half are exported to Funafuti for marketing.

- The Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* to develop management plans or arrangements for the inshore resources of Nukufetau atoll to ensure the sustainable harvest of all marine resources, now and in the future. Also that the existing by-laws be enforced and further management measures considered, (e.g. regulating fishing gears, establishing minimum mesh sizes, and imposing closed seasons for certain species) for controlling fishing effort (These were being discussed by the island leaders at the time of the surveys, as well as the establishment of a marine conservation area that includes both land and sea resources, which is highly recommended.).

- The Tuvalu Fisheries Department encourage the local Falekaupule and *Kaupule* to set up a protected area free of any fishing (which includes both shallow and deep water), which would have good potential for retaining broodstock of important invertebrate species, such as giant clams, and trochus if these were to be re-introduced to Nukufetau atoll.

- The local Falekaupule and *Kaupule* be very cautious with any endeavour to open the sea cucumber fishery on Nukufetau for white teatfish and prickly redfish as stocks are very limited and further work is needed to assess what level of harvest can be allowed. All this should be done through a management plan for this fishery.

Results from fieldwork at Vaitupu

Vaitupu is part of the central group of islands in Tuvalu. The closest island to Vaitupu is Nukufetau, 67 km away. It is also the biggest island in Tuvalu, with a total land area of 5.3 km^2. The reef platform area of lagoons, beaches and reef flats makes up another 10.2 km^2. The island is low-lying, elongated and categorised as a closed atoll encompassing two lagoons, which are open on the northeast of the tidal reef. The lagoon system supports a milkfish fishery, which plays an important role in supplying people with fresh fish during periods when the sea is rough. The most common fishing method is trolling for pelagic fish using either wooden or aluminium skiffs that are equipped with an outboard engine. Gillnets, handlines, rods and fish traps are most commonly used for lagoon fishing. Deep sea handlining, rod fishing and spearfishing are the three most common methods used for the reef area. Spearfishing is usually done at night, and is a common way of collecting lobsters. In the open ocean, trolling, scoop-netting and deep-sea handlining are the three most common methods of fishing. The by-laws that exist in Vaitupu include the restriction of gillnets with small mesh-sizes, and seasonal closures to fishing in the lagoons. Other restrictions include the prohibition of the use of hookah and SCUBA gears for any form of fishing, a ban on dynamiting and the use of fish poisons.

Socioeconomics: Vaitupu

Socioeconomic fieldwork on the island of Vaitupu focused on the village of Tumaseu, with one household at Asau also included in the survey. In total, 29 households were interviewed covering 178 people, with the survey covering about 12% of the island's households (237) and total population (~1455 people). Salaries are the most important source of income for half of all households. While 50% of all households depend on one source of income only, one quarter uses fisheries as a second and complementary source. Around 40% of all households own a boat, of which 58% are canoes. The average annual per capita fresh fish consumption is high at 163 kg, with canned fish consumption low at 2.1 kg/capita/year. Fishing is dominated by males (~70%), targeting finfish, or a combination of finfish and invertebrate species. Females predominantly collect invertebrates. Finfish is mostly caught and invertebrates are exclusively collected for subsistence purposes.

Finfish: Vaitupu

Finfish resources in Vaitupu were found to be fairly impacted. When compared to the outer-reef values for all four study sites, the finfish resources of Vaitupu displayed the lowest biodiversity, density and biomass. Like Niutao, Vaitupu does not have all the available habitats and reef types to enable a wide choice of fishing methods, gears and target species. Therefore, fishing impact was intensive here relative to Funafuti and Nukufetau. Moreover, the high population of the island may have caused fishing pressure to exceed sustainable limits in the outer reefs. Fish density, biomass and size were lower along the leeward side of the island, probably in response to higher fishing pressure as the leeward side is more protected and accessible to fishing.

Although biomass and density were lowest on Vaitupu, mean fish size and size ratios were the highest of the four sites. Sizes of the commercially targeted Acanthuridae, Balistidae, Holocentridae, Scaridae, Serranidae and Siganidae were higher than the 55% of their maximum known size. Therefore, even though fish population levels signalled that stock sizes were low, they were not determined to be at a critically low level.

Populations of the targeted and commercial species of Serranidae, Lutjanidae and Lethrinidae were very low. Similar to the outer-reef environment in Niutao, the large amount of hard rock substrate and high percentage of algae explains the relatively high abundance of Acanthuridae, Balistidae, and to a much lesser extent, Scaridae on the outer reef. The available stocks of Acanthuridae far exceeded that of the other families. At other sites, especially Nukufetau, Lutjanidae and Lethrinidae, and Scaridae were far more abundant. The high abundance of Acanthuridae may also be explained by the frequent incidence of ciguatera on species like *Acanthurus lineatus*, *Ctenochaetus striatus* and *Naso lituratus*.

Invertebrates: Vaitupu

Invertebrate surveys recorded 25 species or species groups at Vaitupu. Giant clams were rarely found, despite the good coverage of the survey. At this density, giant clams are past the critical threshold point where spawning and future recruitment is critically compromised. Therefore, the giant clam resource at Vaitupu was probably heavily depleted by past fishing. Regarding mother-of-pearl stocks, *Trochus niloticus* did not offer a promising prospect for introduction at Vaitupu, while *Tectus pyramis* and *Pinctada margaritifera* resources were poor. Although the general indication of fishing pressure on gastropods and bivalves was high, the rarity of the two species groups was mainly due to the harsh environmental conditions found at Vaitupu. There was a limited number of sea cucumber species available for commercial fishing, and stock densities were limited. The presence of medium-to-high-value surf redfish, *Actinopyga mauritiana*, and low-value brown sandfish (*Bohadschia vitiensis*) were of interest for commercialisation, but this preliminary survey needs to be upgraded before a fishery is considered.

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomic, finfish and invertebrate surveys), the following recommendations are made for Vaitupu:

- The Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur. Monitoring should include the level of fishing effort (e.g. gear types, mesh sizes) and catches (e.g. size limits and landings by species).

- The strict control and successful management of the lagoons by the Falekaupule and *Kaupule* be extended to protect presently targeted species as well as controlling the mesh-size of nets used in the outer reefs. Also that Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* with developing management plans or arrangements for all inshore resources of Vaitupu to ensure the sustainable harvest of these resources, now and in the future.

- The local Falekaupule and *Kaupule* continue to support and encourage trolling for pelagic species outside the reef, to relieve fishing pressure on inshore resources and enable targeted species to be fished within sustainable levels.

- The Tuvalu Fisheries Department encourage the local Falekaupule and *Kaupule* to set up a protected area free of any fishing (shallow and deep water), which would have good potential for retaining broodstock of important invertebrate species, such as giant clams, which are depleted at present.

- The local Falekaupule and *Kaupule* be very cautious with any endeavour to open the sea cucumber fishery based on the two species that had reasonable densities. Further work is needed to assess what level of harvest can be allowed. This should all be done through a management plan for this fishery.

Results from fieldwork at Niutao

Niutao is a single, small, coral flat island with a narrow fringing reef in the northern island group, the third smallest island in Tuvalu (2.5 km^2). The island occupies over three-quarters of the 3.1 km^2 reef platforms exposed at low tide. The entire island, which is basically a reef platform, consists of enclosed lagoon and land (2.4 km^2), beaches (0.02 km^2) and reef flat (0.7 km^2) that gently drops off over the fringing reef. The three relatively shallow and small, fully enclosed lagoons are connected to the sea through subterranean passages. On the fringing reef, two good passages give access to the ocean fishing grounds. The other four passages can only be used during good weather. Common fishing practices included netting and rod fishing on the coastal reef, and handlining and spearfishing on the outer reefs. Ciguatera fish poisoning was a serious concern and known to occur throughout the year but more frequently during the period when westerly winds prevail. Pelagic fishing was very common and excess tuna catches were usually sold to the local community.

Socioeconomics: Niutao

Socioeconomic fieldwork was conducted with 26 households (152 people) interviewed from the two main villages, Kulia and Teava. The survey covered about 18% of the island's households (143) and of the total population (~835 people). Around 35% of households interviewed put fisheries as their first income source. However, only about 10% of the annual finfish catch was sold to generate income. Invertebrates were mainly caught for home consumption. Average annual per capita consumption of fresh fish was 118 kg, which, although large, was still the lowest amount of all four sites surveyed. The consumption of canned fish was low at 3 kg/capita/year, and invertebrates were only eaten once every fortnight. Fishing was dominated by males (~90%) targeting finfish or a combination of finfish and invertebrate species. Females only collected invertebrates.

Finfish: Niutao

Overall, finfish resources on Niutao were found to be in good condition. When compared to the average for the other PROCFish/C study sites, biodiversity was relatively low, but fish density and biomass on the outer reefs were the highest of all the four sites surveyed.

Populations of the targeted and commercial species: Serranidae, Lutjanidae and Lethrinidae were low. However, these carnivorous fish, although rare, were relatively large in size, which suggests they were not overfished in the outer reef. The very high abundance of Acanthuridae and Balistidae correlated well with the high cover of hard bottom and algae. Their high abundance may also be related to the high incidence of ciguatera that mainly affects *Acanthurus lineatus*, *Ctenochaetus striatus* and *Naso lituratus*, species that were all very abundant in Niutao. There was a total absence of Siganidae.

Average mean fish sizes were the largest of all four outer-reef sites, and similar to those in Vaitupu. Sizes of the commercially targeted Acanthuridae, Lutjanidae, Lethrinidae, Scaridae and Serranidae were higher than 55% of maximum known size, indicating that stocks were still healthy, even though numbers were small. Size ratios were very similar for all feeding guilds (e.g. carnivores, herbivores) suggesting a comparable use of the different trophic levels. Low numbers and relatively small sizes of fish were found at the leeward and western side of the island, which is easily accessible and more protected. Early signs of fishing pressure were seen in the low abundance of carnivore species.

Invertebrates: Niutao

Invertebrate surveys on Niutao recorded 20 species or species groups. Despite the good coverage of the survey, giant clams were rare (only three *Tridacna maxima* found). At this density, giant clams are past the critical threshold point where spawning and future recruitment is critically compromised. The isolated nature of Niutao Island and the open reef environment makes recruitment from these broadcast spawners less assured.

The small scale, exposure and lack of suitable habitat affected the potential for mother-of-pearl resource species. *Trochus niloticus* was not present and did not present a promising prospect for Niutao in the future. Populations of *Tectus. pyramis*, a related species, were low in abundance and the black-lipped pearl oyster, *Pinctada margaritifera*, was not found. Fishing pressure, along with environmental conditions, explains the paucity of these results.

A limited number of sea cucumber species was found on Niutao, and stock densities were very low. The presence of medium-high-value surf redfish, *Actinopyga mauritiana*, was of interest, but this preliminary survey suggests that occurrence and density were too low to consider commercial fishing.

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomic, finfish and invertebrate surveys), the following recommendations are made for Niutao:

- In consultation with the local Falekaupule and *Kaupule*, the Tuvalu Fisheries Department conduct further in-water as well as socioeconomic surveys as perhaps the only means to further update trends in fish resources and resource use in the island.

- The local Falekaupule and *Kaupule* consider assisting the development of the immediate offshore pelagic fishery and investigate the use of the enclosed lagoons for milkfish farming. This may also contribute to the effective development of a small-scale subsistence or semi-commercial fishery on the island.

- The Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* to establish a monitoring programme for catch and landings to observe any decrease in fish stocks due to high fisher density and high catches. Effective ways of controlling fishing effort may include regulating fishing methods (e.g. gear types, mesh sizes) and catches (e.g. setting size limits, or total allowable catches of heavily exploited species) for marine resources, finfish and invertebrates.

- The Tuvalu Fisheries Department assist the local Falekaupule and *Kaupule* to develop management plans or arrangements for the inshore resources of Niutao to ensure the sustainable harvest of all marine resources, now and in the future. Ongoing assessments, including socioeconomic surveys, could be used to assess how management arrangements are working, with changes made as necessary.

- The local Falekaupule and *Kaupule* be very cautious in any endeavour to open the sea cucumber fishery at Niutao as the four species recorded have stocks at low to very low levels, and are not sufficient for commercial harvest at this time.

- The local Falekaupule and *Kaupule* consult with the Fisheries Department to look at options for increasing the numbers of giant clams, to allow a small breeding stock to be established at Niutao.

RÉSUMÉ

L'équipe chargée de la composante pêche côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français du Pacifique et pays ACP du Pacifique (PROCFish/C), financé par l'Union européenne, a mené des études de terrain dans quatre sites de Tuvalu d'octobre à novembre 2004 et de mars à avril 2005. Tuvalu est l'un des 17 États et Territoires insulaires du Pacifique visés, sur une période de 5-6 ans, par le projet PROCFish ou le projet CoFish qui lui est associé (Projet de développement de la pêche côtière).

Le but des études de terrain consiste à obtenir des données de référence sur l'état des ressources récifales et à combler l'énorme manque d'informations qui entrave la gestion efficace des ressources récifales.

Les autres résultats attendus du projet sont les suivants :

- première évaluation exhaustive et comparative des pêcheries récifales (ressources marines et exploitation par l'homme) de plusieurs pays de la région océanienne, grâce à une méthode normalisée, appliquée à chaque site d'étude ;
- diffusion de rapports nationaux comprenant un ensemble de « descriptifs 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 jeu d'indicateurs (ou points de référence pour l'évaluation de l'état des stocks), qui serviront de guide à l'élaboration de plans de gestion des ressources récifales à l'échelle locale et nationale, et de programmes de suivi ; et
- élaboration de systèmes de gestion des données et de l'information, dont des bases de données régionales et nationales.

Les enquêtes et études de terrain conduites à Tuvalu étaient axées sur trois volets : inventaire des poissons, inventaire des invertébrés et étude des facteurs socioéconomiques. Ces travaux ont été réalisés au cours de deux visites par une équipe de cinq scientifiques du projet et plusieurs agents du Service des pêches de Tuvalu affectés au projet. L'équipe du projet s'est également occupée du renforcement des capacités locales, en formant des interlocuteurs aux méthodes d'enquête ainsi qu'à la collecte et à la saisie de données.

Les quatre sites retenus pour l'étude PROCFish/C étaient les atolls de Funafuti et de Nukufetau, l'île de Vaitupu appartenant au groupe d'îles du centre et Niutao dans le groupe d'îles du Nord. Ces sites ont été sélectionnés après une première mission des agents de la CPS à Tuvalu, pendant laquelle ils ont eu des rencontres et des discussions avec les principaux organismes publics concernés, l'administration de l'île de Funafuti et les propriétaires du marché de poisson local. Situés aux quatre coins du pays, ces sites représentent des types distincts d'îles et de régions, proches ou éloignés des agglomérations, de sorte à brosser un tableau général des ressources marines de Tuvalu.

Les sites sélectionnés répondent à la plupart des critères définis pour notre étude :

- faire l'objet d'activités de pêche récifale régulières ;
- être représentatif du pays ;
- constituer un système relativement fermé ;
- avoir une superficie adéquate ;
- contenir des habitats diversifiés ;

- ne présenter aucun obstacle logistique majeur rendant les travaux de terrain impossibles ;
- avoir fait l'objet d'études antérieures (critère non applicable à tous les sites) ; et
- présenter un intérêt particulier pour le Service des pêches de Tuvalu.

Résultats des études de terrain à Funafuti

Avec une superficie terrestre totale de 2,79 km², l'atoll de Funafuti, capitale de Tuvalu, est le plus vaste du pays. Il se compose de nombreux îlots ou *motu* éparpillés autour du récif-barrière. La ceinture du récif-barrière est ouverte par des passes profondes en plusieurs endroits de sa face occidentale et en un seul point de sa façade sud-est. L'atoll a une superficie totale de 242,2 km², dont 15 % sont composés de plateforme récifale. La quasi-totalité de cette plateforme récifale (37 km²) est constituée de platiers récifaux nus (92 %), d'îlots couverts de végétation (7 %) et de plages adjacentes (1 %). La pêche à Funafuti est de nature semi-commerciale, à laquelle s'ajoute une pêche vivrière pratiquée par de nombreuses personnes après les heures de travail ou pendant le week-end. L'offre de poisson frais sur le marché peine souvent à répondre à la demande locale élevée. La pêche pélagique à la traîne est couramment pratiquée à l'aide d'embarcations en bois ou en aluminium équipées de moteur hors-bord. La pêche lagonaire se pratique le plus souvent avec des filets maillants, des palangrottes, des cannes à pêche et des pièges. Les modalités courantes de pêche récifale sont la chasse sous-marine, la pêche à la canne et la pêche à la palangrotte. L'aire marine protégée de Funafuti (*Funafuti Conservation Area*) est la seule zone *tapu* du pays délimitée et protégée sur le plan juridique. Protégée depuis 1997, cette zone océanique de 33 km² comprend six petits *motu*, qui englobent à eux seuls quelque 20 % de la surface totale de récifs coralliens du lagon de Funafuti. La protection de la faune et de la flore vivant dans cette aire de conservation s'applique tant sur terre qu'en mer.

Paramètres socioéconomiques de Funafuti

Les enquêtes socioéconomiques conduites dans huit districts de Funafuti ont permis d'interroger 30 ménages au total, correspondant à 245 personnes interrogées. L'échantillon représente environ 5 % du nombre total de ménages vivant sur l'île (551) et de la population totale (4 500 habitants). Il ressort des enquêtes que la pêche est la première source de revenus de 30 % de tous les ménages et la deuxième source de revenus de 23 % des ménages. L'emploi salarié constitue la principale source de revenus (première activité rémunératrice pour 50 % des ménages, et deuxième pour 13 % d'entre eux). À peu près 43 % des ménages interrogés ont déclaré recevoir des transferts d'argent de l'étranger, la moyenne perçue s'élevant à 1 830 dollars des États-Unis par an. Ces transferts jouent une part substantielle dans l'économie des ménages, puisqu'ils couvrent environ deux tiers de leurs dépenses moyennes annuelles (3 080 US$). Le volume moyen de poisson frais consommé par habitant est élevé (135 kg par an), alors que la consommation de poisson en conserve n'atteint qu'un maigre 2,3 kg par habitant par an. Les invertébrés sont consommés moins d'une fois par semaine.

La pêche à Funafuti est principalement pratiquée par les hommes (~ 80 %), qui ciblent des poissons ou un mélange de poissons et d'invertébrés. Les femmes s'adonnent davantage à la pêche d'invertébrés. La plupart des pêcheurs de poissons exploitent les zones lagonaires (40 %) et les récifs côtiers abrités (34 %). La pêche d'invertébrés se fait, dans la majorité des cas, par ramassage (~ 70 %). Plus de 60 % des poissons capturés sont consommés par le ménage, contre 30 % qui sont vendus et moins de 10 % distribués gratuitement. Les invertébrés sont essentiellement pêchés à des fins vivrières et moins de 20 % des prises sont vendues.

Inventaire des ressources en poissons à Funafuti

Les poissons observés dans les eaux de l'atoll de Funafuti présentent les premiers signes de surpêche et leurs effectifs semblent se réduire. Bien que les estimations de la diversité et de la densité des espèces soient élevées, les chiffres des biomasses estimées (les plus bas des quatre sites d'étude, hormis celles calculées pour la pente externe du récif) et les petites tailles des poissons semblent traduire une intensification de la pression de pêche. L'incidence négative de la pêche est aussi démontrée par le faible ratio entre familles de poissons carnivores et familles d'herbivores, les carnivores étant habituellement les premières proies des pêcheurs. Les familles de carnivores *Lutjanidae*, *Lethrinidae* et *Serranidae* sont beaucoup moins représentées dans toutes les zones récifales de Funafuti que dans le site de Nukufetau comparable, tandis que les familles d'herbivores *Acanthuridae* et *Scaridae* sont présentes en grand nombre. Les espèces ciblées appartenant aux familles *Lutjanidae*, *Lethrinidae*, *Serranidae* et *Siganidae* sont de plus en plus victimes de surexploitation.

On constate un accroissement de la biomasse et de la densité de poissons à mesure que l'on s'éloigne des zones côtières et que l'on pénètre les zones lagonaires, d'arrière-récif et de pente récifale externe. Cette variation de la biomasse et de la densité présente une bonne corrélation avec l'accessibilité des lieux de pêche, la santé des habitats et les différents niveaux de pression de pêche exercés sur ces habitats. Les récifs côtiers sont beaucoup plus pauvres en ressources que les autres habitats, peut-être du fait de la forte densité de population sur le littoral et du degré important de dépendance des communautés par rapport à la pêche vivrière et semi-commerciale des ressources marines. L'indice élevé de densité démographique par unité de surface récifale disponible est un indicateur précoce qui doit nous alerter sur la nécessité de surveiller de près les ressources pour éviter tout dépassement des niveaux de pêche que peuvent supporter à long terme les ressources.

Inventaire des ressources en invertébrés à Funafuti

Trente-trois espèces ou groupes d'espèces ont été recensés lors des inventaires d'invertébrés de grande échelle et de petite échelle réalisés à Funafuti. Les bénitiers ont été observés çà et là dans les zones de l'atoll. Les faibles densités de bénitiers dans les eaux de Funafuti et leurs gammes de taille irrégulières indiquent que les stocks sont fortement affectés par la pêche. À ce niveau de densité, le cycle de reproduction des bénitiers et le recrutement postérieur risquent d'être perturbés, et les stocks à proprement parler risquent de se dégrader davantage si aucune mesure de protection n'est appliquée. Les espèces commerciales de mollusques nacriers, tels que le troca *Trochus niloticus*, ont survécu dans le lagon grâce à des translocations, mais restent rares et victimes de la pêche. Le troca n'est pas une espèce endémique à Tuvalu. Bien que les habitats semblent adaptés à l'espèce, la plupart des zones récifales lagonaires sont pauvres en nutriments et n'ont pas vraiment le potentiel requis pour développer une filière du troca. Un petit nombre d'espèces d'holothuries pourrait être pêché à des fins commerciales, mais les densités de stock sont en général basses. La présence d'holothuries blanches à mamelles et d'holothuries ananas, toutes deux très cotées sur les marchés de distribution, peut être intéressante, mais notre étude préliminaire révèle que les stocks sont limités.

Sur la base des inventaires et des évaluations de l'équipe pour les trois volets du projet (paramètres socioéconomiques, inventaire des poissons et inventaires des invertébrés), les recommandations suivantes s'appliquent à l'atoll de Funafuti :

- Le Service des pêches de Tuvalu devrait travailler avec le *Falekaupule* et le *Kaupule* locaux pour mettre en place un programme de surveillance des ressources marines (poissons et invertébrés) comprenant le suivi des captures et des prises débarquées, en vue de prévenir toute surpêche. En effet, la faible biomasse et la petite taille des principales espèces ciblées sont des indicateurs d'un début de surpêche du poisson.

- Il convient d'encourager les pêcheurs, par l'intermédiaire des *Falekaupule* et *Kaupule* locaux, à abandonner rapidement la pêche récifale au profit de la pêche hauturière et de la pêche de grand fond, et à employer plusieurs méthodes de pêche afin de cibler une variété d'espèces pendant une même sortie de pêche. Cette mesure permettrait de relâcher la pression de pêche exercée sur les poissons de récif, d'autant que celle-ci est appelée à s'intensifier à l'avenir avec le développement des opérations de pêche semi-commerciale.

- Le Service des pêches de Tuvalu devrait travailler avec le *Falekaupule* et le *Kaupule* locaux pour mettre au point des plans ou régimes de gestion des ressources littorales de l'atoll de Funafuti en vue de garantir l'exploitation durable de toutes les ressources marines, aujourd'hui et demain.

- La gestion de l'aire marine protégée de Funafuti devrait être renforcée, éventuellement avec le concours des *Falekaupule* et *Kaupule* locaux, afin de veiller au respect de l'interdiction de pêche à l'intérieur de l'aire protégée, en particulier parce que cette dernière présente de bonnes conditions pour l'installation de stocks de géniteurs d'importantes espèces d'invertébrés, telles que le bénitier et le troca.

- Le Service des pêches de Tuvalu devrait transférer certains des individus introduits de bénitier *Tridacna derasa* de leur habitat actuel à un habitat lagonaire plus adapté, situé à l'écart du quai du Service des pêches, si les bénitiers peuvent être protégés de la pêche.

- Si de nouveaux trocas sont introduits à Funafuti, les individus devraient être implantés sur les récifs intra-lagonaires (peut-être à proximité des passes occidentales) pour leur permettre de bien s'installer. Les adultes réimplantés ont besoin d'être protégés des prédateurs lorsqu'ils sont relâchés sur les récifs, et ce jusqu'à ce qu'ils se soient acclimatés aux conditions locales (un lâcher échelonné est donc recommandé).

- Le Service des pêches de Tuvalu devrait faire preuve de beaucoup de prudence avant d'autoriser à Funafuti la pêche des holothuries blanches à mamelles et des holothuries ananas, étant donné que leurs stocks sont limités. Des études plus poussées sont nécessaires pour évaluer le niveau d'exploitation qui peut être autorisé. Un plan de gestion de cette pêche devrait être mis en place avant toute décision, sous la supervision des *Falekaupule* et *Kaupule* locaux.

Résultats des études de terrain à Nukufetau

Situé à environ 120 kilomètres au nord-ouest de Funafuti à peu près au milieu du pays, Nukufetau est, en taille, le deuxième atoll de Tuvalu. Nukufetau se compose de 37 îlots qui couvrent une superficie terrestre totale de 2,99 km^2. La superficie totale de l'atoll s'élève à 116,5 km^2, dont 22 % sont formés de plateforme récifale et 78 % d'un lagon enclavé. La quasi-totalité de cette plateforme récifale (85 %) est constituée de platiers récifaux nus, le reste se composant d'îlots couverts de végétation et de plages adjacentes. Le lagon compte deux chenaux de surface venant du large, et le renouvellement des eaux s'opère par le platier récifal et les passes souterraines. La pêche à la palangrotte et la pêche au filet maillant sont communément pratiquées dans le lagon, tandis que les pêcheurs ciblent les récifs côtiers et les récifs externes peu profonds en chasse sous-marine et au filet maillant. La pêche thonière à la traîne, à visée semi-commerciale, est aussi pratiquée. Il existe des réglementations locales portant sur le maillage des filets maillants et restreignant la pêche indiscriminée de bénitiers et d'holothuries. Pendant la durée des études et enquêtes de terrain à Nukufetau, les chefs de la communauté mettaient la dernière main à un projet de création d'une aire marine protégée, où des restrictions s'appliqueront à l'exploitation tant des espèces marines que terrestres au sein de frontières bien délimitées.

Paramètres socioéconomiques de Nukufetau

Les enquêtes socioéconomiques conduites dans les deux villages d'Aulotu et de Maneapa à Nukufetau ont permis d'interroger 28 ménages au total, correspondant à 164 personnes interrogées. L'échantillon représente environ 24 % des ménages vivant sur l'atoll (118 au total) et du nombre total d'habitants (~ 690 habitants). D'après les résultats d'enquête, chaque ménage compte en moyenne deux pêcheurs. Alors que 70 % de l'ensemble des ménages résidant dans les deux villages possèdent un bateau, la proportion de ménages possédant un bateau à moteur est légèrement supérieure à Aulotu (83 %) qu'à Maneapa (73 %). L'emploi salarié constitue la première source de revenus pour environ 60 % de tous les ménages. D'autres activités rémunératrices, telles que l'artisanat et la vente de glace, sont la principale source de revenus de 18 % des ménages, soit un chiffre supérieur à la proportion de ménages tirant leurs premiers revenus de la pêche (11 %). Cela dit, la pêche fournit une deuxième source de revenus à environ la moitié du nombre total de ménages de Nukufetau. Le volume moyen de poisson frais consommé est élevé, avec 185 kg par an et par habitant, contre seulement 1,5 kg par an et par habitant pour le poisson en conserve. Les ménages ne consomment des invertébrés qu'environ une fois par mois. La pêche est l'apanage des hommes (~ 70 %), qui exploitent principalement du poisson ou un mélange d'espèces de poissons et d'invertébrés. Les femmes s'adonnent davantage à la pêche d'invertébrés. La majorité des poissons capturés à Nukufetau sont consommés par les ménages, tandis que plus de la moitié des prises totales d'invertébrés sont vendues.

Inventaire des ressources en poissons à Nukufetau

Les ressources en poisson vivant dans les eaux de l'atoll de Nukufetau affichent un état de santé relativement bon et supérieur à la santé des poissons de Funafuti, seul site offrant une comparaison possible. La densité et la biomasse des poissons sur les habitats de pente externe récifale, communs aux quatre sites étudiés, enregistrent le deuxième meilleur score des quatre sites. Ce bon état de santé peut être associé à plusieurs facteurs : l'isolement géographique de Nukufetau, le faible indice de population par unité de surface récifale disponible, la superficie assez vaste des zones récifales et la variété des engins et méthodes de pêche employés pour cibler les espèces les plus prisées. Néanmoins, il ne fait aucun doute que le grand nombre et l'emploi fréquent de bateaux à moteur, préférés aux pirogues traditionnelles et embarcations à voiles, ont poussé à la hausse le niveau de la pression de pêche.

Les tailles moyennes des poissons sont inférieures à celles relevées à Niutao et à Vaitupu, mais dans la même gamme ou supérieures à celles de Funafuti. Les tailles observées diffèrent dans les quatre habitats recensés et sont sensiblement supérieures dans les habitats de pente externe pour les familles des *Lethrinidae*, *Labridae*, *Mullidae* et *Scaridae*. Ces variations peuvent être dues à la grande proximité du récif côtier abrité, facilement accessible, d'où sujet à des opérations plus fréquentes et sélectives de chasse sous-marine et de pêche au filet maillant. La pêche à la palangrotte est plus couramment pratiquée dans le lagon et sur la pente externe du récif. La biomasse et la densité de poissons vont croissant à mesure que l'on s'éloigne des habitats côtiers et que l'on pénètre les zones lagonaires, d'arrière-récif et l'extérieur du récif. Les variations de biomasse et de densité présentent une bonne corrélation avec l'accessibilité des lieux de pêche, la santé des habitats et les différents niveaux de pression de pêche exercés sur ces habitats. Certaines familles de poissons, en particulier les familles carnivores des *Lutjanidae* et des *Lethrinidae*, présentent des effectifs supérieurs à ceux des autres sites. Notons toutefois que les assemblages de poissons varient sensiblement d'un type d'habitat à l'autre.

Inventaire des ressources en invertébrés à Nukufetau

Vingt-neuf espèces ou groupes d'espèces ont été recensés lors des inventaires d'invertébrés de grande échelle et de petite échelle réalisés à Nukufetau. D'après la densité et la gamme de tailles relevées pour l'espèce de bénitier *Tridacna maxima*, la ressource est fortement dégradée sur l'atoll de Nukufetau. La présence de concentrations denses d'individus de petite taille indique que le recrutement de *T. maxima* est bon sur les récifs situés dans la partie occidentale du lagon. Les individus *T. squamosa*, espèce de plus grande taille, ont généralement été observés à des densités inférieures à celles de *T. maxima* lors des recensements, et l'on sait que la pression de pêche en est la cause. Les résultats des évaluations laissent penser que le troca ne s'est pas bien installé dans les eaux de Nukufetau après son introduction en 1988. La présence et le recrutement de *Tectus pyramis* sont de faibles à modérés, avec des épisodes de recrutement observés dans le lagon. En général, les récifs de Nukufetau sont fortement influencés par la houle océanique et n'abritent que peu de gastropodes brouteurs. D'après les recensements, les populations de *Pinctada margaritifera* sont peu fournies et touchées par la pression de pêche. Les informations recueillies sur les stocks d'holothuries révèlent que seule une poignée d'espèces présente un intérêt commercial, et la densité de stock des espèces vivant dans les zones récifales peu profondes et les zones lagonaires est généralement faible. La présence d'holothuries blanches à mamelles et d'holothuries ananas, toutes deux très cotées sur les marchés de distribution, peut être intéressante, mais notre étude préliminaire indique que les stocks se limitent à deux zones lagonaires.

Sur la base des inventaires et des évaluations de l'équipe pour les trois volets du projet (paramètres socioéconomiques, inventaire des poissons et inventaires des invertébrés), les recommandations suivantes s'appliquent à l'atoll de Nukufetau :

- Le Service des pêches de Tuvalu devrait aider le *Falekaupule* et le *Kaupule* locaux à mettre en place un programme de surveillance des ressources marines (poissons et invertébrés) comprenant le suivi des captures et des prises débarquées en vue de prévenir toute surpêche, en se concentrant particulièrement sur les espèces d'invertébrés dont la moitié est exportée et commercialisée à Funafuti.

- Le Service des pêches de Tuvalu devrait aider le *Falekaupule* et le *Kaupule* locaux à mettre au point des plans ou régimes de gestion des ressources littorales de l'atoll de Nukufetau en vue de garantir l'exploitation durable de toutes les ressources marines, aujourd'hui et demain. En outre, il convient de faire appliquer les réglementations locales en vigueur et d'envisager de nouvelles mesures de gestion visant à réduire l'effort de pêche (réglementation des engins de pêche, taille minimale de maillage, fermeture saisonnière de la pêche de certaines espèces, etc.).

- Le Service des pêches de Tuvalu devrait encourager le *Falekaupule* et le *Kaupule* locaux à instaurer une zone marine protégée (comprenant des eaux profondes et des eaux superficielles) où toute pêche est interdite et qui présenterait les conditions idéales pour permettre l'installation de stocks de géniteurs d'importantes espèces d'invertébrés, telles que le bénitier et le troca, si celles-ci sont réintroduites sur l'atoll de Nukufetau.

- Le *Falekaupule* et le *Kaupule* devraient faire preuve de beaucoup de prudence avant d'autoriser à Nukufetau la pêche des holothuries blanches à mamelles et des holothuries ananas, étant donné que leurs stocks sont très limités et que des études supplémentaires sont nécessaires pour déterminer le niveau d'exploitation soutenable qui peut être autorisé. Un plan de gestion de cette pêche devrait être mis en place et présider à toute décision.

Résultats des études de terrain à Vaitupu

Vaitupu fait partie du groupe d'îles situé au centre de Tuvalu. L'île la plus proche de Vaitupu est Nukufetau, à 67 kilomètres. Avec ses 5,3 km² de superficie terrestre totale, Vaitupu est aussi la plus vaste île de Tuvalu. La zone de plateforme récifale, formée de lagons, de plages et de platiers, ajoute à cette surface terrestre 10,2 km^2. Il s'agit d'une île basse, allongée et classée comme atoll fermé. Elle comprend deux lagons ouverts au nord-est du récif intertidal. Le système lagonaire accueille une pêcherie de chanidés, qui est une source importante de poisson frais dans les périodes de forte houle. La méthode de pêche la plus couramment utilisée est la pêche à la traîne de poisson pélagique à bord d'embarcations en bois ou en aluminium équipées de moteur hors-bord. La pêche lagonaire se pratique le plus souvent avec des filets maillants, des palangrottes, des cannes à pêche et des pièges. Les zones récifales sont principalement exploitées par trois méthodes : la palangrotte d'eau profonde, la canne à pêche et la chasse sous-marine. La chasse sous-marine se pratique généralement la nuit, et constitue la méthode de prédilection pour ramasser des langoustes. Au large, les pêcheurs se servent essentiellement de trois engins : la traîne, l'épuisette et la palangrotte d'eau profonde. Les réglementations locales en vigueur à Vaitupu prévoient la restriction des filets maillants à petites mailles et la fermeture saisonnière de la pêche dans les lagons. Par ailleurs, le narguilé et le scaphandre autonome sont strictement interdits pour toute forme de pêche, tout comme l'usage de dynamite ou de poison.

Paramètres socioéconomiques de Vaitupu

Les enquêtes socioéconomiques sur l'île de Vaitupu ont ciblé le village de Tumaseu, ainsi qu'un ménage d'Asau. Au total, vingt-neuf ménages ont été interrogés, soit 178 personnes. L'échantillon représente environ 12 % des ménages de l'île (237 au total) et de la population totale (~ 1 455 habitants). L'emploi salarié constitue la première source de revenus de la moitié de l'ensemble des ménages. Si 50 % d'entre eux subviennent à leurs besoins avec une seule source de revenus, un quart se sert de la pêche comme deuxième source ou activité rémunératrice complémentaire. Quelque 40 % des ménages possèdent un bateau, dont 58 % de pirogues. Le volume moyen de poisson frais consommé est élevé, avec 163 kg par an et par habitant, contre seulement 2,1 kg par an et par habitant pour le poisson en conserve. La pêche est principalement pratiquée par les hommes (~ 70 %), qui ciblent des poissons ou un mélange de poissons et d'invertébrés. Les femmes s'adonnent surtout à la pêche d'invertébrés. La majorité des prises de poissons et la totalité des prises d'invertébrés sont consommées par les ménages.

Inventaire des ressources en poissons à Vaitupu

D'après les recensements, les ressources en poisson de Vaitupu sont assez dégradées. Par rapport aux valeurs calculées pour la pente externe du récif des quatre sites d'étude, les poissons de Vaitupu enregistrent les scores les plus bas en termes de biodiversité, de densité et de biomasse. Tout comme à Niutao, l'absence de certains types d'habitats et de récifs empêche les pêcheurs de Vaitupu de choisir parmi un vaste éventail d'espèces ciblées et de méthodes et engins de pêche. Par conséquent, l'incidence de la pêche y est plus marquée qu'à Funafuti et à Nukufetau. De plus, compte tenu de la forte densité démographique de l'île, il se peut que la pression de pêche ait dépassé les limites soutenables sur la pente récifale. La densité, la biomasse et la taille des poissons sont inférieures le long de la côte sous le vent de l'île, probablement du fait que les zones sous le vent, davantage protégées et accessibles aux pêcheurs, font l'objet d'une pression de pêche plus intense.

Alors que Vaitupu enregistre la biomasse et la densité de poissons les plus faibles des quatre sites, l'île arrive en tête concernant la taille moyenne des spécimens et les ratios de taille. Les tailles des espèces exploitées à des fins commerciales (*Acanthuridae*, *Balistidae*, *Holocentridae*, *Scaridae*, *Serranidae* et *Siganidae*) y sont supérieures à 55 % de leur taille maximale connue. Ainsi, bien que la biomasse et la densité des populations de poissons traduisent des bas niveaux de stocks, ces derniers n'ont pas atteint un niveau critique.

Les niveaux des populations des familles exploitées et des espèces commercialisées de *Serranidae*, *Lutjanidae* et *Lethrinidae* sont très bas. Comme pour les habitats de pente externe à Niutao, la présence marquée de substrat rocheux dur et la forte proportion d'algues expliquent pourquoi les *Acanthuridae*, les *Balistidae* et, dans une bien moindre mesure, les *Scaridae* sont relativement abondants sur les habitats de pente externe. Les stocks d'*Acanthuridae* dépassent de loin ceux d'autres familles. Dans les autres sites, et particulièrement à Nukufetau, les *Lutjanidae*, les *Lethrinidae* et les *Scaridae* sont beaucoup plus abondants. L'abondance élevée d'*Acanthuridae* peut aussi s'expliquer par la ciguatera qui touche fréquemment des espèces comme *Acanthurus lineatus*, *Ctenochaetus striatus* et *Naso lituratus*.

Inventaire des ressources en invertébrés à Vaitupu

Vingt-cinq espèces ou groupes d'espèces ont été recensés lors des inventaires d'invertébrés réalisés à Vaitupu. Les bénitiers n'ont été observés qu'à de rares reprises, malgré la bonne couverture des inventaires. Cette densité des bénitiers est déjà inférieure au seuil critique en-dessous duquel la ponte et le recrutement ultérieur sont sérieusement compromis. On peut donc considérer que la ressource en bénitier de Vaitupu a probablement été épuisée par les activités de pêche antérieures. En ce qui concerne les stocks de mollusques nacriers, les possibilités d'introduction de *Trochus niloticus* sont peu encourageantes à Vaitupu, tandis que les stocks de *Tectus pyramis* et de *Pinctada margaritifera* sont pauvres. Bien que les signes généraux de la pression de pêche exercée sur les gastropodes et les bivalves soient bien présents, la rareté de ces deux groupes d'espèces tient principalement aux rudes caractéristiques des habitats de Vaitupu. Seul un petit nombre d'espèces d'holothuries peut être exploité à des fins commerciales et leur densité de stock est limitée. La présence d'holothuries de brisant, *Actinopyga mauritiana*, de valeur moyenne à élevée sur les marchés de distribution, et de *Bohadschia vitiensis*, à faible valeur marchande, peut être intéressante sur le plan de la commercialisation, mais notre étude préliminaire doit être approfondie avant d'envisager l'ouverture de ce type de pêche.

Sur la base des inventaires et des évaluations de l'équipe pour les trois volets du projet (paramètres socioéconomiques, inventaire des poissons et inventaires des invertébrés), les recommandations suivantes s'appliquent à Vaitupu :

- Le Service des pêches de Tuvalu devrait aider le *Falekaupule* et le *Kaupule* locaux à mettre en place un programme de surveillance des ressources marines (poissons et invertébrés) comprenant le suivi des captures et des prises débarquées en vue de prévenir toute surpêche. Le programme devrait couvrir le suivi de l'effort de pêche (types d'engins, maillages, etc.) et des captures (taille minimale des captures, prises débarquées par espèce, etc.).

- Le contrôle rigoureux et la gestion efficace des lagons par le *Falekaupule* et le *Kaupule* devraient être étendus aux espèces actuellement exploitées en vue de les protéger ainsi qu'au maillage des filets employés dans les habitats de pente externe. En outre, le Service des pêches de Tuvalu devrait aider le *Falekaupule* et le *Kaupule* locaux à mettre au point des plans ou régimes de gestion pour toutes les ressources littorales de Vaitupu en vue de garantir l'exploitation durable de ces ressources marines, aujourd'hui et demain.

- Le *Falekaupule* et le *Kaupule* locaux devraient continuer de soutenir et de favoriser la pêche d'espèces pélagiques à la traîne à l'extérieur du récif afin d'alléger la pression de pêche exercée sur les ressources littorales et d'assurer que les espèces exploitées sont pêchées dans la limite des niveaux soutenables.

- Le Service des pêches de Tuvalu devrait encourager le *Falekaupule* et le *Kaupule* locaux à instaurer une zone marine protégée (comprenant des eaux profondes et des eaux superficielles) où toute pêche est interdite et qui présenterait les conditions idéales pour permettre l'installation de stocks de géniteurs d'importantes espèces d'invertébrés, telles que le bénitier et le troca, dont les stocks sont actuellement épuisés.

- Le *Falekaupule* et le *Kaupule* locaux devraient faire preuve de beaucoup de prudence avant d'autoriser la pêche des deux espèces d'holothuries qui présentent des densités de stock décentes. Des études plus poussées sont nécessaires pour évaluer le niveau d'exploitation qui peut être autorisé. Un plan de gestion de cette pêche devrait être mis en place et présider à toute décision.

Résultats des études de terrain à Niutao

Appartenant au groupe des îles du Nord, Niutao est une petite île corallienne sans relief associée à un récif frangeant allongé. Couvrant 2,5 km² de superficie, c'est la troisième plus petite île de Tuvalu. L'île occupe plus de 75 % des 3,1 km² de plateformes récifales émergées à marée basse. La totalité de l'île, qui revient en gros à la plateforme récifale, est constituée d'un lagon fermé, de surfaces émergées (2,4 km²), de plages (0,02 km²) et de platier récifal (0,7 km²) qui forme un léger tombant sur le récif frangeant. Les trois lagons entièrement fermés, assez petits et peu profonds, sont reliés à la mer par des passes souterraines. Le récif frangeant est ouvert par deux grandes passes qui permettent l'accès aux lieux de pêche situés au large. Les quatre autres passes ne peuvent être empruntées que par beau temps. La pêche est habituellement pratiquée au filet et à la canne à pêche sur le récif côtier, et à la palangrotte et en chasse sous-marine sur les pentes récifales externes. La ciguatera est une préoccupation majeure et on sait qu'elle sévit toute l'année avec des pics en périodes de vents dominants d'ouest. La pêche pélagique est très fréquente et les prises de thons excédentaires sont généralement vendues à la communauté locale.

Paramètres socioéconomiques de Niutao

Les enquêtes socioéconomiques conduites dans les deux principaux villages de Niutao, Kulia et Teava, ont permis d'interroger 26 ménages (152 personnes). L'échantillon représente environ 18 % des ménages vivant sur l'île (143) et du nombre total d'habitants (~ 835 personnes). À peu près 35 % des ménages interrogés classent la pêche comme première source de revenus. Toutefois, seul 10 % environ des captures annuelles de poisson sont vendues pour générer des revenus. Les invertébrés sont principalement pêchés pour la consommation du ménage. La consommation moyenne annuelle de poisson frais par habitant s'élève à 118 kg, volume certes important, mais le plus bas des quatre sites étudiés. Le volume de poisson en conserve consommé est maigre (3 kg par an et par habitant) et les invertébrés ne sont consommés qu'une fois tous les quinze jours en moyenne. La pêche est surtout pratiquée par les hommes (~ 90 %) qui ciblent le poisson ou un mélange de poissons et d'invertébrés. Les femmes se cantonnent au ramassage d'invertébrés.

Inventaire des ressources en poissons à Niutao

Dans l'ensemble, l'état de santé des poissons de Niutao a été jugé bon. Si l'on compare la biodiversité estimée pour Niutao à la moyenne enregistrée dans les autres sites étudiés dans le cadre de PROCFish/C, la valeur obtenue à Niutao est assez faible, mais la densité et la biomasse de poissons sur les pentes récifales externes affichent le score maximal des quatre sites étudiés.

Les populations de *Serranidae*, de *Lutjanidae* et de *Lethrinidae*, espèces exploitées et commercialisées, présentent de basses densités. Néanmoins, quoique rares, ces poissons carnivores sont assez grands, ce qui laisse penser qu'ils ne sont pas surpêchés sur les pentes récifales externes. On constate une bonne corrélation entre la forte abondance d'*Acanthuridae* et de *Balistidae* et le couvert important de substrat dur et algal. Cette importante abondance peut également s'expliquer par l'incidence élevée de la ciguatera qui frappe souvent *Acanthurus lineatus, Ctenochaetus striatus* et *Naso lituratus*, trois espèces observées en très grande abondance à Niutao. Les *Siganidae* sont complètement absents du panorama.

Les tailles moyennes des poissons sont supérieures à celles relevées sur les habitats de pente externe des quatre autres sites d'étude et proches de celles relevées à Vaitupu. Les tailles des *Acanthuridae*, des *Lutjanidae*, des *Lethrinidae*, des *Scaridae* et des *Serranidae*, espèces commercialisées, sont supérieures à 55 % de la taille maximale connue, ce qui témoigne d'une vigueur des stocks malgré leurs petits effectifs. Les ratios de taille sont très proches pour toutes les guildes trophiques (carnivores, herbivores, etc.), ce qui donne à penser que l'exploitation des ressources est bien répartie entre les différents niveaux de la chaîne trophique. Les populations dépouillées et les poissons relativement petits ont été observés dans les eaux de la côte sous le vent et de la face occidentale de l'île, faciles d'accès et davantage protégées des intempéries. La faible abondance d'espèces carnivores est un signe précoce de pression de pêche excessive.

Inventaire des ressources en invertébrés à Niutao

Vingt espèces ou groupes d'espèces ont été recensés lors des inventaires des invertébrés à Niutao. Malgré la vaste superficie couverte lors des inventaires, les bénitiers ont rarement été observés (seuls trois *Tridacna maxima* ont été repérés). Cette densité de bénitiers est déjà inférieure au seuil critique en-dessous duquel la ponte et le recrutement ultérieur sont sérieusement compromis. L'isolement de l'île de Niutao et son système récifal ouvert réduisent les probabilités de recrutement à partir de ces quelques individus épars appelés à pondre.

Le potentiel de développement des espèces de mollusques nacriers est entravé par le petit nombre d'habitats adaptés à leur survie, leur faible superficie et leur exposition à l'influence océanique. *Trochus niloticus* n'a pas été observé et la possibilité de l'introduire à l'avenir à Niutao semble peu prometteuse. Les populations de *Tectus pyramis*, espèce voisine, ont été observées à de faibles abondances et l'huître à lèvres noires, *Pinctada margaritifera*, est absente de l'inventaire. La pression de pêche, couplée aux conditions intrinsèques du milieu, explique ces résultats médiocres.

Un petit nombre d'holothuries a été observé à Niutao, et leur densité de stock est très basse. La présence d'holothuries de brisant, *Actinopyga mauritiana*, de valeur moyenne à élevée sur les marchés de distribution, peut être intéressante sur le plan de la commercialisation, mais notre étude préliminaire révèle que l'occurrence et la densité de l'espèce ne sont pas suffisantes pour supporter une pêche commerciale.

Sur la base des inventaires et des évaluations de l'équipe pour les trois volets du projet (paramètres socioéconomiques, inventaire des poissons et inventaires des invertébrés), les recommandations suivantes s'appliquent à Niutao :

- En concertation avec les *Falekaupule* et *Kaupule* locaux, le Service des pêches de Tuvalu devrait conduire de nouvelles enquêtes socioéconomiques et inventaires en plongée des ressources, la seule façon peut-être de connaître l'évolution des stocks de poissons et des tendances relatives à leur exploitation sur l'île.

- Les *Falekaupule* et *Kaupule* locaux devraient envisager de favoriser le développement d'une filière pélagique dans les eaux du large adjacentes au lagon et d'étudier les possibilités d'élevage des chanidés dans les eaux du lagon fermé. Cette mesure pourrait contribuer au développement concret d'une filière à petite échelle de subsistance ou semi-commerciale sur l'île.

- Le Service des pêches de Tuvalu devrait aider les *Falekaupule* et *Kaupule* locaux à mettre en place un programme de surveillance des captures et des prises débarquées afin de pouvoir déceler toute dégradation des stocks de poissons qui serait associée à une hausse de la densité de pêcheurs et à des captures élevées. Pour restreindre concrètement l'effort de pêche, on peut penser à réglementer les méthodes de pêche (engins de pêche, maillage des filets, etc.) et les prises (taille minimale du poisson capturé ou total de captures autorisé pour les espèces fortement exploitées) tant pour les poissons que pour les invertébrés.

- Le Service des pêches de Tuvalu devrait aider les *Falekaupule* et *Kaupule* locaux à mettre au point des plans ou régimes de gestion des ressources littorales de Niutao en vue de garantir l'exploitation durable de toutes les ressources marines, aujourd'hui et demain. Les évaluations disponibles, y compris les enquêtes socioéconomiques, pourraient servir à évaluer l'efficacité des régimes de gestion et, ainsi, à y apporter des changements si nécessaire.

- Les *Falekaupule* et *Kaupule* locaux devraient faire preuve de circonspection avant d'autoriser la pêche d'holothuries à Niutao, étant donné que les quatre espèces inventoriées présentent de faibles à très faibles densités de stocks, qui sont incapables à l'heure actuelle de supporter une exploitation commerciale.

- Les *Falekaupule* et *Kaupule* locaux devraient examiner, en concertation avec le Service des pêches, des moyens d'accroître les effectifs de bénitiers, afin qu'un petit stock de géniteurs puisse s'installer à Niutao.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
ADB	Asian Development Bank
AIMS	Australian Institute of Marine Science
AUD	Australian dollar (s)
AusAID	Australian Agency for International Development
BdM	bêche-de-mer (or sea cucumber)
B-S	broad-scale
CCA	crustose coralline algae
CFCs	community fishing centres
CMT	customary marine tenure
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
FSM	Federated States of Micronesia
GDP	gross domestic product
GPS	global positioning system
GRT	gross registered tonnage
ha	hectare
HH	household
JICA	Japan International Cooperation Agency
MCA	marine conservation area
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MOP	mother-of-pearl
MOPs	mother-of-pearl search
MOPt	mother-of-pearl transect
MPA	marine protected area
MRM	marine resource management
MSA	medium-scale approach
NASA	National Aeronautics and Space Administration (USA)

NAFICOT	National Fishing Corporation of Tuvalu
NCA	nongeniculate coralline algae
Ns	night search
OCT	Overseas Countries and Territories
PICTs	Pacific Island countries and territories
PNG	Papua New Guinea
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
RDA	RDA International, Inc.
RFID	Reef Fisheries Integrated Database
RFs	reef-front search
RFs_w	reef-front search by walking
SBq	soft-benthos quadrat
SBt	soft-benthos transect
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SOPAC	Pacific Islands Applied Geosciences Commission
SPC	Secretariat of the Pacific Community
SPREP	Secretariat of the Pacific Regional Environment Programme
t	tonne
UNDP	United Nations Development Programme
US	United States
USAID	United States Agency for International Development
USD	United States dollar(s)
WCPO	western and central Pacific Ocean
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 project (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).

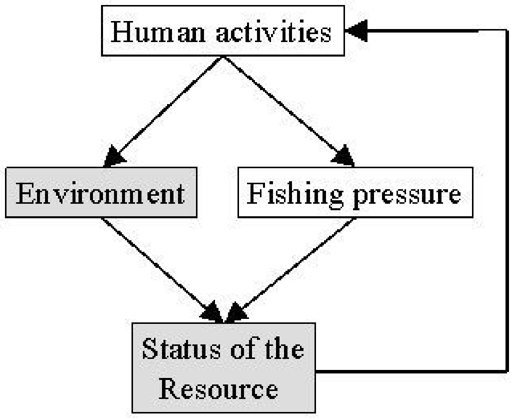

Figure 1.1: Synopsis of the PROCFish/C* multidisciplinary approach.
PROCFish/C conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the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

* PROCFish/C denotes the coastal (as opposed to the oceanic) component of the PROCFish project.

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).

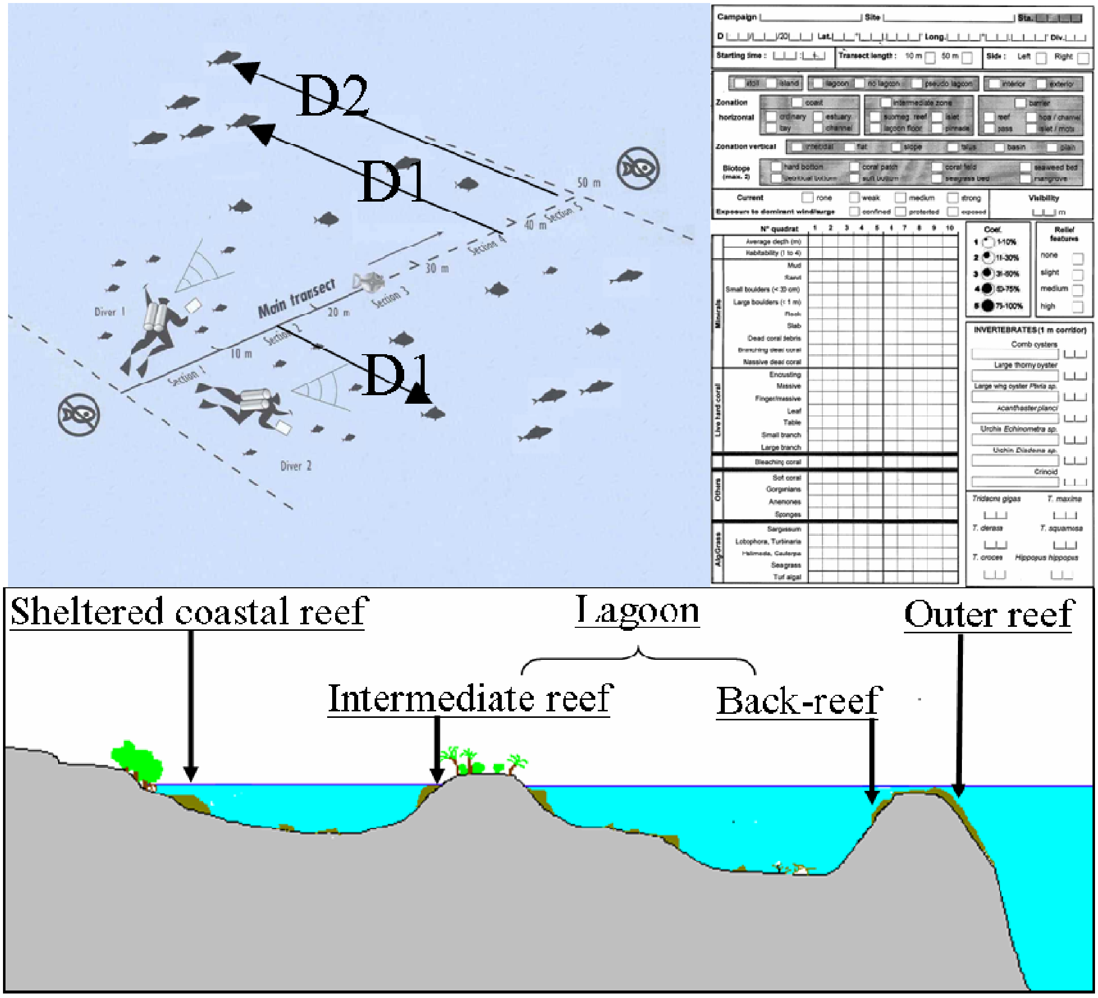

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys 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).).[2]

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.).

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

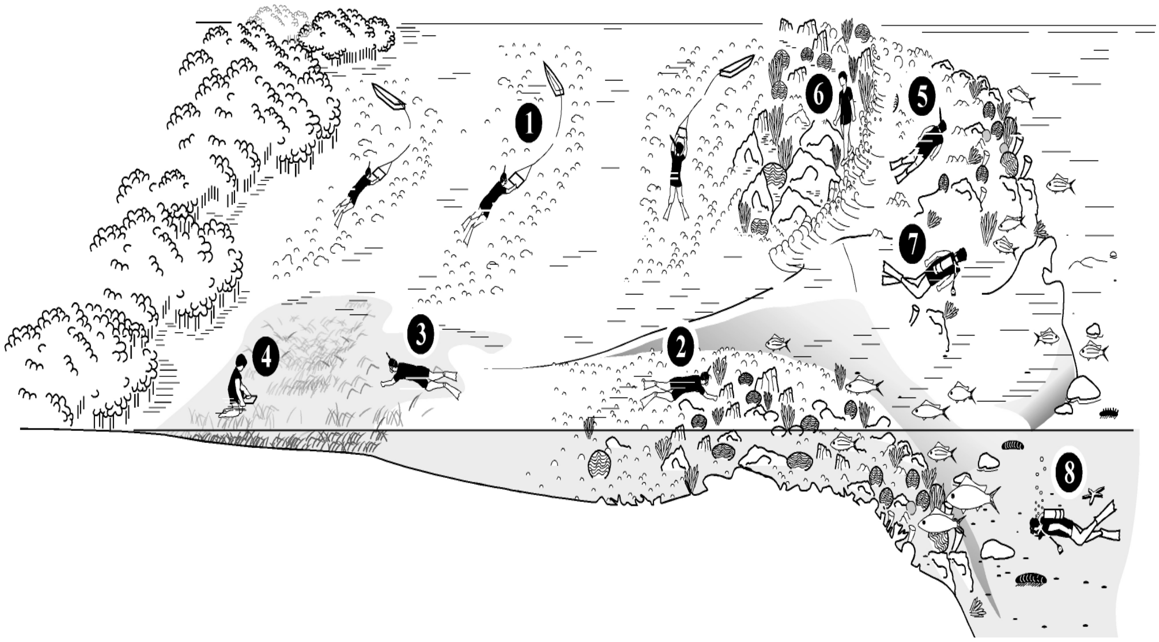

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal 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 Tuvalu

1.3.1 General

The five islands and four atolls that make up Tuvalu (Figure 1.4) are scattered diagonally (southeast to northwest) across 741 km of ocean, with distances of 40–100 km between any two adjacent islands. Tuvalu has a combined land area of about 26 km^2, and a large exclusive economic zone (EEZ) covering 900,000 km^2 of ocean. Most of the country lies less than three metres above sea level. Scattered throughout the EEZ are many submarine seamounts whose summits may rise to within 30 m of the surface (Sauni 1997). Tuvalu's shallow marine environments are dominantly fringing and patch reefs. Patch reefs and relatively barren coralline sand flats within shallow (≤50 m) lagoon waters are surrounded by open ocean. There is no continental shelf seaward of any of the islands, the only substantial areas of shoal being found in the internal lagoons (Sauni 2000; McLean and Hosking 1991).

Tuvalu's atolls and low coral islands are subject to constant change as the forces of wave action are countered by coral growth. The lagoons reach depths of 60 m and are composed of coralline sand flats. They are of low productivity due to the lack of any land-based nutrient runoff and of higher-productivity reef flats. Intermittent coral heads protruding from the sand cover large areas of the lagoon floor. The atoll-islands are characterised by relatively narrow reef platforms and limited lagoon area. The Funafuti atoll has the largest lagoon in the Tuvalu group (McLean and Hosking 1991).

The population of Tuvalu at the 2002 national census was 9562 people (SPC 2005). Most of the population (~97%) are indigenous Tuvaluans, 82% of whom live in rural areas; the remaining 18% live in the capital atoll of Funafuti (SPC 2005). The remaining population comprises I-Kiribati, other Pacific Islanders, Chinese, and Europeans who are generally concentrated on Funafuti. The population, especially the rural population, is therefore a relatively homogenous group, both economically and racially, when compared with some other Pacific Island nations. About 35% of the population are below 15 years of age and the annual population growth rate in 2002 was estimated at 0.5% per annum, the lowest compared to previous years. The country's fluctuating annual growth rate is affected by temporary labour migration patterns. Total population density is high at 373 residents per km^2 (SPC 2005).

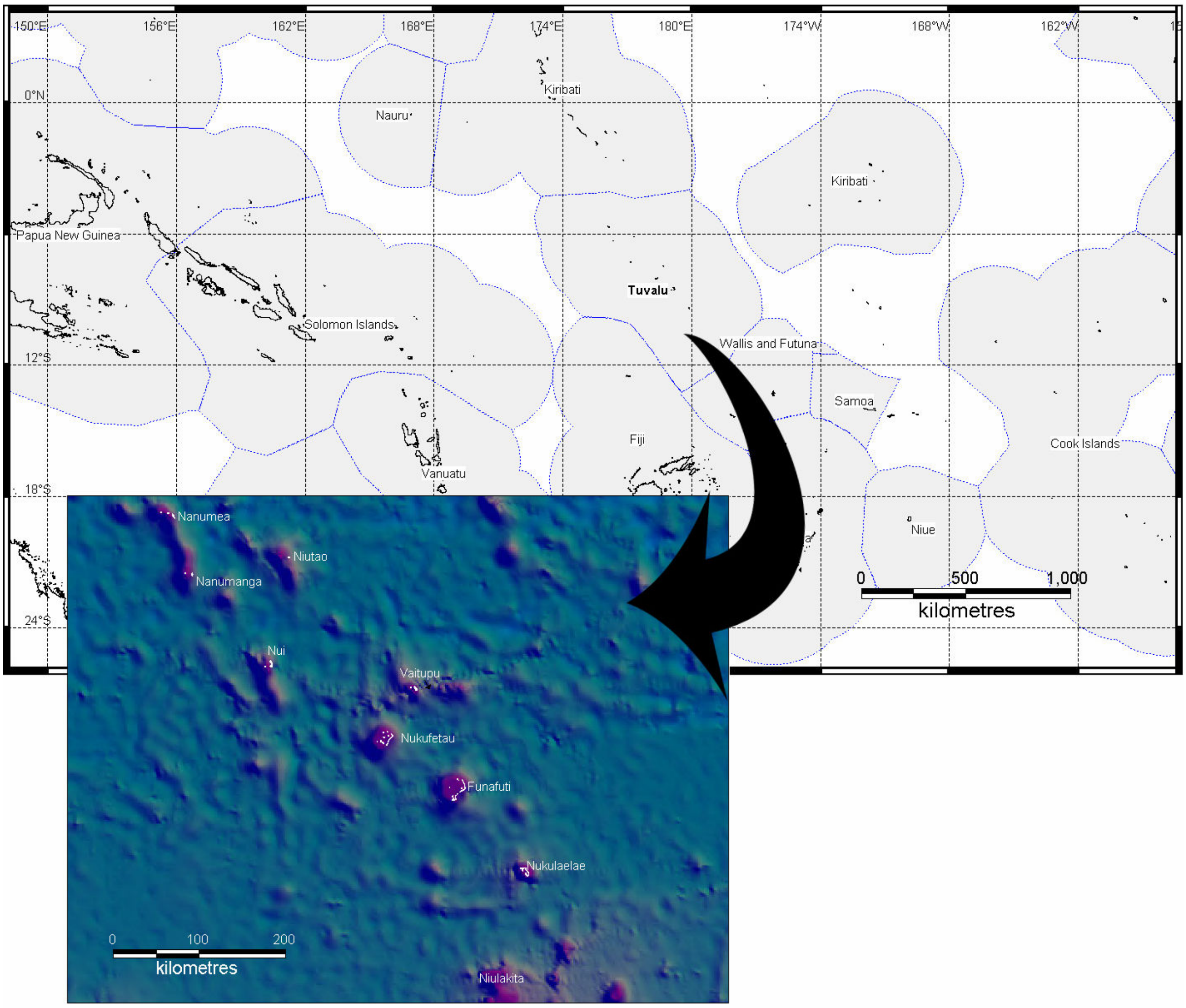

Figure 1.4: Location of Tuvalu.

Tuvalu is an independent nation with a constitutional monarchy type of government based on parliamentary democracy. The Governor-General is appointed by the monarchy and the government is headed by a Prime Minister. The economy of Tuvalu is based on access fees from tuna fisheries, public-sector employment, remittances, tourism, handicrafts and copra. National government revenue comes from the sale of stamps, coins and remittances from seamen on merchant ships abroad and Tuvaluans working in other Pacific Island countries and New Zealand. Substantial income is received annually from an international trust fund established in 1987 by Australia, New Zealand and the United Kingdom, and supported by Japan and South Korea (Gillett and Lightfoot 2001).

Tuvalu is a strong member of the Forum Fisheries Agency's (FFA) negotiated multilateral fishing treaty with the United States, deriving benefit from treaty contributions in addition to licence fees collected by bilateral access fishing vessels. Fishing licence fees form a substantial part of the Tuvalu government revenue. For instance, revenue collected from access fees in 1999 was estimated at around USD 5.9 million (Gillett and Lightfoot 2001). On the subsistence level, farming and fishing are the primary economic activities for Tuvaluans. Income from sale of marine products is supplemented by remittances sent home by family members working overseas. Fortunately, Tuvalu has made a name for itself by owning the 'tv' internet domain that is being leased out to television companies around the world. Substantial income from royalties from the lease of the internet domain name is being injected into infrastructure development, such as roads and electricity around Funafuti (Gillett and Lightfoot 2001). Limited production of copra makes its production unattractive. Tourism contributes little to the economy, but there could be some potential in the future.

1.3.2 The fisheries sector

The people of Tuvalu are heavily reliant on the sea for their subsistence needs, and marine resources are regarded as Tuvalu's foremost asset for long-term economic development. Tuna is the main economic option, while reef resources are important for subsistence and domestic-based economic activities (Gillett and Lightfoot 2001). The fisheries sector of Tuvalu is composed of the oceanic fishery for tuna and other pelagic species, the small deep-water snapper fishery, the shallow-reef fisheries for finfish, and the invertebrate fisheries for shellfish, bêche-de-mer and crustaceans. These resources are targeted by the subsistence, artisanal and semi-commercial sector.

Tuna fishery

Tuna is the only known natural resource option the country has for economic development. Geographically, Tuvalu is within the rich tuna fishing ground of the western and central Pacific Ocean (WCPO) region, and is a strong party to the FFA multilateral fishing treaty with the US. Tuvalu's EEZ accounts for 2% of the total tuna catch from the WCPO (SPC 2003). The National Tuna Development and Management Plan (2000 to 2006), estimated stocks in Tuvalu's EEZ at 125,000 t of skipjack, 160,000 t of yellowfin tuna, and lesser but significant stocks of bigeye and albacore. Catch analysis estimated that the purse-seine catch in Tuvalu's EEZ can be sustained at 45 to 50,000 t annually, with a value of AUD 80 to 120 million. The National Tuna Management and Development Plan (2000 to 2006) has been gazetted and implemented. The long-term goal for the plan is to promote sustainable development and management and maximise the return from Tuvalu's vast tuna resources. However, the main factors that limit the development of the domestic tuna fishery include the lack of shore-based tuna development facilities, the long distance from major markets, a lack of freshwater resources, limited space and high cost, especially for transportation.

The tuna industry is based offshore, through sale of foreign fishing licences under the 1994 bilateral access arrangement and the US multilateral fishing treaty. Distant water fishing nations that fish in Tuvalu's waters include Japan, Korea, New Zealand, Taiwan, Marshall Islands, Federated States of Micronesia, Papua New Guinea, Europe and US. The fleet structure is composed of longliners, purse seiners and a Japanese pole-and-line fleet. The majority of the catch (80%) is from purse seiners, mainly from the US multilateral fleet. Annual catch is affected by the El Niño/La Niña phenomenon. Catches are offloaded in

Japan, American Samoa and other regional ports, and there are no transhipment activities in Tuvaluan ports.

The National Fishing Corporation of Tuvalu (NAFICOT) was established in 1981 under the Ministry of Fisheries to develop industrial tuna fishing in Tuvalu. The Government of Japan donated a 173 GRT pole-and-line vessel to Tuvalu in 1982, and this was placed under NAFICOT to manage and operate (Chapman 2004). Poor baiting grounds around Tuvalu limited the operations of this vessel and other pole-and-line fishing operations (Wilson 1995). The vessel was chartered from 1984 to 1986 to undertake resource surveys in the waters around Fiji and Tuvalu, and later fished commercially (1987–88) in Fiji and Solomon Islands, landing 1090 t of tuna in 1988. In 1989, this vessel was chartered by SPC for four years to conduct a regional tuna tagging project. After 1992, the vessel ceased fishing operations.

In 2004, NAFICOT was given two vessels by the Government of Korea. These vessels were fitted out as tuna longline vessels, and SPC supervised the refit and training of the local crews in tuna longline fishing activities (Sokimi and Chapman 2005). However, financial constraints limited the operation of these two vessels (Tupou 2006). While NAFICOT's initial attempts to develop a domestic tuna fishery have not been successful, Tuvalu still continues to work towards the development of a domestic tuna fishery in the country.

Small-scale tuna activities

Small-scale tuna fishing was a traditional fishing method used in Tuvalu from paddling or sailing outrigger canoes, with male fishers using pearlshell lures with barbless hooks attached by braided coconut-fibre line to a bamboo pole. In the late 1960s and early 1970s, outboard motors were introduced and added to some canoes, as well as some outboard-powered aluminium skiffs introduced to the country (Chapman 2004). With the introduction of outboards, the fishing method changed to trolling using artificial lures and some natural bait. In the 1970s it was estimated that around 350 t of tuna was landed annually. By the 1990s, it was estimated that there were around 125 small-scale tuna fishing vessels, with 10–20 of these fishing semi-commercially and selling their catch (Chapman 2004).

NAFICOT was also involved in small-scale trolling activities for tuna, using several inboard diesel-powered fibreglass vessels in the late 1980s and 1990s. Skippers and crew were hired to fish these vessels, with the catch landed to NAFICOT, who marketed the catch locally on Funafuti (Chapman 2004).

Coupled with the small-scale tuna fishery development in the 1980s and 1990s was the introduction of moored fish aggregating devices (FADs), which served to aggregate tuna schools and other pelagic species. The first FADs were deployed in 1983, with around 18 deployed around the country by 1989 (Petaia and Chapman 1997). From 1993 to 1995, one FAD was deployed at each of the nine atolls and islands in the country. SPC provided training in the mid-1990s in the rigging and deploying of FADs, with several units deployed (Petaia and Chapman 1997). With no records of FADs being deployed after 1996, local small-scale fishers have reverted back to chasing free-swimming tuna schools and using trolling as the main fishing method.

Establishment of community fishing centres (CFCs)

An offshoot of NAFICOT was the establishment of community fishing centres (CFCs) in the islands and atolls around Tuvalu. NAFICOT had a fish market that was established on Funafuti in the mid-1980s. However, NAFICOT was not able to catch enough fish to meet the local market demands. Therefore, the aim of the CFCs was to develop small-scale fisheries in the outer islands, with the fish being purchased by the CFCs and transported to Funafuti for marketing by NAFICOT (Chapman 2004).

The first CFC was constructed on Vaitupu in 1993, with CFCs established on Nanumea and Nukufetau in 1996. These facilities focused on processing local tuna catches into tuna jerky for marketing in Funafuti. Four more CFCs were established between 1998 and 2000, which for a time provided both fresh and processed fish (tuna jerky and salted and dried fish) to Funafuti (Chapman 2004). At times, there was an oversupply of these products at the Funafuti market, and this has affected outer island fishers. Despite the good services CFCs provide in the rural areas, most of the centres run at a loss due to a combination of issues, including transport costs, limited markets and management issues. The CFCs are heavily subsidised and run by the government, but there are plans to privatise to give communities an opportunity to run them, although this has not happened yet (Vunisea in press). By the mid-2000s, several of the CFCs had ceased operation due to machinery breakdown, the lack of availability of parts, and the cost of maintaining the equipment.

Night scoop-netting of flyingfish using light attraction

Night fishing for flyingfish using light attraction and a scoop-net is a traditional method used from paddling canoes. The light attraction traditionally came from tightly bound coconut fronds with the end set alight. With the frond tightly bound, it would take some time to slowly burn, thus providing light for fishers to see the flying fish in the water. As is the case with traditional tuna fishing, the introduction of outboard motors and aluminium skiffs in the late 1960s and early 1970s changed this fishery considerably. In the 1970s, the annual catch of flyingfish was estimated at 420 t (Chapman 2004). The use of torches, and in some cases car batteries and spotlights, now provides the lighting; however, scoop-nets based on the traditional design are still used in this fishery, and this is still a major fishing method used in Tuvalu.

Deep-water snapper fishery

Initial fishing trials and training of local Tuvaluan fishers in deep-water snapper fishing techniques were undertaken in 1976–77 (Eginton and Mead 1978), 1980–81 (Taumaia and Gentle 1982), and 1983 (Chapman and Cusack 1990) by the coastal fisheries programme of SPC. The methods and gear were introduced to fishers on Funafuti, Nukulaelae, Vaitupu and Nukufetau. Although fishers were interested in the methods, they did not adopt them due to the cost and lack of availability of the gear, and the added vessel operating costs to travel outside the reef to suitable fishing locations. A summary of the SPC catch results and species composition are provided in Dalzell and Preston (1992). In addition, during the mid-1980s, Japan conducted resource surveys in Tuvalu and Fiji, with some 100 species of deep-water snappers and seamount-associated species recorded in Tuvalu waters (JICA 1987).

In 1991, the USAID funded a three-year deep-water snapper project, which included resource assessments of the deep-water snapper resource, training of fishers, and an economic evaluation of developing a deep-water snapper fishery (Rowntree 1995; Chapman 2004). Rowntree (1994) conducted an economic evaluation of commercial deep-water snapper fishing, which included the need to construct purpose-built vessels to fish the seamounts in southern Tuvalu waters. King (1995) drafted a national management plan for deep-water snapper as nine important commercial species of the genera including *Etelis*, *Pristipomoides*, *Aphareus* and *Caranx* were recorded during the surveys. However, the plan was not implemented by the government.

Further attempts were made to develop a commercial deep-water snapper fishery in 2004–05, by NAFICOT, with the focus being on the seamounts in southern Tuvalu waters. However, the two vessels given to them by the Government of Korea, and fitted out for tuna and deep-water snapper fishing, ceased fishing after a few trips due to a lack of funds to keep the operations going.

Shallow-water finfish fishery

Shallow-water finfish resources caught from reefs and lagoons comprise a large portion of the catch in the subsistence and artisanal fishery sector (Wilson 1995). Fishing is a way of life for Tuvaluans and reef fish make up a significant component of their diet (FAO 2008). As in most other island states in the region, shallow-water reef fishes are not well documented except for commercially important species, and very little research is conducted on finfish resources. Given Tuvalu's remoteness and the high cost of transportation, there is no exporting of reef fish, although fish are transported from the outer islands to Funafuti for marketing.

There are 33 fishing techniques, including gillnet, spear, scoop-nets and handlining used in Tuvalu to harvest reef fish resources. The use of modern gears propelled by high demand is putting pressure on the finfish resource, especially in urban areas. Reef fishes around Funafuti are showing signs of being overfished (Wilson 1995). Milkfish (*Chanos chanos*) is an important fish caught in lagoons using drive nets and was sold at AUD 2.00 per kg in 1990. However, very little is known about the stock of this species (Anon. 1990). Another concern for fishers and fish sellers is the presence of ciguatera fish poisoning in some reef fish species.

The Fisheries Department of Tuvalu with technical assistance from SPC has conducted surveys of species important in the aquarium trade. Results have been positive; however, developing this fishery and exporting the catch will be challenging given the limited infrastructure and high cost of transportation.

Invertebrate fishery

There are 14 species of sea cucumber recorded from Tuvalu waters, including two high-value species (*Holothuria fuscogilva*, *H. nobilis*) and one medium-value species (*Thelenota ananas*), with the remaining ten species being of low value. Production of bêche-de-mer has been sporadic over the years, and has been dependent on the presence of buyers. A total of just over six tonnes was exported between 1979 and 1994 (Wilson 1995). There is no information on sea cucumber stocks, although they are known to be limited by the lack of suitably large habitat areas.
The commercial mother-of-pearl (MOP) topshell *Trochus niloticus* was naturally absent in Tuvalu waters, but was introduced from Fiji and Cook Islands in the 1980s. Assessment on

the reseeded sites in 1990 recorded only 24 shells on Nanumea out of all the release sites around Tuvalu. The low recovery is due to a number of factors, including the initial loss of introduced stock in an accident at Nukufetau, where a parachute failed to open, causing the shells to be severely damaged before they could be released (Wilson 1995).

Three species of Tridacnidae are present; *Tridacna maxima*, *T. squamosa* and *T. gigas*, but *T. gigas* has become extinct in many locations. In addition, *T. derasa* was introduced in 1990 but survival of this introduced stock has been poor, and only 144 living specimens were recorded in a 1991 survey. Giant clam meat is part of the subsistence diet for Tuvaluans, and Nukufetau residents are the highest consumers of clam meat at around one to two clams per person per week. The local market price at that time was AUD 50 per 5 gallon (20 litres) drum full of clam meat (Braley 1988a).

Two species of commercial crustaceans found in Tuvalu are the land-based coconut crab (*Birgus latro*) and the rock lobster *Panulirus penicillatus*. Coconut crab is collected for subsistence use and is known to be limited in abundance due to threats from population pressure and habitat loss. Rock lobster is limited and is especially reserved for feasts. Information on the status of both resources is lacking (Wilson 1995).

The collection of shells, mainly by women gleaning the reef at low tide, is an important pastime in Tuvalu. The shells are used in handicrafts that are mainly sold to tourists and visitors to the country.

The Tuvalu Fisheries Department has been carrying out trials to investigate options for restocking and/or relieving pressure from intensive exploitation of inshore resources (e.g. farming seaweed and setting up giant clam sanctuaries). The intention has been to enhance productivity in the wild in order to replenish available stocks, particularly among commercial species of sea cucumbers, pearl oysters and giant clams (Belhadjali 1998).

Aquaculture

Tilapia mossambica was introduced to Tuvalu in the 1960s from Fiji by SPC, to be farmed in *babai* pits as an alternative source of food, and to control mosquitoes. The species has infested much of the water bodies in Tuvalu, and is regarded as a pest and unfit for human consumption (Wilson 1995). Some milkfish culture was conducted on Vaitupu, but these activities have not been continued, and tilapia has been blamed for out-competing milkfish in the culture ponds. The country is looking at ways to eradicate tilapia to make way for milkfish culture.

1.3.3 Inshore fisheries management

All atolls and islands of Tuvalu have an open-access system where everyone has equal access to sea resources. At the same time, the State owns everything up to and including the coastal highest-water mark. This form of ownership extends to living (fish and invertebrates) and non-living (e.g. minerals, sand and rubbles, gravels, etc.) resources, below and above the seabed. The management of the resources therefore rests primarily with the State. Regulations pertaining to management include the Fisheries Act of 1978, Local Government Act, Maritime Act, *Falekaupule* Act and the Marine Conservation Area Act. The last two laws were recently passed in the House of Parliament and gazetted.

However, all resource management decisions regarding the entire coastal zone/area of each island or atoll fall under the Island Council, locally known as the *Falekaupule*. The *Falekaupule* consists of all men over the age of 50 years, who regularly meet to discuss issues pertaining to the welfare of the people, including genuine concerns related to marine resources. The *Falekaupule*, though operating independently of the national government, is formerly administered by the *Kaupule* (nominated Council Members on local government) that reports directly to the Ministry of Local Government, and also back to the *Falekaupule*. The local rules or by-laws debated and agreed upon during meetings of the *Falekaupule* are immediately implemented. Though not gazetted, the State recognises these by-laws and imposes penalties (local or others) through the *Falekaupule* on perpetrators. In addition, these by-laws are also legally scrutinised and, if proven to possess merits in the national interest, they will be formulated into a bill and debated in parliament. If the bill is passed in parliament it is in turn gazetted and the act is enforced (Government of Tuvalu 1995a). The *Falekaupule* is the most powerful institution in the island, even more so than the Town Council. No Town Council resolutions or by-laws can be passed without the consent of the *Falekaupule* (Government of Tuvalu 1995a).

The types of by-laws developed and implemented by the *Falekaupule* include mesh-size restrictions, control on giant clams and sea cucumber stocks, and seasonal fishing and no fishing zones for certain parts of the lagoon. In addition, the setting up of the Funafuti conservation area in 1997 was partially successful in protecting resource stocks and educating communities about resource management. However, continuation of effective management and enforcement of the conservation area by the authorities concerned was weakened when project funds dried up, which has resulted in an increase in fishing incursions (Wilkinson 2004).

1.3.4 Inshore fisheries research

Tuvalu relies on the support of external agencies to undertake inshore fisheries research. Research that has taken place in Tuvalu is in three main areas; monitoring and assessment of the status of the main fisheries; snapshot assessment of resources to provide status report of specific resources; and development-oriented research activities, e.g. for tuna, baitfish, deep-water snapper and aquaculture.

The baseline assessment of the Funafuti Conservation Area, established in 1997 jointly by SPREP and Funafuti Town Council with funding from the Australian International Development Assistance Bureau, recorded 141 food fishes and 149 mobile invertebrates (Kaly *et al.* 1999). Results of a follow-up assessment in 2003 are available (Berdach 2003). In addition, a biological assessment of the reefs of Funafuti in 2001 also provided records of fishes, invertebrates and the status of corals on Funafuti atoll (Sauni *et al.* unpub.).

The ongoing coral reef monitoring programme is being implemented by the Tuvalu Fisheries Department. Recent status information on Tuvalu coral reefs are provided in the 2004 publication, *Status of Coral Reefs of the Pacific*.

Other areas where recent inshore fisheries research has been undertaken with assistance from regional organisations include an assessment of the aquarium fish resource around Funafuti, and a review of the aquaculture potential for farming milkfish, growing seaweed, and giant clam mariculture.

1.4 Selection of PROCFish/C sites in Tuvalu

Four PROCFish/C study sites were selected in Tuvalu: the atolls of Funafuti and Nukufetau and the islands of Vaitupu in the central group and Niutao in the northern group (Figure 1.4). These sites were selected after a visit to Tuvalu by SPC staff. Final site selection was made after meetings and discussions with the staff of the Fisheries Department and other key agencies including NAFICOT, the Environment Department, Customs and Immigration, Shipping, Ministry of Local Government, Funafuti Island Government and local fish market owners. The selected sites shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country, were relatively closed systems[3], were appropriate in size, possessed diverse habitats, presented no major logistic limitations that would make fieldwork unfeasible, had been investigated by previous studies (some), and presented particular interest for Tuvalu's Department of Fisheries.

By spreading sites over the country, covering island types and areas both near and far from population centres, a contrasting view of Tuvalu was sought. Funafuti and Nukufetau share similar characteristics of being atoll islands, but Funafuti is the capital and centre of population and economic activities. Nukufetau is the closest atoll to Funafuti, with the only fresh fish marketing facility in rural Tuvalu, and shares a fish marketing advantage with Funafuti. Vaitupu and Niutao are isolated, single, oceanic islands with narrow fringing reefs, less populated and remote from the central economic activities. Salting and drying of fish is the only processing method and the pressure on resources here is expected to be lower as these islands are distant from the main centres.

[3] A fishery system is considered 'closed' when only the people of a given site fish in a well-identified fishing ground.

2. PROFILE AND RESULTS FOR FUNAFUTI

2.1 Site characteristics

Funafuti atoll (Figure 2.1), the capital of Tuvalu, is the largest atoll in the country and occupies a total land area of 2.79 km^2, consisting of many separate islets or *motu* (Government of Tuvalu 1995a). Funafuti has the largest reef and lagoon areas (205 km^2 and 40–50 m deep) in the country; the highest land reaches only 3–5 m above sea level. The only airport in the country is on Funafuti, and people travelling by air to the outside world need to travel from the outer islands and atolls to Funafuti by boat. Transportation by sea is also possible through the inter-island shipping and services of Tuvalu passenger ships. Other than visitors and travellers, inter-island transportation is particularly important for marketing or trading of fresh and value-added fish products. There is some migration of people out of the island for the purpose of paid jobs, medical treatment, overseas travel and further education.

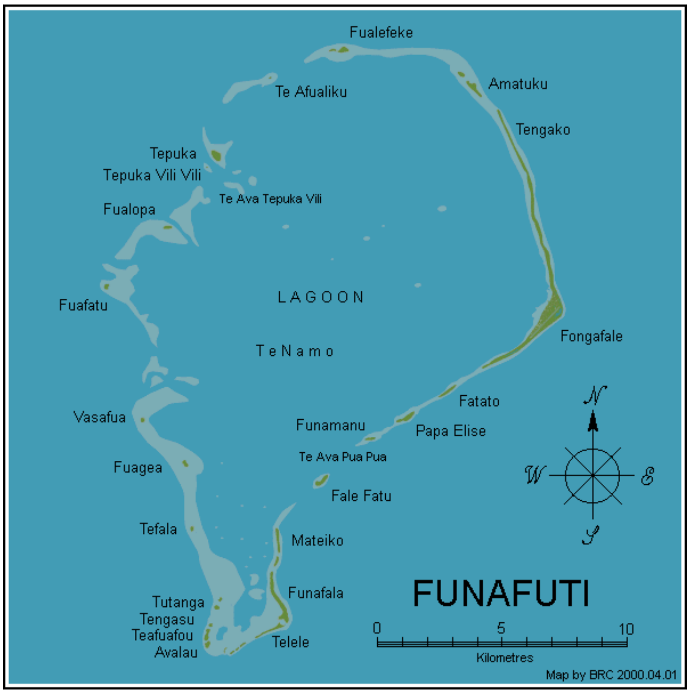

Figure 2.1: The islets that make up Funafuti atoll.

Funafuti is the most populated island, accounting for 47% (~4500 people) of the total population of the country (SPC 2005). It has a population density of 1610 people/km^2 based on the population by island of usual residence, one of the highest in the Pacific region. It has also the highest average household size in the country at 6.2–7.0 people[4]. The population of Funafuti has increased very fast from 1931 to 1973 due to the massive migration of people from the outer islands to Funafuti, the centre of trade, employment and business in Tuvalu (Government of Tuvalu 1995a).

The primary source of household cash income on the island is employment in the formal and mainly public sector, followed by remittances sent by overseas relatives from abroad (including money sent from seafarers working on foreign merchant and fishing vessels).

[4] PROCFish/C socioeconomic surveys 6.2 people per household and 2002 Government census 7.0 people per household.

Other sources of cash income in the island are: private small businesses, the sale of fish or produce, handicraft production, and pensions (Government of Tuvalu 1995a). With all the facilities available on the island, GDP (AUD 1363 per capita in 1994) is concentrated in Funafuti, giving growth and opportunities for modest developments in the fishing sector (Government of Tuvalu 1995a).

Most of the reefs in Funafuti concentrate around the barrier and coastal fringing reefs. The barrier reef rim is cut by several deep passages along its western side, and a single deep passage to the southeast. Large cruise ships can only pass through this one deep passage, while smaller passenger ships can pass through any of the passages that are relatively deep and wide. Other small fishing crafts (powered boats or canoes) can use any passage, particularly during high tides and good sea conditions. The atoll has an area of 242.2 km^2, of which 15% is reef platform. The bulk of the reef platform (37 km^2) consists of bare reef flats (92%), vegetated islets (7%) and adjacent beaches (1%) (McLean and Hosking 1992). There are a few stands of mangrove, which are only found in certain coastal areas of the islets and around the fringes of excavated ponds on Fongafale.

Fishing on the island is semi-commercial, and many people still fish for food after office hours and on the weekends (Sauni 1997; Sauni and Fay-Sauni 2005). The local demand for fresh fish is high and often market supply falls short of demand. Fishers easily sell their fish at the landing site as well as along the road, or even directly to NAFICOT. Trolling for pelagic fish is common using either wooden or aluminium skiffs that are equipped with an outboard engine. Lagoon fishing is mostly performed using gillnets, handlines, rods and fish traps. Spearfishing, rod and handlines are common methods for reef fishing.

The by-laws that are in existence in Funafuti include a ban on catching *Selar crumenophthalmus* (*salala*), a restriction of gillnet mesh-sizes, a ban on the indiscriminate harvesting of giant clams and sea cucumbers in certain reef areas, the prohibition of the use of hookah and SCUBA gears for any form of fishing, dynamiting, and all forms of fish poisons. All of the fishing gear restrictions endorsed by the Fisheries Department are observed on the atoll, however, some of the prohibitive measures are not observed all the time.

The Funafuti Conservation Area is the only legal localised *tapu* area in the country. Since its establishment in 1997, the 33 km^2 of protected ocean area include six small *motu* encompassing about 20% of the total coral reef area of Funafuti lagoon. The protection of animals and plants extends from land to the sea. The protection also includes the prohibition of excavation of beach sand and gravels for construction. There are at least 400 fish species (Kaly 1997), 36 coral species (Sauni *et al.* unpub.), 22 species of seabirds and shorebirds (Watling 1998) and coconut crabs and sea turtles that have been recorded in the conservation area.

2.2 Socioeconomic surveys: Funafuti

PROCFish/C socioeconomic fieldwork on Funafuti covered 8 districts: Alapi, Fakaifou, Lofeagai, Senala, Teavamangoo, Tekavatoetoe, Teone, Vaiaku, and the Van camp. In total 30 households were interviewed covering 245 people. Thus, the survey covered about 5% of the island's households (total number of households 551) and total population (4500 people).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 29 individual interviews of finfish fishers (27 males, 2 females) and 25 invertebrate fishers (21 males, 4 females) were conducted. These fishers belonged to one of the 30 households surveyed. Sometimes, the same person was interviewed for both finfish and invertebrate fishing.

2.2.1 The role of fisheries in the Funafuti community: fishery demographics, income and seafood consumption patterns

Survey results (Table 2.1) suggested an average of 2.4 fishers per household. Applying this average to the total number of households gave a total of 1322 fishers on Funafuti. Applying the household survey data concerning the type of fisher (finfish or invertebrate) by gender, we projected a total of 477 finfish fishers only (males), a total of 165 invertebrate fishers only (females) and 680 (606 males, 74 females) fishers who fished for both finfish and invertebrates.

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

Survey coverage	Funafuti (n = 30 HH)	Average across sites (n = 113 HH)
Demography		
HH involved in reef fisheries (%)	100	100
Number of fishers per HH	2.4 (±0.3)	2.0 (±0.13)
Male finfish fishers per HH (%)	36.1	38.3
Female finfish fishers per HH (%)	0	0.4
Male invertebrate fishers per HH (%)	0	0
Female invertebrate fishers per HH (%)	12.5	14.1
Male finfish and invertebrate fishers per HH (%)	45.8	41.0
Female finfish and invertebrate fishers per HH (%)	5.6	6.2
Income		
HH with fisheries as 1st income (%)	30	24
HH with fisheries as 2nd income (%)	23	25
HH with agriculture as 1st income (%)	0	25
HH with agriculture as 2nd income (%)	0	1
HH with salary as 1st income (%)	50	52
HH with salary as 2nd income (%)	13	11
HH with other sources as 1st income (%)	20	20
HH with other sources as 2nd income (%)	27	14
Expenditure (USD/year/HH)	3080 (±429.09)	2102 (±155)
Remittance (USD/year/HH) (1)	1929 (±322.99)	1940 (±173.5)
Seafood consumption		
Quantity fresh fish consumed (kg/capita/year)	135.0 (±12.2)	151.0 (6.30)
Frequency fresh fish consumed (times/week)	5.6 (±0.4)	6.1 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	n/a	n/a
Frequency fresh invertebrate consumed (times/week)	0.7 (±0.2)	0.4 (±0.07)
Quantity canned fish consumed (kg/capita/year)	30.0 (±0.9)	2.2 (±0.36)
Frequency canned fish consumed (times/week)	0.6 (±0.2)	0.5 (±0.07)
HH eat fresh fish (%)	97	99
HH eat invertebrates (%)	73	54
HH eat canned fish (%)	63	66
HH eat fresh fish they catch (%)	93	97
HH eat fresh fish they buy (%)	63	61
HH eat fresh fish they are given (%)	43	62
HH eat fresh invertebrates they catch (%)	70	50
HH eat fresh invertebrates they buy (%)	0	0
HH eat fresh invertebrates they are given (%)	13	11

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

The number and type of boats available to the households on Funafuti varied among the different districts surveyed. However, generally most (67% of Fakaifou, 71% of Tekavatoetoe) if not all (100% of Alapi, Teavamangoo, Vaiaku, Van camp) households owned a boat, with the exemption of Lofeagai and Senala where only 20% and 25% respectively of the households owned a boat. Most boats were equipped with an outboard engine; however, in some districts non-motorised canoes were also frequent (Tekavatoetoe, Fakaifou, Alapi, Teone). There were no motorised boats, only canoes, in Teavamangoo.

Ranked income sources suggested that fisheries did not play the most significant role for people on Funafuti. Salaries (Figure 2.2) were the most important income source for half of all households (50% 1st income, 13% 2nd income), while fishing provided the first income source for 30% of all households and the second for 23% of the households. Other income sources, which typically included home-based businesses (sewing, shops, handicrafts, bars, etc.) were the first income source for 20% of all households and the most important second income source (27% of all households).

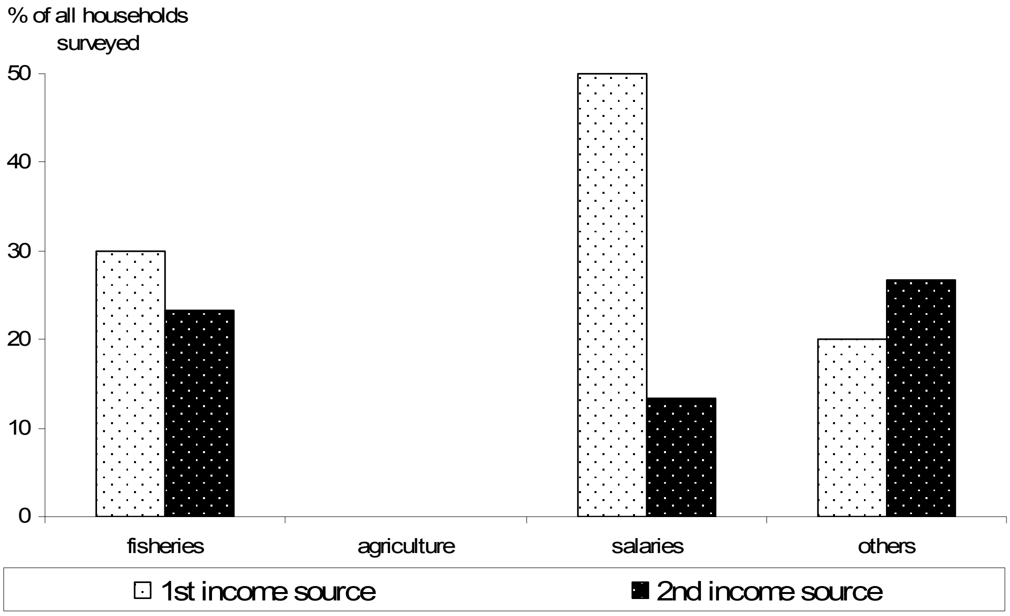

Figure 2.2: Ranked sources of income (%) in Funafuti.
Total number of households = 30 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based and small businesses.

Data reported by survey respondents supported this observation. Most of the catch on Funafuti from both finfish and invertebrate fisheries was used for subsistence purposes and not for sale.

About 43% of all households interviewed reported receiving remittances. The average amount these households received from external sources (USD 1830 per year) was substantial as it covered about two-thirds of the average household expenditure (USD 3080 per year).

Average per capita fresh fish consumption (135 kg/year) was high compared to the regional average, and it also exceeded the average national figure of 98.4 kg/year presented in Gillett 2002b (Figure 2.3). It was the second lowest among all PROCFish/C sites in Tuvalu. However, it should be noted that previous estimates ranged between 60 kg/year (SPC 1997, cited in Gillett and Lightfoot 2001; page 206) and 146 kg/year (Fisheries Department 1994, cited in Gillett and Lightfoot 2001; page 209), with considerable variations between islands.

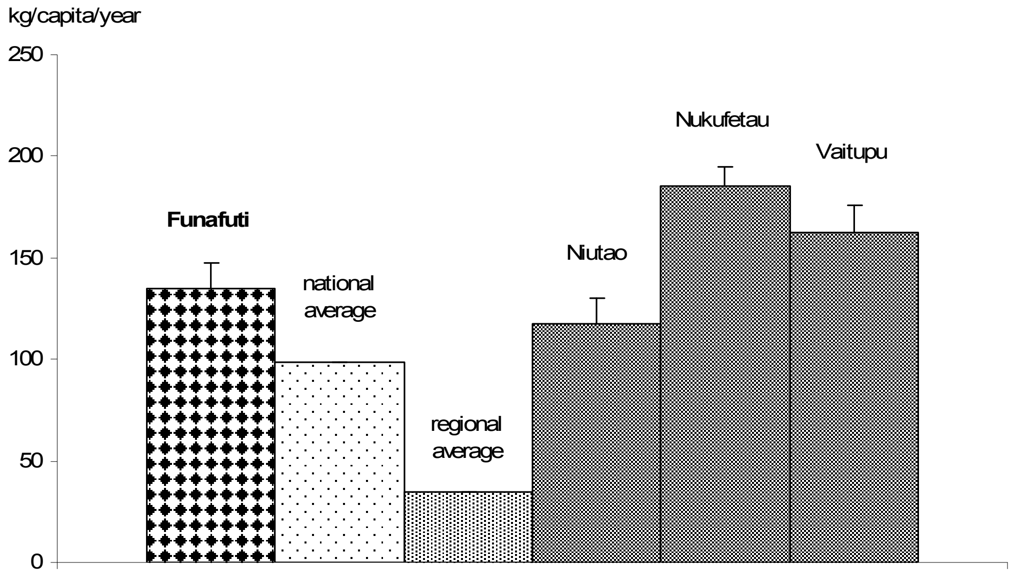

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Funafuti (n = 30) compared to national and regional averages (Gillett 2002b), and other PROCFish/C sites in Tuvalu.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The frequency and quantity of canned fish consumption were low (0.6 times/week, 2.3 kg/capita/year). Invertebrates were consumed less than once a week (on average 0.7 times/week). While almost all respondents reported eating fish caught by a member of their household, about 60% of all households also sometimes bought finfish (from a neighbour, or at the roadside), and 50% of all households also were sometimes given finfish without paying. Invertebrates consumed were mostly caught by a member of the household. They were not bought and rarely received as a gift.

By comparison with all PROCFish/C sites in Tuvalu (Table 2.1), Funafuti had a moderate rather than high dependency on fisheries for income, although the highest average number of fishers per household. A high percentage of households ate invertebrates and finfish that had been caught by a household member rather than bought. Invertebrates and canned fish were the most frequent food items; only small quantities of fresh fish and canned fish were eaten, and fresh fish were eaten infrequently. People in Funafuti had the highest annual household expenditures, which reflected the urban influence. Dependency on external finances was moderate in terms of the share of households receiving remittances and in terms of the average annual amount received.

2.2.2 Fishing strategies and gear: Funafuti

Degree of specialisation in fishing

Fishing on Funafuti was dominated by males: ~80% of all fishers were males, and only about 20% females. Furthermore, there was a gender separation between fishing exclusively for finfish, which was only performed by males, and fishing exclusively for invertebrates, which was only performed by females. Most male fishers, but fewer female fishers, targeted both finfish and invertebrates (Figure 2.4).

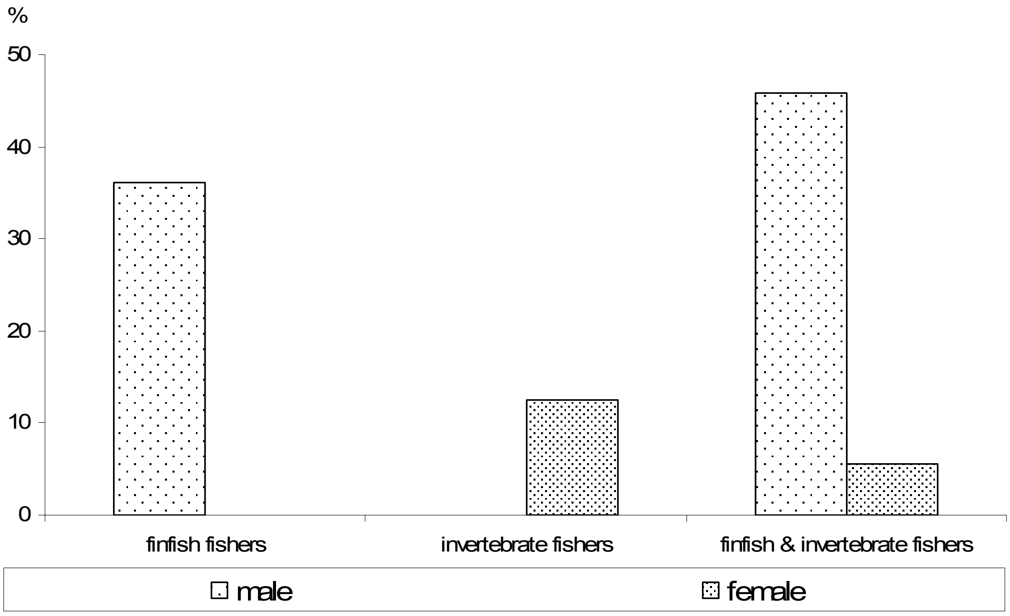

Figure 2.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Funafuti.
All fishers = 100%.

Targeted stocks/habitats

Fishers on Funafuti benefited from a wide range of habitats for both finfish fishing and invertebrate collection. Mainly finfish and lobster were targeted by small-scale commercial operations. The survey coverage of fishers targeting the various habitats and/or performing the various fisheries is summarised in Table 2.2.

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

Resource	Stock	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	70.4	100.0
	Lagoon	88.9	50.0
	Lagoon & outer reef	7.4	0
	Outer reef	63.0	0
Invertebrates	Soft benthos	47.6	50.0
	Reeftop	28.6	50.0
	Intertidal	14.3	100.0
	Intertidal & soft benthos	4.8	0
	Lobster	42.9	0
	Other	19.1	0

'Other' refers to the giant clam and *Lambis truncata* fisheries.
Finfish fisher interviews, males: n = 27; females: n = 2. Invertebrate fisher interviews, males: n = 21; females: n = 4.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip were the basic factors used to estimate the fishing pressure imposed by people from Funafuti on their fishing grounds.

The survey sample suggested that most finfish fishers target the lagoon (40%) and sheltered coastal reef (34%) areas, followed by the outer reef (23%) and lastly, lagoon and outer reef (3%) during one fishing trip.

On Funafuti, most invertebrates were caught by gleaning (~70%). Dive fisheries mainly targeted lobsters and, to a lesser extent, giant clams and the spider conch, *Lambis truncata*. The soft-benthos fishery attracted most of the gleaners, followed by intertidal and reeftop fisheries (Figure 2.5).

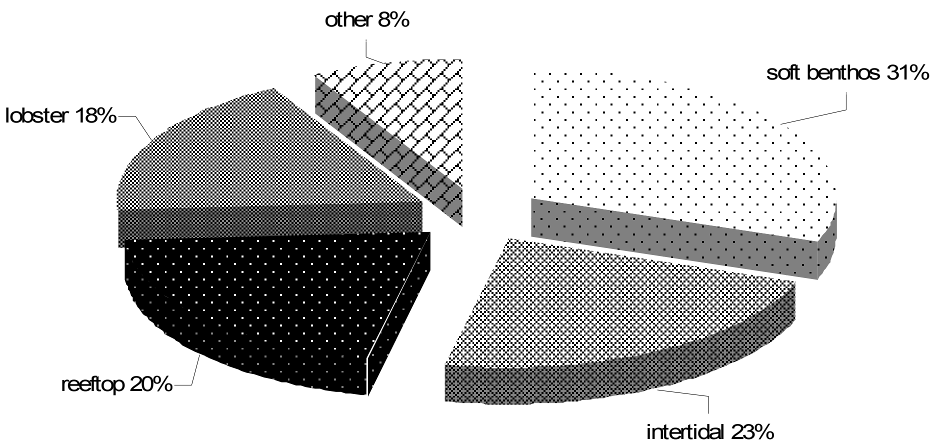

Figure 2.5: Proportion (%) of fishers targeting the five primary invertebrate habitats found in Funafuti.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to giant clam and *Lambis truncata* dive fishery.

There was a clear distinction between gleaning and dive fisheries as far as gender participation is concerned. Dive fisheries, including lobsters, giant clams and *L. truncata* are performed by males only. Generally, more females than males were engaged in gleaning and most males targeted the reeftop. Most females targeted intertidal habitats, followed by soft benthos and reeftop (Figure 2.6).

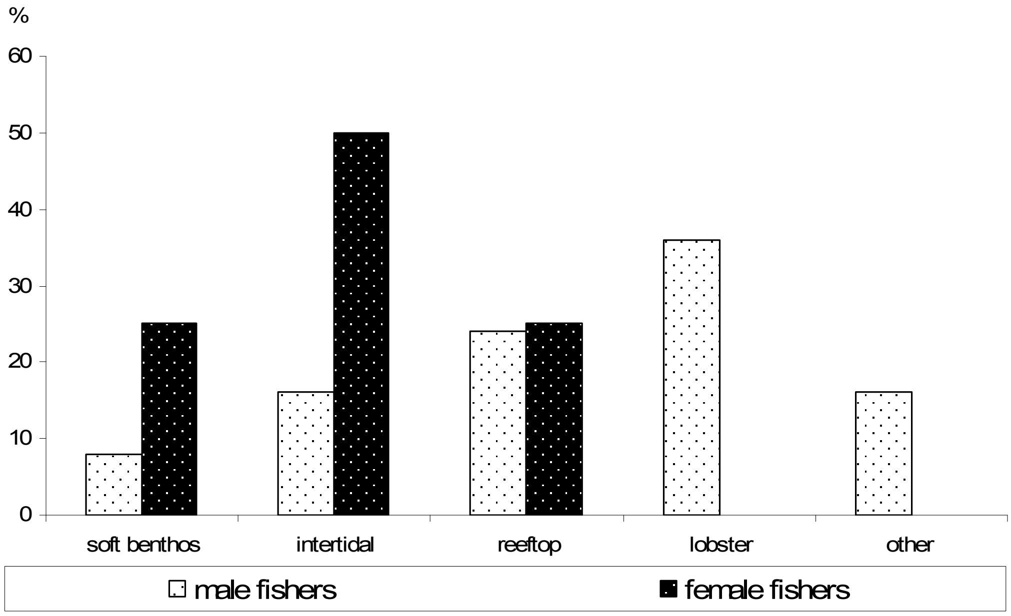

Figure 2.6: Proportion (%) of male and female fishers targeting various invertebrate habitats in Funafuti.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 34 for males, n = 8 for females; 'other' refers to giant clam and *Lambis truncata* dive fishery.

Gear

Figure 2.7 shows that Funafuti's fishers used a variety of different gear. Gillnetting (and some cast-netting) was done in sheltered coastal reef areas; handlining (and diving with hook and line) complemented by spearfishing in the lagoon; and the inverse, spearfishing complemented by handlining (including diving with hook and line) at the outer reef.

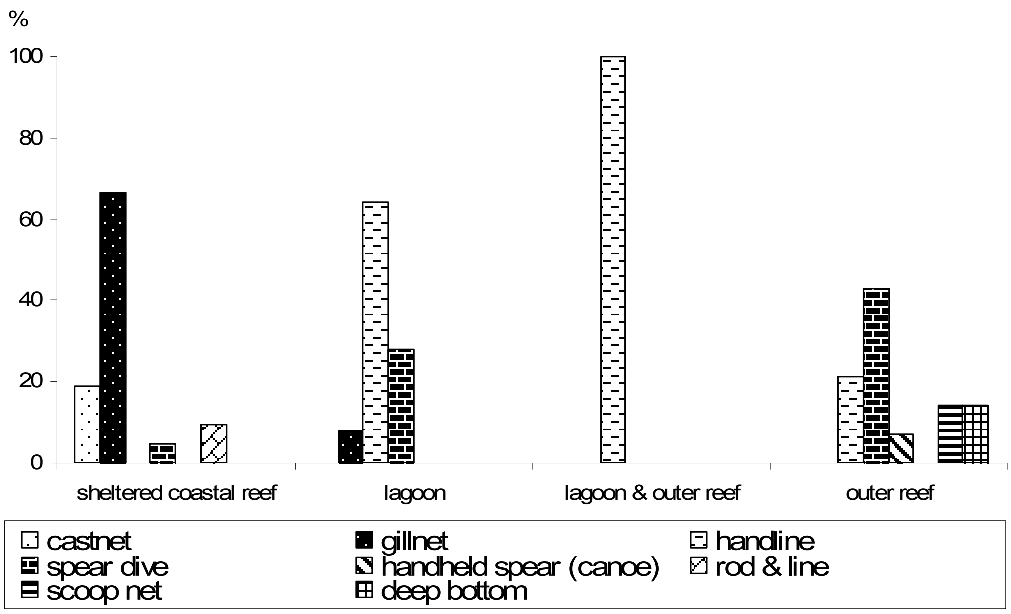

Figure 2.7: Fishing methods commonly used in different habitat types in Funafuti.

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.

Gleaning on Funafuti was done by walking using simple collection tools. Lobster and giant clam diving was often performed using motorised boat transport (45% of all trips for lobster and 75% of all trips for giant clam and *L. truncata* diving). Lobster fishing was only performed at night; reeftop gleaning was performed more often during the night than the day. All other invertebrate fisheries were done during the day. All invertebrate fisheries were continuously performed throughout the year.

Frequency and duration of fishing trips

As shown in Table 2.3, there was little difference in frequency between trips to the sheltered coastal reef and lagoon areas (~2.5 times/week). Fishing trips to the outer reef were less frequent (~ twice per week). The small sample size for fishers who combined both habitats (lagoon and outer reef) during one trip may explain the high data variation. The average duration of fishing trips was 3–5 hours. On average, fishing trips targeting the coastal reef were the shortest and those targeting the lagoon longest. A major difference was in the use of boat transport for fishing in the different habitats. Boats were hardly ever used to fish the coastal reefs, but more than half of all trips to the lagoon area and to the outer-reef area were made by boat. Fishing was typically performed throughout the year and there was no clear indication on the preference of fishing by day or night.

The soft-benthos fishery had the highest proportion of all invertebrate fishers and was also most frequently performed (1.3 times/week). The frequency of fishing trips to the other fisheries was less, ranging between 0.4 times/week for lobster diving and 0.9 times/week for intertidal gleaning. The average fishing trip lasted 2–4 hours; lobster diving was the longest (3–4 hours) and intertidal fishing trips the shortest (2 hours).

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

Resource	Fishery	Trip frequency (trip/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	2.71 (±0.28)	3.08 (±1.92)	2.97 (±0.28)	2.00 (±0.00)
	Lagoon	2.31 (±0.21)	3.00 (n/a)	5.23 (±0.70)	4.00 (n/a)
	Lagoon and outer reef	2.50 (±1.50)	0	8.00 (±4.00)	0
	Outer reef	1.52 (±0.34)	3.00 (n/a)	4.65 (±0.75)	4.00 (n/a)
Invertebrates	Soft benthos	1.38 (±0.28)	0.79 (±0.21)	2.10 (±0.10)	2.50 (±0.50)
	Reeftop	0.36 (±0.05)	0.73 (±0.27)	2.08 (±0.20)	3.00 (±0.00)
	Intertidal	0.65 (±0.42)	0.99 (±0.37)	2.00 (±0.00)	2.25 (±0.25)
	Intertidal and soft benthos	0.46 (n/a)	0	2.00 (n/a)	0
	Lobster	0.37 (±0.06)	0	3.56 (±0.38)	0
	Other	0.63 (±0.29)	0	2.75 (±0.25)	0

Figures in brackets denote standard error; n/a = no standard error calculated; 'other' refers to giant clam and *Lambis truncata* dive fishery.
Finfish fisher interviews, males: n = 27; females: n = 2. Invertebrate fisher interviews, males: n = 21; females: n = 4.

2.2.3 Catch composition and volume – finfish: Funafuti

Catches from the sheltered coastal reef were mainly made up by *Kyphosus* spp. (16%), *Lethrinus* spp. (13%) and *Acanthurus triostegus* (13%); those from the lagoon by *Lutjanus gibbus* (23%), *Lethrinus* spp. (23%) and Serranidae (23%); and those from the outer reef by *Cypselurus* spp. (22%), *Serranidae* (13%) and *Caranx lugubris* (10%). If the lagoon and the outer reef were both fished in one trip, catches were composed of Serranidae (36%), *Lutjanus gibbus* and *L. kasmira* (34%) and *Lethrinus* spp. (30%). Details on the estimated annual reported catch by vernacular and scientific family names are given in Appendix 2.1.1.

The survey sample of finfish fishers interviewed represents about 2% of the projected total number of finfish fishers on Funafuti only. Extrapolation of the survey data is therefore questionable. Thus, the focus is on the reported and collected survey data that is summarised in Figure 2.8.

Figure 2.8 shows that the majority of the reported annual catch was sourced from lagoon and sheltered coastal reef areas. Catches from the outer-reef area contributed to only about 20% of the total catch. Overall, and in agreement with the low involvement and hence low survey representation of females in finfish fishing, female's contribution to the catch was small.

In order to estimate the total annual catch on Funafuti, the total annual consumption figure of 571 t/year was used. This figure is subject to three considerations. Firstly, there was a considerable import of fish from the outer islands to Funafuti. Secondly, the total demand on Funafuti exceeded the consumption figure, presumably considerably, because Funafuti's people frequently sent reef fish by boat and air to their relatives overseas. Thirdly, the consumption figure includes pelagic species. Although we cannot determine the proportion made up by reef and pelagic species separately, the total consumption figure of ~571 t/year provides an estimate of the fishing pressure that was exerted at the time by Funafuti's population only.

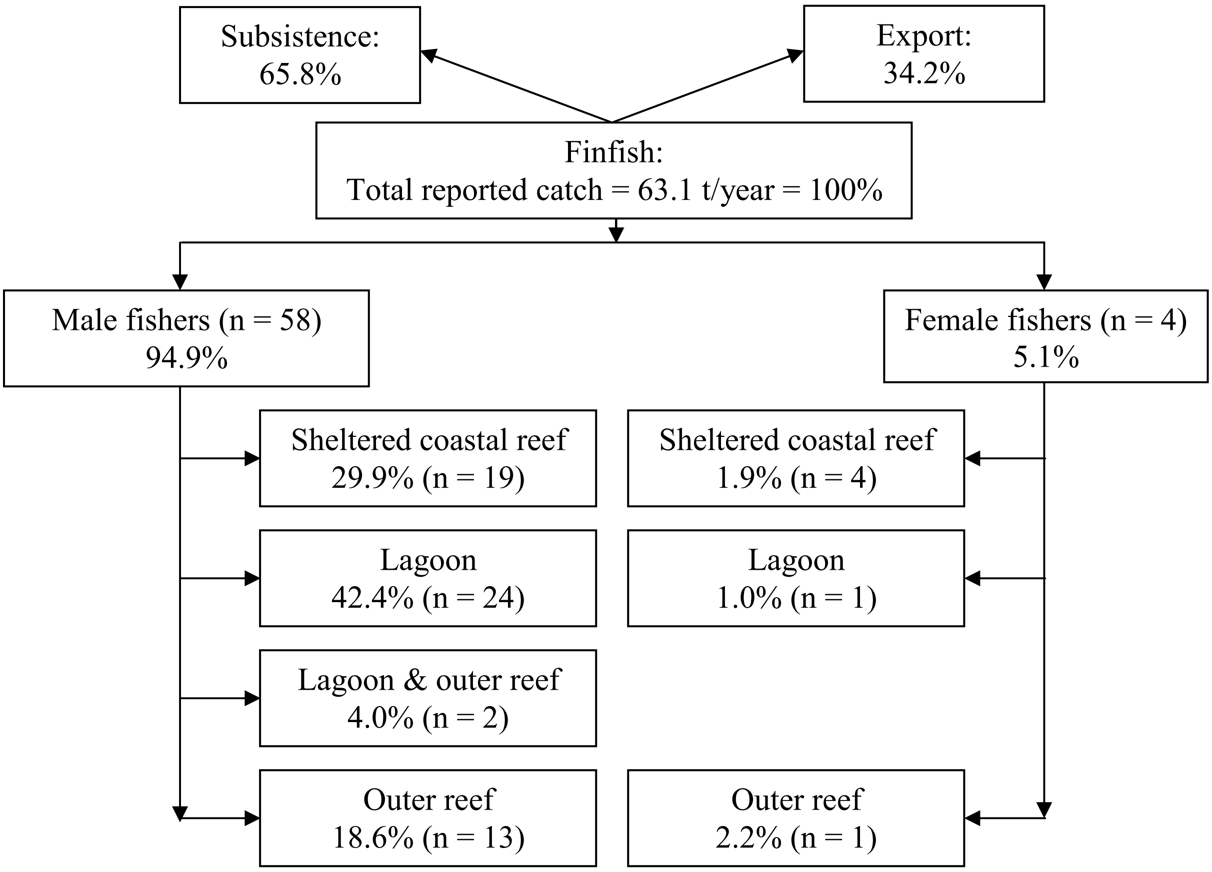

Figure 2.8: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Funafuti.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The higher contribution made by male fishers was not only determined by their number, but also by their higher average annual catch as compared to female fishers, with the exception of the outer reef (Figure 2.9). However, the latter may be explained by the limited (n = 1) sample size of female fishers targeting the outer reef. Fewer males targeted the outer reef than the sheltered coastal reef and lagoon, and their average annual catch was also less. Differences between female and male fishers are not discussed due to the small (and therefore unrepresentative) sample size of females.

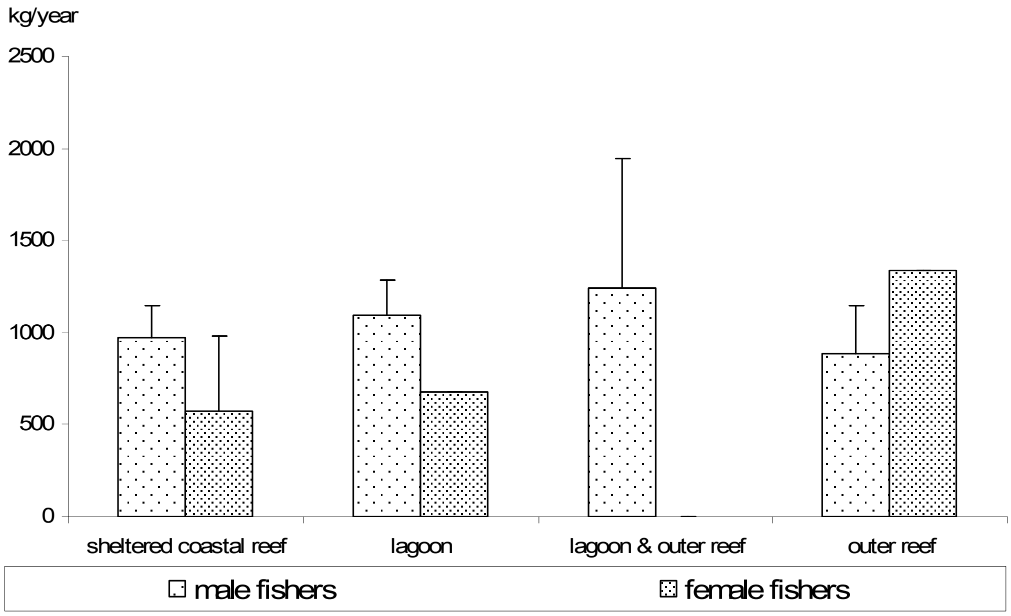

Figure 2.9: Average annual finfish catch (kg/year) per fisher by habitat and gender in Funafuti.
Bars represent standard error (+SE).

The comparison of catch per unit effort (CPUE) for males and females suffers from the small sample size of female fishers. Variability of data also suggests that differences in the CPUE were not very pronounced. However, the CPUE at the sheltered coastal reef and outer reefs was higher than in the lagoon area. The few data entries available for female fishers show lower CPUE figures for all habitats (Figure 2.10).

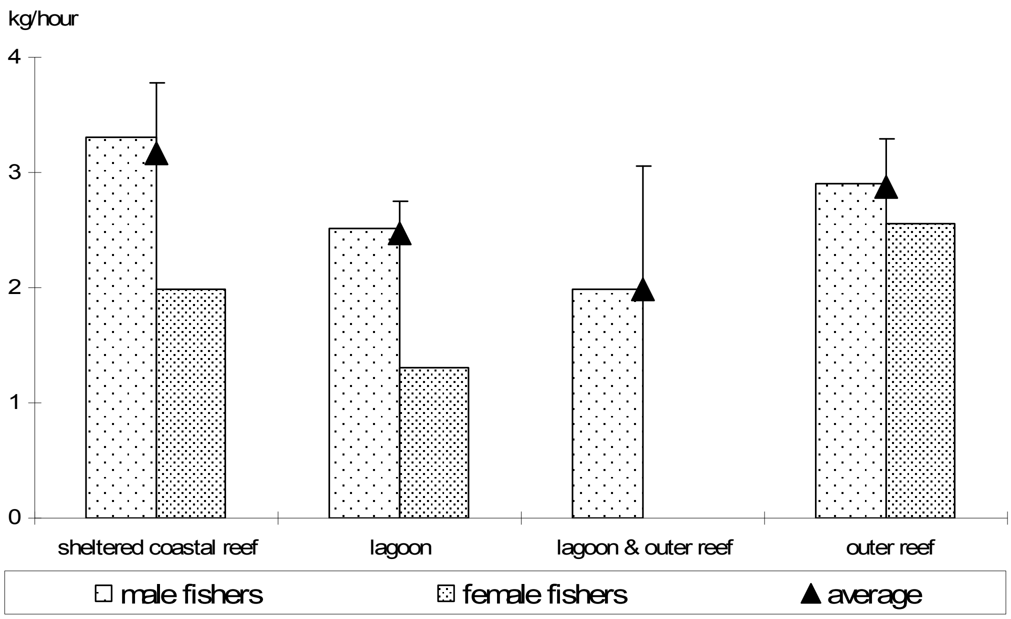

Figure 2.10: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Funafuti.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data also show that most of the catch was taken to satisfy subsistence needs (Figure 2.11). This was particularly evident for catches from sheltered coastal reef areas. The proportion of fish taken for sale increases with lagoon fishing, and becomes equally important (sale and subsistence) for catches from the outer reef (Figure 2.11).

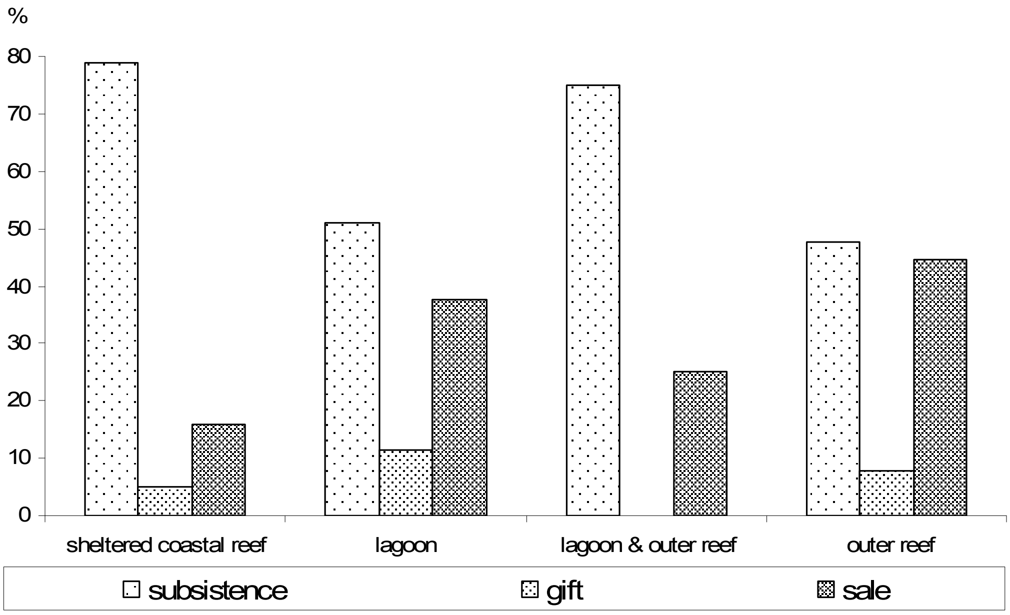

Figure 2.11: The use of finish catches for subsistence, gift and sale, by habitat in Funafuti. Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and by habitat as shown in Figure 2.12 show three trends:

1. Average fish sizes increased from catches of sheltered coastal reef to lagoon and the outer reef in the case of Acanthuridae, Lutjanidae and, to a lesser extent, Kyphosidae. Carangidae were also smaller in the sheltered coastal reef than in the outer-reef area.
2. The average sizes of Lethrinidae and Serranidae were similar in the sheltered coastal and outer reefs, but larger in the lagoon.
3. The average sizes of Scaridae and Siganidae were similar regardless of where they were caught.

In addition, some families were only reported from one habitat, e.g. Caesionidae, Gerreidae, Mugilidae and Pomacentridae from the sheltered coastal reef, Balistidae and Sphyraenidae from the lagoon and Cirrhitidae and Holocentridae from the outer reef.

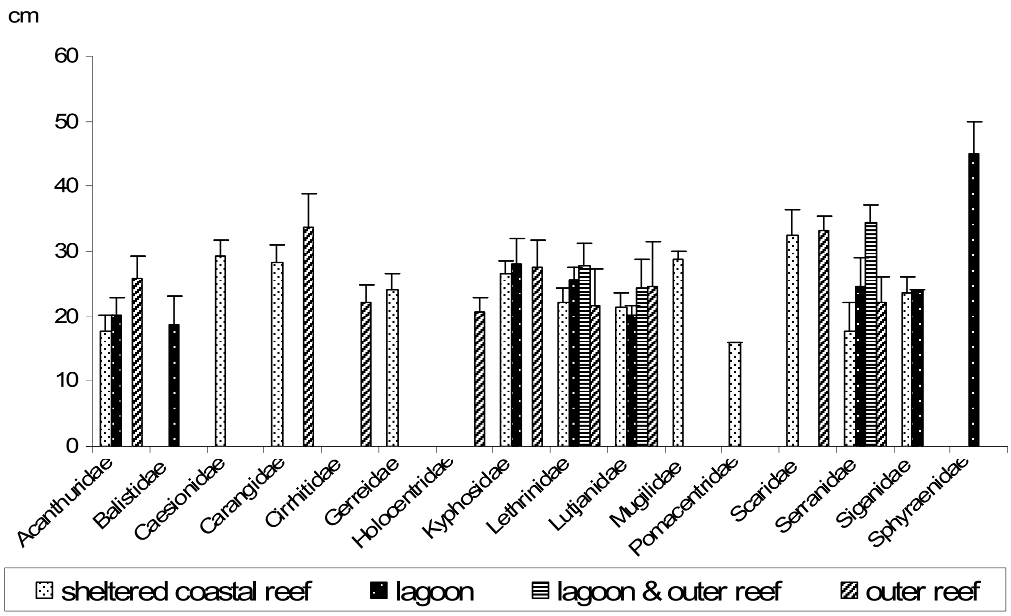

Figure 2.12: Average sizes (cm fork length) of fish caught by family and habitat in Funafuti.
Bars represent standard error (+SE).

Some selected parameters used to assess the fishing pressure on Funafuti's living reef resources are shown in Table 2.4. The comparison of habitat surfaces that were included in Funafuti's fishing ground show that the lagoon area was the largest, followed by the outer- and the sheltered coastal reef areas. Overall fisher density was low to moderate, with an average of only 5 fishers/km^2 of total fishing ground. Density was highest (23 fishers/km^2) in the sheltered coastal reef where annual average catches were lower than those from the lagoon. Lowest fisher density (2 fishers/km^2) occurs in the lagoon, where average annual catches are high.

Table 2.4: Parameters used in assessing fishing pressure on finfish resources in Funafuti

Parameters	Habitat					
	Sheltered coastal reef	Lagoon	Lagoon & outer reef	Outer reef	Total reef	Total fishing ground (1)
Fishing ground area (km^2)	17.21	213.18		17.05	62.88	247.44
Density of fishers (number of fishers/km^2 fishing ground) (2)	23	2		15	18	5
Population density (people/km^2) (3)					72	18
Average annual finfish catch (kg/fisher/year) (4)	934.7 (±163.0)	1074.9 (±185.3)	1238.5 (±708.5)	918 (±245.3)		
Total fishing pressure of subsistence catches (t/km^2)					9.0	2.3

Figures in brackets denote standard error; (1) includes lagoon area; (2) total number of fishers is extrapolated from household surveys; (3) total population = 4500; total number of finfish fishers = 1157; total subsistence demand = 566.02 t/year; (4) catch figures are based on recorded data from survey respondents only.

2.2.4 Catch composition and volume – invertebrates: Funafuti

Calculations of the reported annual catch rates per species groups are shown in Figure 2.13. The graph shows that the major catch by wet weight was of the strawberry conch, *Strombus luhuanus* (panea). In addition, but to a much lesser extent, catches of lobster, *Panulirus penicillatus*, giant clams (*Tridacna maxima*, *T. squamosa*), *Malambus* spp. (*misa*, collected for handicrafts), *Asaphis violascens* (*kasi*) and *Lambis truncata* (*kalea*) were also important. Catches of the other six reported species or species groups were negligible.

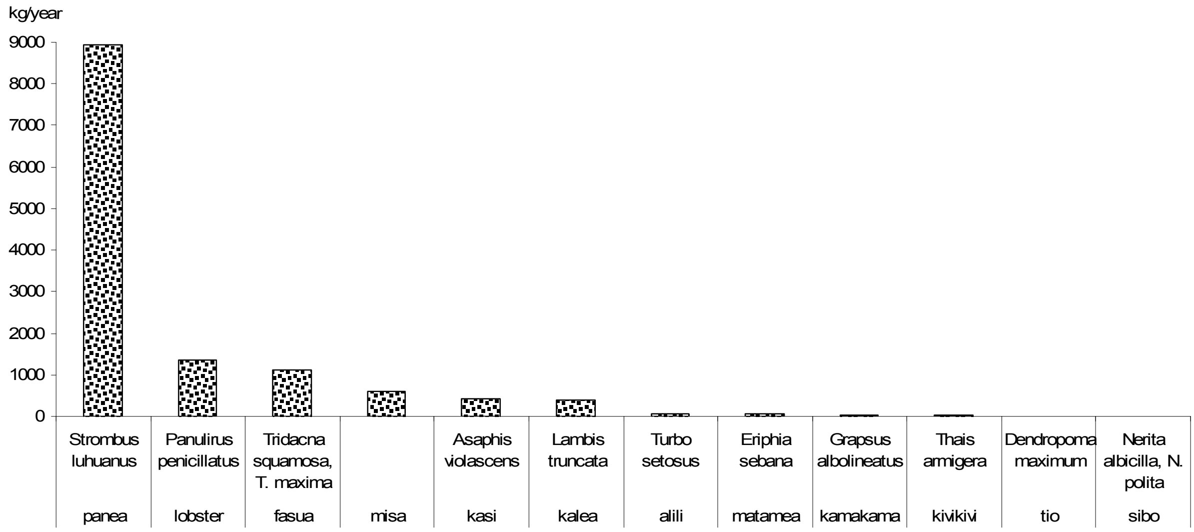

Figure 2.13: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Funafuti.

Figure 2.14 reveals that the diversity of Funafuti's invertebrate fisheries was very low. For most fisheries only two species were reported. Reeftop gleaning was the exception with five target species.

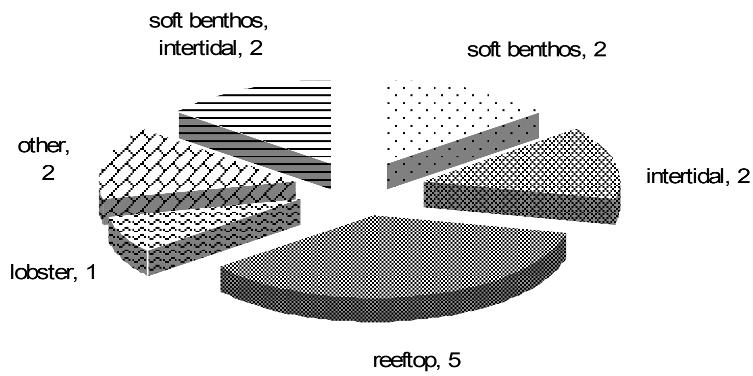

Figure 2.14: Number of vernacular names recorded for each invertebrate fishery on Funafuti.

Details on the species distribution per habitat and on size distribution by species are provided in Appendices 2.1.2 and 2.1.3 respectively.

Figure 2.15 shows that the annual reported catch rates by fisher, gender and fisheries were highest for male fishers targeting the soft benthos. By comparison, all other catches were very low. Female fishers' catch rates were low; however, their highest catches from intertidal fisheries exceeded those of male fishers.

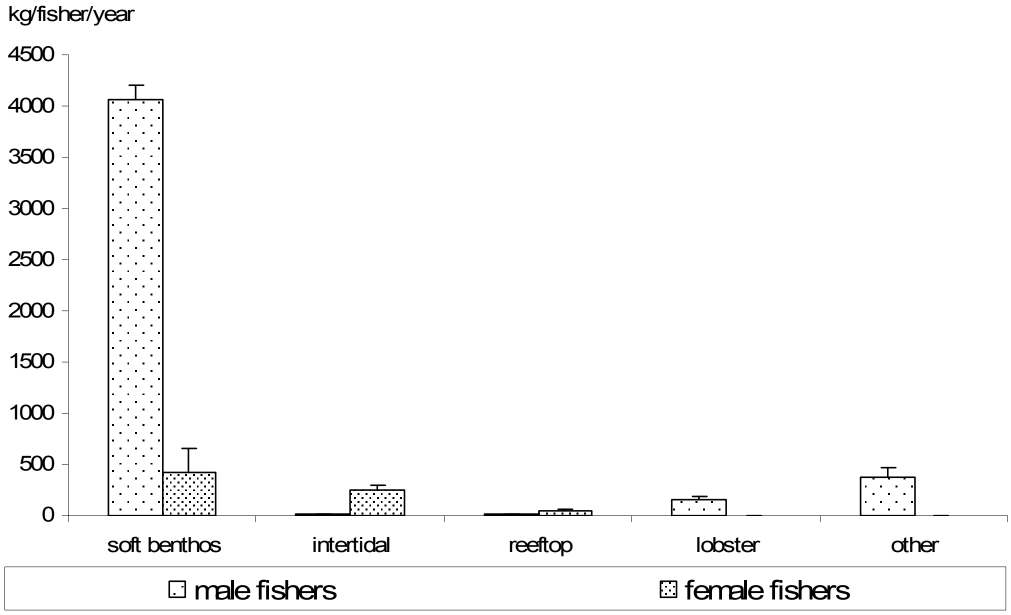

Figure 2.15: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Funafuti.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 25 for males, n = 8 for females). 'Other' refers to giant clam and *Lambis truncata* dive fishery.

The ratio between invertebrates caught for subsistence and sale as shown in Figure 2.16 highlights the high orientation of the fisheries towards subsistence. Assuming that consumption and sale each made up 50% of the combined category 'consumption & sale', the share collected for commercial purposes did not exceed 20% of the annual reported catch.

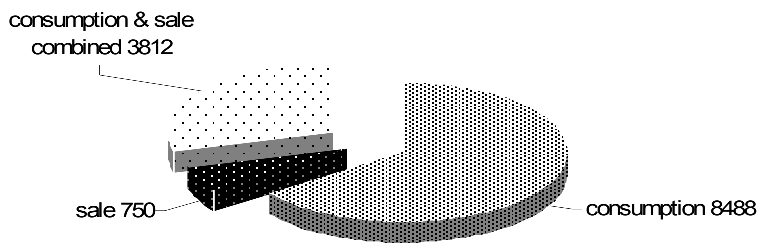

Figure 2.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Funafuti.

The total annual catch volume expressed in wet weight based on the data from all respondents interviewed amounted to 13 t/year (Figure 2.17). Catches from soft benthos, the fishery that attracted the highest number of fishers and that was performed the most frequently, also accounted for the major share, i.e. 66% of the catch. Both dive fisheries ('lobster' and 'giant clam plus *Lambis truncata*') contributed substantially with 10% and 12% of the total annual reported catch (wet weight) respectively. By comparison, intertidal (8%) and reeftop (1%) played a minor role in terms of annual wet weight extraction.

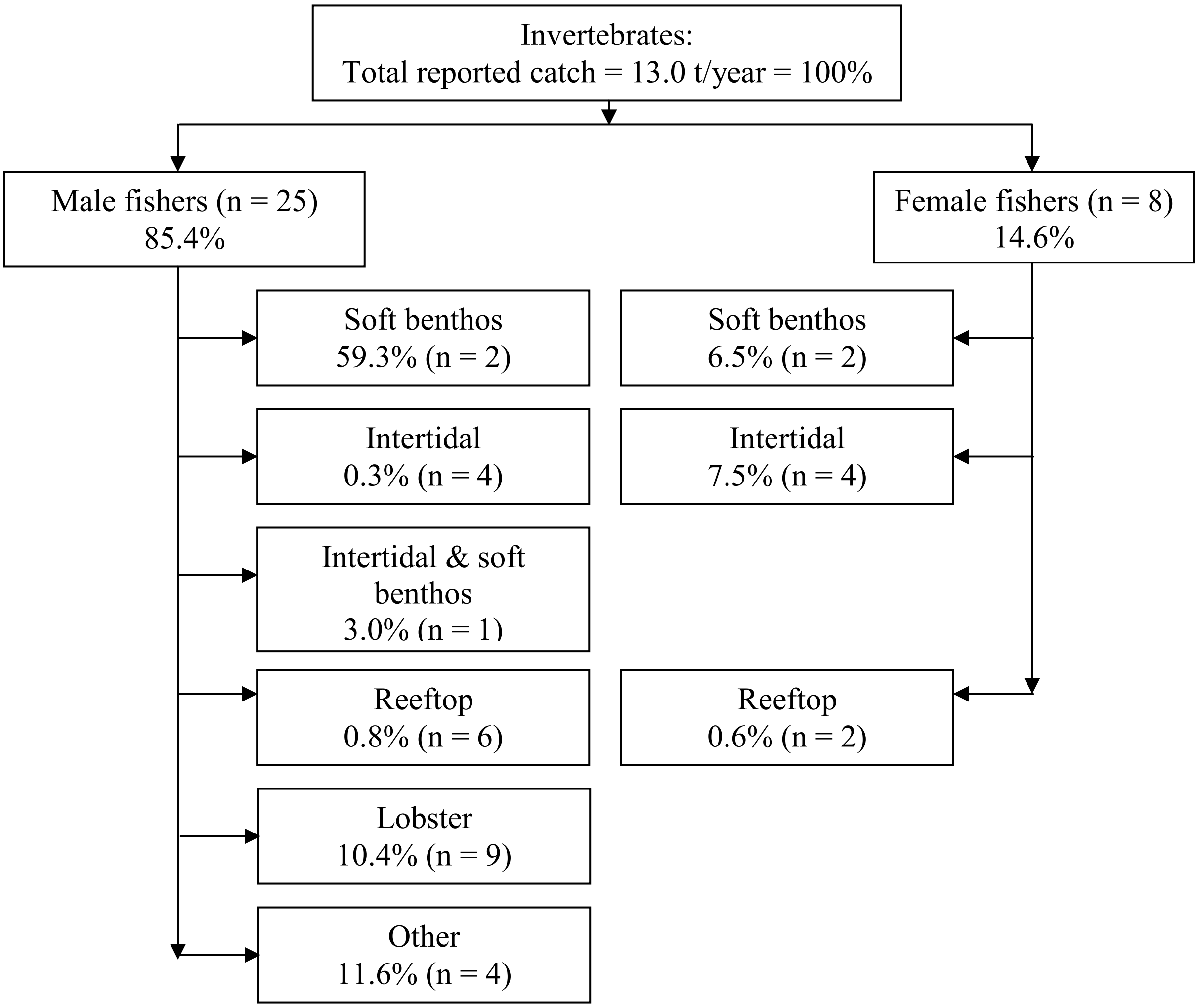

Figure 2.17: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Funafuti.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to giant clam and *Lambis truncata* dive fishery.

The parameters presented in Table 2.5 show a high variability in the size of the available fishing grounds for the various fisheries. Taking into consideration the average reported annual catch per fisher (wet weight) and the density of fishers, fishing pressure on soft benthos, a subsistence fishery, appeared to be alarmingly high. Regarding the dive fishery for giant clams plus *Lambis truncata*, the annual productivity was relatively high, the size of the fishing ground was moderate, and there were basically only two target species, i.e. giant clams and *Lambis truncata* being fished. All these parameters give reason for concern in this fishery. These arguments may also apply to some extent to the lobster fishery.

Table 2.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Funafuti

Parameters	Fishery				
	Soft benthos	Intertidal	Reeftop	Lobster	Other
Fishing ground area (km^2)	4.707 [(1)]	4.707 [(1)]	64.80	71.08 [(2)]	17.73
Number of fishers (per fishery) [(3)]	508	412	340	302	134
Density of fishers (number of fishers/km^2 fishing ground)	108	88	5	4[(2)]	8
Average annual invertebrate catch (kg/fisher/year) [(4)]	716.07 (±135.18)	146.29 (±54.61)	22.45 (±6.95)	151.03 (±29.29)	377.74 (±93.60)

Figures in brackets denote standard error; 'other' refers to giant clam and *Lambis truncata* dive fishery; [(1)] the accessible soft benthos and intertidal fishing grounds are scattered and are assumed to make up about 10% of the inside lagoon shallow reef area (total area = 47.07 km^2); [(2)] the lobster fishing ground is expressed in km of accessible and potential reef length, hence the fisher density is the number of fishers per km reef length; [(3)] total number of fishers is extrapolated from household surveys; [(4)] catch figures are based on recorded data from survey respondents only.

2.2.5 Discussion and conclusions: socioeconomics in Funafuti

- Most of Funafuti's people fished for food rather than income. Income was mainly sourced from salaries, complemented by a high dependency on remittances to meet the relatively high level of average household expenditure. Overall, fisheries provided the first income for 30% of all households and the second income for a further 23% of all households.

- Seafood consumption mainly focused on finfish (135 kg/capita/year). Invertebrates were consumed less frequently (0.7 times/week) and canned fish consumption was low (2.3 kg/capita/year). The relatively high importance of fisheries for food was also represented by the high number of household members involved in fisheries, the fact that most fish consumed was caught rather than bought, the higher percentage of finfish catches used for subsistence rather than sale, and the small proportion of invertebrates collected for sale.

- Data suggest the existence of traditional gender roles in fisheries as males seemed to be more involved in finfish fishing and females tended to focus more on invertebrate collection. Overall fisher density was estimated at 5 fishers/km^2 of total fishing ground. The highest fisher density occurred in the sheltered coastal reef, followed by the outer reef. Fisher density was lowest in the lagoon. However, the CPUE figures showed the opposite trend, i.e. they were lowest for lagoon and highest for sheltered coastal and outer-reef fishing. These differences in CPUE may partly be determined by the fishing techniques used, but may also be explained by the variations in fishing pressure.

- Different fishing methods were used in each of Funafuti's three major habitats: handlines in the lagoon, gillnets in the sheltered coastal reef, and spearfishing in the outer-reef areas. This difference in techniques may explain some trends observed in the average reported fish sizes, in particular an increase in average sizes of Acanthuridae and Lutjanidae from the sheltered coastal to the outer-reef areas.

- Funafuti supports a wide range of invertebrate fisheries. However, most invertebrates were collected by gleaners (both genders) mainly from the soft benthos (66% of the reported total annual catch, wet weight) rather than by male fishers diving on hard benthos. The survey data indicated the highest pressure was on soft benthos in terms of total biomass (wet weight) removed (particularly *Strombus luhuanus*), followed by the biomass removed by diving for lobsters (*Panulirus penicillatus*), giant clams, and *Lambis truncata*. Reeftop and intertidal fisheries played less important roles in terms of total reported biomass removed. Fisher density and productivity gave reason for concern in the soft-benthos fishery and in the dive fishery for giant clams plus *Lambis truncata* and lobsters.

- Given the fact that fishing on Funafuti was mainly for subsistence, that finfish and selected invertebrates were imported from outer islands to supplement Funafuti's local supply, and that average household expenditures were relatively high, the data suggest the following three possible scenarios or conclusions:
  1. Funafuti's people were mostly engaged in governmental and other paid employment and therefore had less time to fish for their own needs, but had more cash to purchase fresh seafood on the local market; and/or
  2. the current resource level in Funafuti's fishing ground was not sufficient to satisfy the local population's demand; and/or
  3. fishing did not represent a sufficiently competitive and lucrative income option, hence local commercial fishery production was low and demand was satisfied by importing seafood from other outer islands where fishing represented either a more attractive income option, or where alternative income options were fewer.

2.3 Finfish resource surveys: Funafuti

Finfish resources and associated habitats were assessed 4–11 November 2004. The survey covered 24 transects (4 sheltered coastal reef transects, 6 lagoon-intermediate transects, 8 back-reef transects and 6 outer-reef transects, Figure 2.18). Transects were haphazardly placed and randomly distributed throughout all hard diveable habitats (64.7 km^2) found on Funafuti. Variation in the number of transect stations for each habitat resulted from re-categorising their exact locations into the proper geomorphologic zones after the surveys were completed. For instance, there were only four coastal-reefs transects surveyed, as the other two considered as 'coastal-reef' transects during the surveys were later re-categorized as 'back-reef' stations. Appendix 3.1.1 provides the coordinates by GPS positions for all 24 transects. Lagoon reefs represented the smallest area (3%), while 27% and 31% were the areas covered by coastal reef and back-reef, respectively. Outer reefs represented 39% of the total atoll area.

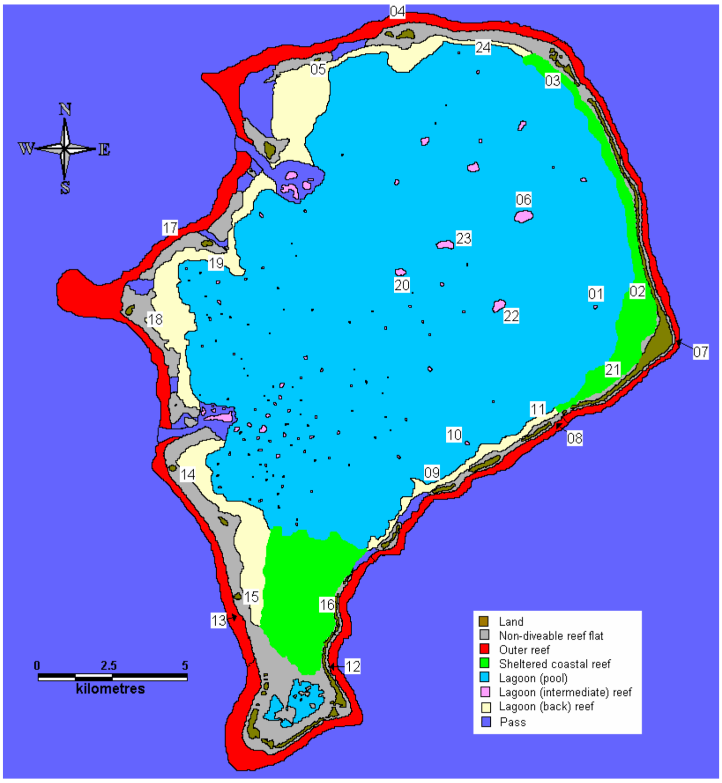

Figure 2.18: Habitat types and transect locations for finfish assessment in Funafuti.

2.3.1 Finfish assessment results: Funafuti

A total of 21 families, 57 genera, 153 species and 11,720 fishes were recorded in the 24 transects (Appendix 3.2). Data relating to 13 of the 15 most dominant families in the region form the basis of this report (Neither Nemipteridae nor Kyphosidae were found in Funafuti.), with key results presented below. This includes information on 45 genera, 137 species and 10,399 individuals.

Table 2.6: Primary finfish habitat and resource parameters recorded in Funafuti (average values ±SE)

Parameters	Habitat				
	Sheltered coastal reef (1)	Lagoon (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	4	6	8	6	24
Total habitat area (km^2)	17.2	1.8	20.0	25.7	64.7
Depth (m)	2 (1-4) (3)	6 (1-12) (3)	3 (1-7) (3)	8 (5-14) (3)	5 (1-14) (3)
Soft bottom (% cover)	7.9 ±2.1	4.6 ±1.9	8.4 ±3.2	0	4.8
Rubble & boulders (% cover)	5.4 ±1.1	10.4 ±4.5	8.4 ±4.5	1.2 ±0.7	4.8
Hard bottom (% cover)	70.1 ±2.7	67.0 ±5.1	62.2 ±4.7	78.3 ±3.6	70.8
Live coral (% cover)	16.4 ±3.8	17.7±4.5	21.0 ±4.2	20.5 ±3.4	19.5
Soft coral (% cover)	0.12 ±0.12	0	0	0	0.1
Biodiversity (species/transect)	34 ±4	46 ±5	36 ±4	45 ±6	41
Density (fish/m^2)	0.6 ±0.1	0.8 ±0.1	0.8 ±0.1	0.9 ±0.2	0.8
Size (cm FL) (4)	12.1 ±0.6	15.5 ±0.6	14.9 ±0.5	17.4 ±0.6	15.1
Size ratio (%)	40.3 ±2.0	47.5 ±1.8	45.7 ±1.6	50.7 ±1.8	46.3
Biomass (g/m^2)	43.1 ±10.8	154.6 ±36.9	124.6 ±33.3	220.8 ±70.3	141.8

(1) Unweighted average; (2) weighted average that takes into account relative proportion of habitat in the study area; (3) depth range; (4) FL = fork length.

The Funafuti reef system spreads across some 64.7 km^2 and consists predominantly of outer reef (25.7 km^2), back-reef (20 km^2), coastal reef (17.2 km^2) and finally lagoon reef, with the least surface cover (1.8 km^2).

Finfish resources differed slightly among the main reef habitats of Funafuti (Table. 2.6). Biomass increased markedly from coastal to outer reefs, with almost double (or more) fish biomass in the outer reefs compared to other reef habitats. However, biomass of commercial reef stocks on Funafuti reefs was the lowest compared to the same habitats in Niutao and Nukufetau. On the other hand, abundance of reef fishes on Funafuti was relatively similar to that in other study sites (whose average values ranged between 0.7 and 1.0 fish/m^2) and relatively similar across reef habitats (ranging between 0.6 and 0.9 fish/m^2). Size structure showed variation among the types of reef, with size ratio increasing from sheltered reef, to back-reef, lagoon and outer reefs. A greater number of species were recorded in the lagoon and outer reefs compared to the coastal reef and back-reef environments. Species richness was higher than in corresponding habitats at Nukufetau, except in the back-reef.

Rare commercial and edible fish families included Pomacanthidae, Holocentridae and Zanclidae; conversely, no counts of Kyphosidae and Nemipteridae were recorded as the territorial and cryptic behaviour of these fishes makes them unsuitable for the UVC method employed.

The composition of the benthic community changed, with similar live coral cover in back-reefs (21.0 ±4.2%) and outer-reef habitats (20.5 ±3.4%) and lower coral cover in lagoon and sheltered coastal reefs (Table 2.6). The coastal, internal and back-reefs showed a combination of hard and soft substrates, while the outer reef was predominantly composed of hard substrate.

Sheltered coastal reef environment: Funafuti

The sheltered coastal reef fish community was dominated by herbivorous fish families, most notably Acanthuridae (density = 0.16 ±0.05 fish/m^2, biomass = 10.1 ±4.0 g/m^2), Scaridae (density = 0.14 ±0.02 fish/m^2, biomass = 12.9 ±5.8 g/m^2) and, in lower density, Mullidae (density = 0.11 ±0.03 fish/m^2, biomass = 2.7 ±0.8 g/m^2) and Siganidae (density = 0.05 ±0.03 fish/m^2, biomass = 3.3 ±1.6 g/m^2). Carnivorous Lethrinidae showed high biomass although rather low density (density = 0.04 ±0.02 fish/m^2, biomass = 7.4 ±5.1 g/m^2). Lutjanidae displayed significant biomass as well (2.0 ±1.1 g/m^2).

The most relevant species of the most important families, ordered by decreasing density, were: *Monotaxis grandoculis*, *Ctenochaetus striatus*, *Lutjanus gibbus*, *L. fulvus*, *Chlorurus sordidus*, *Parupeneus multifasciatus*, *Mulloidichthys flavolineatus* and *Siganus spinus* (Table 2.7). The large-sized piscivorous and invertebrate-eating species of Serranidae, Lutjanidae and Labridae contributed little to the total biomass and density structure of commercial fish counts in coastal habitats. These trends were also reflected in the coastal reefs of Nukufetau, the only other site with this habitat, except for Lutjanidae, which were much more important than in Funafuti. Close proximity and easy access to fishing activities, rather than habitat and environmental factors, may explain this trend.

Table 2.7: Finfish species contributing most to main families in terms of densities and biomass in the sheltered coastal reef environment of Funafuti

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.09 ±0.03	3.7 ±1.3
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.04 ±0.02	6.8 ±2.4
Mullidae	*Parupeneus multifasciatus*	Many-bar goatfish	0.02 ±0.01	0.5 ±0.1
	Mulloidichthys flavolineatus	Yellow-stripe goatfish	0.02 ±0.02	0.3 ±0.2
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big eye bream	0.10 ±0.02	21.3 ±6.8
Siganidae	*Siganus spinus*	Little spinefoot	0.01 ±0.0	1.4 ±1.3
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.07 ±0.06	21.2 ±16.1
	Lutjanus fulvus	Flametail snapper	0.05 ±0.04	10.3 ±9.9

The sheltered coastal reefs of Funafuti showed the lowest density and biomass, size and size ratio of all habitats. It is possible that the lower density relates to fishing pressure, conditions of the reef environment or both. While reefs surveyed were predominantly of hard substrate, there were nonetheless pockets of soft habitat and rubbles–boulders mixed with live coral. The sheltered coastal reefs of Funafuti are relatively patchy with extensive reef areas fringed by large *motu*. The finfish assessment concentrated on a mean depth of 2 m of mostly hard bottom (>70%), and at this depth spearfishing and gillnetting were common practices.

Sheltered coastal reefs are only found in Funafuti and Nukufetau. Therefore it was not possible to make comparisons to the other two study sites. Biological parameters of biomass, density and size of finfish resources in the sheltered coastal reefs of Funafuti were lower than those recorded in Nukufetau. Biomass was almost three times lower on Funafuti than Nukufetau, suggesting very high fishing pressure on coastal reefs. Biodiversity was however higher in Funafuti than Nukufetau coastal reefs.

Estimated density and biomass of Acanthuridae, Lutjanidae and Lethrinidae were particularly low on Funafuti coastal reefs compared to Nukufetau. Conversely, counts and biomass of Siganidae, and density of Mullidae and Scaridae were higher on Funafuti compared to

Nukufetau. Acanthuridae were the most abundant fish on Funafuti, similarly to all study sites. Variations in fishing pressure among the study sites and the fact that large carnivore and edible fishes were targeted may best explain such trends. The overall picture shown by results from coastal-reef habitats on Funafuti, however, was similar to that in Nukufetau.

Survey work focused only on hard-bottom habitats, where live coral cover was the lowest compared to other substrates. Similar to back-reef habitats, 'mobile bottom' (soft bottom and rubble) cover in coastal reef habitats was >15%, a substantial quantity in reference to the other reef types. The substrate composition was different than in Nukufetau, with comparatively higher live coral cover and hard-bottom substrates in Funafuti (Table 2.6, Figure 2.19). These differences in substrate may also partially explain variations in abundance and biomass of fishes found in coastal reefs.

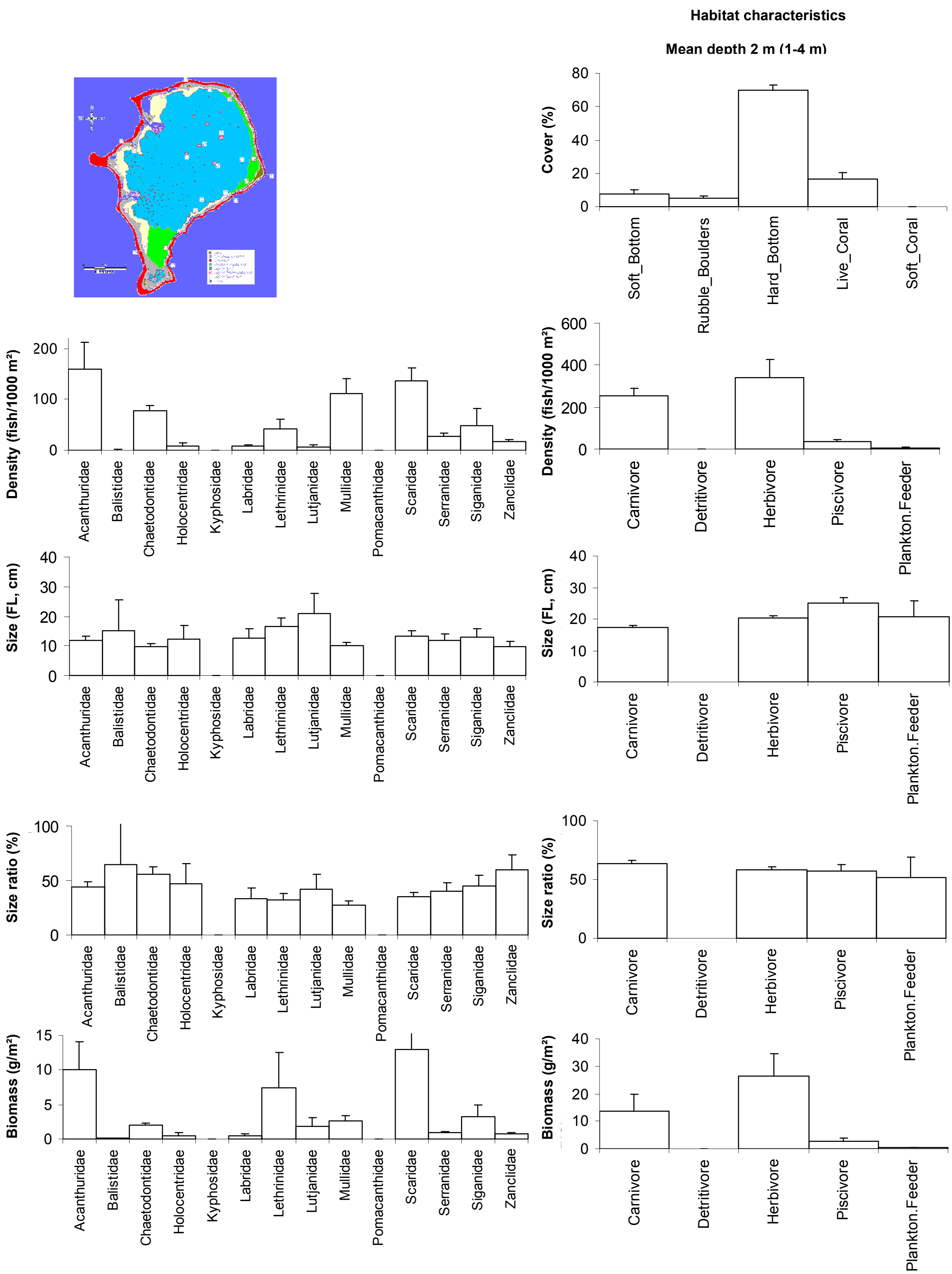

Figure 2.19: Profile of finfish resources in the sheltered coastal reef environment of Funafuti. Bars represent standard error (+SE); FL = fork length.

Lagoon-reef environment: Funafuti

Survey work focused primarily on hard-bottom habitats (67.0 ±5%). Cover of live coral (17.7 ±4.5%) was higher than in coastal reefs but lower than in back and outer reefs (Table 2.6). Despite the predominance of hard bottom, there were also patches of soft bottom, live coral colonies, soft corals and even dead corals and rubbles. The lagoon was a preferred fishing area, where the male fishers engaged in handlining and spearfishing around reef patches, particularly during periods when rough sea conditions prevented fishing on the outer reef. Unlike Nukufetau, the lagoon reefs of Funafuti were spread over a large area and were accessible even during adverse sea conditions, thus they were fished all year round.

The lagoon intermediate-reef environment of Funafuti was dominated in density by both herbivorous and carnivorous fish families, most notably Acanthuridae (density = 0.36 ±0.04 fish/m^2, biomass = 90.3 ±33.1 g/m^2, Table 2.8, Figure 2.20), with *Ctenochaetus striatus* as the most abundant species, followed by *Zebrasoma scopas*, *Acanthurus nigricans*, *A. lineatus* and *Naso lituratus* (these last two species with very high biomass). Mullidae (*Mulloidichthys vanicolensis* and *M. flavolineatus*), Scaridae (with *Scarus niger* and *Chlorurus sordidus* the most abundant), Siganidae (*Siganus spinus*) and Lethrinidae (*Monotaxis grandoculis*, of very high biomass) were next in importance in terms of abundance and biomass. The remaining commercial fish families, including the targeted fish families of Labridae, Serranidae and Lutjanidae, were recorded at <0.05 fish/m^2.

Density estimates of fish in lagoon reefs (0.8 ±0.1 fish/m^2) were higher than in coastal and back-reefs. Similarly, the fish biomass of lagoon reefs (154.6 ±36.9 g/m^2) was higher than coastal and back-reefs, however lower than outer reefs. The biomass of Acanthuridae (90.3 ±33.1 g/m^2) alone was highly dominant in lagoon reefs; Lethrinidae, Scaridae and Lutjanidae followed but with much lower biomass values (< 20 g/m^2).

Table 2.8: Finfish species contributing most to main families in terms of densities and biomass in the lagoon-reef environment of Funafuti

Family	Species	Common name	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.10 ±0.02	5.9 ±0.8
	Zebrasoma scopas	Brush-tail tang	0.08 ±0.02	1.6 ±0.3
	Acanthurus nigricans	White-cheek surgeonfish	0.05 ±0.02	3.6 ±1.4
	Acanthurus lineatus	Striped surgeonfish	0.04 ±0.03	20.7 ±17.8
	Naso lituratus	Orange-spine unicornfish	0.04 ±0.01	19.3 ±8.1
Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	0.05 ±0.04	0.18 ±0.2
	Mulloidichthys flavolineatus	Yellowstripe goatfish	0.04 ±0.02	1.1 ±0.8
Scaridae	*Scarus niger*	Swarthy parrotfish	0.03 ±0.01	0.6 ±0.2
	Chlorurus sordidus	Bullethead parrotfish	0.02 ±0.01	3.5 ±2.0
Siganidae	*Siganus spinus*	Scribbled rabbitfish	0.05 ±0.03	4.2 ±3.0
Lethrinidae	*Monotaxis grandoculis*	Humpnose big-eye bream	0.03 ±0.01	9.9 ±3.7

Overall, the distribution pattern of fish density and biomass in the lagoon reef environment was very variable and corresponded partly to the relatively large size of the reef system on Funafuti, where fishing was frequently concentrated on key targeted fishing spots. This held true for specific target species, such as Scaridae, Lethrinidae, Serranidae and Siganidae, though numbers were relatively low.

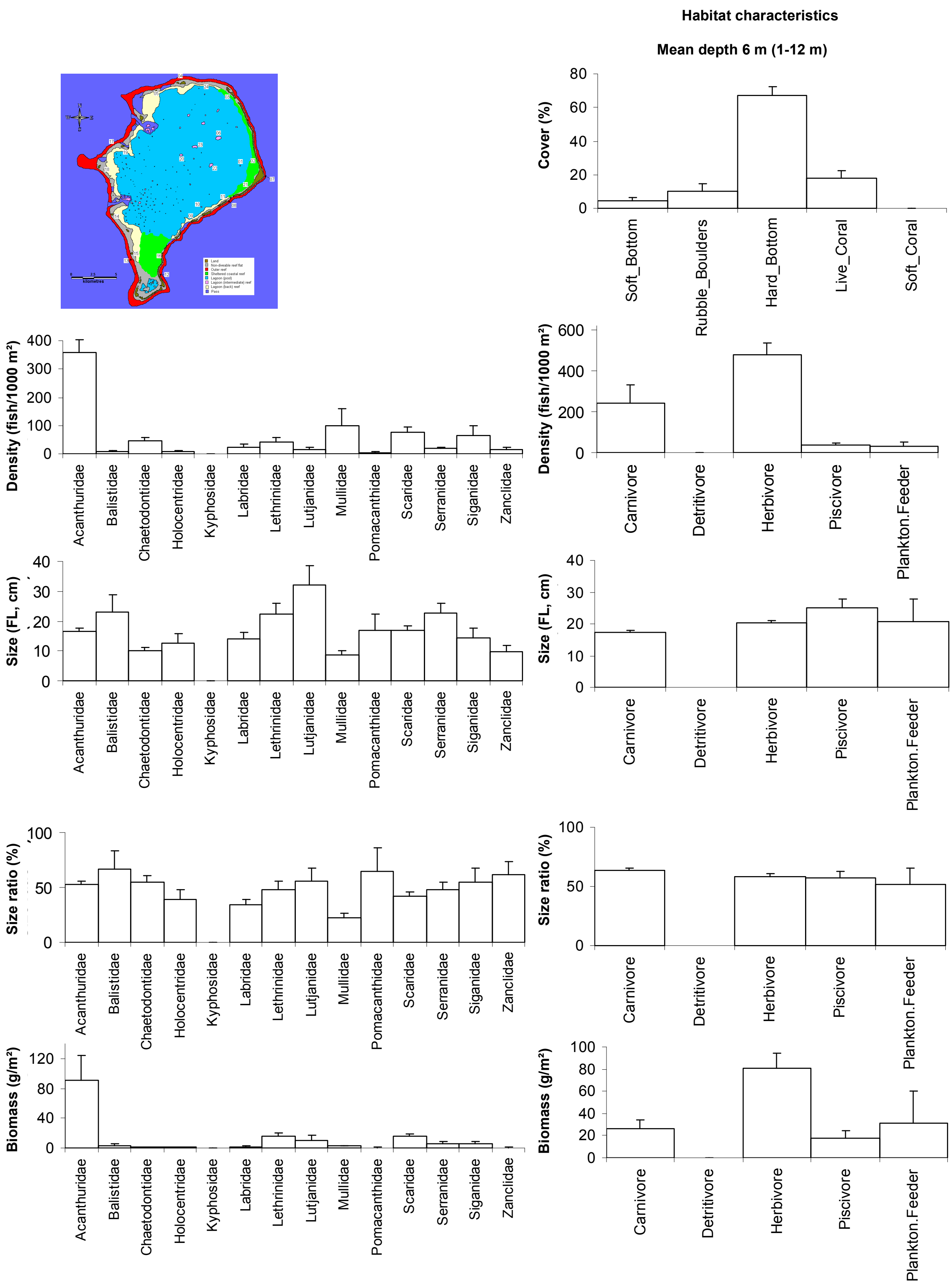

Figure 2.20: Profile of finfish resources in the lagoon-reef environment of Funafuti.
Bars represent standard error (+SE); FL = fork length.

Lagoon patch reefs are only found in Nukufetau and Funafuti, and comparisons are therefore only possible between these two study sites. Overall average density was greater in Funafuti, while total fish biomass and average fish size were lower than in Nukufetau. The records showed also clear differences in the distribution pattern of prominent targeted commercial reef fishes between the lagoon reefs of Nukufetau and Funafuti. In particular, Acanthuridae and Mullidae, but also Siganidae and Lethrinidae, were more abundant in Funafuti, while Scaridae, Kyphosidae, Lutjanidae and Serranidae were more abundant and of much higher biomass in Nukufetau.

Back-reef environment: Funafuti

The back-reef system occupied the second largest reef area (20.0 km^2) compared to other reef types on the atoll (Table 2.6). Despite this, fish biomass in the back-reefs was lower than in the lagoon and outer reefs. Also, fish abundance was comparable to other reef habitats and slightly lower than in the lagoon reef. Fishing pressure may influence fish population in the back-reefs due to easy access by foot or canoes and boats, sheltered and good sea conditions and the possibility of using multi-fishing methods (e.g. spearfishing and hand lining).

Survey work focused primarily on hard-bottom habitats (62.2 ±4.7%). However, patches of soft bottom (8.4 ±3.2%) were also common features of the back-reef system. Live coral cover was the highest among the four habitats (21.0 ±4.2%). The soft-bottom cover was higher than at the other reef habitats, indicating the narrow margin of the barrier reef which gently drops off to the sandy fringing terrace of the lagoon.

The back-reef environment of Funafuti was dominated mainly by herbivorous fish families, most notably Acanthuridae (density = 0.36 ±0.07 fish/m^2, biomass = 43.9 ±14.6 g/m^2) and Scaridae (density = 0.15 ±0.02 fish/m^2, biomass = 29.2 ±6.7 g/m^2). Abundance of Mullidae (density = 0.05 ±0.02 fish/m^2, biomass = 1.5 ±0.5 g/m^2) and Lethrinidae (density = 0.05 ±0.02 fish/m^2, biomass = 17.9 ±9.4 g/m^2,) followed, but with much lower values (Figure 2.21, Table 2.9). Other major targeted fish families Serranidae and Siganidae were very low in abundance. Both Lethrinidae and Lutjanidae (biomass = 18.1 ±17.4 g/m^2) showed a relatively high biomass. Acanthuridae alone were predominant in both density and biomass, perhaps due to the overgrowth of algae. The predominance of this type of fish in the back-reef environment was relatively consistent with that of coastal reefs.

The most important species in terms of density and biomass were *Ctenochaetus striatus, Chlorurus sordidus, Acanthurus nigricans, A. lineatus, A. triostegus, Scarus niger, Monotaxis grandoculis* and *Lutjanus gibbus*. Siganidae were very rare; fishing pressure no doubt has influenced their numbers given that they are highly sought after on Funafuti as a good eating fish. The use of large scoop nets to catch hundreds of Siganidae at one time has proved too efficient.

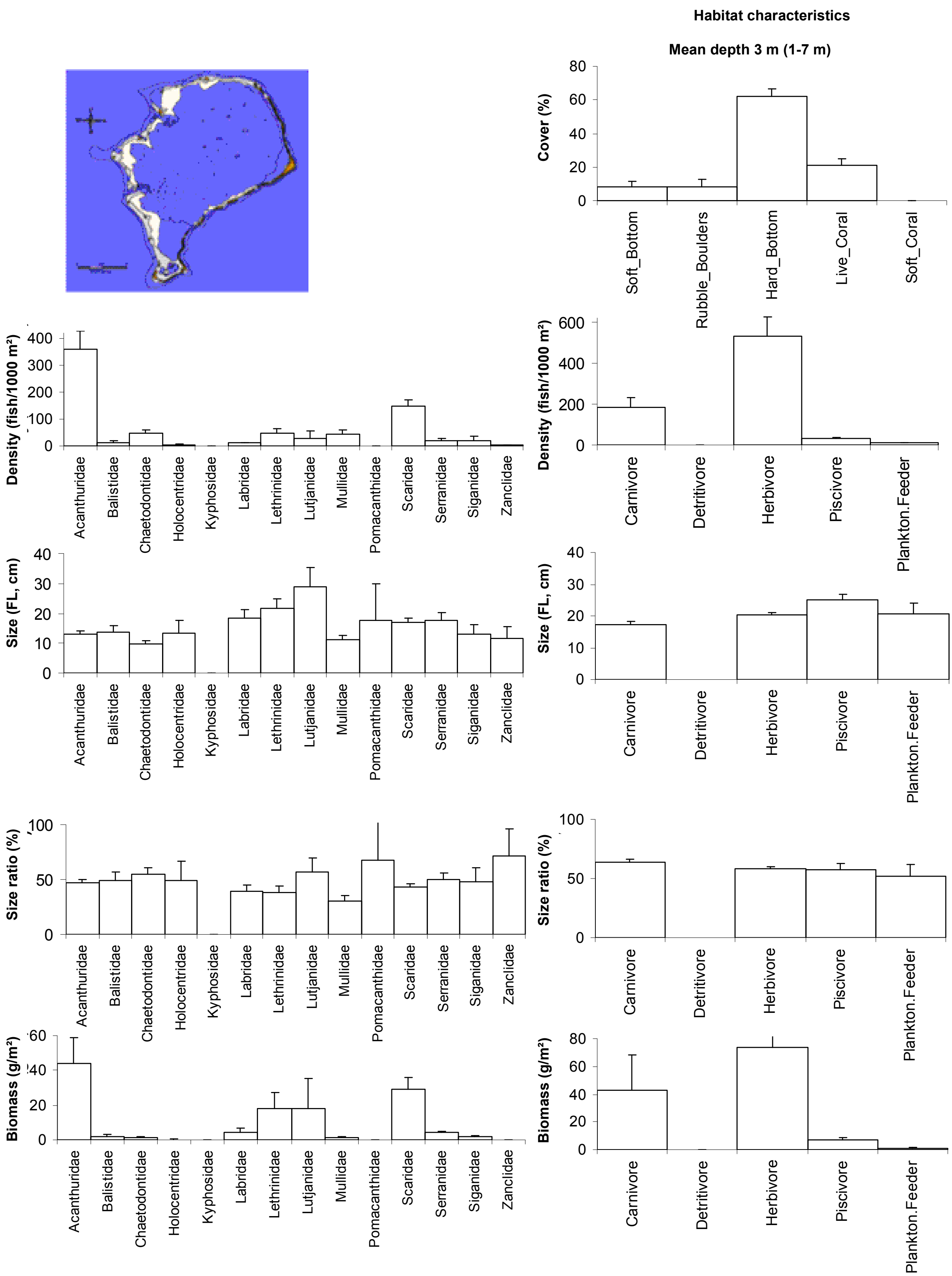

Figure 2.21: Profile of finfish resources in the back-reef environment of Funafuti.
Bars represent standard error (+SE); FL = fork length.

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth	0.11 ±0.01	5.8 ±0.8
	Acanthurus nigricans	White-cheek surgeonfish	0.06 ±0.02	4.0 ±1.5
	Acanthurus lineatus	Striped surgeonfish	0.06 ±0.03	13.6 ±8.4
	Acanthurus triostegus	Convict tang	0.06 ±0.03	2.1 ±1.1
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.06 ±0.01	12.1 ±2.2
	Scarus niger	Swarthy parrotfish	0.05 ±0.01	1.2 ±0.3
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big-eye bream	0.04 ±0.02	15.9 ±9.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.03 ±0.02	16.3 ±16.1

Similar to the case for the lagoon and coastal reefs, the uneven distribution of fish density and biomass corresponded partly to the relatively large size of the reef system on Funafuti. Also, fishing in the back-reefs was frequently concentrated in key fishing spots and target species, using a range of fishing methods, e.g. spearfishing and gillnetting.

Back-reefs were only found in Funafuti and Nukufetau, and comparisons were therefore only possible between these two study sites. Fish biodiversity and density in back-reefs of Funafuti were higher than in Nukufetau. The reverse held true for size, size ratio and biomass. This same trend of relatively low biomass was also seen in the other reef habitats of Funafuti. The lower abundance of large-sized target species of Lethrinidae, Lutjanidae and Serranidae perhaps explains the low biomass on the atoll. In contrast, density and biomass of Acanthuridae and Scaridae were markedly higher on Funafuti. Also there were more live-coral cover and hard-bottom substrates in the back-reefs in Funafuti than Nukufetau (Table 2.6).

Outer-reef environment: Funafuti

The outer reef of Funafuti occupied the largest reef area (25.7 km^2) compared to other reef types on the atoll (Table 2.6). There was an exceptionally high cover of hard bottom (78.3 ±3.6%) and high coral cover (20.5 ±3.4%), with no cover of soft corals or soft substrates.

The values of total density, biomass, size and size ratio (over 50% for all feeding guilds, and for the families of Lutjanidae, Serranidae and Siganidae) were much higher in the outer reef compared to the other environments, indicating that resources in this area were healthy.

Species composition was largely dominated by herbivorous fish families, most notably Acanthuridae (density = 0.37 ±0.08 fish/m^2, biomass = 50.8 ±24.0 g/m^2) and Scaridae (density = 0.21 ±0.05 fish/m^2, biomass = 79.6 ±33.8 g/m^2) (Figure 2.22). Other major target families, Balistidae, Lutjanidae, Serranidae, Lethrinidae, Labridae and Mullidae were low in abundance. The predominance of Acanthuridae was common to other reef habitats. However, Scaridae showed the highest biomass, followed closely by Acanthuridae, then by Lutjanidae, Lethrinidae, Serranidae and Labridae.

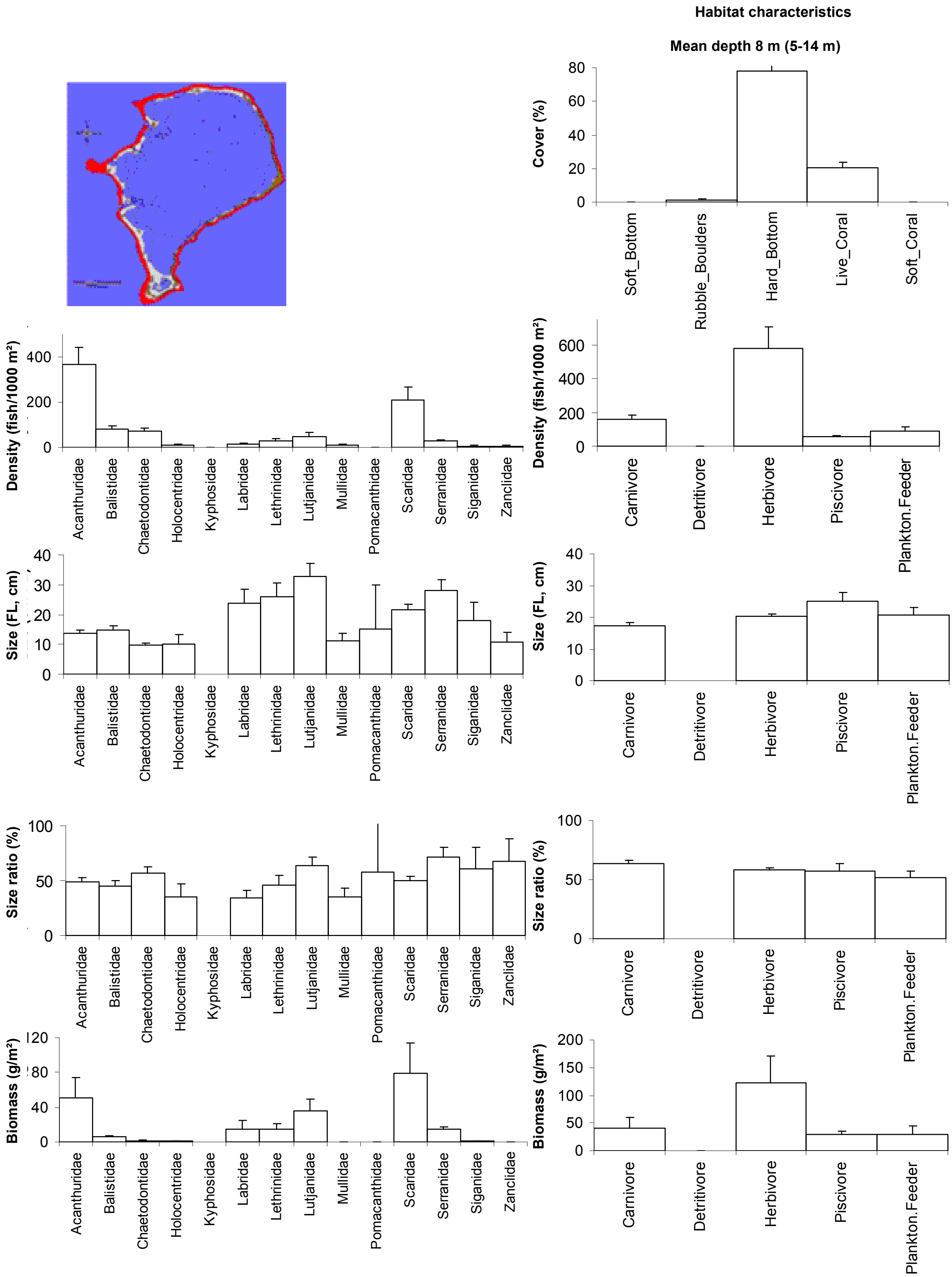

Figure 2.22: Profile of finfish resources in the outer-reef environment of Funafuti.
Bars represent standard error (+SE); FL = fork length.

The most important species in terms of density and biomass were *Ctenochaetus striatus*, *Acanthurus nigricans*, *Chlorurus sordidus*, *Naso lituratus*, *S. altipinnis*, *Monotaxis grandoculis* and *Macolor macularis* (The latter two species had low abundance but relatively high biomass.). No large-sized *Plectropomus* spp., *Cephalopholis* spp. or other *Lethrinus* spp. (all commonly targeted by fishers on the atoll) were recorded during surveys. Similarly distributions of *Naso* spp. and *Scarus* spp. were very patchy, with good numbers in certain parts of the outer reefs. Unicornfish and parrotfish were increasingly targeted by fishers using spears and nets.

Table 2.10: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Funafuti

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth	0.17 ±0.02	7.2 ±1.1
	Acanthurus nigricans	White-cheek surgeonfish	0.10 ±0.03	6.2 ±1.6
	Naso lituratus	Orange-spine unicornfish	0.03 ±0.02	21.2 ±17.3
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.07 ±0.02	13.7 ±5.3
	Scarus altipinnis	Filament-fin parrotfish	0.02 ±0.02	28.7 ±28.7
Lujtianidae	*Macolor macularis*	Midnight snapper	0.02 ±0.01	16.8 ±10.7
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big-eye bream	0.02 ±0.01	12.5 ±6.2

Unlike coastal reefs, lagoon patch reefs and back-reefs, outer reefs occurred in all study sites of Tuvalu; thus comparisons could be made across all the sites. Density in Funafuti was lower only than in outer reefs of Niutao but very similar to that in Nukufetau. Fish sizes and size ratios in Funafuti were the lowest of all sites and biomass was lower than in both Niutao and Nukufetau.

Fishing methods employed by male fishers were very selective and thus resulted in low numbers of targeted species. For instance, abundance and biomass of Acanthuridae and Balistidae were lower. Conversely, Scaridae, Labridae and Lethrinidae had higher biomass and densities than found in outer reefs of the other sites. Perhaps, this was because spearfishing was more commonly practised on Vaitupu and Niutao outer reefs due to the lack of fishing ground choices.

Overall reef environment: Funafuti

The data on all reef types were combined to determine the overall state of the fish assemblage on Funafuti atoll.

The study found that two main families were consistently dominant, Acanthuridae (density = 0.31 fish/m^2, biomass = 38.9 g/m^2) and, with higher biomass but lower density, Scaridae (density = 0.17 fish/m^2, biomass = 44.5 g/m^2). Other families that followed closely with similar values of biomass were Lutjanidae (density = 0.03 fish/m^2, biomass = 20.8 g/m^2) and Lethrinidae (density = 0.04 fish/m^2, biomass = 13.7 g/m^2). Mullidae were relatively important in abundance but low in biomass (density = 0.05 fish/m^2, biomass = 1.4 g/m^2). Siganidae, Serranidae and Labridae were both low in numbers and biomass. Overall density and biomass were dominated by the species *Ctenochaetus striatus*, *Chlorurus sordidus*, *Acanthurus nigricans*, *Scarus niger*, *Monotaxis grandoculis*, *Naso lituratus* and *Lutjanus gibbus* (Table 2.11). As expected, the overall fish assemblage in Funafuti more closely resembled that recorded in the back- and outer-reef environment (71% of habitat) than that of the coastal and intermediate lagoon reef environment (29% of habitat).

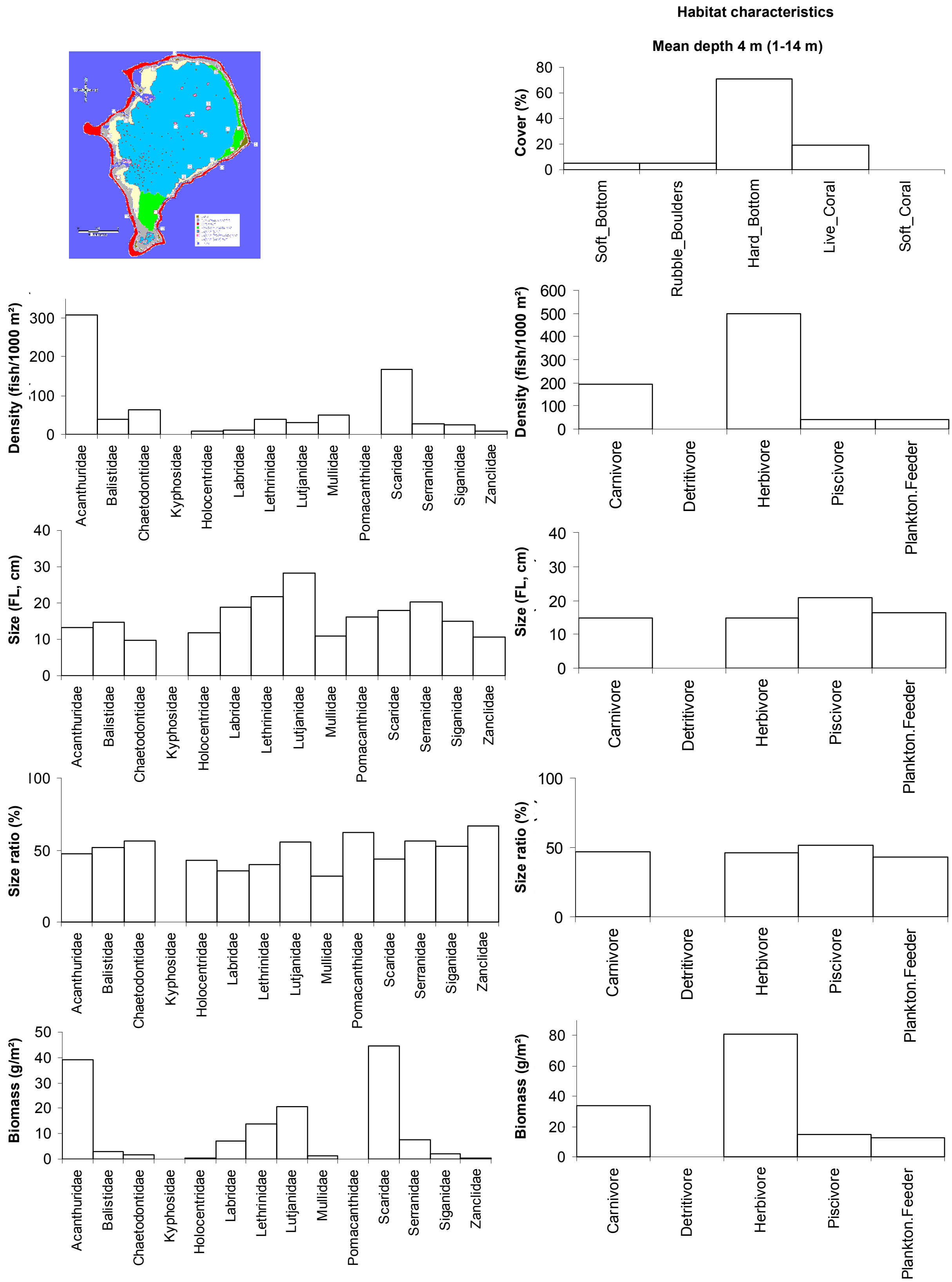

Figure 2.23: Profile of finfish resources in the combined reef habitats of Funafuti (weighted average).
FL = fork length.

Table 2.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Funafuti (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristletooth surgeonfish	0.13	6.3
	Acanthurus nigricans	Whitecheek surgeonfish	0.06	3.9
	Naso lituratus	Orange-spine unicornfish	0.02	12.4
Scaridae	*Chlorurus sordidus*	Bullethead parrotfish	0.06	11.3
	Scarus niger	Swarthy parrotfish	0.05	1.2
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big-eye bream	0.03	12.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.01	7.22

When compared to the average for all four Tuvalu study sites, the finfish resources of Funafuti atoll displayed the second highest biodiversity and density, but the lowest biomass and size compared to other site averages (Figure 2.23). Detailed assessment at the reef level suggested that the condition of Funafuti's finfish resources was comparable to the other sites for most biological parameters except for biomass, which was notably lower than the average estimated for all sites combined. Like Nukufetau, Funafuti atoll offered all the available habitats and reefs for a choice of fishing methods and gears. Therefore, the level of fishing impact was less intensive than that of the other survey sites. However, population pressure on the atoll appeared to influence fishing pressure to levels that may exceed sustainable limits in certain reef habitats.

The substrate composition was dominated by hard bottom (much more extensive than in Nukufetau) with relatively good coral coverage, although slightly less than in the other comparable atoll site.

2.3.2 Discussion and conclusions: finfish resources in Funafuti

- Survey results showed that the status of finfish resources in Funafuti atoll was significantly different to that of the other three PROCFish/C sites in Tuvalu and that these resources were showing early signs of impact from fishing. This difference may be explained by any single biological parameter or combination of parameters and habitat characteristics, coupled with variation in fishing pressure levels. The results showed that average biomass and size estimates on Funafuti were lower than average estimates at the other sites. Species diversity index and density estimates were, however, in the higher part of the range, with number of species only second to Nukufetau and density lower only than Niutao. Habitat characteristics were similar to those in Nukufetau atoll except that cover of hard substrate was much higher in Funafuti.

- At Funafuti, fish biomass was the lowest and fish sizes small, both signs of increased fishing pressure. The study particularly noted indications of species-specific and habitat-specific impact, e.g. the predominance of certain fish families, especially Acanthuridae and Scaridae, and the differences in the status of fish stocks among coastal, lagoon and outer-reef habitats. Preliminary results suggested that these differences may have resulted from the high population density and the corresponding high demand for marine resources for subsistence and semi-commercial purposes. The high population index per unit area of available reefs was an early warning that close monitoring of the resources was needed in order not to exceed sustainable fishing levels.

- Target species of Lutjanidae, Lethrinidae, Serranidae and Siganidae were becoming increasingly over-exploited. There was quite a different assemblage of fish among the four habitats. The predominance and relatively high biomass of herbivorous Acanthuridae and Scaridae was particularly prominent at the coastal, back- and outer reefs. Fish biomass and density increased from coastal fishery to lagoon, back- and outer-reef fisheries. This trend correlated well with the level of accessibility to fishing spots, habitat health and the uneven level of fishing pressure exerted on these fisheries.

2.4 Invertebrate resource surveys: Funafuti

The diversity and abundance of invertebrate species at Funafuti atoll were independently determined using a range of survey techniques (Table 2.12), broad-scale assessment (using the 'manta tow' technique (See Appendix 1.3); locations shown in Figure 2.24) and finer-scale assessment of specific reef and benthic habitats (Figures 2.25 and 2.26).

Table 2.12: Number of stations and replicates completed at Funafuti

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	13 (+1)	83 transects
Reef-benthos transects (RBt)	18	108 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)	5	30 search periods
Reef-front searches (RFs)	9	54 search periods
Sea cucumber day searches (Ds)	5	30 search periods
Sea cucumber night searches (Ns)	2	12 search periods

(+1) comprises another broad-scale transect station with only three replicates.

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. Fine-scale assessment was conducted in target areas to specifically describe the status of resources in those areas of naturally higher abundance and/or most suitable habitat.

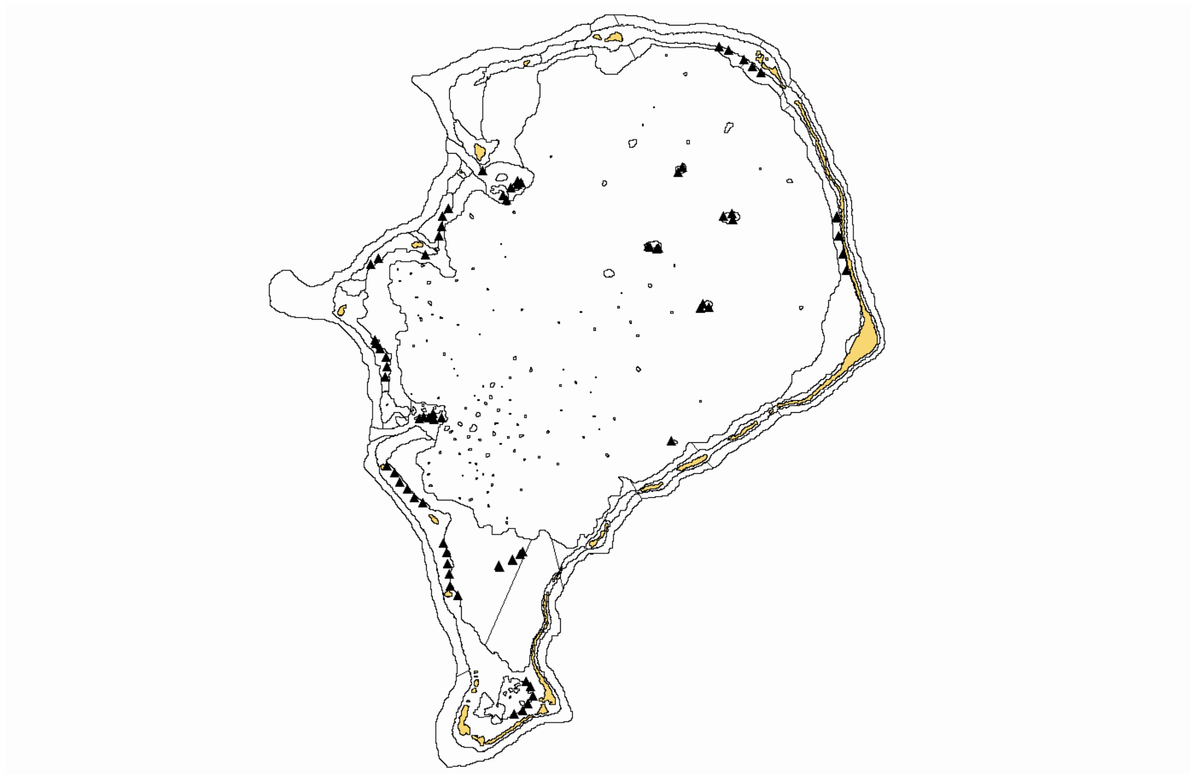

Figure 2.24: Broad-scale survey stations for invertebrates in Funafuti.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

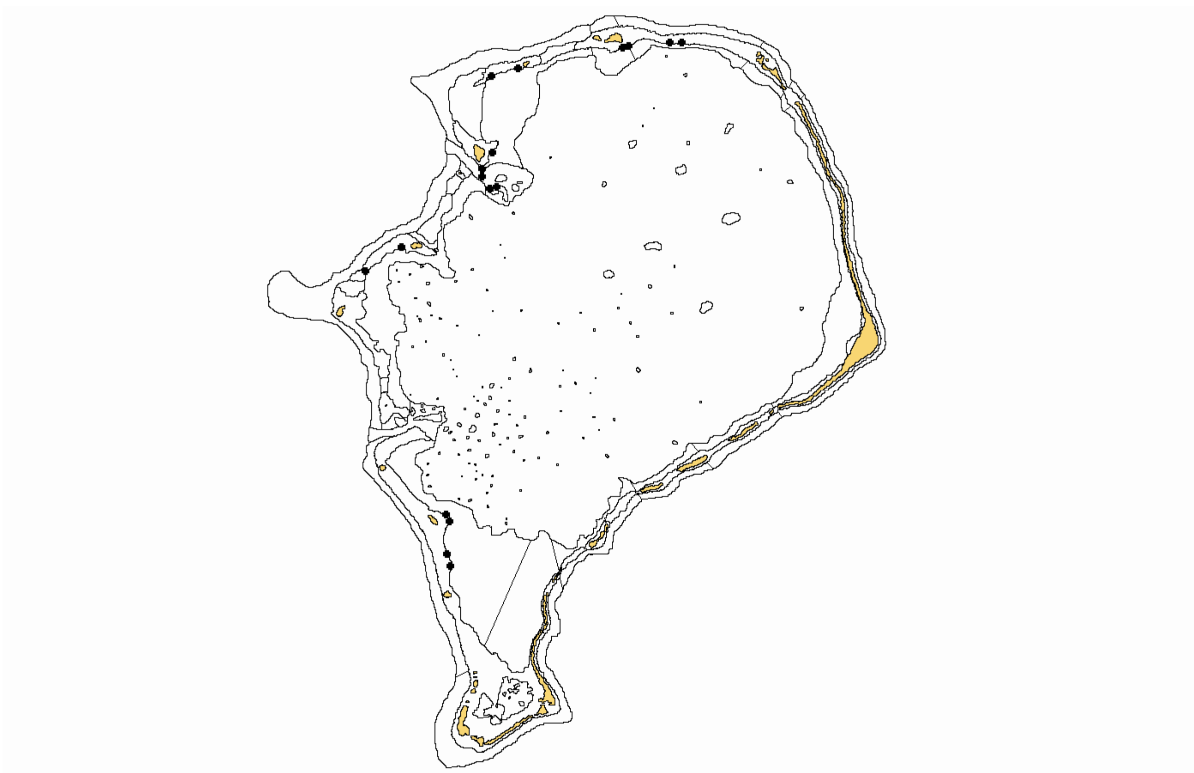

Figure 2.25: Fine-scale reef-benthos transect survey stations for invertebrates in Funafuti.
Black circles: reef-benthos transect stations (RBt).

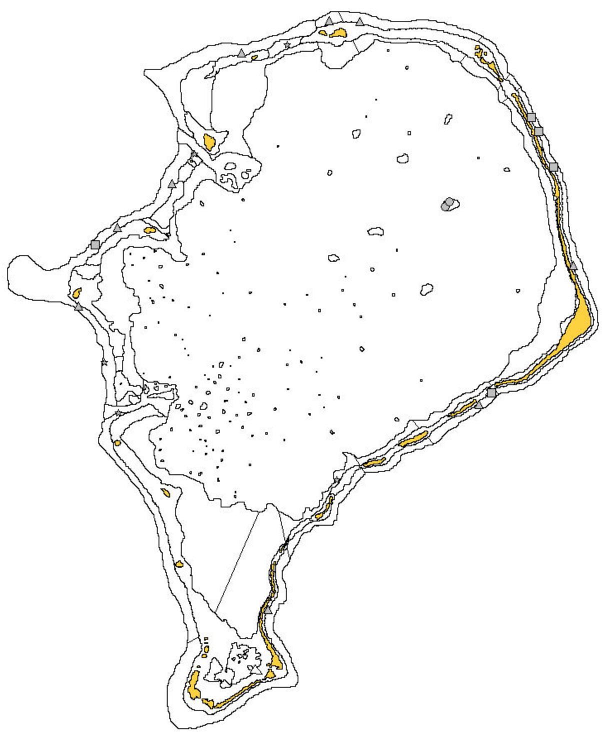

Figure 2.26: Fine-scale survey stations for invertebrates in Funafuti.
Grey triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey circles: sea cucumber night search stations (Ns);
grey stars: sea cucumber day search stations (Ds).

Thirty-three species or species groupings (groups of species within a genus) were recorded in the Funafuti invertebrate surveys. These included, among others, 4 bivalves, 14 gastropods, 10 sea cucumbers, 2 urchins, 1 sea star, 1 cnidarian and 1 lobster (Appendix 4.1.1). Information on key families and species is detailed below.

2.4.1 Giant clams: Funafuti

Shallow-reef habitat that is suitable for giant clams was extensive across Funafuti atoll (64.8 km^2: 47 km^2 within the lagoon and 17 km^2 on the reef front or slope). Although the lagoon at first glance looks quite enclosed, it is relatively open to oceanic influences, with little land influence; there are at least six passes and water flows between the lagoon and the open sea through the passes and over submerged areas of barrier reef.

Broad-scale sampling provided an overview of giant clam distribution across Funafuti atoll. Two giant clam species were recorded during the survey of the diverse reef habitats present: the elongate clam *Tridacna maxima* and the fluted clam *T. squamosa*. A third species, the smooth giant clam *T. derasa* was also present, but only at one location, having been introduced from Palau in 1988. These *T. derasa* were stockpiled at 8–10 m water depth in front of the Fisheries Department's mooring, near the main port. No true giant clams, *T. gigas*, were seen.

In broad-scale assessments, stations near the main settlement of Funafuti held no clams, whereas 'middle' areas and more exposed 'outer' reef areas of the lagoon held aggregations at low density (See methods.). *T. maxima* was the most common species with the widest occurrence (found in 8 broad-scale stations and 27 transects) followed by *T. squamosa* (4 broad-scale stations and 5 transects, Figure 2.27).

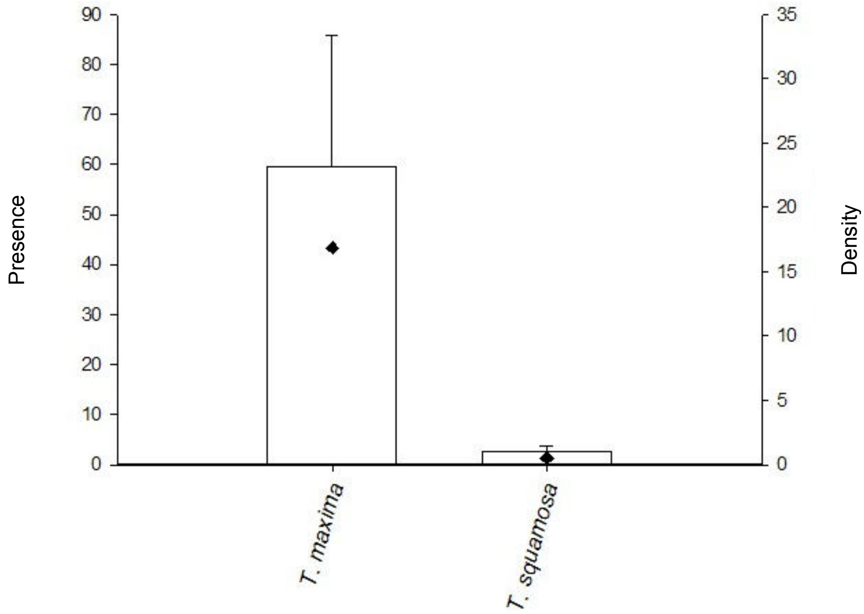

Figure 2.27: Presence and mean density of giant clam species at Funafuti based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys were conducted to target specific areas of clam habitat. In these reef-benthos assessments (RBt) *T. maxima* was present at 72% of reef-benthos stations. At these stations (Clams were recorded at 13 stations.), the mean density of *T. maxima* was 163.5 individuals/ha (Figure 2.28). *T. squamosa*, a species that is normally found at lower density than *T. maxima*, was quite common in Tuvalu, and found at a third of the reef-benthos stations.

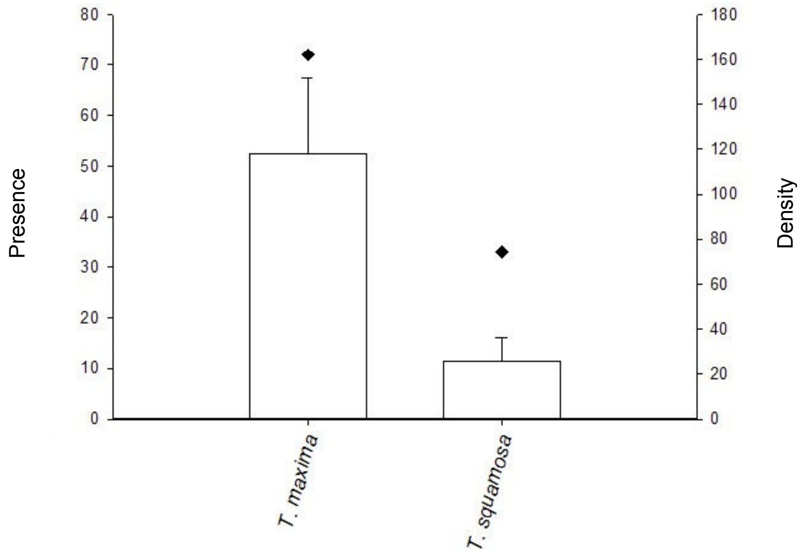

Figure 2.28: Presence and mean density of giant clam species at Funafuti based on fine-scale reef-benthos survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

The UNDP, SPREP, and Tuvalu Fisheries Department established a marine park within the Funafuti lagoon in 1997. This marine conservation area (MCA) covered an area of approximately 33 km². Areas surveyed within the MCA generally had a higher density of both *T. maxima* and *T. squamosa* than did shallow reef-benthos outside (Table 2.13; Figure 2.29).

Table 2.13: Presence and mean density of clams in Funafuti
Based on the fine-scale reef-benthos transect assessment technique in shallow reef; mean density measured in numbers per ha (±SE).

	Density	SE	% of transects with species
Tridacna maxima			
All stations	118.1	33.6	31/108 = 29
Marine Conservation Area (MCA)	194.4	55.1	24/54 = 44
Outside MCA	41.7	19.3	7/54 = 13
Tridacna squamosa			
All Stations	25.5	10.7	9/108 = 8
Marine Conservation Area (MCA)	32.4	19.4	5/54 = 9
Outside MCA	20.8	11.1	4/54 = 7
Tridacna derasa			
All Stations	0	0	0/108 = 0

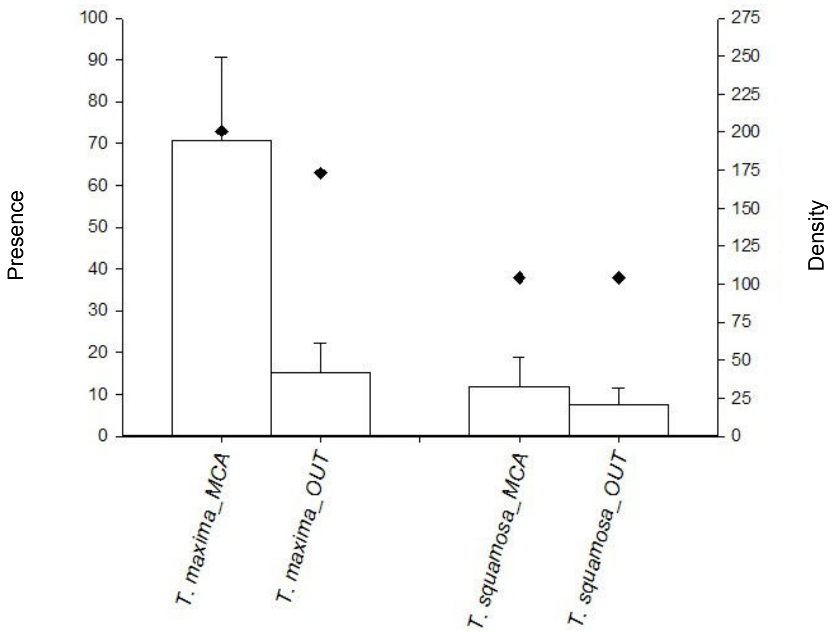

Figure 2.29: Presence and mean density of giant clam species 'in' and 'out' of the MCA based on fine-scale RBt survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

T. maxima recorded in reef-benthos transects (on shallow-water reefs) had an average length of 9.2 ±0.5 cm. Despite there being evidence of continued fishing in the MCA, *T. maxima* within the protected area were marginally, but significantly, larger than those recorded outside (9.7 cm compared to 6.6 cm). When clams from deeper water and more exposed locations were included in the calculation (from other assessments), the mean size was slightly larger at 10.9 ±0.3 cm, which equates to a *T. maxima* of approximately 4–5 years old. The faster-growing *T. squamosa* (which grows to an asymptotic length $L\infty$ of 40 cm) averaged 15.3 ±1.8 cm on reef-benthos transects and 19.1 ±2.1 cm in all assessments (This mean length also equates to 4–5 years of age.). *T. squamosa* within the MCA had a smaller average size than those recorded from reef-benthos transects outside the MCA (13.4 cm compared to 17.8 cm). In this case, only 11 *T. squamosa* clams were measured from assessments inside and outside the MCA, and the difference in size was not significant in preliminary analysis. As can be seen from the length-frequency graphs for both species (Figure 2.30), there were very few large clams; i.e. clams around the asymptotic length ($L\infty$) for that species.

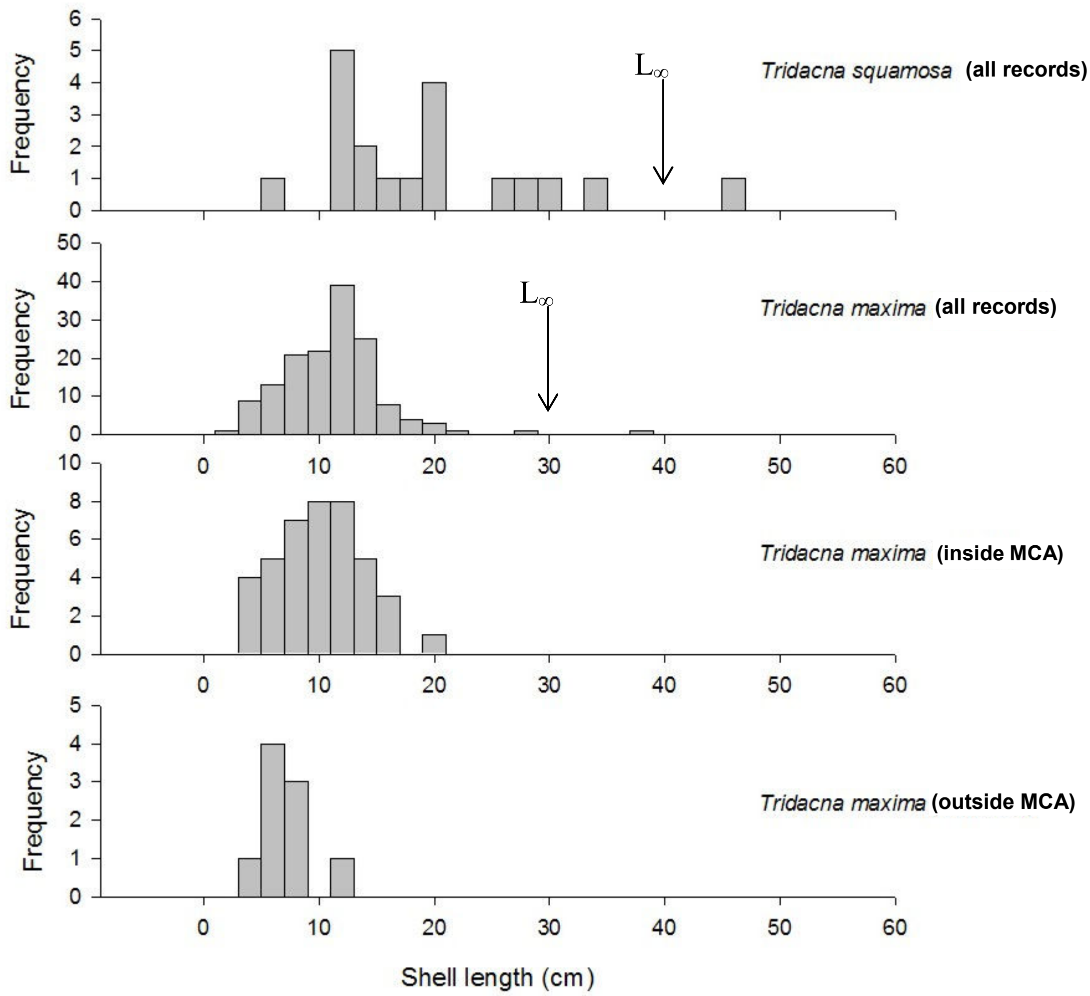

Figure 2.30: Comparison of average shell length (cm) of giant clams from inside and outside the marine conservation area of Funafuti.
L_∞ is the asymptotic length.

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

Tuvalu is not within the natural distribution of the commercial topshell, *Trochus niloticus*, however, specimens were introduced through translocation in the mid to late 1980s. Trochus was transplanted into Funafuti in 1985 (181 adult shells) and 1987 (180 adult shells). In 1988 and 1989 a further 2672 individual trochus transplants were made (Gillett 1993).

The reefs around Funafuti constitute an extensive benthos suitable for *T. niloticus* and this area could potentially support significant populations of this commercial species. However, although extensive reef platform and shallow-water reef slope exists (71 km lineal distance of atoll reef perimeter), the number and density of grazing gastropods were low. This was possibly a result of the very strong oceanic influence affecting the lagoon and reefs. The grazers that were present were found mainly within the channels and on reef inside the lagoon, where food availability seemed more able to support aggregations.

In recent years there have been various reports of trochus being recorded at Funafuti (Ministry of Natural Resources and Development 1997 and FAO 2008), although most of these cursory surveys located few trochus. The present PROCFish/C survey work also recorded *T. niloticus* at Funafuti, but this commercial species was still rare (Table 2.14).

Table 2.14: Presence and mean density of mother of pearl species in Funafuti
Based on various assessment techniques; mean density measured in numbers per ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	0.2	0.2	1/14 = 7	1/83 = 1
RBt	0	0	0/18 = 0	0/108 = 0
RFs	0.4	0.4	1/9 = 11	1/54 = 2
MOPs	0	0	0/5 = 0	0/30 = 0
Tectus pyramis				
B-S	3.6	1.1	9/14 = 64	13/83 = 16
RBt	60.2	16.9	11/18 = 61	21/108 = 19
RFs	3.1	1.1	4/9 = 44	7/54 = 13
MOPs	0	0	0/5 = 0	0/30 = 0

B-S = broad-scale; RBt = reef-benthos transect; RFs = reef-front search; MOPs = mother-of-pearl search.

Although trochus release sites and 'other' exposed reef areas (offshore reef slopes, reef flats and lagoon reef) were surveyed at Funafuti (Figure 2.26), no trochus were recorded at these locations. The two live trochus that were found both came from more sheltered areas; one within an offshore reef embayment, and the other from back-reef inside the lagoon. The mean size (basal width) of these trochus was 12.1 ±0.05 cm.

The green topshell (*Tectus pyramis*), a related but less valuable species with a similar life history to trochus, was also more predominant in sheltered areas (reefs inside the lagoon; see Table 2.14.). Despite the small number of recordings in reef-benthos stations (n = 33 individuals), the density of *T. pyramis* in the MCA was higher than the density on un-protected reefs (97.2 per ha ±26.9 versus 26.0 per ha ±13.5). The mean size (basal width) of *T. pyramis* was 6.1 ±0.2 cm (n = 26). Appendix 4.1.8 reviews all size recordings.

The blacklip pearl oyster, *Pinctada margaritifera,* a normally cryptic and sparsely distributed pearl oyster species, was not recorded during assessments at Funafuti atoll.

2.4.3 Infaunal species and groups: Funafuti

The soft benthos of the shallow-water lagoon was sandy without seagrass or muddy areas, and did not hold beds of in-ground shell resource species, such as arc shells (*Anadara* spp.) or venus shells (*Gafrarium* spp.). There was mention of fishing for *Asaphis violascens*, but this species is found amongst stone and rock, which does not facilitate quadrat surveys. The strawberry conch, *Strombus luhuanus*, is an important soft-benthos species, but aggregations of this species are visible on the surface of the substrate, and can be recorded in broad-scale surveys. No fine-scale assessments of soft benthos or infaunal stations (quadrat surveys) were made at Funafuti.

2.4.4 Other gastropods and bivalves: Funafuti

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs) was detected in broad-scale (64% of stations) and reef-benthos (44% of stations) surveys at reasonable density. However, anecdotal reports from divers suggest much higher densities were present in the recent past. The strawberry conch *Strombus luhuanus* was common throughout the lagoon, and was recorded in broad-scale (21% of stations) and reef-benthos surveys (17% of stations; see Appendices 4.1.1 to 4.1.7.). Turban shells, such as *Turbo* *argyrostomus*, were recorded at reef-benthos stations at low-to-medium density, and *Turbo setosus* were rare in reef-front searches. Other species targeted by fishers (resource species, e.g. *Cerithium, Chicoreus, Conus, Cypraea, Tectus* and *Thais*) were also recorded during independent surveys (Appendices 4.1.1 to 4.1.7). Data on other bivalves, such as *Chama* and *Spondylus* recorded in broad-scale and fine-scale benthos surveys, are also in Appendices 4.1.1 to 4.1.7.

No creel survey was conducted at Funafuti atoll, although fishers were seen collecting small cowries (*Cypraea annulus*) within shoreline boulder fields at the south of the lagoon. These cowries are collected for handicrafts.

2.4.5 Lobsters: Funafuti

There was no dedicated night reef-front search for lobsters (See Methods and Appendix 1.3.). No *Panulirus* or *Parribacus* lobsters were recorded on reef-benthos stations or during night searches (Ns) for nocturnal sea cucumber species. However, burrows of the sand lobster *Lysiosquillina* spp. (also known as 'banded prawn killer'), were recorded in one broad-scale transect.

2.4.6 Sea cucumbers[5]: Funafuti

Funafuti atoll has a relatively small land mass (33 islets together make up 2.4 km^2) and an extensive lagoon (18 km long). No rivers are present and allochthonous input (riverine or other inputs from land) were limited. The reef system near Funafuti's main settlement presented the one exception, and in this area reef was overgrown with epiphytes in localised areas. General sea cucumber habitats in the form of reef margins and shallow, mixed hard- and soft-benthos habitat were extensive in the lagoon and outside the barrier reef (47 km^2 and 18 km^2 respectively). Throughout the lagoon, water movement was dynamic, and there was a high degree of exposure.

Sea cucumbers at all sites in Tuvalu reflected the oceanic nature of the environment, which impacted heavily on the potential densities of these deposit feeders (which eat organic matter in the upper few mm of bottom substrates). Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.15; Appendices 4.1.1 to 4.1.8, also see Methods and Appendix 1.3.). Despite the lack of significant nutrient inputs into the lagoon, ten commercial species of sea cucumber were recorded during in-water assessments (Table 2.15), the highest for all PROCFish/C sites in Tuvalu.

Species associated with shallow reef, such as leopardfish (*Bohadschia argus*) and the high-value black teatfish (*Holothuria nobilis*) were present but not common (found in 5–16% of broad-scale transects, similar rates to Nukufetau, the other lagoon PROCFish/C site in Tuvalu).

Surf redfish *Actinopyga mauritiana* were recorded at a few locations, but again no high densities were recorded. The overall occurrence and densities for this species were unexpectedly low considering the nature and extent of the reef and surge zone present.

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[5] 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.

In the lagoon, more protected areas of reef and soft benthos held some blackfish (*Actinopyga miliaris*), plus a few lower-value species, e.g. brown sandfish (*Bohadschia vitiensis*), elephant trunkfish (*Holothuria fuscopunctata*) and lollyfish (*Holothuria atra*). The occurrence and density of all these species was low.

Deep dives on SCUBA (25–35 m) were conducted to obtain a preliminary assessment of deep-water stocks, such as the high-value white teatfish (*Holothuria fuscogilva*) and the lower-value amberfish (*Thelenota anax*). In these assessments (average 27.6 m depth), white teatfish (*Holothuria fuscogilva*) were present at moderate to high densities, while prickly redfish (*Thelenota ananas*) and amberfish (*Thelenota anax*) were present, but at lower densities. Of the five 'day search' stations, white teatfish were common in three passages, although absent from another suitable passage location. Prickly redfish (*T. ananas*) and amberfish (*T. anax*) were also recorded in broad-scale assessments in shallow water.

As there is pressure to develop a sea cucumber fishery in Tuvalu, an extra warning is presented here, to be very cautious. Although there does look to be some potential for harvest of these valuable but fragile deeper-water stocks, the history of white teatfish harvesting across the Pacific, even from island systems with far greater capacity than is found in Funafuti (more extensive lagoon and reef systems), teaches that rapid development of this fishery is high in risk, as is shown below.

1. In Solomon Islands, the take of high-value sea cucumber stocks fell by 99% between 2000 and 2003. This 400 t annual fishery (all species) subsequently collapsed completely and was closed in December 2005.
2. In Tonga white teatfish harvesting 'boomed' and then collapsed in the early to mid 1990s. The fishery is still under a moratorium.
3. In Papua New Guinea, the take fluctuated between 9–74 t annually (white teatfish only). The latest figures show a decline from a 2002 high of 4.4 t.

The previous examples reveal the fragility of white teatfish fisheries in other Pacific Island situations. In comparison, the potential fishery for Funafuti atoll is very small in scale (See PROCFish/C advice sent to the Tuvalu Fisheries Department in August 2006.).

Habitat descriptors for independent assessments can be found at Appendix 4.1.9.

Table 2.15: Sea cucumber species records for Funafuti

Species	Common name	Commercial value [5]	B-S transects n = 83			Reef-benthos stations n = 18			Other stations MOPs = 5; RFs = 9			Other stations Ds = 5; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H							16.7 2.6	20.8 7.8	80 MOPs 33 RFs			
Actinopyga miliaris	Blackfish	M/H	1.0	16.7	6							0.5 4.4	2.4 8.9	20 Ds 50 Ns
Bohadschia argus	Leopardfish	M	4.0	25.6	16							26.7	26.7	100 Ns
Bohadschia vitiensis	Brown sandfish	L	0.4	33.3	1									
Holothuria atra	Lollyfish	L	10.6	147.2	7									
Holothuria fuscogilva [4]	White teatfish	H										23.8	39.7	60 Ds
Holothuria fuscopunctata	Elephant trunkfish	M	2.0	23.8	8							0.5 35.6	2.4 35.6	20 Ds 100 Ns
Holothuria nobilis [4]	Black teatfish	H	1.2	24.9	5									
Thelenota ananas	Prickly redfish	H	3.4	25.7	13							5.7	7.1	80 Ds
Thelenota anax	Amberfish	M	7.0	44.9	16							8.6 4.4	8.6 8.9	100 Ds 50 Ns

[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; MOPs = mother-of-pearl search; RFs = reef-front search; Ds = day search; Ns = night search.

2.4.7 Other echinoderms: Funafuti

No edible slate urchins, *Heterocentrotus mammillatus* or collector urchins, *Tripneustes gratilla* were recorded during the survey. *Echinometra mathaei* and *Echinothrix diadema* were relatively uncommon (recorded at only 33% of reef-benthos stations at moderate density, 370 per ha ±157).

Starfish (e.g. *Linckia laevigata*, the blue starfish) were absent from assessments, and corallivore (coral eating) starfish were rare. The cushion star *Culcita novaeguineae* was present on 13% of broad-scale transects, while the crown of thorns star *Acanthaster planci* was not recorded in Funafuti atoll (See presence and density estimates in Appendices 4.1.1 to 4.1.7.).

2.4.8 Discussion and conclusions: invertebrate resources in Funafuti

- Giant clams were not consistently recorded across Funafuti Atoll. Both *T. maxima* and *T. squamosa* giant clams were absent near the populated areas of Funafuti (However, *T. derasa* was found in the protected holding area.). There was no obvious environmental reason for the absence of clams in this area, although waste metal, plastics, cloth and fishing gear were common on these reefs, and water circulation was less vigorous.

- The low densities and skewed size ranges for giant clams within Funafuti atoll suggest that stocks are heavily impacted by fishing. Reproductive success and therefore subsequent recruitment is likely to be impaired at these levels, and giant clam stocks at these low densities are likely to decline further unless action is taken to further protect clams. The present aggregations of clam within the MCA are the best source of broodstock for recovery of these stocks and this area needs greater protection from fishing. In addition, some of the introduced *T. derasa* should be moved to a more suitable habitat (of greater water flow and oceanic influence) within the lagoon. These locations also need to be secured from fishing.

- The data on trochus distribution and shell size suggest that trochus at Funafuti have not become well established following their translocation from Fiji and Cook Islands. It is possible that some early spawning and recruitment was successful, as the shells recorded in this survey were remote from release sites and were not old, thickened shell (which might be expected if they were part of the transplanted stock). Despite the low densities of trochus recorded, there were anecdotal reports that the legislation in place to protect trochus was not well known at the time when the translocation occurred, and some of the initial stock was fished in the weeks following release (Satalaka Petaia, NAFICOT General Manager, pers. comm.). In addition, the release methods were not staged, and mass releases of unprotected and stressed stock may have resulted in large, early losses.

- On a more promising note, it is good to see that trochus may have spawned and established secondary generations in Funafuti. The abundance of adult and juvenile stock of the related topshell, *Tectus pyramis*, was moderate, indicating that there was some habitat for grazing gastropods, and that recruitment in this dynamic lagoon was occurring. It is suggested that, if any future releases of trochus are made, careful consideration is given to initially placing trochus on reefs within the lagoon. In these locations, water movement is still dynamic, crustose coralline algae cover is high, but epiphytic growth (and potential food sources for trochus) is more developed. A more staged release would also be advised, with shells initially being protected from predators after initial release, until they acclimatise to the local conditions.

- In summary, commercial MOP, such as *Trochus niloticus*, survived in the lagoon following translocation, but were still rare and considered impacted by fishing. Trochus are not endemic to Tuvalu and, although habitats looked suitable, much of the lagoon reefs were nutrient poor. This does not suggest a very promising potential for developing a trochus fishery. In addition, *P. margaritifera* populations were degraded and commercially extinct[6].

- The limited range and density of sea cucumbers recorded in this survey predominantly reflect the oceanic environment found at Funafuti. Prior to this survey the export fishery for sea cucumbers had been closed in Tuvalu for six years, after a rapid depletion of stock, and accidents which claimed the life of a diver in 1999. Based on the information collected on sea cucumber stocks, there was a limited number of species available for commercial fishing, and stock densities were generally low. The presence of high-value white teatfish and prickly redfish were of interest for commercialisation, but this preliminary survey suggests stocks were limited. Further work will need to be completed to assess what level of commercial fishing can be allowed, and to devise a management plan around such results.

2.5 Overall recommendations for Funafuti

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomics, finfish and invertebrates), the following recommendations are made for Funafuti atoll:

- The Tuvalu Fisheries Department work with the local *Falekaupule* and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur, as there are signs of this starting to occur with finfish, given the low biomass and small fish size of the main target species.

- A swift transition from reef fishing to oceanic and deep-bottom fishing be encouraged, coupled with the use of multi-fishing methods to target a variety of species during any one fishing trip. This would relieve fishing pressure on reef finfish resources, which is likely to continue to gain momentum into the future along with the increase of semi-commercial fishing operations.

- The Tuvalu Fisheries Department work with the local *Falekaupule* and *Kaupule* to develop management plans or arrangements for the inshore resources of Funafuti Atoll to ensure the sustainable harvest of all marine resources, now and in the future.

- The management of the marine conservation area (MCA) at Funafuti be strengthened, possibly with assistance from the local *Falekaupule* and *Kaupule*, to ensure that no fishing occurs within its boundaries, as this area holds good potential for retaining broodstock of important invertebrate species, such as giant clams and trochus.

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

- The Tuvalu Fisheries Department move some of the introduced giant clams *Tridacna derasa* from their current location to a more suitable habitat within the lagoon, in areas far from the Fisheries Department's wharf, if the clams can be protected from fishing.

- If a further movement of trochus to Funafuti is undertaken, that firstly transplants be put on reefs inside the lagoon (possibly near the west passages) to enable them to get established. Translocated adults need protection from predators when they are released onto reefs, and need to remain protected until they have become acclimatised to local conditions (that is, a staged release is recommended).

- The Tuvalu Fisheries Department be very cautious with any endeavour to open the sea cucumber fishery on Funafuti for white teatfish and prickly redfish, as stocks are limited. Further work is needed to assess what level of harvest can be allowed. This should all be done through a management plan for this fishery, under the control of the local *Falekaupule* and *Kaupule*.

3. PROFILE AND RESULTS FOR NUKUFETAU

3.1 Site characteristics

Nukufetau (Figure 3.1) is the second biggest atoll of Tuvalu. It is situated about 120 km northwest of Funafuti, almost in the middle of the country. Nukufetau ranks second to Funafuti in terms of reef and lagoon areas. The only form of transportation between Nukufetau and other atolls and islands is by passenger or cargo ships. There are at least 2–3 visits by these ships each month. Nukufetau consists of 37 *motu* (islets) with a total land area of 2.99 km^2. The local population (~590) resides on the main islet of Savave. Most of the islanders own a motor boat to travel to the other *motu*, which takes about 15–30 minutes.

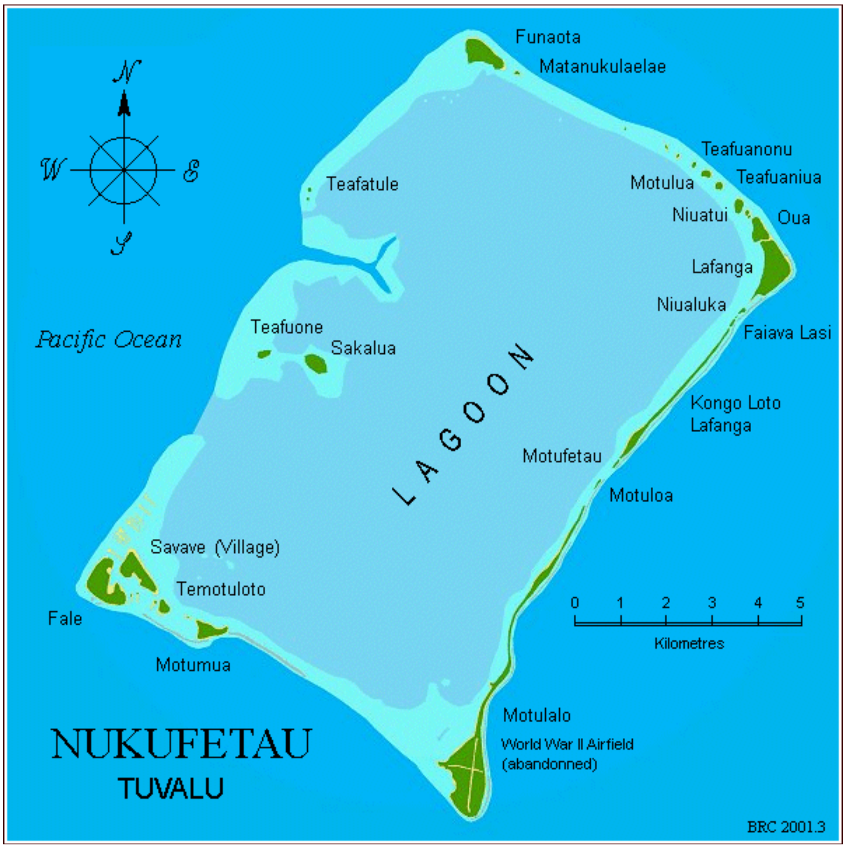

Figure 3.1: The islets that make up Nukufetau.

Most of the reefs in Nukufetau concentrate around the outer and coastal fringing reefs, with a relatively small lagoon reef area. The total atoll has an area of 116.5 km^2, of which 22% is reef platform and 78% the enclosed lagoon. The bulk of the reef platform (85%) consists of bare reef flat; vegetated islands and adjacent beaches account for the remainder (McLean and Hosking 1991). There are a few stands of mangrove, which are only found in certain coastal areas of the *motu.* The lagoon has two surface channels (*Te Ava Amua* and *Te Ava Lasi*) from the open sea and fills and drains across the reef flat and through subterranean passages. *Te Ava Amua* is the deepest channel and is also very narrow. Only canoes and powered boats can move through both channels, while only *Te Ava Lasi* channel is commonly used by big boats to enter the lagoon. It is also possible to access the lagoon via other parts of the barrier reef during high tides and good sea conditions.

The main sources of income on the island include remittances, fishing, shell handicrafts, employment in the village council (*Kaupule*), and other small businesses, e.g. those selling ice blocks, bread, rolled tobacco, etc. Common fishing practices in the lagoon include handlining and gillnetting, whereas spearfishing and gillnetting are used at the coastal and shallow outer reefs. Semi-commercial trolling for tuna is prevalent especially behind Fale islet. Invertebrates are collected off the reef during the day or night, targeting lobsters, and cowry shells for handicrafts. Handicrafts are sold locally or sent to middlemen in Funafuti.

The by-laws that exist in Nukufetau include restrictions on gillnet mesh sizes and on indiscriminate harvesting of giant clams and sea cucumbers. Also, all other fishing gear restrictions and other prohibitive measures endorsed by the Fisheries Department are observed on the atoll. During the time of surveys on Nukufetau, community leaders were in the process of finalising plans for creating a marine protected area (MPA), with restrictions extended to both sea and land resources within demarcated boundaries. Results of the socioeconomic and resource studies would serve as baseline data in assessing the success of such an MPA. There was no fishers' association on Nukufetau during the time of surveys. However, small community groups, such as youth groups, males' groups, and females' groups, were present on the atoll, with specific roles and functions within the community. For instance, the females' groups are organised and well set up and focus on trading ornamental shells, among other activities.

3.2 Socioeconomic surveys: Nukufetau

PROCFish/C socioeconomic fieldwork on Nukufetau covered the two villages of Aulotu and Maneapa. In total 28 households were interviewed, covering 164 people. Thus, the survey covered about 24% of the island's households (total number of households 118) and 24% of the total population (~690 people).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 34 individual interviews of finfish fishers (30 males, 4 females) and 19 invertebrate fishers (13 males, 6 females) were conducted. These fishers belonged to one of the 28 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

3.2.1 The role of fisheries in the Nukufetau community: fishery demographics, income and seafood consumption patterns

The survey results suggested an average of two fishers per household. When this average was applied to the total number of households, we arrived at a total of 237 fishers on Nukufetau. Applying our household survey data concerning the type of fisher (finfish fishers, invertebrate fishers) by gender, we projected a total of 55 fishers who only fished for finfish (males), a total of 30 fishers who only fished for invertebrates (females) and 152 (114 males, 38 females) fishers who fished for both finfish and invertebrates (Table 3.1).

While about 70% of all households in both villages owned a boat, Aulotu had a slightly higher percentage of households with motorised boats (83%) than Maneapa (73%).

Data from Figure 3.2 suggested that salaries were the most important source of income for about 60% of all households. Other sources, such as handicrafts and selling ice blocks, provided more households (18%) with first income than fisheries (11%). However, fisheries represented a second and complementary source of income for about half of all households on Nukufetau (Table 3.1; Figure 3.2). Reported data from survey respondents supported this observation. Most of the finfish catch on Nukufetau served subsistence needs but more than half of all invertebrate catches were for sale.

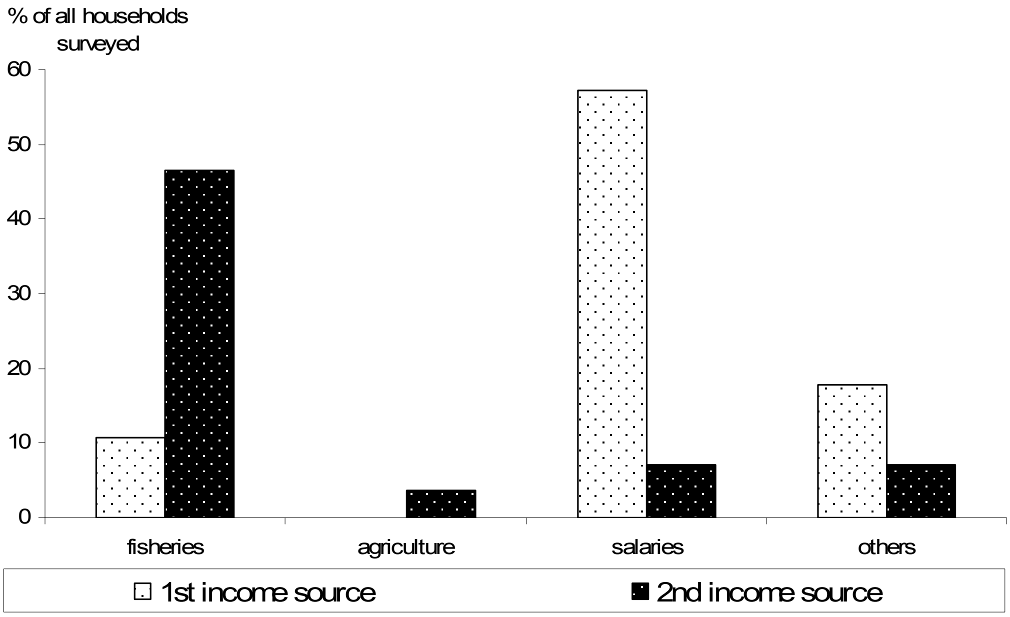

Figure 3.2: Ranked sources of income (%) in Nukufetau.
Total number of households = 28 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

Table 3.1: Fishery demography, income and seafood consumption patterns in Nukufetau

Survey coverage	Nukufetau (n = 28 HH)	Average across sites (n = 113 HH)
Demography		
HH involved in reef fisheries (%)	100	100
Number of fishers per HH	2.0 (±0.19)	2.0 (±0.13)
Male finfish fishers per HH (%)	23.2	38.3
Female finfish fishers per HH (%)	0	0.4
Male invertebrate fishers per HH (%)	0	0
Female invertebrate fishers per HH (%)	12.5	14.1
Male finfish and invertebrate fishers per HH (%)	48.2	41.0
Female finfish and invertebrate fishers per HH (%)	16.1	6.2
Income		
HH with fisheries as 1st income (%)	11	24
HH with fisheries as 2nd income (%)	46	25
HH with agriculture as 1st income (%)	0	25
HH with agriculture as 2nd income (%)	4	1
HH with salary as 1st income (%)	57	52
HH with salary as 2nd income (%)	7	11
HH with other source as 1st income (%)	18	20
HH with other source as 2nd income (%)	7	14
Expenditure (USD/year/HH)	1421 (±93.42)	2102 (±155)
Remittance (USD/year/HH) (1)	1660 (±281.43)	1940 (±173.5)
Seafood consumption		
Quantity fresh fish consumed (kg/capita/year)	185.3 (±9.3)	151.0 (6.30)
Frequency fresh fish consumed (times/week)	6.7 (±0.1)	6.1 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	n/a	n/a
Frequency fresh invertebrate consumed (times/week)	0.2 (±0.1)	0.4 (±0.07)
Quantity canned fish consumed (kg/capita/year)	1.5 (±0.5)	2.2 (±0.36)
Frequency canned fish consumed (times/week)	0.3 (±0.1)	0.5 (±0.07)
HH eat fresh fish (%)	100	99
HH eat invertebrates (%)	43	54
HH eat canned fish (%)	57	66
HH eat fresh fish they catch (%)	100	97
HH eat fresh fish they buy (%)	39	61
HH eat fresh fish they are given (%)	75	62
HH eat fresh invertebrates they catch (%)	43	50
HH eat fresh invertebrates they buy (%)	0	0
HH eat fresh invertebrates they are given (%)	4	11

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

Almost half (46%) of all households interviewed reported receiving remittances. The average amount these households received from external sources (USD 1660 per year) was substantial as it exceeded the average household expenditure (USD 1421 per year).

Average per capita fresh fish consumption (185 kg/year) was high compared to the regional average. It also exceeded the average national consumption figure used here (98.4 kg – Figure 3.3), as well as previous estimates that ranged between 60 kg/year (SPC 1997, cited in Gillett and Lightfoot 2001; page 206) and 146 kg/year (Fisheries Department 1994, cited in Gillett and Lightfoot 2001; page 209). In fact, fresh fish consumption on Nukufetau was the highest among all PROCFish/C sites in Tuvalu. While all respondents reported that they ate fish caught by a member of their household, about 40% of all households also sometimes bought fish (from a neighbour, or at the roadside), and 75% of all households were sometimes given fish as a gift.

The frequency and quantity of per capita consumption of canned fish were very low (0.3 times/week, 1.5 kg/year). Invertebrates were not frequently consumed (on average 0.2 times/week) and only by about 40% of all households, mostly when caught by a household member. Invertebrates were not bought within the Nukufetau community (although they were sold as export to Funafuti) and were rarely received as a gift (4%).

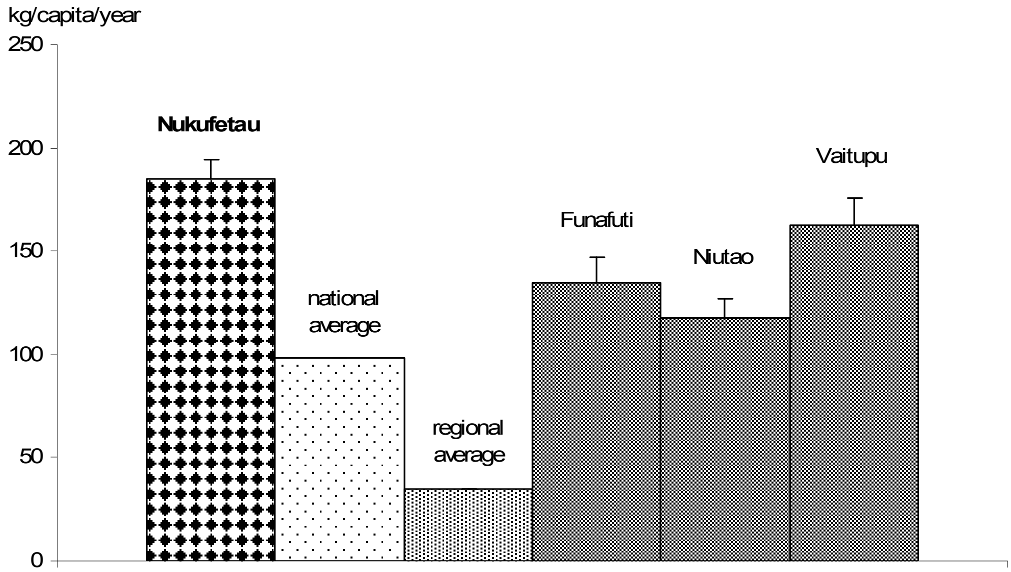

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Nukufetau (n = 28) compared to national and regional averages (Gillett 2002b) and other three PROCFish/C sites in Tuvalu. Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Compared to all PROCFish/C sites in Tuvalu (Table 3.1), Nukufetau was highly dependent on fisheries for subsistence needs. This island had the highest frequency and per capita consumption of finfish, the highest percentage of households who caught the fish they ate and depended on fishing as a complementary, secondary source of income. The importance of fisheries for subsistence also showed in the relatively high average number of fishers per household. Nukufetau scored low in financial dependency on fisheries, i.e. fisheries was the main source of income for very few households. Also people had a low level of household expenditure, and rarely bought fish. Canned fish was not often eaten, nor in large quantities, and neither were invertebrates. Nukufetau's dependency on external finances was relatively high as represented by the high percentage of households that receive remittances. However, the average amount of remittances received was moderate compared to the average across all sites surveyed in Tuvalu.

3.2.2 Fishing strategies and gear: Nukufetau

Degree of specialisation in fishing

Fishing on Nukufetau was dominated by males: ~70% of all fishers. The survey found a difference between male and female fishers; only males fished exclusively for finfish and only females fished exclusively for invertebrates. However, most male fishers, and more than half of all female fishers targeted both finfish and invertebrates (Figure 3.4).

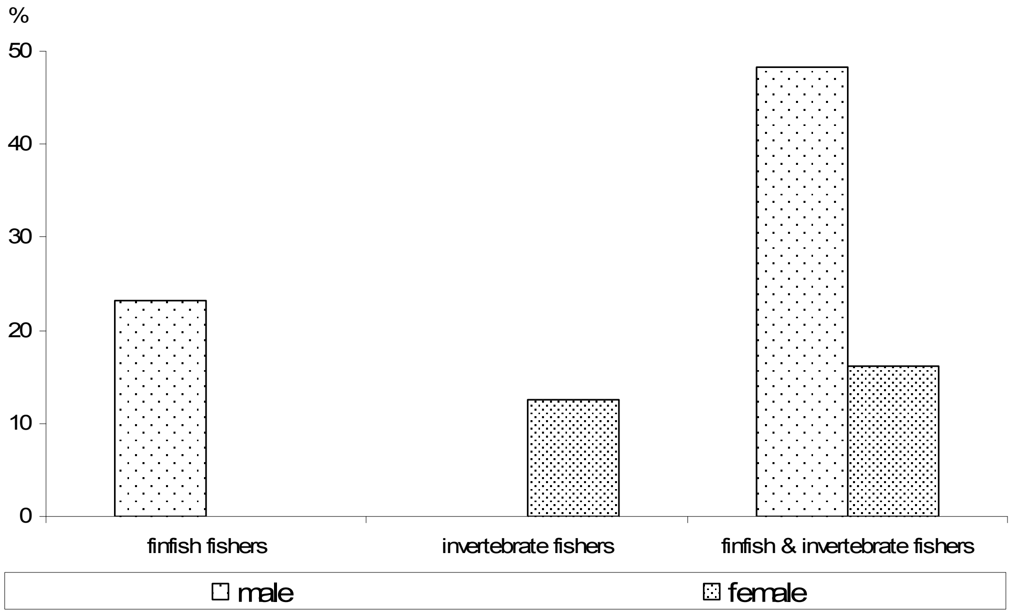

Figure 3.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Nukufetau.
All fishers = 100%.

Targeted stocks/habitats

Fishers on Nukufetau had the choice between three major finfish fishing grounds: sheltered coastal reef, lagoon and outer reef. For invertebrate fisheries the main areas were reef and intertidal habitats (Table 3.2).

Table 3.2: Proportion (%) of interviewed male and female fishers harvesting finfish and invertebrate stocks across a range of habitats (reported catch) in Nukufetau

Resource	Stock	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	60.0	100.0
	Lagoon	50.0	0
	Sheltered coastal reef and outer reef	6.7	0
	Lagoon and outer reef	26.7	0
	Outer reef	20.0	0
Invertebrates	Soft benthos	7.7	0
	Reeftop	76.9	83.3
	Intertidal	15.4	100.0
	Other	61.5	0

'Other' refers to giant clams and *Lambis truncata* fishery.
Finfish fisher interviews, males: n = 30; females: n = 4. Invertebrate fisher interviews, males: n = 13; females: n = 6.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip were the basic factors used to estimate the fishing pressure imposed by people from Nukufetau on their fishing grounds.

The survey sample suggests that most fishers targeted the sheltered coastal reef areas (48%), followed by the lagoon (25%) and the outer reef (10%). Fishers who targeted both the sheltered coastal and outer reef, or both the lagoon and the outer reef represented 4% and 13% of all fishers respectively.

On Nukufetau, most invertebrates were caught by gleaning (~80%, Figure 3.5). Dive fisheries ('other') mainly targeted giant clams and *Lambis truncata*. The reeftop fishery attracted most of the gleaners, followed by the intertidal fisheries. The soft-benthos fishery did not play a major role.

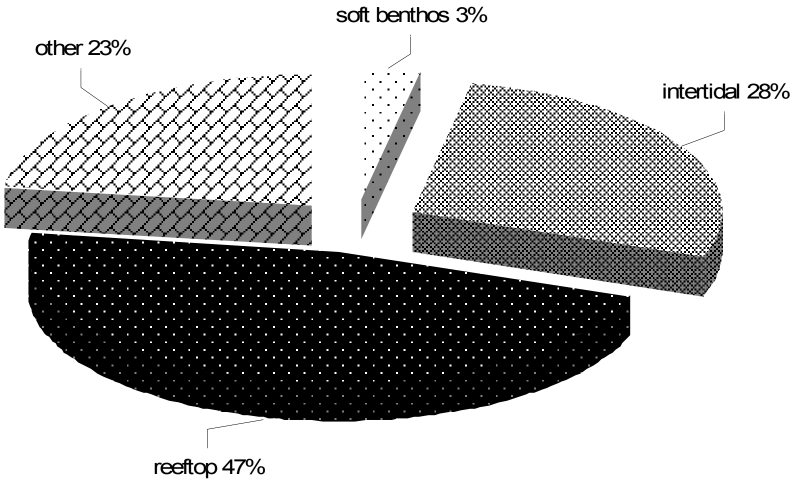

Figure 3.5: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Nukufetau.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to giant clam and *Lambis truncata* fishery.

Regarding gender roles, females dominated the intertidal fishery, and males the dive fisheries (‘other’). In the reeftop fishery, participation was high and the proportion of male and female fishers was similar (Figure 3.6).

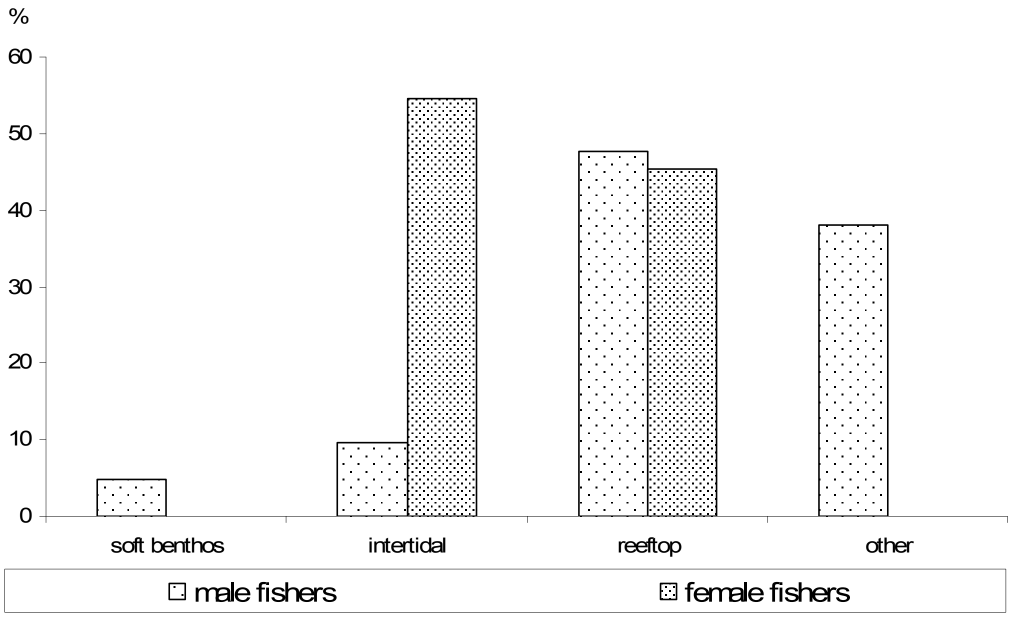

Figure 3.6: Proportion (%) of male and female fishers harvesting invertebrate stocks in Nukufetau.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; figures refer to the proportion of all fishers involved in each fishery: n = 21 for males, n = 11 for females; ‘other’ refers to giant clams and *Lambis truncata* fishery.

Gear

Figure 3.7 shows that, although Nukufetau fishers used a variety of different gears, there were three main techniques. Gillnets were predominantly used in sheltered coastal reef areas, handlines in the lagoon and, to some extent, in the outer reefs, and speardiving at the outer reef. Other techniques of minor importance included the manual collection of fish, lantern fishing, castnetting, rod and line and, at the outer reef, deep-bottom fishing and trolling.

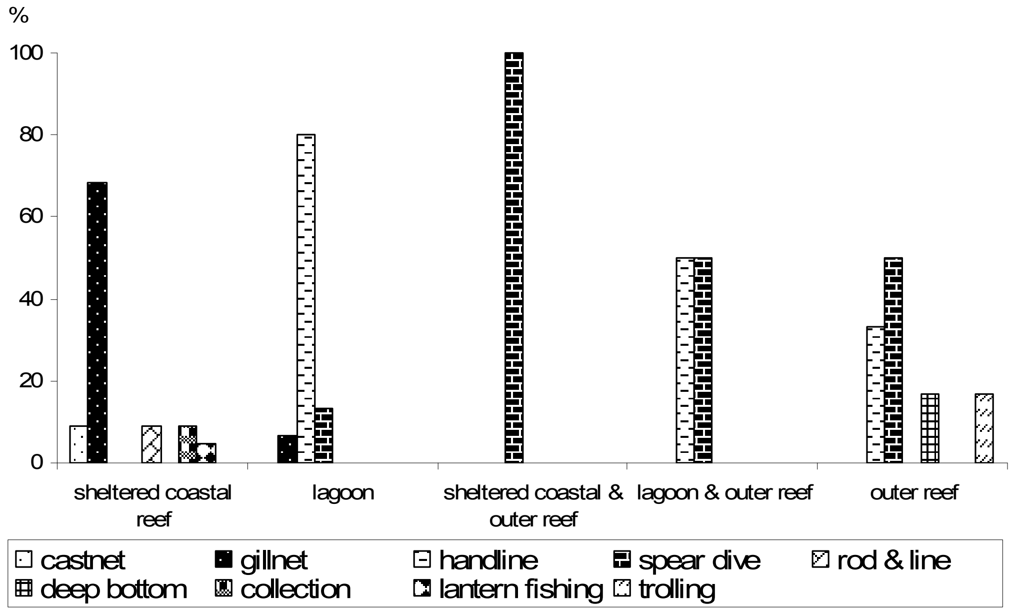

Figure 3.7: Fishing methods commonly used in different habitat types in Nukufetau.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Most fishing on Nukufetau required boat transport. Boats were used for more than two-thirds of all fishing trips to the lagoon and outer reef. However, fishing at the sheltered coastal reef was mainly done by walking, and boats were rarely used (14% of trips). This was also true when sheltered coastal and outer-reef areas were both visited during one trip.

Fishing was performed continuously throughout the year and either during the day or night, i.e. according to the tides. In the case of outer-reef fishing, half of the fishers preferred night fishing and half preferred day fishing. Apart from very rare occasions, no ice was used on any fishing trip.

Gleaning on Nukufetau was done by walking, using simple collection tools. Divers for giant clams and *Lambis truncata* mostly (75%) used motorised boats, while the remainder walked out to dive from the reef. Gleaning and diving were continued throughout the year. Invertebrate fishing was mostly performed during the day, except for reeftop gleaning. About half of all reeftop gleaners preferred fishing during the day, half preferred fishing at night. Intertidal gleaning is rarely done at night (12.5%).

Frequency and duration of fishing trips

As shown in Table 3.3, there were some differences in the frequency of visits to the various habitats. Trips to the lagoon for finfish, and trips to the lagoon and outer reef combined were the most frequent (2.1–2.4 times/week), while trips to the sheltered coastal reef and to the outer reef were slightly less frequent (1.9 and 1.6 times/week, respectively). Due to the small sample size, not too much weight should be given to the fact that trips that combined sheltered coastal and outer reef were the least frequent (once per week). Trips to the lagoon, the lagoon and outer reef combined, and the outer reef all took on average about 5 hours each. Trips to the sheltered coastal reef were considerably shorter with an average of <3 hours/trip.

Table 3.3: Average frequency and duration of fishing trips reported by male and female fishers

Resource	Fishery	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.97 (±0.29)	1.39 (±0.30)	2.75 (±0.30)	3.25 (±0.48)
	Lagoon	2.40 (±0.23)	0	5.20 (±0.61)	0
	Sheltered coastal reef and outer reef	1.00 (±0.00)	0	4.00 (±0.00)	0
	Lagoon and outer reef	2.06 (±0.33)	0	4.94 (±0.63)	0
	Outer reef	1.58 (±0.20)	0	5.00 (±1.32)	0
Invertebrates	Soft benthos	0.23 (n/a)	0	1.00 (n/a)	0
	Reeftop	0.47 (±0.10)	0.58 (±0.07)	3.10 (±0.18)	3.00 (±0.00)
	Intertidal	0.40 (±0.17)	0.65 (±0.16)	2.50 (±0.50)	2.33 (±0.33)
	Other	0.61 (±0.07)	0	2.88 (±0.13)	0

Figures in brackets denote standard error; 'other' refers to giant clams and *Lambis truncata* fishery; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 30; females: n = 4. Invertebrate fisher interviews, males: n = 13; females: n = 6.

Fishing trips for invertebrates were not as frequent as finfish fishing trips. On average, reeftop, intertidal and dive ('others': giant clams, *Lambis truncata*) fisheries were targeted once every two weeks. Soft benthos was targeted only once a month. The duration of each fishing trip varied between 1–3 hours, with soft benthos being the shortest and reeftop gleaning the longest fishing trips.

3.2.3 Catch composition and volume – finfish: Nukufetau

Catches from the sheltered coastal reef were mainly dominated by *Valamugil seheli* (*kanase*, 33%) and *Liza vaigiensis* (*kafakafa*, 17%), together with *Naso unicornis* (*ume*, 37%), Serranidae (*gatala*, 26%) and *Scarus ghobban* (*ulafi*, 27%) if sheltered coastal and outer reefs were combined in one fishing trip. Lagoon catches were reported to mainly consist of *Lutjanus gibbus* (*taea*, 34%) and Serranidae (*gatala*, 19%); if lagoon and outer reef were combined in one fishing trip, *Lethrinus* spp. (*filoa*, 15%) and *Selar crumenophthalmus* (*atule*, 13%) also played a role. *Lutjanus gibbus* (*taea*, 28%), Serranidae (*gatala*, 25%) and *Myripristis violacea* (*malau*, 10%) were mainly caught at the outer reef. More details on the catch composition per habitat fished are provided in Appendix 2.2.1.

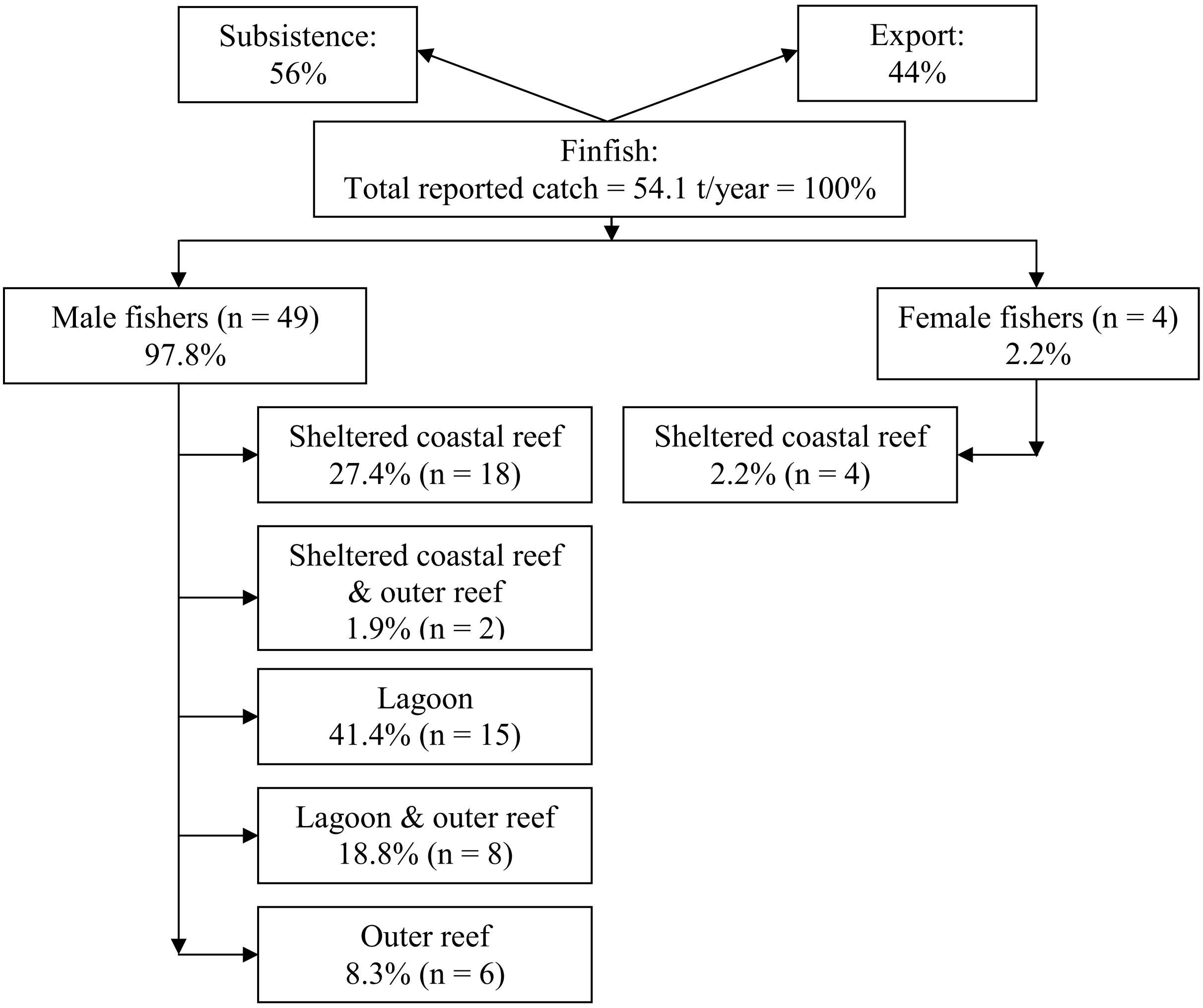

Figure 3.8: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Nukufetau.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The survey sample of finfish fishers interviewed represents about 16% of the projected total number of finfish fishers on Nukufetau. Extrapolation of the survey data must therefore be considered with care. The reported and collected survey data that is summarised in Figure 3.8 showed that most of the reported annual catch came from the lagoon and sheltered coastal areas. Catch from the outer reef accounted for only 8% of the total annual catch. Females' contribution to the annual catch was small.

In order to illustrate the possible total impact of fishing on Nukufetau, the reported survey data is extrapolated to the island's entire population. Accordingly, the total annual catch calculated amounted to 193.1 t/year. Most of the catch, i.e. 83% (160.1 t/year) was consumed by the island's population, and 17% (33 t/year) was caught for export to Funafuti.

The average annual catch data represented in Figure 3.9 show that the highest annual catches were taken by male fishers targeting the lagoon habitat, or the lagoon and outer-reef habitats combined. Gender comparison was restricted to the sheltered coastal reef catches. Female fishers caught far less per year than did males.

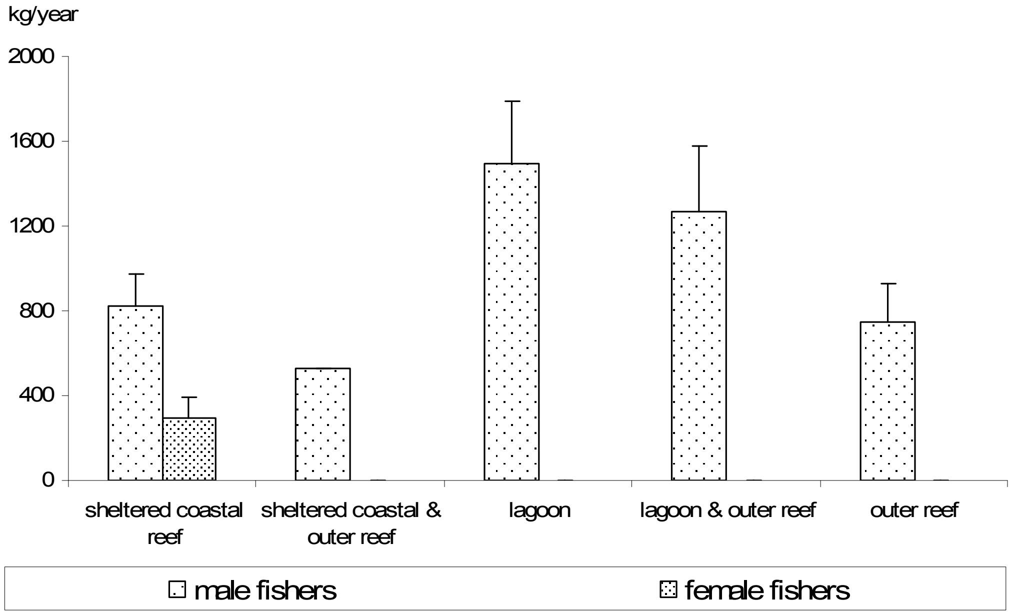

Figure 3.9: Average annual finfish catch (kg/year) per fisher by habitat and gender in Nukufetau.
Bars represent standard error (+SE).

The comparison of the catch per unit effort (CPUE) for males and females suffered from the comparatively small sample size of female fishers. CPUE data for male fishers showed a significant difference only between the much higher values for sheltered coastal reef as compared to all other fishing. The few data entries available for female fishers suggested a considerably lower CPUE for sheltered coastal reef fishing as compared to the CPUE of male fishers (Figure 3.10).

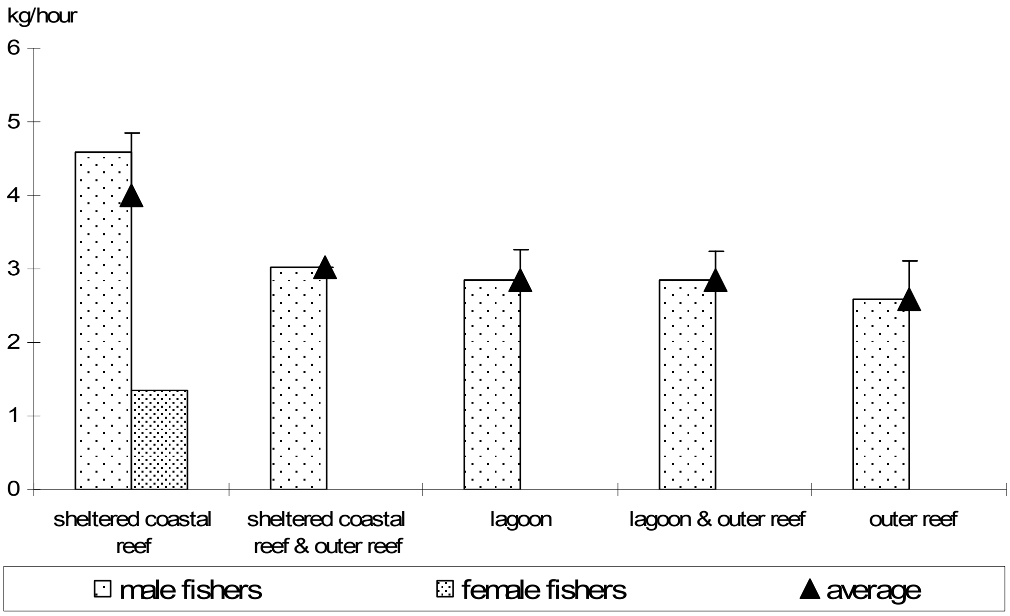

Figure 3.10: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Nukufetau.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Information provided by fishers on the proportion of catch per habitat that is used for subsistence and for sale (export to Funafuti) suggests that the shorter trips to the sheltered coastal reef mainly served subsistence needs (Figure 3.11). Fishing trips targeting the lagoon and the outer reef served both subsistence and commercial interests. Nukufetau fishers continued to catch fish that were given away for free.

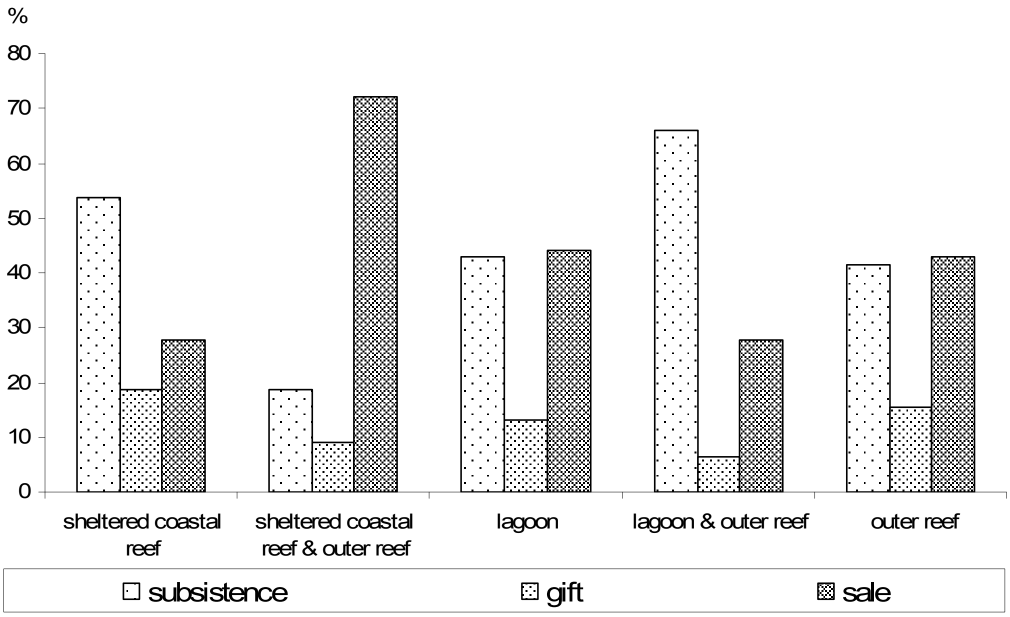

Figure 3.11: The use of finfish catches for subsistence, gift and sale, by habitat in Nukufetau.
Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and by habitat as shown in Figure 3.12 showed that, in most cases, the average size per fish family increased for catches from the sheltered coastal reef to the outer reef (Carangidae, Lethrinidae, Lutjanidae, and Serranidae). There were indications that average fish sizes from catches in the lagoon were larger or comparable to those at the outer reef (Acanthuridae, Holocentridae). Interestingly, Scaridae were not reported for catches at the outer reef, but for sheltered coastal reef fishing.

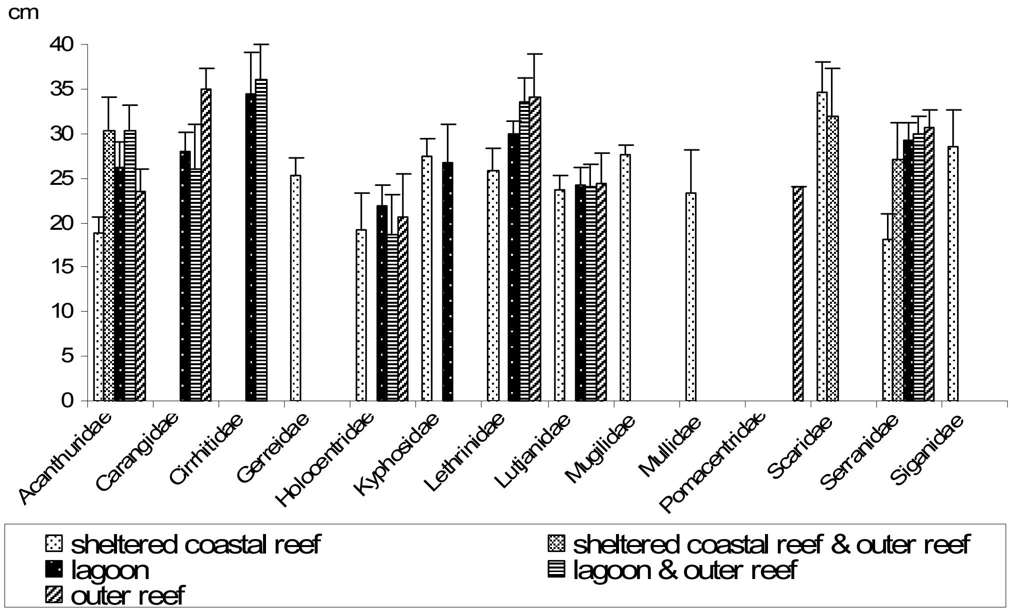

Figure 3.12: Average sizes (cm fork length) of fish caught by family and habitat in Nukufetau. Bars represent standard error (+SE).

The values obtained for selected parameters suggest that the level of finfish fishing pressure on reef resources was low (Table 3.4). On average there were 2–5 fishers/km² of total fishing ground; this density was double in the sheltered coastal reef and decreased to 1 fisher/km² for the lagoon area. The average annual catch per fisher, however, was relatively high if compared to other survey sites in Tuvalu. Highest annual average catches were from the lagoon and the lagoon and outer reef combined. Annual catch rates obtained at the sheltered coastal and the outer reef were similar.

Table 3.4: Parameters used in assessing fishing pressure on finfish resources in Nukufetau

Parameters	Habitat						
	Sheltered coastal reef	Sheltered coastal and outer reef	Lagoon	Lagoon and outer reef	Outer reef	Total reef	Total fishing ground
Fishing ground area (km^2)	10.31		81.02		5.60	38.69	96.93
Density of fishers (number of fishers/km^2 fishing ground) (1)	10		1		4	5	2
Population density (people/km^2) (2)						18	7
Average annual finfish catch (kg/fisher/year) (3)	727.0 (±131.6)	525.3 (±0.0)	1493.1 (±294.4)	1268.4 (±306.3)	744.4 (±182.5)		
Total fishing pressure of subsistence catches (t/km^2)						2.8	1.1

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 691; total number of finfish fishers = 207; total subsistence demand = 108.2 t/year; (3) catch figures are based on recorded data from survey respondents only.

3.2.4 Catch composition and volume – invertebrates: Nukufetau

Calculations of the reported annual catch rates per invertebrate species groups are shown in Figure 3.13. The major catch by wet weight was focused on one species group, i.e. *Cypraea annulus* and *C. moneta*. In addition, but to a much lesser extent, impact also showed on the giant clam species *Tridacna maxima* and *T. squamosa*; the lobster species *Panulirus penicillatus*; the snakehead cowry *Cypraea caputserpensis*; octopus; and *Lambis truncata*. Catches of the other seven reported species or species groups were negligible.

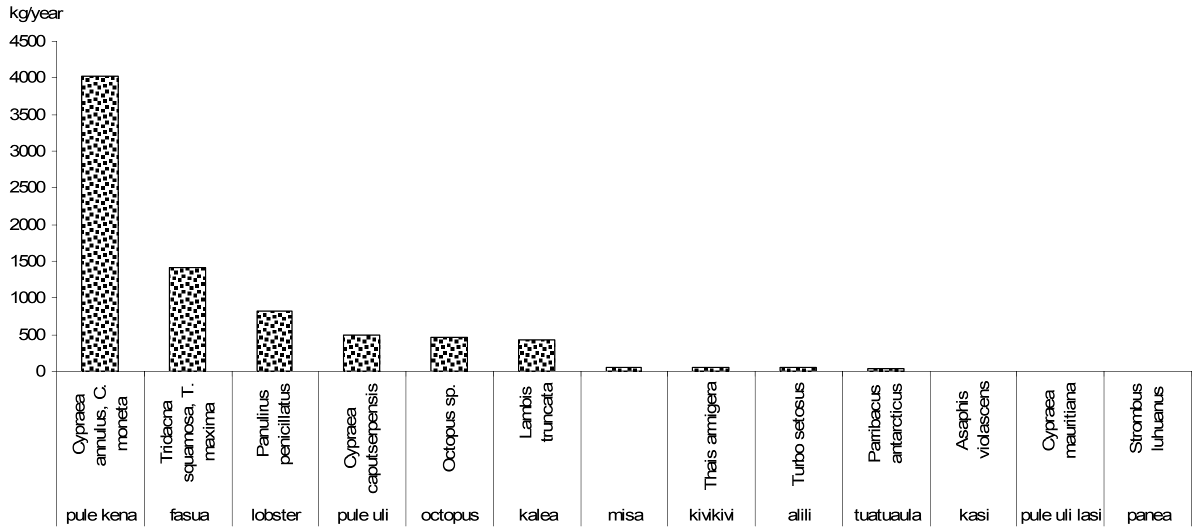

Figure 3.13: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Nukufetau.

Figure 3.14 reveals that the diversity of Nukufetau's invertebrate fisheries was generally low. For most fisheries only 1–4 species were reported. Reeftop gleaning was the exception, with a total of eight target species.

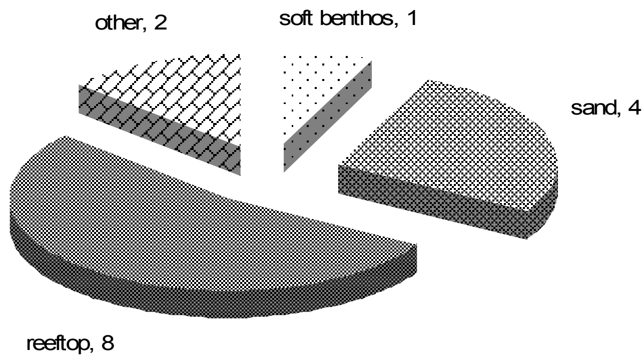

Figure 3.14: Number of vernacular names recorded for each invertebrate fishery in Nukufetau. 'Other' refers to the giant clams and *Lambis truncata* fishery.

Details on the species distribution per habitat and on size distribution by species are provided in Appendices 2.2.2 and 2.2.3 respectively.

Comparison of the annual reported invertebrate catch rates by fisher, gender and fisheries (Figure 3.15) shows that the highest average catches per year were taken by female fishers from the intertidal fisheries. Male fishers' average catches were similar across intertidal and reeftop fisheries and the dive fishery for giant clams and *Lambis truncata*. Average annual catch rates for reeftop gleaning were far higher for male fishers than female fishers.

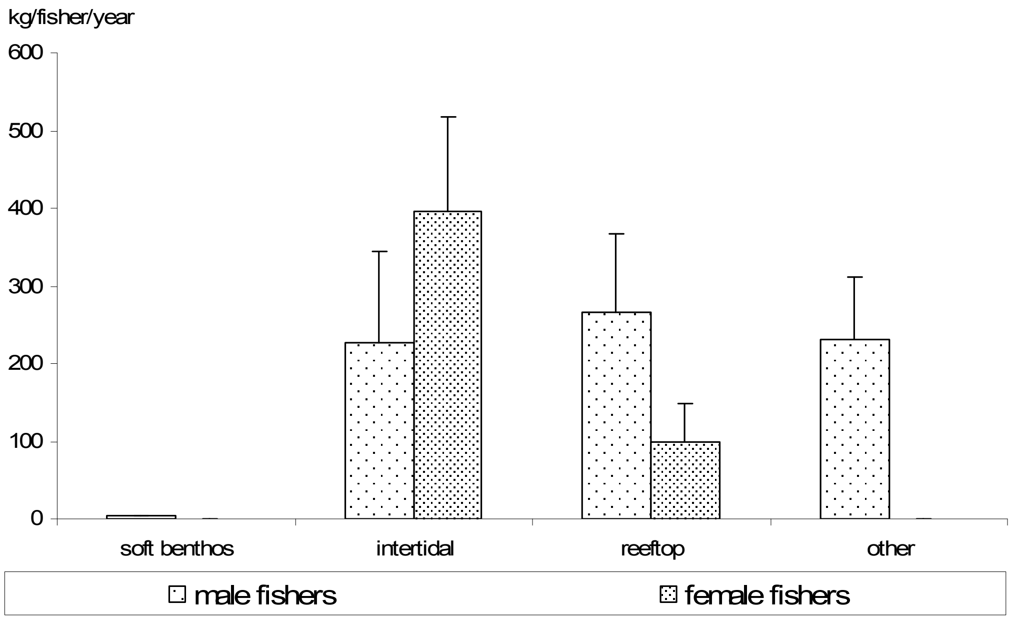

Figure 3.15: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Nukufetau.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 21 for males, n = 9 for females). 'Other' refers to the giant clams and *Lambis truncata* fishery.

The ratio between invertebrates caught for subsistence and sale is shown in Figure 3.16. More than half of all invertebrate fishing was performed for commercial purposes.

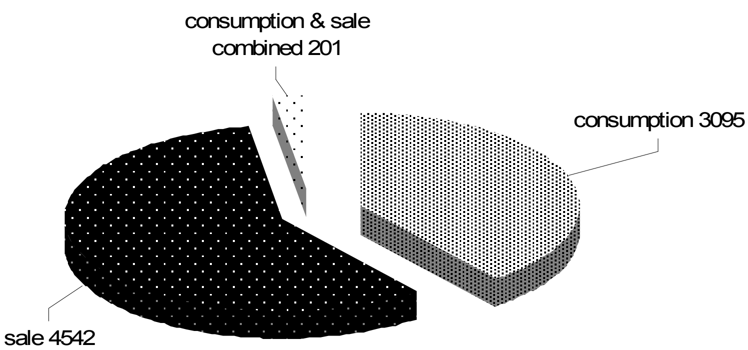

Figure 3.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Nukufetau.

The total annual catch volume expressed in kg wet weight was based on the reported data from all respondents interviewed and amounted to 7.9 t/year (Figure 3.17). Catches from the reeftop and intertidal fisheries accounted for the major share, i.e. 40% and 36% respectively. The proportion taken from the giant clam and *Lambis truncata* dive fishery was also substantial (24%).

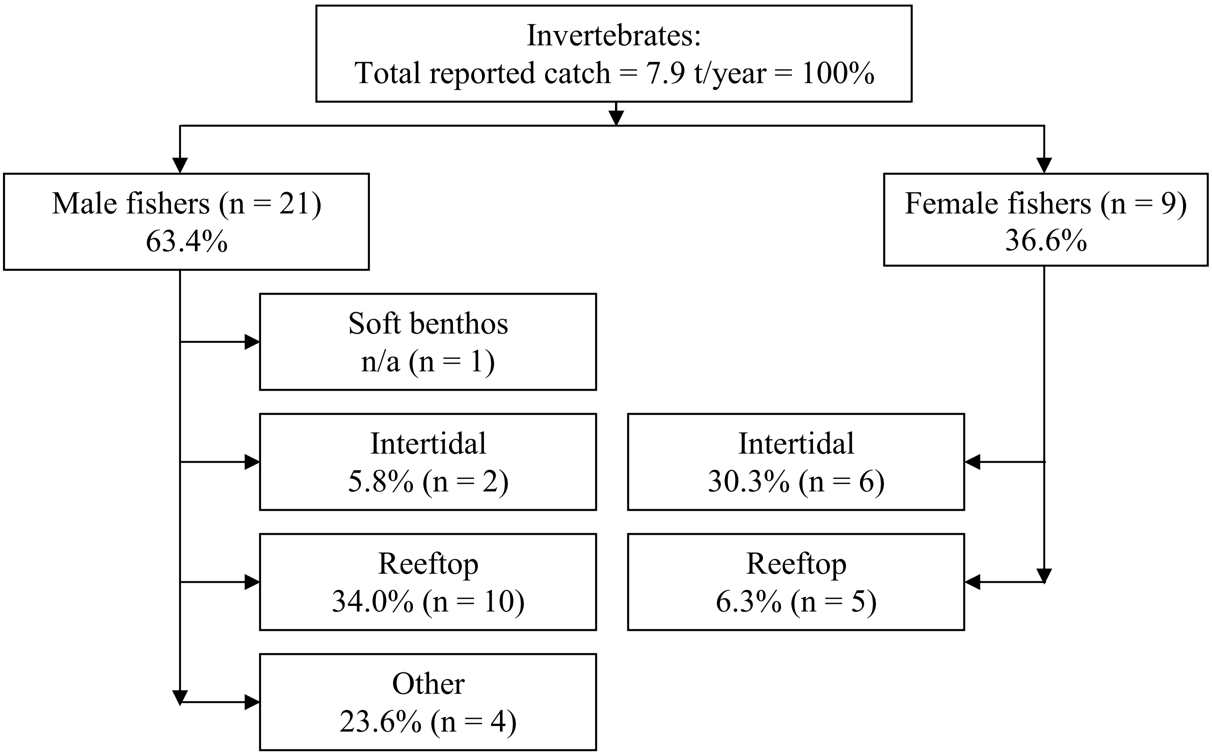

Figure 3.17: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Nukufetau.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to the giant clams and *Lambis truncata* fishery.

Table 3.5: Parameters used in assessing fishing pressure on invertebrate resources in Nukufetau

Parameters	Fishery			
	Soft benthos	Intertidal	Reeftop	Other
Fishing ground area (km^2)	1.02 (3)	2.04 (4)	20.40	12.07
Number of fishers (per fishery) (1)	9	85	144	70
Density of fishers (number of fishers/km^2 fishing ground)	9	42	7	6
Average annual invertebrate catch (kg/fisher/year) (2)	4.58 (n/a)	353.66 (±95.83)	210.59 (±70.57)	230.71 (±79.71)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clams and *Lambis truncata* fishery; (1) total number of fishers is extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only; (3) accessible soft-benthos fishing ground is assumed to represent 5% of the inside and outside lagoon reeftop; (4) accessible intertidal fishing ground is assumed to represent 10% of the inside and outside lagoon reeftop.

Table 3.5 reveals a relatively high fisher density for the intertidal fishery only. Also, the reported average annual catch per fisher was highest for intertidal catches, followed by 'other' (the dive fishery for giant clams and *Lambis truncata*), and reeftop fisheries. Taking into account the small available area for the intertidal fishery, the high fisher density and the average annual catch per fisher, fishing pressure on this resource was considered of possible concern.

3.2.5 Discussion and conclusions: socioeconomics in Nukufetau

- On Nukufetau, fisheries were more important as a food source rather than as a source of income. Fisheries only provided complementary income sources for about half of all households. Accordingly, most households relied on salaries, small businesses and remittances to meet the low-to-moderate average household expenditure level. Catch records suggest that while most finfish were caught for subsistence needs, half of all invertebrate catches were sold.

- The finfish per capita consumption on Nukufetau was the highest across all PROCFish/C sites in Tuvalu (185 kg/year). Finfish was mostly caught by a member of the household, an observation that corresponds well to the relatively high average number of fishers per household. Canned fish consumption was small; invertebrates were not often consumed. Finfish and invertebrate fisheries on Nukufetau were generally dominated by males, with the exception of intertidal gleaning, which was exclusively performed by females.

- Nukufetau offers a range of possible fishing habitats. Overall, finfish fishing pressure was relatively low, but highest for sheltered coastal reef fishing. However, the highest CPUE was also reported for sheltered coastal reef areas; CPUEs for lagoon and outer-reef fishers were similar. The different fishing techniques used may explain some of these differences. The main fishing methods used were: gillnetting at the sheltered coastal reef, handlining in the lagoon, and speardiving together with handlining in the outer reefs. Data on the average finfish sizes caught in the three different habitats suggest that spearfishing, which was mainly used at the outer reef but also in the lagoon, has impacted the Scaridae population as Scaridae were only reported for catches from the sheltered coastal reef.

- Invertebrate fisheries were dominated by gleaning, which generally targeted a very limited number of species. The highest impact in terms of total annual biomass removed (wet weight) was reported for intertidal, 'other' and reeftop fisheries. Annual catches seem to be outstandingly high for the intertidal fishery, which may be a cause for concern regarding the fishing impact on the current and future resource status. In terms of impact on individual species or species groups, the greatest biomass (wet weight/year) was removed by the collection of *Cypraea* spp. Impact was also detected (although significantly less) on giant clams (*Tridacna* spp.), lobster (*Panulirus penicillatus*), octopus, and *Lambis truncata*. Catches of the other seven species were small.

- Data collected for Nukufetau suggest a traditional community with a high dependency on fisheries for subsistence rather than financial income. The conclusion that fisheries on Nukufetau was predominantly subsistence-oriented is supported by the relatively high average number of fishers per household, the low proportion of finfish that is bought for consumption, and the role of fisheries as a complementary second income source only. Even though the invertebrate catch was limited in total value, data also suggest that invertebrates played a significant role for commercial purposes, i.e. half of the reported catch volume was exported to Funafuti. Reasons for the limited role of fisheries for income generation may be related to the resource status and/or reduced marketing options.

3.3 Finfish resource surveys: Nukufetau

Finfish resources and associated habitats were assessed from 24 transects (6 sheltered coastal transects, 3 lagoon-intermediate transects, 9 back-reef transects and 6 outer-reef transects, Figure 3.18) between 27 October and 2 November 2004. Variation in transect stations for each habitat resulted after re-categorising their exact locations into the proper and marked geomorphologic zones after the surveys. For instance, there were only three lagoon patch reefs surveyed, as the other three considered as 'lagoon' transects during the surveys were later re-categorised as 'back-reef' stations. Regardless, lagoon patch reefs only represented a small fraction of all habitats (about 0.1%). Transects were haphazardly placed and randomly distributed throughout all hard diveable habitats (38.7 km^2) found on Nukufetau.

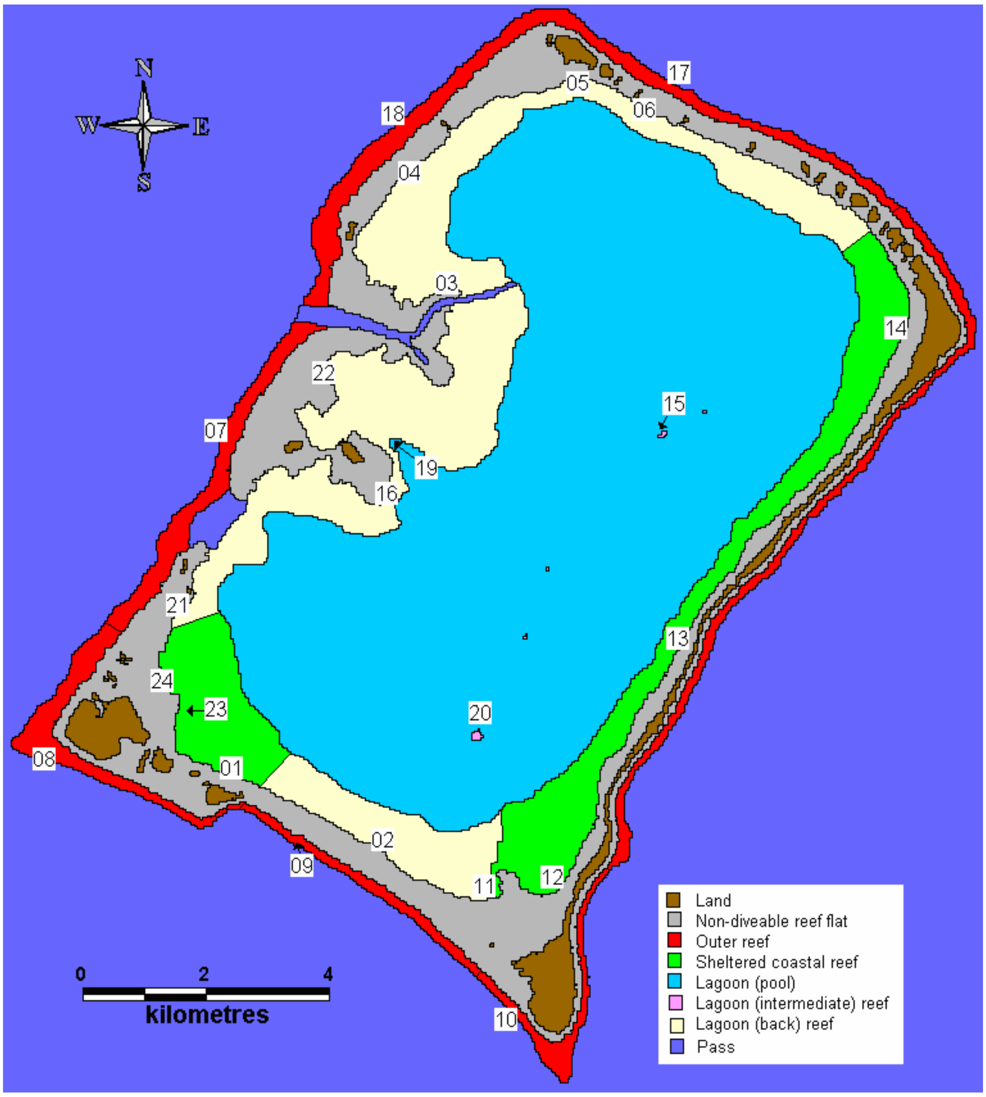

Figure 3.18: Habitat types and transect locations for finfish assessment in Nukufetau.

3.3.1 Finfish assessment results: Nukufetau

A total of 19 families, 54 genera, 154 species and 10,929 fishes were recorded in the 24 transects (Appendix 3.2.1). Data relating to the 14 regionally most dominant families form the basis of this report. These results therefore include information covering 44 genera, 137 species and 9446 individuals.

The Nukufetau reef system spreads across some 38.7 km^2 and consists predominantly of back-reef (18.6 km^2), coastal reef (10.3 km^2) and outer reef (9.7 km^2) with very little lagoon reef (0.1 km^2). Finfish resources differed slightly among the main reef types of Nukufetau (Table 3.6). Biomass increased markedly from coastal reefs to outer reef, while density was lowest at the lagoon habitat, and highest at outer reefs. Size structure also changed irregularly from coastal to outer reef with both size and size ratio largest in the lagoon and lowest at coastal reefs. The coastal-to-outer-reef trend was also reflected in the conditions of the benthic community, with an increase in live coral cover from sheltered coastal reefs (13.5 ±2.7%) towards the outer-reef habitats (33.0 ±3.3%) (Table 3.6).

Table 3.6: Primary finfish habitat and resource parameters recorded in Nukufetau (average values ±SE)

Parameters	Habitat				
	Sheltered coastal reef (1)	Lagoon reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	3	9	6	24
Total habitat area (km^2)	10.3	0.05	18.6	9.7	38.7
Depth (m)	2 (1-5) (3)	8 (1-12) (3)	4 (1-10) (3)	8 (4-14) (3)	5 (1-14) (3)
Soft bottom (% cover)	17.6 ±3.7	13.2 ±7.0	16.4 ±3.0	0	12.6
Rubble & boulders (% cover)	6.8 ±3.5	3.3 ±1.5	12.4 ±7.5	0.7 ±0.3	7.9
Hard bottom (% cover)	62.0 ±4.2	68.3 ±4.0	53.2 ±5.4	66.1 ±3.5	58.8
Live coral (% cover)	13.5 ±2.7	15.2 ±4.5	17.8 ±2.7	33.0 ±3.3	20.5
Soft coral (% cover)	0.08 ±0.08	0	0	0.2 ±0.2	0.07
Biodiversity (species/transect)	28 ±5	44 ±10	41 ±5	41 ±3	38 ±3
Density (fish/m^2)	0.7 ±0.2	0.6 ±0.1	0.7 ±0.1	0.9 ±0.1	0.7
Size (cm FL) (4)	15.1 ±0.6	20.2 ±1.1	18.5 ±0.6	17.8 ±0.7	17.5
Size ratio (%)	42.1 ±1.8	49.2 ±2.6	46.7 ±1.5	49.2 ±1.9	46.1
Biomass (g/m^2)	104.7 ±37.8	175.7 ±74.8	191.4 ±57.3	222.8 ±75.9	176.2

(1) Unweighted average; (2) weighted average that takes into account relative proportion of habitat in the study area; (3) depth range; (4) FL = fork length.

Sheltered coastal reef environment: Nukufetau

The sheltered coastal reef environment of Nukufetau was dominated by both carnivorous and herbivorous fish families, most notably Acanthuridae (density = 0.16 ±0.04 fish/m^2, biomass = 15.2 ±5.6 g/m^2), Lutjanidae, with the highest biomass and high density (density = 0.13 ±0.08 fish/m^2, biomass = 36.1 ±21.7 g/m^2), Lethrinidae (density = 0.10 ±0.02 fish/m^2, biomass = 21.4±6.8 g/m^2) and Scaridae (density = 0.09 ±0.03 fish/m^2, biomass = 20.0 ±6.8 g/m^2, Figure 3.19). The most important species of these dominant families were, in order of decreasing density, *Monotaxis grandoculis, Ctenochaetus striatus, Lutjanus gibbus, L. fulvus*, *Chlorurus sordidus* and *Scarus oviceps* (Table 3.7). The large-sized piscivorous species of Serranidae, Balistidae and Labridae contributed little to the total biomass and density structure of commercial fish counts in coastal habitats. These trends were also reflected in the coastal reefs of the other Tuvalu study sites. The seasonal occurrence of Serranidae may explain their low stocks during the time of surveys. Market-sized groupers are commonly known to aggregate for mating in Nukufetau around June to August every year. Moreover, the close proximity of fishing grounds to the village and the easy access to fishing activities may explain such low abundance of these target families, rather than habitat and environmental factors. *Lutjanus kasmira (savane)* and *Selar crumenophthalmus* (*atule*) are also well known to form aggregations. In particular, *atule* species tend to be disoriented when approaching shores of *motu* in large schools.

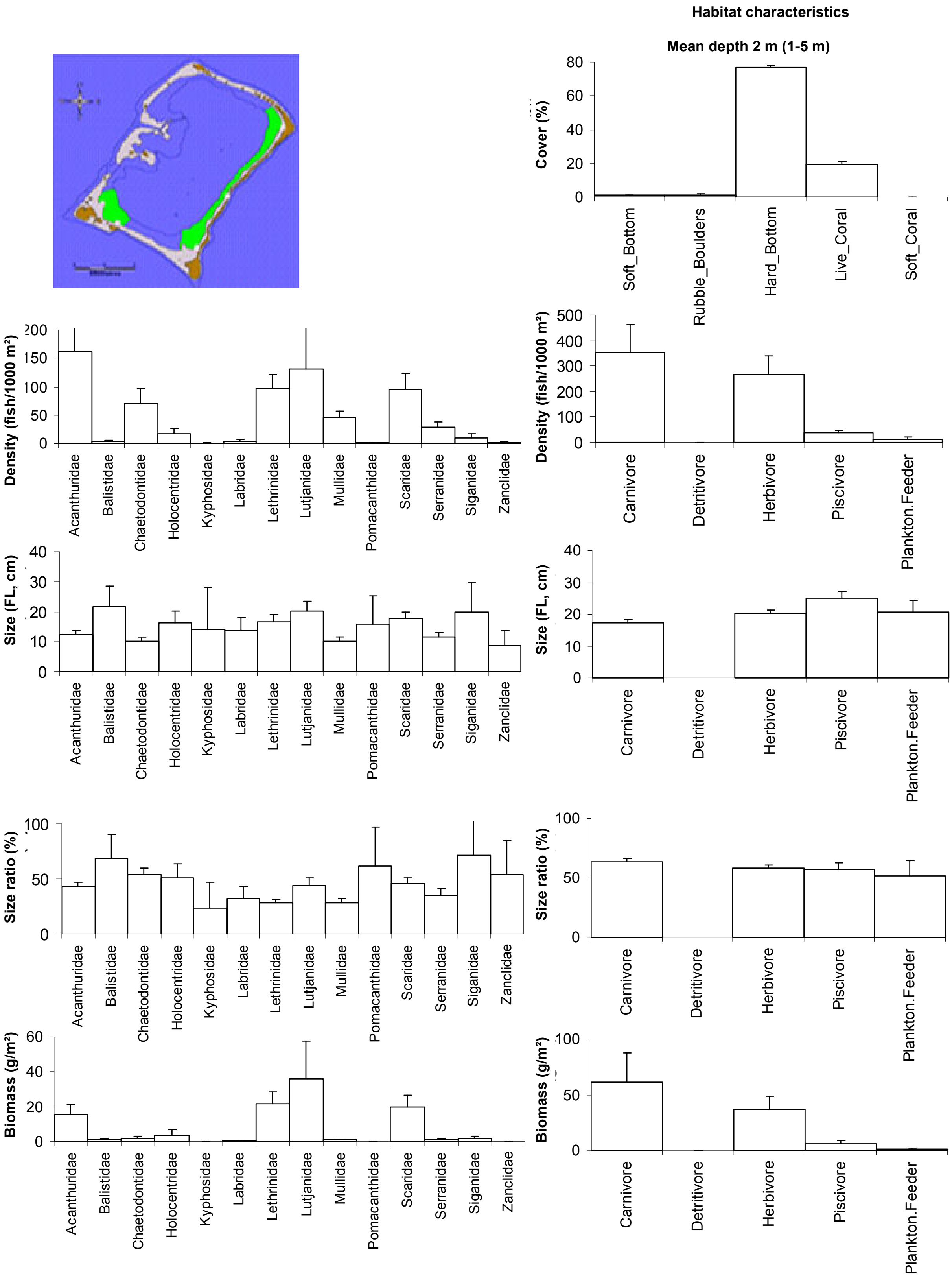

Figure 3.19: Profile of finfish resources in the sheltered coastal reef environment of Nukufetau.
Bars represent standard error (+SE); FL = fork length.

Fish biomass in sheltered coastal reefs was low compared to the other reef habitats. However, fish numbers were higher than in the lagoon reefs and similar to the back-reef. It is possible that this trend relates to fishing pressure, conditions of the reef environment or both. Fish sizes and size ratios were also much smaller than in the other reef habitats, which suggests a negative response to fishing activity.

The finfish survey concentrated on a mean depth of 2 m of mostly hard substrate (62%); at this depth spearfishing and gillnetting are common. Live coral cover was the lowest among all reef habitats and lower also than in Funafuti coastal reefs.

Table 3.7: Finfish species contributing most to main families in terms of densities and biomass in the sheltered coastal reef environment of Nukufetau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big eye bream	0.10 ±0.02	21.3 ±6.8
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.09 ±0.02	3.7 ±1.3
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.07 ±0.06	21.2 ±16.1
	Lutjanus fulvus	Flametail snapper	0.05 ±0.04	10.3 ±9.9
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.04 ±0.02	6.7 ±2.4
	Scarus oviceps	Dark-capped parrotfish	0.02 ±0.01	3.3 ±2.0

Sheltered coastal reefs are only found in Nukufetau and Funafuti. Therefore it is not possible to make comparisons to the other two study sites. Biological parameters of finfish resources in the sheltered coastal reefs of Nukufetau were different to those recorded in Funafuti: biodiversity was much lower in Nukufetau, but density, size, size ratio and biomass were higher. Density and biomass distribution among the trophic guilds also differed between the two sites: the trophic composition was dominated by carnivores in Nukufetau, while herbivores dominated both density and biomass structure in Funafuti. Estimated density and biomass of Acanthuridae, Lutjanidae and Lethrinidae were considerably higher on Nukufetau. Variation in fishing pressure between these study sites may best explain this trend.

Survey work focused predominantly on hard-bottom habitats. Live-coral cover in Nukufetau coastal reef was the lowest compared to the other habitats. Similar to back-reef habitats, soft-bottom cover was >15%, a substantial quantity relative to other habitats. The live-coral cover and hard-bottom cover were less in Nukufetau than Funafuti coastal reefs (Table 3.6, Figure 3.19). These differences in substrate may partially explain the lower abundance and biomass of species associated with hard-bottom substrates (Scaridae and Siganidae) found in Nukufetau coastal reefs.

Lagoon-intermediate-reef environment: Nukufetau

The lagoon-intermediate-reef environment of Nukufetau was dominated by four herbivorous and carnivorous fish families, most notably Acanthuridae (density = 0.20 ±0.01 fish/m^2, biomass = 47.2 ±25.9 g/m^2), Scaridae (density = 0.10 ±0.04 fish/m^2, biomass = 32.2 ±18.2 g/m^2), Lutjanidae (density = 0.05 ±0.02 fish/m^2, biomass = 36.5 ±16.6 g/m^2) and Serranidae (density = 0.05 ±0.01 fish/m^2, biomass = 19.3 ±79.9 g/m^2) (Figure 3.20). The remaining commercial fish families, including the targeted fish families of Lethrinidae, Mullidae, Labridae, Kyphosidae, Siganidae and Balistidae were recorded at much lower biomass and density <0.05 fish/m^2. The most important species of these dominant families were, in order of decreasing abundance, *Ctenochaetus striatus, Naso lituratus, Chlorurus sordidus, Monotaxis grandoculis, Scarus rubroviolaceus, Lutjanus bohar* (which had the maximum biomass)*, N. vlamingii, Hipposcarus longiceps, C. microrhinos*, and *L. gibbus* (Table 3.8).

Table 3.8: Finfish species contributing most to main families in terms of densities and biomass in the lagoon-intermediate-reef environment of Nukufetau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.09 ±0.01	4.0 ±0.7
	Naso lituratus	Orange-spine unicornfish	0.03 ±0.01	12.8 ±6.9
	Naso vlamingii	Bignose unicornfish	0.02 ±0.02	15.1 ±15.1
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.03 ±0.01	3.3 ±1.3
	Hipposcarus longiceps	Pacific long-nose parrotfish	0.02 ±0.01	8.4 ±4.3
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big eye bream	0.03 ±0.01	10.4 ±5.1
Lutjanidae	*Lutjanus bohar*	Red snapper	0.02 ±0.01	17.5 ±9.2
	Lutjanus gibbus	Humpback snapper	0.01 ±0.01	12.3 ±6.9

Average fish biomass of lagoon intermediate reefs (175.6 ±74.8 g/m^2) was similar to the average for all reef types (176.2 g/m^2) and intermediate between coastal and back-reef values. In contrast, fish density (0.6 ±0.1 fish/m^2) was very low, the lowest compared to other reef types (ranging from 0.7 to 0.9 fish/m^2), and even lower than all pooled reef types (0.7 fish/m^2, Table 3.6). It is possible that the trend relates to fishing pressure, conditions of the reef environment or both. However, lower density may also be explained by the low sample replica of transect stations in lagoon reefs. Also, one should consider that the finfish assessment concentrated on a mean depth of 8 m of mostly hard substrate (>65%), where spearfishing and gillnetting are common.

Similar to coastal reefs, lagoon patch reefs are only found in Nukufetau and Funafuti, and comparisons with all four study sites are therefore not possible. Survey work focused primarily on hard-bottom habitats (68.3 ±4.0%); live-coral cover was relatively low (15.2 ±4.5%) and also soft bottom (13.2 ±7.0 %). This composition of substrate types is relatively similar to the lagoon habitat of Funafuti, although Nukufetau had slightly less live-coral cover than Funafuti (Table 3.6). The average density of finfish resources was lower, while size, size ratio and consequently biomass were higher in Nukufetau lagoon reefs compared to those of Funafuti. In particular, density and biomass of Lutjanidae, Scaridae and Serranidae were higher, while that of Acanthuridae and Siganidae were lower on Nukufetau.

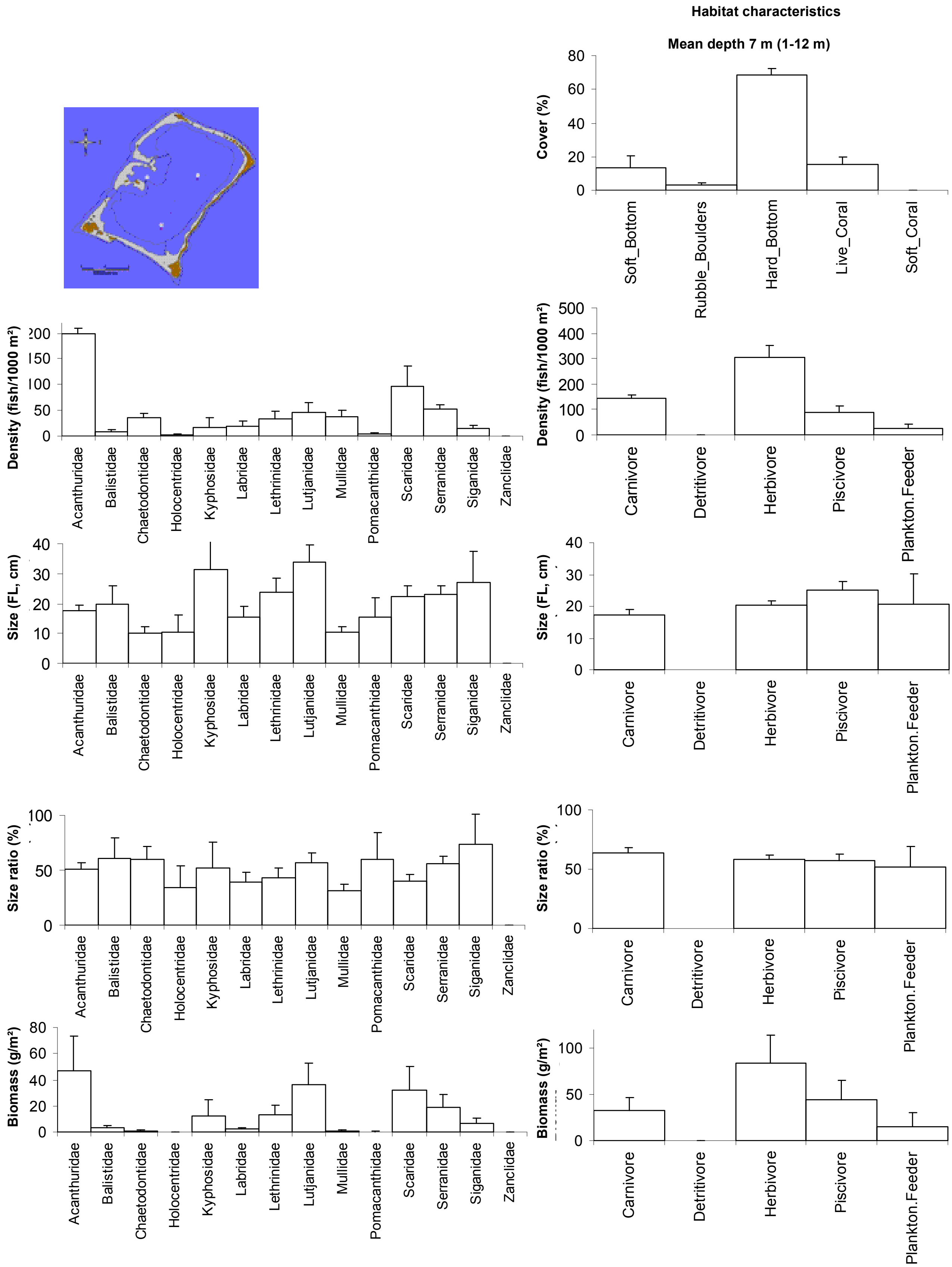

Figure 3.20: Profile of finfish resources in the lagoon environment of Nukufetau.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Nukufetau

Survey work focused primarily on hard-bottom habitats (53.2 ±5.4%), with relatively low cover of live coral (17.8 ±2.7%), though more than at the lagoon and coastal reefs. However, patches of soft bottom (16.4 ±3.0%) were also common features of the back-reef system (Table 3.6).

The back-reef environment of Nukufetau was composed of both herbivorous and carnivorous fish families, most notably Acanthuridae (density = 0.18 ±0.03 fish/m^2, biomass = 37.4 ±14.1 g/m^2), Lethrinidae (density = 0.12 ±0.03 fish/m^2, biomass = 29.6±8.5 g/m^2), Lutjanidae (density = 0.10 ±0.04 fish/m^2, biomass = 48.4 ±16.2 g/m^2), Scaridae (density = 0.10 ±0.02 fish/m^2, biomass = 21.2 ±7.7 g/m^2) and Kyphosids (density = 0.04 ±0.04 fish/m^2, biomass = 25.9 ±22.4 g/m^2) (Figure 3.21). The most important species representing these dominant families were, in order of decreasing abundance, *Monotaxis grandoculis, Ctenochaetus striatus, Lutjanus gibbus, Scarus niger, Kyphosus vaigiensis, Chlorurus sordidus, L. monostigma, Acanthurus blochii, A. nigricaudus* and *L. bohar* (Table 3.9).

Other major targeted fish families of Mullidae, Serranidae and Balistidae were low in abundance. Unlike on the coastal reefs and lagoon reefs, density and especially biomass of Lethrinidae and Kyphosidae were particularly high on the back-reefs. Kyphosidae were not highly targeted in Nukufetau, contrary to the other sites. Siganidae showed very low abundance; fishing pressure no doubt influenced their numbers given that they were highly sought after on Nukufetau as a good eating fish. The large scoop nets used to catch this fish are too efficient; one scoop of the net can catch over a hundred fish.

The back-reef system occupied the largest reef area (18.6 km^2). It is possible that the relatively high abundance and biomass (higher than the average estimate for all reefs combined) of reef fishes in the back-reef correlates with the size of the reef area.

Table 3.9: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Nukufetau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth surgeonfish	0.07 ±0.01	2.8 ±0.7
	Acanthurus blochii	Ringtail surgeonfish	0.01 ±0.01	5.5 ±3.5
	Acanthurus nigricaudus	Black-streak surgeonfish	0.01 ±0.01	7.7 ±2.7
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big eye bream	0.08 ±0.01	20.3 ±5.3
Scaridae	*Scarus niger*	Swarthy parrotfish	0.04 ±0.01	5.3 ±2.1
	Chlorurus sordidus	Bullet-head parrotfish	0.03 ±0.01	4.8 ±1.6
Kyphosidae	*Kyphosus vaigiensis*	Lowfin rudderfish	0.04 ±0.03	21.7 ±18.3
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.04 ±0.01	26.8 ±9.5
	Lutjanus monostigma	One spot snapper	0.03 ±0.02	6.7 ±4.9
	Lutjanus bohar	Red snapper	0.01 ±0.01	8.5 ±3.9

Similar to coastal reefs and lagoon patch reefs, the back-reefs were only found in Nukufetau and Funafuti, and comparisons were therefore only possible for these two study sites. While density was slightly higher in Funafuti, biodiversity, size and biomass of finfish were higher in Nukufetau. Generally, the records showed no marked differences in the distribution pattern of prominent, targeted commercial reef fishes between the back-reefs of Nukufetau and Funafuti, except for higher abundance and biomass of the herbivore families Acanthuridae and Scaridae in Funafuti and higher abundance and biomass of Lutjanidae, Lethrinidae, Serranidae and Kyphosidae in Nukufetau. Similar to the case in coastal and lagoon reefs, there was less live-coral and hard-bottom cover in Nukufetau than in Funafuti (Table 3.6).

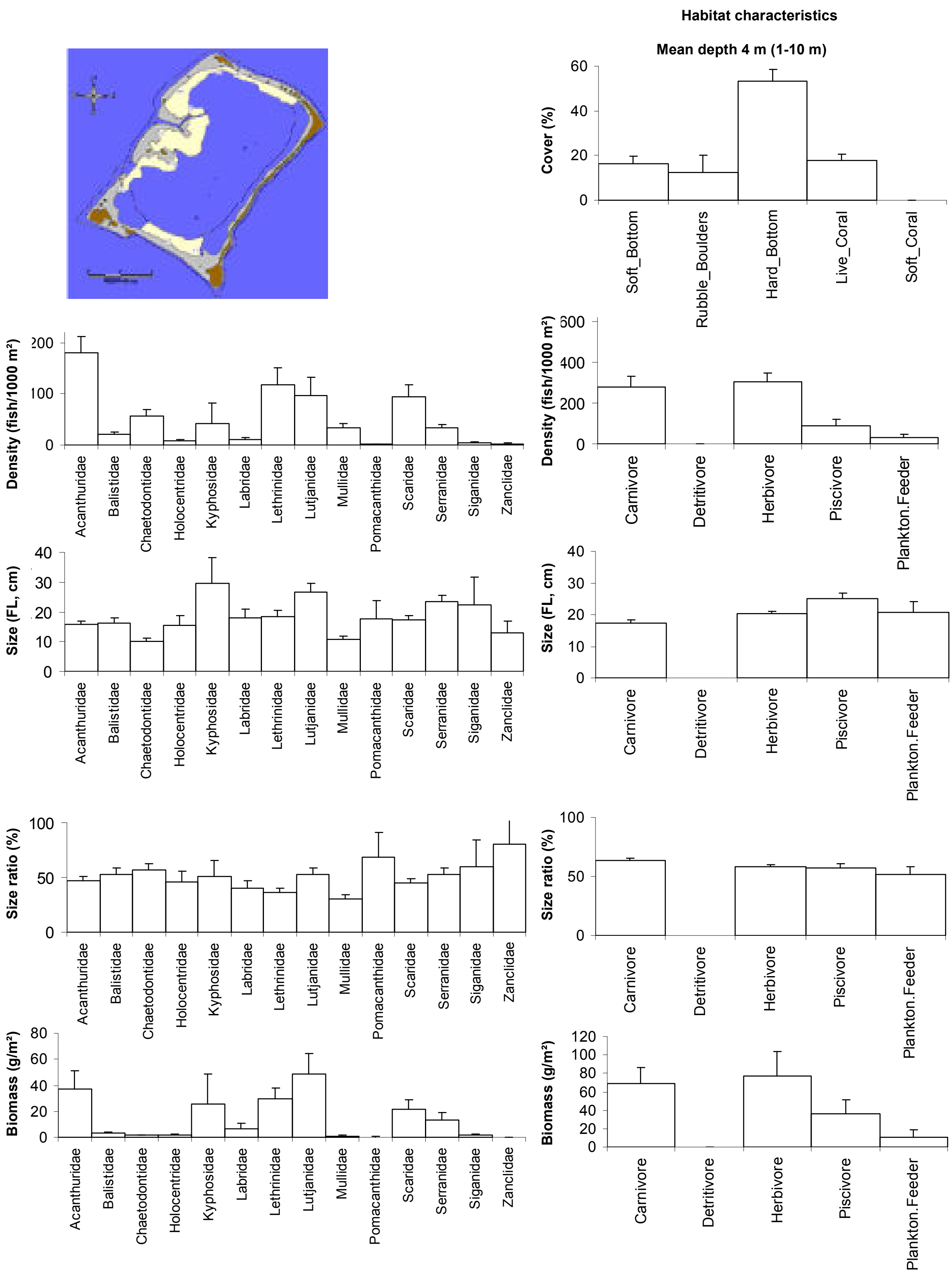

Figure 3.21: Profile of finfish resources in the back-reef environment of Nukufetau.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Nukufetau

The benthic communities on the outer reefs were exceptional, with the highest percentage of coral cover (33.0 ±3.3%) among all reefs (Table 3.6). Cover of hard bottom (66.1 ±3.5%) was the lowest among all outer reefs.

The outer reef of Nukufetau was largely dominated by four families of herbivorous and carnivorous fish: Acanthuridae (density = 0.33 ±0.06 fish/m^2, biomass = 42.5 ±11.7 g/m^2), Balistidae (density = 0.16 ±0.02 fish/m^2, biomass = 12.5 ±3.2 g/m^2), Lutjanidae (density = 0.12 ±0.07 fish/m^2, biomass = 77.9 ±45.6 g/m^2) and Scaridae (density = 0.11 ±0.03 fish/m^2, biomass = 53.4 ±30.6 g/m^2) (Figure 3.22). The most important species were, in order of decreasing density, *Ctenochaetus striatus, Acanthurus nigricans, Lutjanus gibbus, A. lineatus, Chlorurus sordidus, Scarus niger, Lutjanus bohar, Naso lituratus, Monotaxis grandoculis* and *Macolor macularis*. Other major targeted fish families were low in abundance.

The study also found considerable low density and biomass of specific Serranidae and Lethrinidae in the outer reefs. There were no records, during surveys, of large-sized *Plectropomus* spp., *Cephalopholis* spp. or other *Lethrinus* spp. targeted by fishers on the atoll. Similarly, the distributions of *Naso* spp. and *Scarus* spp. were very patchy, with good numbers in certain parts of the outer reefs. In fact fishing that targeted unicornfish and parrotfish was becoming very frequent through use of spears and nets.

Table 3.10: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Nukufetau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristle-tooth	0.10 ±0.03	5.8 ±1.2
	Acanthurus nigricans	White-cheek surgeonfish	0.07 ±0.03	3.5 ±1.7
	Acanthurus lineatus	Striped surgeonfish	0.06 ±0.04	5.7 ±3.0
	Naso lituratus	Orange-spine unicornifish	0.02 ±0.01	10.5 ±6.5
Lutjanidae	*Lutjianus gibbus*	Humpback snapper	0.06 ±0.03	37.1 ±20.8
	Lutjianus bohar	Red snapper	0.03 ±0.02	20.1 ±14.0
	Macolor macularis	Black-and-white snapper	0.01 ±0.01	13.8 ±13.8
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	0.05 ±0.01	14.5 ±8.3
	Scarus niger	Swarthy parrotfish	0.03 ±0.02	11.4 ±10.2
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big eye bream	0.02 ±0.01	5.7 ±2.7

Both fish biomass and density were greater in the outer reef than all other reef habitats (Table 3.10). Unlike coastal reefs, lagoon patch reefs and back-reefs, outer reefs are found in all study sites of Tuvalu and therefore fish parameters on outer reefs can be compared across all sites. Density was very similar to that found in Funafuti outer reefs, and intermediate between those of Niutao and Vaitupu. Biomass was the second highest value, lower only than in Niutao. Fishing pressure on Nukufetau was less intense compared to all other study sites, which perhaps explains this trend. Average size was however the second lowest for the four sites. The records show some differences in the distribution pattern of prominent targeted commercial reef fishes among the outer reefs of all study sites: lower abundance and biomass of Acanthuridae and Balistidae but higher abundance and biomass of Lutjanidae, higher density of Serranidae, and higher biomass of Siganidae were recorded in Nukufetau. The low fishing pressure may perhaps explain the high importance of large carnivores compared to other sites. It is not possible to determine whether the disparity in outer-reef fish populations between Nukufetau and other study sites was due to fishing pressure or habitat characteristics.

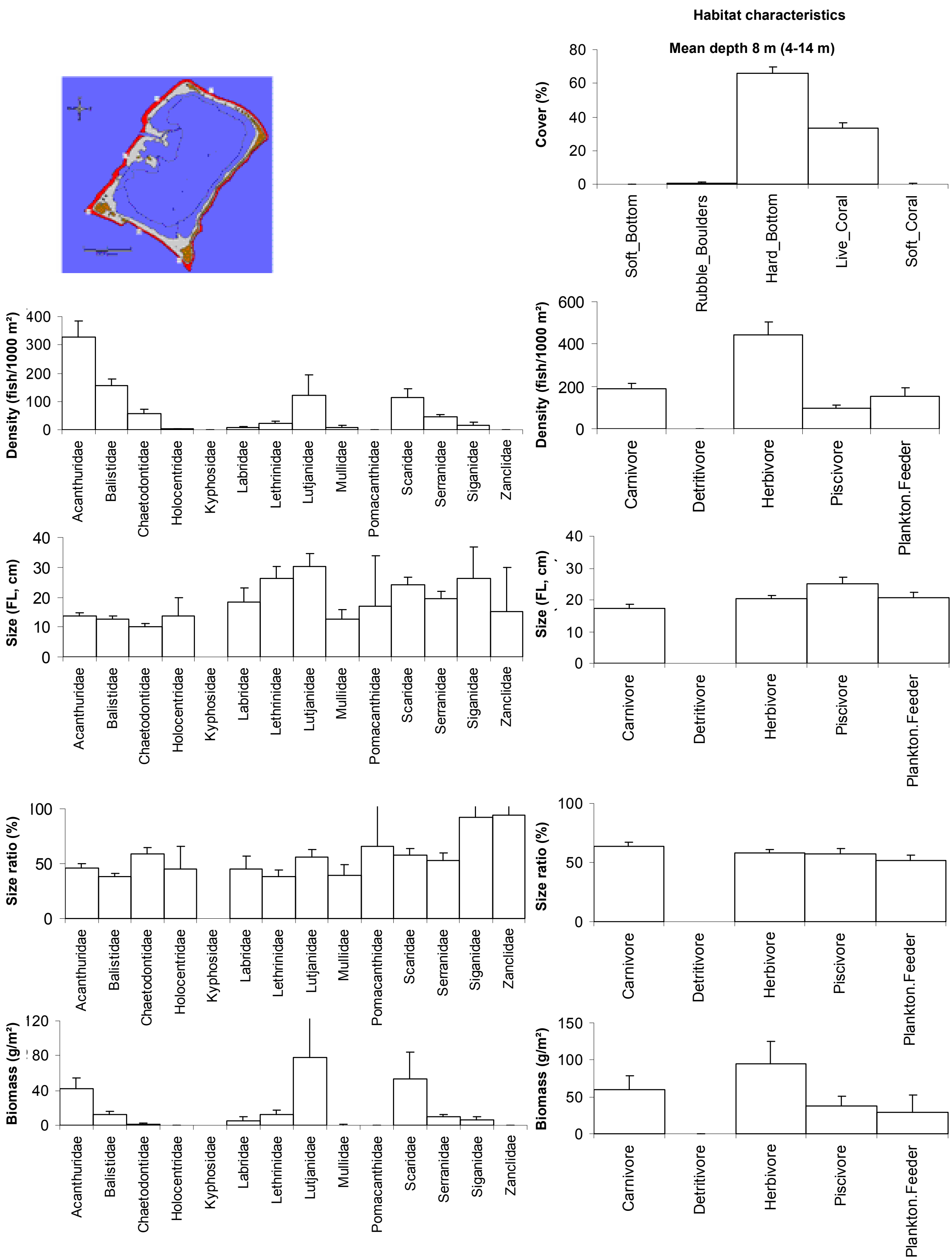

Figure 3.22: Profile of finfish resources in the outer-reef environment of Nukufetau.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Nukufetau

The data from all reef types were combined to determine the overall state of the fish assemblage on Nukufetau atoll. The study found that four main families were consistently predominant: the herbivore families Acanthuridae (density = 0.21 fish/m², biomass = 32.8 g/m²) and Scaridae (density = 0.10 fish/m², biomass = 29 g/m²), and carnivore families Lutjanidae (density = 0.11 fish/m², biomass = 52.5 g/m²) and Lethrinidae (density = 0.09 fish/m², biomass = 23.1 g/m²), with density dominated by Acanthuridae and biomass by Lutjanidae. The most important species from the point of view of density and biomass were *Ctenochaetus striatus*, *Monotaxis grandoculis*, *Lutjanus gibbus*, *Chlorurus sordidus*, *Scarus niger*, *Acanthurus lineatus*, *Lutjanus bohar* and *Naso lituratus* (Table 3.11). As expected, the overall fish assemblage in Nukufetau more closely resembled that recorded in the sheltered coastal and back-reef environment (75% of habitat) than in the intermediate lagoon and outer-reef environment (25% of habitat).

Table 3.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Nukufetau (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristletooth surgeonfish	0.09	3.8
	Acanthurus lineatus	Striped surgeonfish	0.02	1.7
	Naso lituratus	Orange-spine unicornfish	0.01	5.3
Scaridae	*Chlorurus sordidus*	Bullethead parrotfish	0.04	7.7
	Scarus niger	Swarthy parrotfish	0.03	5.7
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.06	27.9
	Lutjanus bohar	Twinspot snapper	0.01	9.2
Lethrinidae	*Monotaxis grandoculis*	Hump-nose big-eye bream	0.07	16.9

When compared to the average of each Tuvalu PROCFish/C study site, the finfish resources of Nukufetau atoll displayed:

- lowest biodiversity (38 ±3 versus a range of 39 to 40 species/transect),
- lowest density (0.74 versus a range between 0.75 to 1.03 fish/m^2),
- second lowest biomass (176.9 versus a range of 141.8 to 258.7 g/m^2) and
- second lowest size (17.5 versus a range of 15.2 to 20.2 cm FL, Figure 3.23).

Detailed assessment at reef level suggests that the condition of the Nukufetau finfish resources was poorer than those of Niutao and Vaitupu and slightly healthier than those of Funafuti. However Niutao and Vaitupu both had richer outer-reef habitats; therefore any comparison between them and the whole of the Nukufetau site is biased. Nukufetau offered all the available habitats and reefs for a choice of fishing methods and gears.

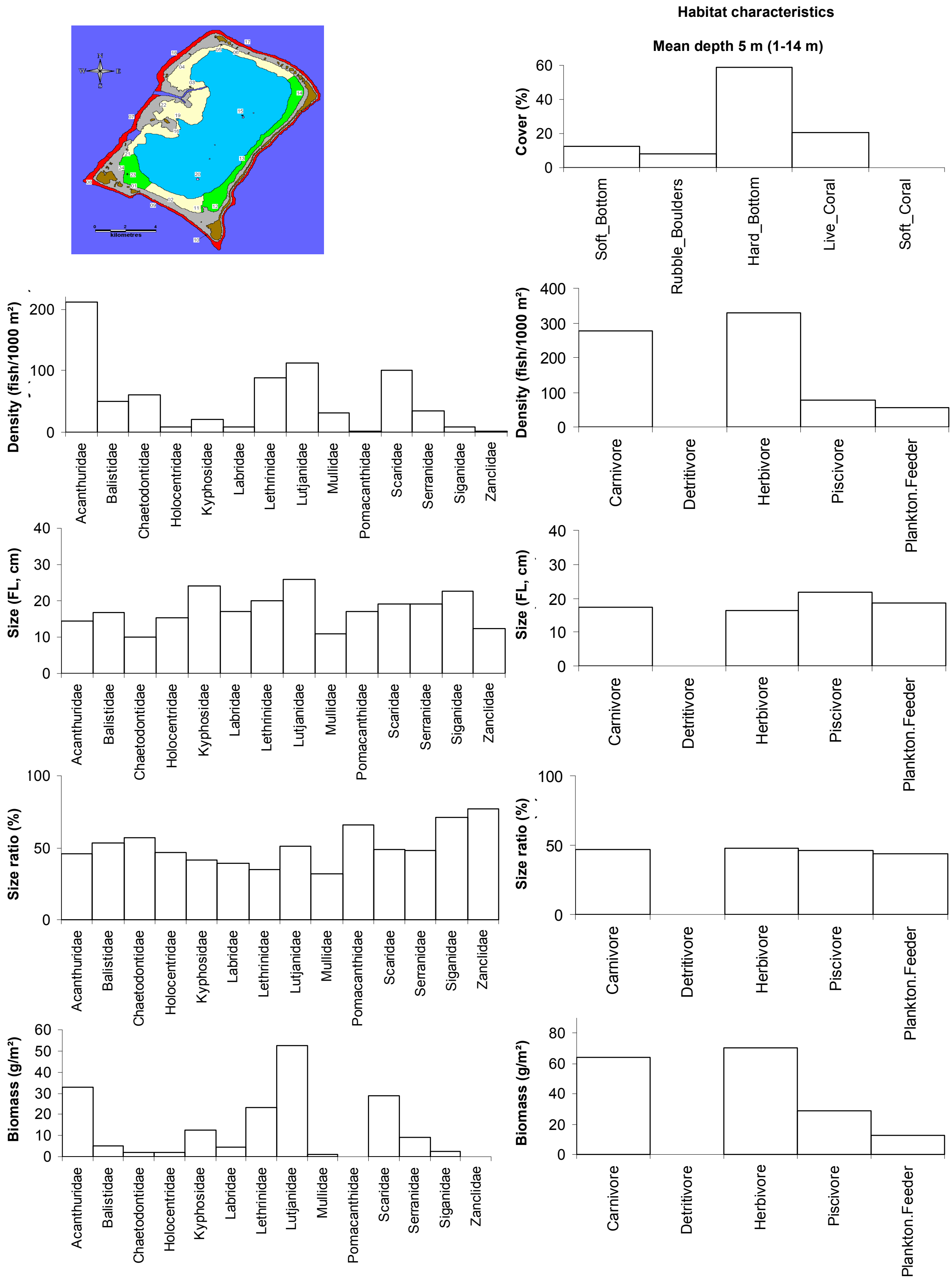

Figure 3.23: Profile of finfish resources in the combined reef habitats of Nukufetau (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Nukufetau

- Survey results showed that the status of finfish resources in Nukufetau atoll was better than in Funafuti, the only comparable site. When comparing outer-reef habitats, which were present in all four survey sites, Nukufetau had the second highest fish density and biomass, lower only than Niutao. Fish biomass and density increased from coastal fishery to lagoon, back-reef and outer reef. This possibly correlates with habitat health, accessibility to fishing spots and the uneven level of fishing pressure exerted on these fisheries. The study noted the predominance of certain fish families and species, especially carnivores Lutjanidae and Lethrinidae, although fish assemblages varied among sheltered coastal, back-reef, lagoon and outer-reef fisheries. Specifically, the lagoon fishery of Nukufetau was the highest in both abundance and biomass of Serranidae, and in biomass of Acanthuridae and Siganidae. The sheltered coastal fishery appeared to have the highest density of Lutjanidae. The back-reefs had the highest density and biomass of Lethrinidae and highest biomass of Kyphosidae. The outer reefs were the richest of the four habitats, with high biomass of Lutjanidae, Scaridae and Balistidae, and high density of Acanthuridae, Balistidae, Scaridae and Siganidae.

- Preliminary results suggested that the relatively good quality of the fishery resources was possibly the consequence of:
  - the geographical isolation of Nukufetau, located far from the main market of the populated capital of Funafuti,
  - the low population index per unit area of available reefs,
  - the relatively large reef area and habitats available for fishing activities, and
  - the use of a variety of fishing gears and methods to target a range of preferred species.

- During the surveys, group fishing using nets was frequently observed in the lagoon and coastal reefs. Species targeted were schooling Siganidae, Mugilidae, Scaridae, Acanthuridae and other schooling species, using efficient gear (e.g. *kupega*[7]) at depths of 0–6 m. Handlining was predominantly carried out at depths >6 m, targeting large-sized Lethrinidae, Lutjanidae and Serranidae.

- There were a few by-laws in place at the time of the survey; however, these were poorly enforced and policed. Also, there was discussion among the island leaders regarding the need for further management measures for controlling fishing effort (e.g. regulating fishing gears, establishing minimum mesh sizes, and imposing closed seasons for certain species). The harvesting of giant clams was also prohibited. The proposal to establish a conservation area that would include both land and sea resources, was also a subject of discussion.

- The study noted the high number and frequent use of motorised boats for fishing as opposed to the traditional use of canoes and sails. The use of motorised boats and advanced fishing gears has no doubt increased the level of fishing pressure.

[7] A traditional fishing method using monofilament gillnet, by female fishers in a triangular form with wooden sticks mounted onto the net on either end to open it up. Once the school of Siganidae is sighted, a group of fishers cautiously drives the school to a shallow area, encircles the school while it is approaching the open net, drives the school straight into the net and closes the net by bringing the two wooden poles together.

3.4 Invertebrate resource surveys: Nukufetau

The diversity and abundance of invertebrate species at Nukufetau atoll were independently determined using a range of survey techniques (Table 3.12); broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 3.24) and finer-scale assessment of specific reef and benthic habitats (Figures 3.25 and 3.26).

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 resources in those areas of naturally higher abundance and/or most suitable habitat.

Table 3.12: Number of stations and replicates completed at Nukufetau

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	13	78 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrate group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	3	18 search periods
Reef-front search_walks	3	18 search periods
Sea cucumber day searches (Ds)	8	48 search periods
Sea cucumber night searches (Ns)	2	12 search periods

Figure 3.24: Broad-scale survey stations for invertebrates in Nukufetau.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 3.25: Fine-scale reef-benthos transect survey stations in Nukufetau.
Black circles: reef-benthos transect stations (RBt).

Figure 3.26: Fine-scale survey stations for invertebrates in Nukufetau.
Grey circles: sea cucumber night search stations (Ns);
grey stars: sea cucumber day search stations (Ds);
grey triangles: reef-front search stations (RFs);
inverted grey triangles: reef-front search by walking stations (RFs_w).

Twenty-nine species or species groupings (groups of species within a genus) were recorded in the Nukufetau invertebrate surveys; among these were 5 bivalves, 9 gastropods, 9 sea cucumbers, 2 urchins, 2 sea stars and 1 lobster (Appendix 4.2.1). Information on key families and species is detailed below.

3.4.1 Giant clams: Nukufetau

Shallow reef habitat that is suitable for giant clams was moderately extensive (32.5 km²) at Nukufetau atoll, with the most suitable habitat concentrated along the western and southern edges, where water movement was the most dynamic. The lagoon was only truly 'open' along the western edge, with two main passages linking the lagoon to open sea. Intermediate reef in the lagoon was limited, and the 'closed' eastern edge only supported a narrow strip of fringing reef on the lagoon edge.

Broad-scale sampling provided an overview of giant clam distribution across Nukufetau atoll and two giant clam species were recorded during survey: the elongate clam *Tridacna maxima*, and the fluted clam *T. squamosa*. Broad-scale sampling stations revealed *T. maxima* to have the widest occurrence (found in all 12 stations and 35 transects), followed by *T. squamosa* (5 stations and 5 transects – Figure 3.27).

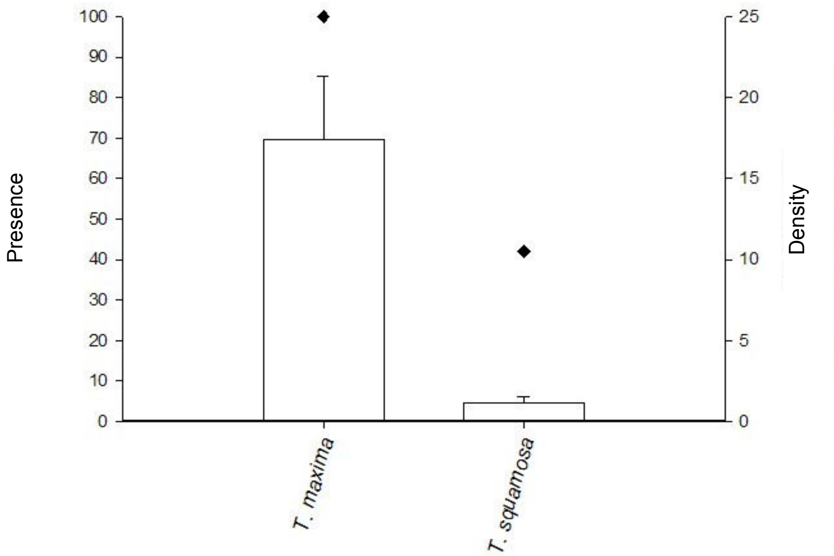

Figure 3.27: Presence and mean density of giant clam species at Nukufetau based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat. In these reef-benthos transect assessments (RBt), *T. maxima* was present within 85% of stations. At these stations (11 stations where clams were recorded), the mean density was 189.4 ±44.7 individuals/ha. *T. squamosa*, a species that is normally found at lower density than *T. maxima*, was not found in reef-benthos stations, but was recorded in deeper water during day searches (Table 3.13; Figure 3.28).

Table 3.13: Presence and mean density of clams in Nukufetau
Based on various assessment techniques; mean density measured in numbers per ha (±SE).

	Density	SE	% of transects with species
Tridacna maxima			
RBt	160.3	42.4	32/78 = 41
Ds	2.4	1.1	5/30 = 17
Tridacna squamosa			
RBt	0	0	0/78 = 0
Ds	1.0	0.6	2/30 = 7

RBt = reef-benthos transect; Ds = day search.

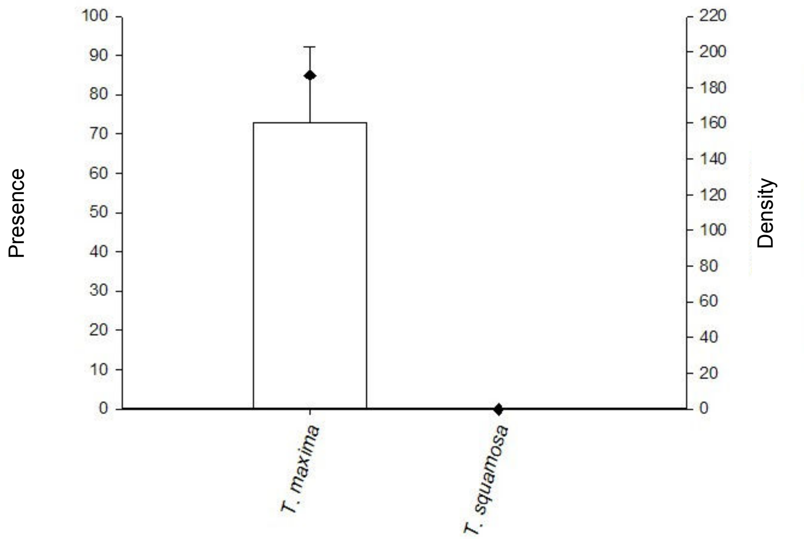

Figure 3.28: Presence and mean density of giant clam species at Nukufetau based on fine-scale reef-benthos survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

As mentioned, clams were not distributed evenly across reefs at Nukufetau. *T. maxima* was common around the passages and not found in abundance near the populated areas of Nukufetau or along the eastern edge of the lagoon. *T. squamosa* was common in shallow-water areas, but most individuals were dead (recently harvested). Live individuals were recorded in broad-scale assessments or during sea cucumber assessments conducted in deeper water (Average depth for Ds search where *T. squamosa* was present was 19.9 m, n = 10.).

T. maxima from reef-benthos transects (shallow-water reefs) had an average length of 6.2 ±0.4 cm. When *T. maxima* clams from deeper water and more exposed locations were included in the calculation (from other assessments), the mean size was slightly larger at 10.1 ±0.4 cm, which equates to an age of approximately 4–5 years. The faster-growing *T. squamosa* clams (which grow to an asymptotic length L_∞ of 40 cm) averaged 32.4 ±3.2 cm in all assessments (>6 years old at mean length). As can be seen from the length frequency graphs (Figure 3.29), there were a few records of large *T. squamosa* (around the asymptotic length) from deeper regions in the lagoon, but most *T. maxima* were small.

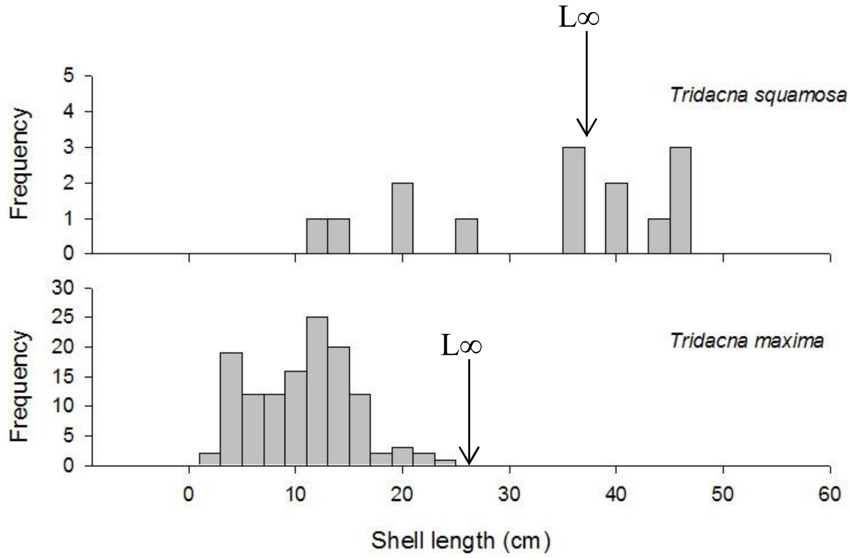

Figure 3.29: Size frequency histograms of giant clam shell length (cm) for Nukufetau.

3.4.2 Mother-of-pearl species (MOP): trochus and pearl oysters – Nukufetau

Tuvalu is not within the natural distribution of the commercial topshell, *Trochus niloticus*; however, there was an attempt to introduce specimens through translocation in 1988 (Gillett 1988; 2002a). Trochus from Aitutaki (844 pieces) were flown and parachuted into Nukufetau using military aircraft; however, the parachute failed to open and survival was limited by the fall, and then again by the subsequent handling and release procedure adopted.

T. niloticus was surveyed across oceanic-influenced reef slopes, barrier reef flats, reef in the lagoon and trochus release sites (Figure 3.26; Table 3.14; Appendices 4.2.2 to 4.2.5).

Table 3.14: Presence and mean density of mother-of-pearl species in Nukufetau
Based on various assessment techniques; mean density measured in numbers per ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
All methods	0	0	0	0
Tectus pyramis				
B-S	2.3	0.8	6/12 = 50	10/72 = 14
RBt	57.7	13.8	8/13 = 62	15/78 = 19
RFs	0	0	0/3 = 0	0/18 = 0

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

No live trochus were found during assessments, although parts of dead shell were seen. These old broken pieces of shell were likely the remains of the original stock which was parachuted onto the reef flat. *Tectus pyramis* the green topshell (of low commercial value), was present in reasonable numbers at more sheltered areas (reefs inside the lagoon and passages). The mean size (basal width) of *T. pyramis* was 6.1 ±0.3 cm (n = 18).

Reefs around Nukufetau atoll were extensive (46.3 km lineal distance of barrier reef front) and although this reef area could potentially support significant numbers of trochus, numbers of grazing gastropods in general were at low density, both inside the lagoon and on the outer slope of the barrier. Grazers were at their greatest density within the channels and reef within the lagoon, where epiphyte growth was more evident (Most of the other reefs had little epiphyte growth.). Any future releases of trochus may consider initial placement on reef within the lagoon or passes, where crustose coralline algae is still strong, but epiphytic growth (and potential food sources for trochus) is more developed.

The blacklip pearl oyster, *Pinctada margaritifera,* a normally cryptic and sparsely distributed pearl oyster species, was not recorded during broad-scale or reef-benthos assessments. A recording of two individuals was made within the lagoon on sea cucumber day searches (Ds), although the identification was uncertain as the Fisheries Officer, Mr Tataua Alefaio, who listed the find had no previous experience with this species.

3.4.3 Infaunal species and groups: Nukufetau

The soft benthos of the shallow-water lagoon was sandy and did 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.

3.4.4 Other gastropods and bivalves: Nukufetau

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs) was detected in broad-scale and reef-benthos surveys at medium-to-low density. *Strombus luhuanus* was quite common throughout the lagoon and was recorded in broad-scale and reef-benthos surveys (Appendices 4.2.1 to 4.2.7). *Turbo* spp. were recorded during broad-scale surveys but not during reef-benthos transects or reef-front searches (RFs and RFs_w, see Methods.). Other species targeted by fishers (resource species, e.g. *Chicoreus, Conus,* and *Cypraea*) were also recorded during independent surveys (Appendices 4.2.1 to 4.2.7).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus*, are also in Appendices 4.2.1 to 4.2.7. No creel survey was conducted at Nukufetau atoll.

3.4.5 Lobsters: Nukufetau

One reef-front search was conducted at night (Ns) on the exterior reef slope near the passage closest to Nukufetau's main settlement. No lobsters were seen. However, one lobster was recorded in a single sea cucumber day search (Ds) in deeper water. No lobsters were recorded on reef-benthos stations or during other lagoon assessments completed at night to determine the abundance of nocturnal sea cucumber species (Ns).

3.4.6 Sea cucumbers[8]: Nukufetau

Nukufetau atoll, like Funafuti, has a relatively small land mass (more than 20 *motu* at approximately 3.6 km^2) and an extensive lagoon (98.3 km^2). Reef margins and shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were relatively extensive in the lagoon (20 km^2) and outside the barrier reef (12 km^2). There was a moderately high degree of exposure, but water movement in the lagoon was not as dynamic as in Funafuti, and reef habitats within the lagoon reflected this lack of circulation of water, especially on the

[8] 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.

eastern side of the lagoon. On this side, silt levels on the reef were high, and some surfaces were notably overgrown with epiphytes in localised areas.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.15; Appendices 4.2.2 to 4.2.8, see also Methods and Appendix 1.3.). The range of valuable commercial species at Nukufetau was similar to that of Funafuti, and both these 'lagoon' sites had far greater diversity and number of sea cucumbers than the raised limestone island sites of Niutao and Vaitupu (with no true lagoon). Despite the lack of significant nutrient inputs into Nukufetau lagoon, nine commercial species of sea cucumbers were recorded during in-water assessments (Table 3.15).

Sea cucumber species associated with reef, such as leopardfish (*Bohadschia argus*) and the high-value black teatfish (*Holothuria nobilis*) were present (found in 4 or 18% of broad-scale transects) but not common (similar rates to Funafuti).

Surf redfish *Actinopyga mauritiana* were uncommon, and no high-density areas were recorded despite the suitable nature and extent of the reef and surge zone.

More protected areas of reef and soft benthos in the lagoon held no blackfish (*Actinopyga miliaris*), but the lower-value species, e.g. brown sandfish (*Bohadschia vitiensis*), elephant trunkfish (*Holothuria fuscopunctata*) and lollyfish (*Holothuria atra*) were present. The occurrence and density of all these species was generally low.

Deep dives on SCUBA (generally 25–35 m) were conducted to obtain a preliminary assessment of deep-water stocks such as the high-value white teatfish (*Holothuria fuscogilva*) and the lower-value amberfish (*Thelenota anax*). In these deep-water assessments (average depth 22.6 m) white teatfish (*Holothuria fuscogilva*) were present at high density in some areas, while prickly redfish (*Thelenota ananas*) and amberfish (*Thelenota anax*) were also present, but at lower densities. Of the eight sea cucumber day searches completed, white teatfish were common in both passages, but were not generally found within the lagoon (average density was 55.3 per ha ±30.1). *H. fuscogilva* was most common in the shallow water pass closest to Nukufetau's main settlement, at a depth easily dived by snorkellers. Unusually, three white teatfish (two in a single transect) were also recorded on reefs bordering the passage, in approximately 2 m of water.

In general, sea cucumber presence at all sites in Tuvalu reflected the fact that there was little land mass (nutrient input) and that sites were exposed and subject to considerable oceanic influence. This impacted the potential for sea cucumber presence and density, as these commercial resources are mostly deposit feeders that eat organic matter in the upper few millimetres of bottom substrates. Although the environment was not very suitable for most species, the export fishery in Nukufetau has remained closed since 1999 (approximately six years), following declines in catches and a diving accident, which prompted the closure of the fishery. The abundances reported, especially those for white teatfish, thus reflect a relatively 'protected' stock.

Table 3.15: Sea cucumber species records for Nukufetau

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef-benthos stations n = 13			Other stations RFs = 3; RFs_w = 3			Other stations Ds = 8; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H							1.3	3.9	33 RFs			
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M	5.1	28.2	18	3.2	41.7	8				1.5 13.3	4.0 26.7	38 Ds 50 Ns
Bohadschia vitiensis	Brown sandfish	L	0.2	16.7	1									
Holothuria atra	Lollyfish	L				67.3	875.0	8	122.2	366.7	33 RFs_w			
Holothuria fuscogilva [4]	White teatfish	H	0.5	33.3	1							55.3 8.9	73.8 17.8	75 Ds 50 Ns
Holothuria fuscopunctata	Elephant trunkfish	M	0.2	16.7	1							0.6	2.4	25 Ds
Holothuria nobilis [4]	Black teatfish	H	1.2	27.8	4							0.3	2.4	13 Ds
Thelenota ananas	Prickly redfish	H	0.9	33.3	3							3.7	6.0	63 Ds
Thelenota anax	Amberfish	M										13.2	17.7	75 Ds

[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; Ds = day search; Ns = night search.

3.4.7 Other echinoderms: Nukufetau

No edible slate urchin *Heterocentrotus mammillatus* or collector urchins *Tripneustes gratilla* were recorded, although *Echinometra mathaei* and *Echinothrix diadema* were present in the survey. *E. diadema* was uncommon and *E. mathaei* was found at 38% of reef-benthos stations at low density (61 per ha ±23).

Starfish were generally rare. Only two individuals of the blue starfish *Linckia laevigata* were recorded, while the corallivorous (coral eating) starfish, such as the pincushion star, *Culcita novaeguineae* was recorded on 8% of broad-scale transects (presence and density estimates in Appendices 4.2.1 to 4.2.7). Crown of thorns (COTS, *Acanthaster planci*) was not recorded in assessments at Nukufetau atoll.

A review of the size of species recorded by all techniques is provided at Appendix 4.2.8, while Appendix 4.2.9 provides habitat descriptors for Nukufetau for independent assessment.

3.4.8 Discussion and conclusions: invertebrate resources in Nukufetau

- The density and size range of *T. maxima* clams in Nukufetau atoll found during the survey describe a heavily impacted resource. The presence of dense aggregations of small *T. maxima* sizes is promising as it indicates that recruitment was good on reefs in the west of the lagoon.

- Although the larger species *T. squamosa* was generally found at lower density than *T. maxima* in this survey, fishing pressure was the noted cause of the low density records. The large number of recently harvested shells in the shallow reef areas (harvested as a gift to a departing cleric), suggested that the lagoon was especially suitable for this species, and that deeper water stocks in the lagoon needed protection from fishing if these clams were to remain an important resource for village use.

- Although the harvesting of giant clams was prohibited during the time of the survey, a permanent area needs to be set aside to protect both species of clams from fishing. This will help by allowing the numbers of mature, older clams to rebuild. This is important to the fishery as stocks of large older clams are the main source of female gametes (clams develop as males first and only produce eggs when they are at a large size, later in their life history).

- Assessment results suggest that trochus did not become established at Nukufetau atoll following their introduction in 1988. It is likely that the parachute failure and placement of stressed and damaged individuals on outer-reef fronts made the transplant unsuccessful. However, any future releases of trochus may consider initial placements on inner reefs within the lagoon or passes, where crustose coralline algae is still strong, but epiphytic growth (and potential food sources for trochus) is more developed. In addition, staged releases will allow the shells some level of protection from predators while they acclimatise to local conditions. This should be done before they are placed out at their final release sites.

- Presence and recruitment of *Tectus pyramis* was low to moderate, although recruitment in the lagoon was occurring. In general, reefs at Nukufetau were predominantly oceanic influenced without significant numbers of grazing gastropods. Based on the information collected, *P. margaritifera* populations were low, and considered to be impacted by fishing.

- Information collected on sea cucumber stocks showed that there was a limited number of species available for commercial fishing, and stock densities were generally low for shallow-water reef and lagoon species. The presence of high-value white teatfish and prickly redfish were of interest for commercialisation, but this preliminary survey suggested stocks were limited to two areas in the lagoon. If commercialisation was initiated, further work would need to be completed to assess what level of fishing could ensure sustainability of the fishery. A strict management plan would be needed to protect such a small resource.

3.5 Overall recommendations for Nukufetau

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomic, finfish and invertebrates), the following recommendations are made for Nukufetau:

- The Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur, especially with invertebrate species of which half are exported to Funafuti for marketing.

- The Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* to develop management plans or arrangements for the inshore resources of Nukufetau atoll to ensure the sustainable harvest of all marine resources, now and in the future. Also that the existing by-laws be enforced and further management measures considered, (e.g. regulating fishing gears, establishing minimum mesh sizes, and imposing closed seasons for certain species) for controlling fishing effort (These were being discussed by the island leaders at the time of the surveys, as well as the establishment of a marine conservation area that includes both land and sea resources, which is highly recommended.).

- The Tuvalu Fisheries Department encourage the local *Falekaupule* and *Kaupule* to set up a protected area free of any fishing (which includes both shallow and deep water), which would have good potential for retaining broodstock of important invertebrate species, such as giant clams, and trochus if these were to be re-introduced to Nukufetau atoll.

- The local *Falekaupule* and *Kaupule* be very cautious with any endeavour to open the sea cucumber fishery on Nukufetau for white teatfish and prickly redfish as stocks are very limited and further work is needed to assess what level of harvest can be allowed. All this should all be done through a management plan for this fishery.

4. PROFILE AND RESULTS FOR VAITUPU

4.1 Site characteristics

Vaitupu (Figure 4.1) is part of the central group of islands in Tuvalu. The closest island to Vaitupu is Nukufetau, 67 km away. Vaitupu is also the biggest island in Tuvalu with a total land area of 5.3 km². The reef-platform area of lagoons, beaches and reef flats makes up another 10.2 km² (MacLean and Hosking 1991). The island is low-lying, elongated and categorised as a closed atoll encompassing two lagoons, which are open on the northeast of the tidal reef. Te Namo is the larger and deeper of the two lagoon systems and is located at the broader southern end of Vaitupu. The only form of transportation to and from the island is by sea through the inter-island shipping services of Tuvalu. Other than visitors and travellers, inter-island transportation is particularly important for marketing or trading fresh and value-added fish products.

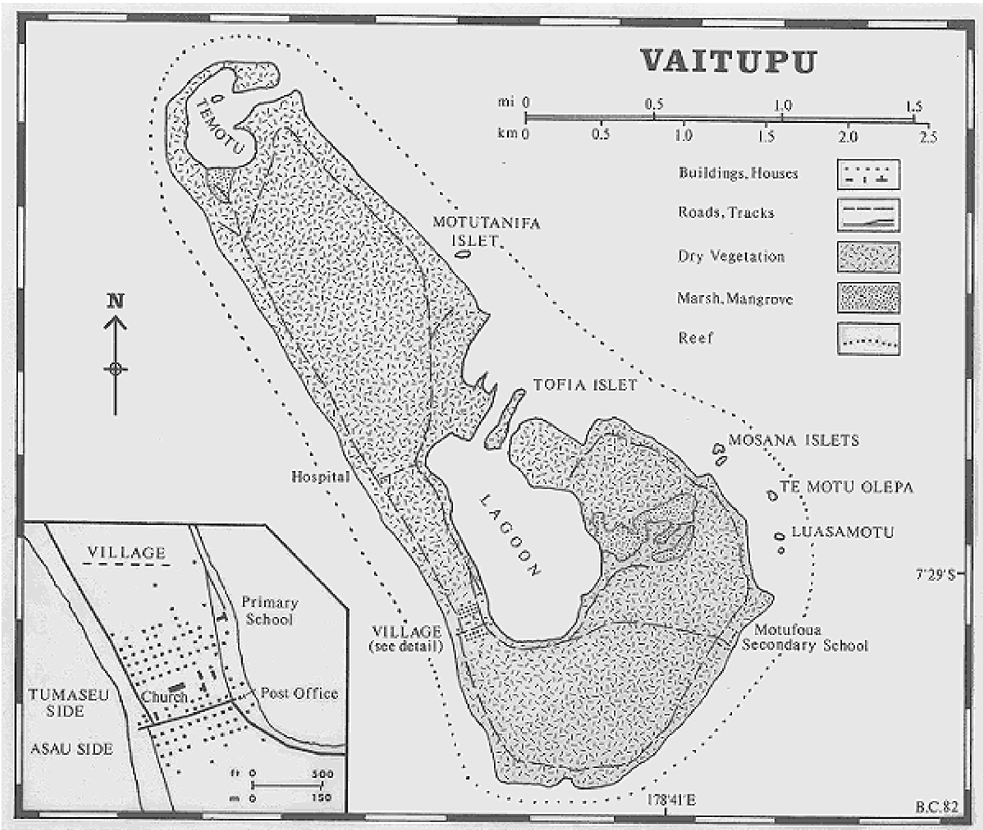

Figure 4.1: Map of Vaitupu Island.

Vaitupu is the second most populated island in the country with a total population of around 1600. The main settlement is located on the southwestern side of the island, and hosts the only secondary school of Tuvalu. The main sources of income are employment in the formal sector, as many people are employed at the secondary school and island council offices on the island, as well as remittances. The other sources of cash income are casual labour, sale of goods, such as fish, produce or handicrafts, and copra production (Government of Tuvalu 1995c).

Fishing on Vaitupu is mainly for family consumption except for a few male fishers who sell their fish. The demand for fresh fish is relatively high given the limited reef areas for fishing and the high population. Male fishers sell their fish at the landing site or directly to the Community Fishing Centre (CFC), where most of the dried and salted fish are processed. The CFC is owned by the island community but run by the Island Council. However, there is no structured fish market. Male fishers sell their catches at the landing site, to the CFC or the secondary school. Females are more engaged in handicraft production and sale of goods, while males are involved in fishing and farming (Government of Tuvalu 1995c).

The lagoon system supports a milkfish fishery, which plays an important role in supplying people with fresh fish during periods when the sea is rough. There are many traditional and non-traditional fishing methods used in the island. The most common method by far is trolling for pelagic fish using either wooden or aluminium skiffs that are equipped with an outboard engine.

Gillnets, handlines, rods and fish traps are most commonly used for lagoon fishing. Gillnetting is restricted to only two persons who are selected by the island chiefs and penalties are imposed to those who use netting without a permit. Deep-sea handlining, rod fishing and spearfishing are the three most common methods used for the reef area. Spearfishing is usually done at night, which is popular among young males. It is a common way of collecting lobsters. In the open ocean, trolling, scoop netting and deep-sea handlining are the three most common methods of fishing (Government of Tuvalu 1995c). Given the small area of fishable reefs, an ongoing FAD programme has greatly helped male fishers engaged in pelagic fishing.

The by-laws that exist in Vaitupu include the restriction of gillnets with small mesh-sizes, and seasonal closures to fishing in the lagoons. Other restrictions include the prohibition of the use of hookah and SCUBA gears for any form of fishing; dynamiting; and fish poisons.

No one is allowed to fish in the lagoon without the permission of the *Kaupule*, which is the custodian of the two lagoons in the island. Further, a milk fish experimentation pond was rehabilitated under the auspices of the FAO and Tuvalu Fisheries Division. The *Kaupule* was tasked to encourage the people to set up their own fish ponds to cater for their daily fish requirements especially during bad weather (Government of Tuvalu 1995c). No established MPA exists on the island. There is a male fishers' association on the island with active members who own boats and are frequently engaged in fishing. There had been several cases where the price range of catches was set by the association to meet the demands of members.

4.2 Socioeconomic survey: Vaitupu

PROCFish/C socioeconomic fieldwork on the island of Vaitupu focused on the village of Tumaseu. Only one household located at Asau was included in the survey. In total, 29 households were interviewed covering 178 people. Thus, the survey covered about 12% of the island's households (total number of households 237; total population ~1455 people).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 28 individual interviews of finfish fishers (27 males, 1 female) and 15 invertebrate fishers (10 males, 5 females) were conducted. These fishers belonged to one of the 29 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

4.2.1 The role of fisheries in the Vaitupu community: fishery demographics, income and seafood consumption patterns

The survey results (Table 4.1) suggested an average of 2 fishers per household. We applied this average to the total number of households, and arrived at a total of 474 fishers on Vaitupu. Analysing our household survey data according to the type of fisher (finfish or invertebrate fishers) by gender, we can project a total of 266 fishers who fished only for finfish (258 males, 8 females), a total of 104 fishers who harvested only invertebrates (females) and 104 fishers (96 males, 8 females) who fished for both finfish and invertebrates.

Table 4.1: Fishery demography, income and seafood consumption patterns in Vaitupu

Survey coverage	Vaitupu (n = 29 HH)	Average across sites (n = 113 HH)
Demography		
HH involved in reef fisheries (%)	100	100
Number of fishers per HH	2.0 (±0.26)	2.0 (±0.13)
Male finfish fishers per HH (%)	54.2	38.3
Female finfish fishers per HH (%)	1.7	0.4
Male invertebrate fishers per HH (%)	0	0
Female invertebrate fishers per HH (%)	22.0	14.1
Male finfish and invertebrate fishers per HH (%)	20.3	41.0
Female finfish and invertebrate fishers per HH (%)	1.7	6.2
Income		
HH with fisheries as 1st income (%)	21	24
HH with fisheries as 2nd income (%)	24	25
HH with agriculture as 1st income (%)	0	25
HH with agriculture as 2nd income (%)	0	1
HH with salary as 1st income (%)	52	52
HH with salary as 2nd income (%)	14	11
HH with other source as 1st income (%)	24	20
HH with other source as 2nd income (%)	14	14
Expenditure (USD/year/HH)	2024 (±270.76)	2102 (±155)
Remittance (USD/year/HH) (1)	1748 (±417.14)	1940 (±173.5)
Seafood consumption		
Quantity fresh fish consumed (kg/capita/year)	162.5 (±13.2)	151.0 (6.30)
Frequency fresh fish consumed (times/week)	6.4 (±0.3)	6.1 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	n/a	n/a
Frequency fresh invertebrate consumed (times/week)	0.4 (±0.1)	0.4 (±0.07)
Quantity canned fish consumed (kg/capita/year)	2.1 (±0.5)	2.2 (±0.36)
Frequency canned fish consumed (times/week)	0.6 (±0.1)	0.5 (±0.07)
HH eat fresh fish (%)	100	99
HH eat invertebrates (%)	59	54
HH eat canned fish (%)	62	66
HH eat fresh fish they catch (%)	97	97
HH eat fresh fish they buy (%)	62	61
HH eat fresh fish they are given (%)	72	62
HH eat fresh invertebrates they catch (%)	55	50
HH eat fresh invertebrates they buy (%)	0	0
HH eat fresh invertebrates they are given (%)	17	11

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

About 40% of all households in Tumaseu villages owned a boat. Most boats were canoes (58%); fewer were motorised (42%).

Data from Figure 4.2 suggest that salaries were the most important source of income for half of all households. Other sources, such as handicrafts, shops and bakeries were slightly more important than fisheries as a first income source. While 50% of all households depended on one source of income only, 25% used fisheries as a second and complementary income source. The remaining 25% of households that had a second source of income relied on salaries and home-based small businesses.

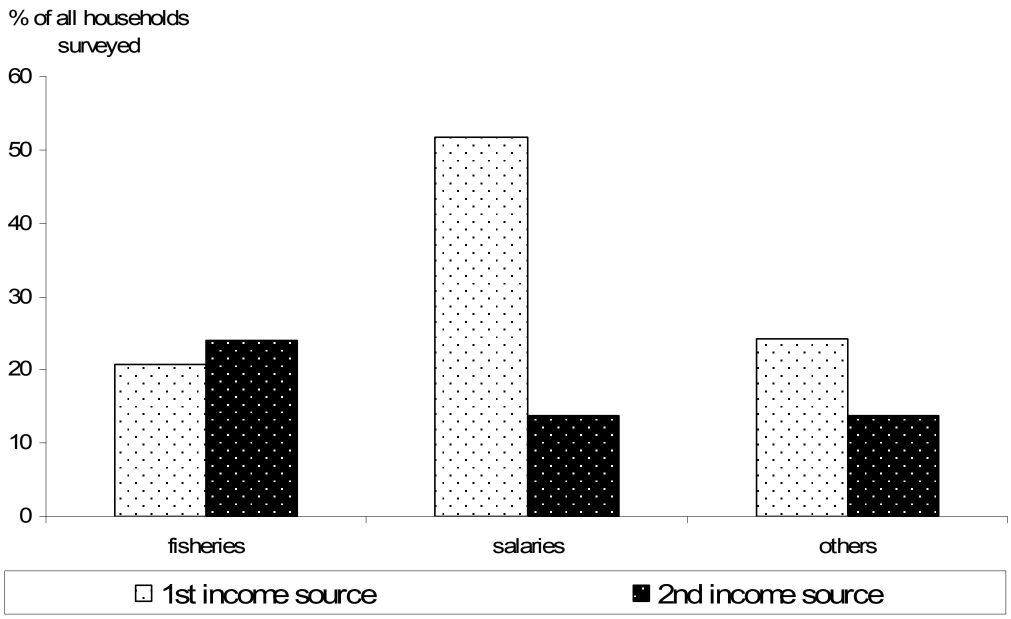

Figure 4.2: Ranked sources of income (%) in Vaitupu.
Total number of households = 29 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly handicrafts and private businesses.

The relatively low importance of fisheries for generating income is supported by other survey data. Finfish were caught mostly, and invertebrates exclusively, for subsistence needs.

Only 28% of all households interviewed reported receiving remittances. The average amount of remittances received by these households, however, was USD 1748/year, which almost reached the average annual household expenditure level (USD 2024).

Average per capita fresh fish consumption (163 kg/year) was high compared to the regional average. It exceeded the average national figure used here (98.4 kg – Figure 4.3), as well as previous estimates that ranged between 60 kg/year (SPC 1997, cited in Gillett and Lightfoot 2001; page 206) and 146 kg/year (Fisheries Department 1994, cited in Gillett and Lightfoot 2001; page 209). Vaitupu's fresh fish consumption was the second highest among all PROCFish/C sites in Tuvalu.

The frequency and quantity of canned fish consumption were low (0.6 times/week, 2.1 kg/capita/year). Invertebrates were not frequently consumed (on average 0.4 times/week). While almost all respondents reported that they consumed fish caught by a member of their household, over 60% of all households also bought finfish (from a neighbour, or at the roadside), and 72% of all households also received finfish as a gift. Only 55% of all households consumed invertebrates, and these were mostly caught by a household member. Invertebrates were never bought and rarely received as a gift (17%).

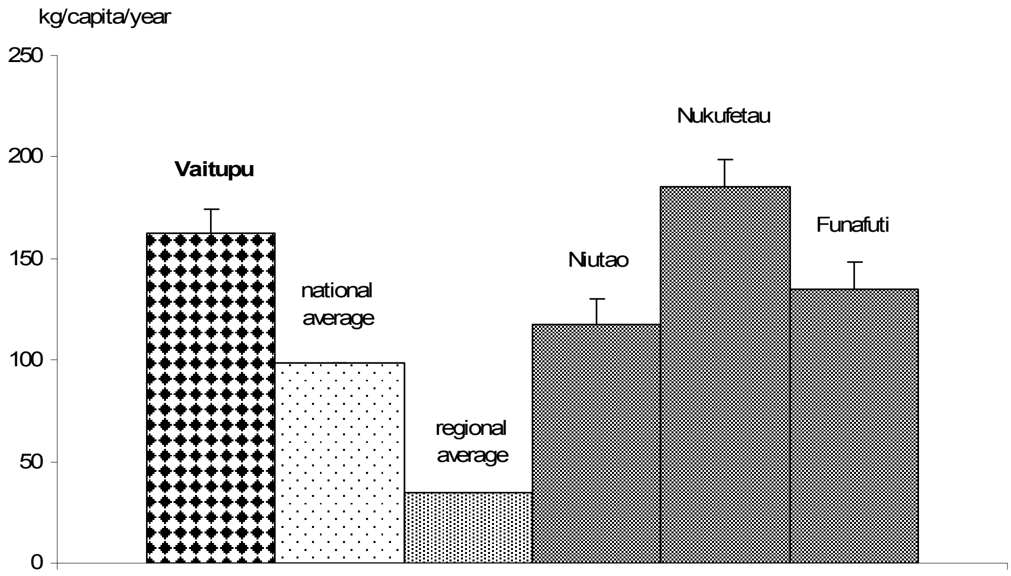

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Vaitupu (n = 29) compared to national and regional averages (Gillett 2002b), and other PROCFish/C sites in Tuvalu.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

By comparison with average figures from all PROCFish/C sites in Tuvalu (Table 4.1), Vaitupu's dependency on fisheries as a first and second income source was average or above average. The average household expenditure level was about average, while the percentage of households receiving remittances and the average amount of remittances received were below average. While frequency and per capita consumption of fresh fish were slightly above the average, little variation was found between the average figures and Vaitupu's frequency of canned fish and invertebrate consumption. The percentage of households owning a boat was low. The number of fishers per household was average and corresponded to an average percentage figure of households consuming fish they caught.

4.2.2 Fishing strategies and gear: Vaitupu

Degree of specialisation in fishing

Fishing on Vaitupu was dominated by males. Over 70% of all fishers were males, and less than 30% females. While 55% of all male fishers fished only for finfish, most female fishers collected invertebrates. The percentage of male and female fishers who fished for both finfish and invertebrates was very low (Figure 4.4).

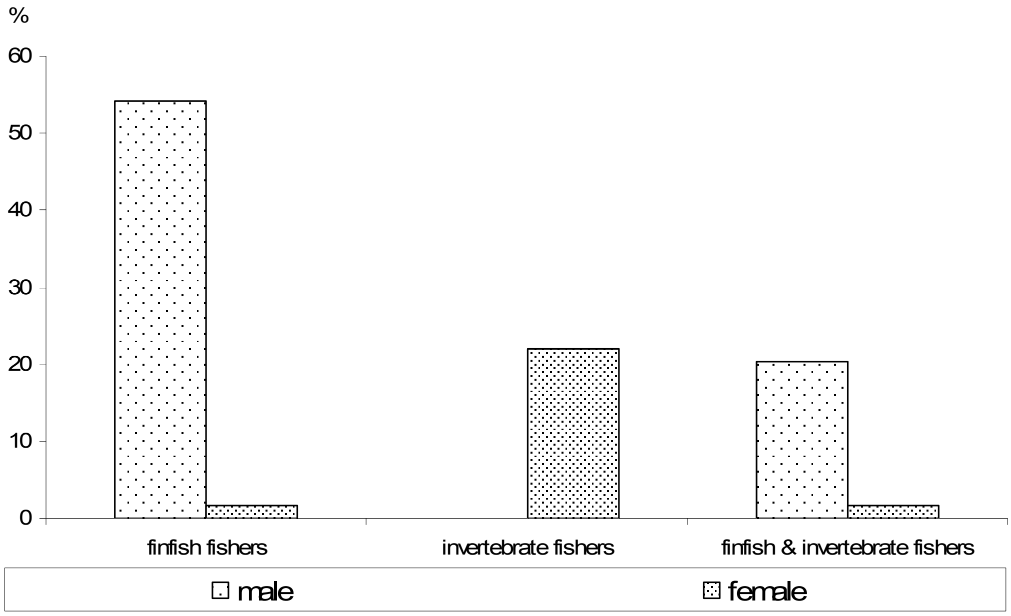

Figure 4.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Vaitupu.
All fishers = 100%.

Targeted stocks/habitats

As shown in Table 4.2, fishing in Vaitupu was limited to intertidal reef flats, lagoon and an outer reef. Invertebrates were also collected along the beach front.

Table 4.2: Proportion (%) of male and female fishers harvesting finfish and invertebrate stocks across a range of habitats (reported catch) in Vaitupu

Resource	Stock	% male fishers interviewed	% female fishers interviewed
Finfish	Intertidal reef flat	77.8	
	Lagoon	33.3	100.0
	Outer reef	63.0	
Invertebrate	Reeftop	60.0	20.0
	Intertidal	50.0	100.0

Finfish fisher interviews, males: n = 27; females: n = 1. Invertebrate fisher interviews, males: n = 10; females, n = 5.

Fishing patterns and fishing strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip were the basic factors used to estimate the fishing pressure imposed by people from Vaitupu on their fishing grounds.

Vaitupu has a very small lagoon area enclosed by land that is connected by a small strip of intertidal reef flats to the outer reef, i.e. there is no lagoon between the two reef habitats. The intertidal reef flats are exposed, at least partly, at during low tide. Therefore the existence of two separate reef habitats could be argued. However, due to the fact that Vaitupu's fishers targeted all three habitats: the small lagoon, the intertidal reef flats and the outer reef, and that the fishing strategies used in each zone varied considerably, the results of the socioeconomic survey are presented for each of these three habitats separately.

If we extrapolate our survey sample to the total population on Vaitupu, about 34% of all fishers targeted the lagoon, 33% targeted the intertidal reef flats and 33% the outer reef. Fishers did not combine any of the three habitats, but targeted only one during each fishing trip (Table 4.2).

On Vaitupu, all invertebrates were caught by gleaning (Figure 4.5). Intertidal fisheries attracted most of the gleaners, followed by reeftop fisheries.

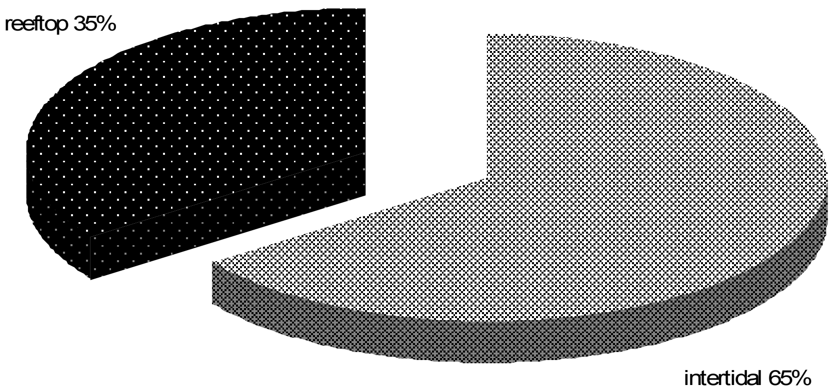

Figure 4.5: Proportion (%) of fishers targeting the two primary invertebrate habitats found in Vaitupu.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

Regarding gender roles, females dominated the intertidal fisheries; males the reeftop fisheries (Figure 4.6).

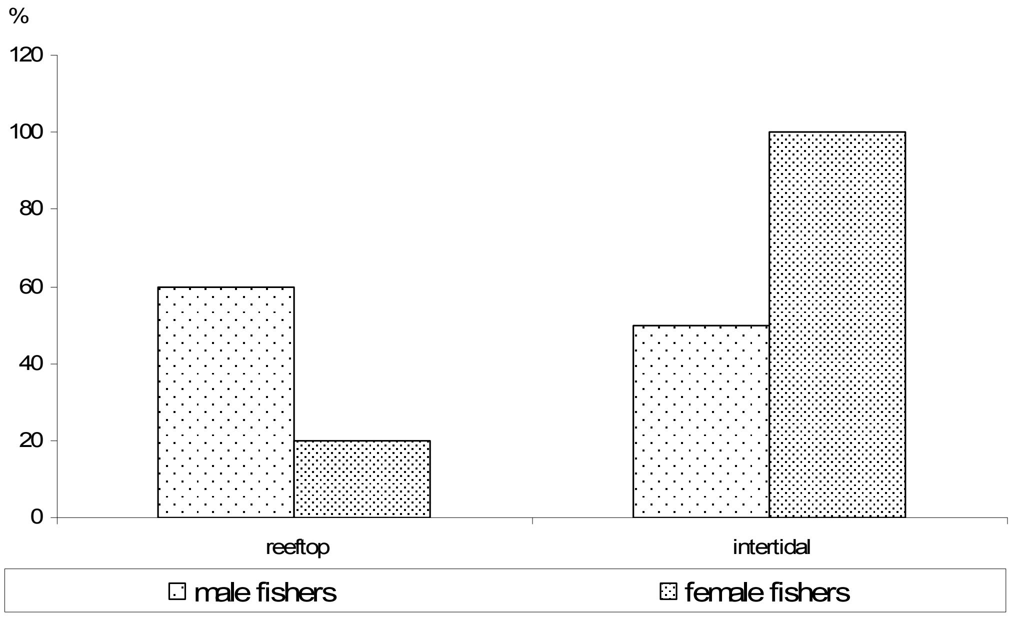

Figure 4.6: Proportion (%) of male and female fishers targeting various invertebrate habitats in Vaitupu.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 11 for males, n = 6 for females.

Gear

Figure 4.7 shows that Vaitupu's finfish fishers used a variety of different gears. Gillnetting was the main method used on the intertidal reef flat; rod and line fishing in the lagoon. In the outer-reef area, three techniques are most frequently used: handlining, speardiving and deep-bottom fishing. Trolling, scoop-netting and castnetting were of minor importance.

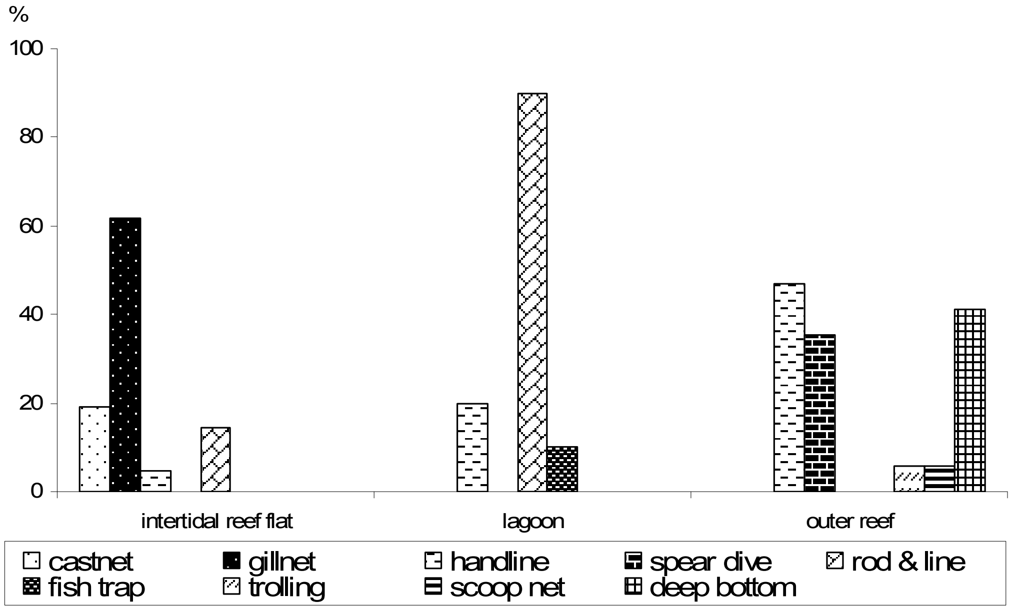

Figure 4.7: Fishing methods commonly used in different habitat types in Vaitupu.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Gleaning on Vaitupu was done by walking using simple collection tools. Gleaning was performed continuously throughout the year, mainly during the day, but sometimes reeftop gleaning was also performed at night (14%).

Frequency and duration of fishing trips

As shown in Table 4.3, there were some differences in the frequency of visits to the various habitats. Fishing trips to the lagoon were the least frequent (2.5 times/week). The intertidal reef flats and the outer reefs were visited ~3 times/week each. The average duration of fishing trips to the outer reef was considerably longer (>4 hours/trip) than trips to the intertidal reef flats and the lagoon (~2 hours/trip).

Table 4.3: Average frequency and duration of fishing trips reported by male and female fishers in Vaitupu

Resource	Stock	Trip frequency (trip/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Intertidal reef flat	3.19 (±0.32)	0	1.74 (±0.16)	0
	Lagoon	2.48 (±0.58)	2.50 (n/a)	2.17 (±0.30)	2.50 (n/a)
	Outer reef	2.80 (±0.29)	0	4.38 (±0.60)	0
Invertebrates	Reeftop	0.45 (±0.11)	1.00 (n/a)	2.33 (±0.21)	3.00 (n/a)
	Intertidal	0.55 (±0.14)	0.70 (±0.15)	2.50 (±0.45)	2.40 (±0.40)

Figures in brackets denote standard error; n/a: standard error not calculated.
Finfish fisher interviews, males: n = 27; females: n = 1. Invertebrate fisher interviews, males: n = 10; females: n = 5.

Invertebrate fishing trips were not as frequent as finfish fishing trips. On average, intertidal and reeftops were visited once every two weeks (0.45–1.00 times/week respectively). The duration of each fishing trip did not vary considerably between fisheries and took 2.3–3 hours on average.

Boats were not often used for fishing the intertidal reef flats and the lagoon but, for fishing the outer reef, about half of all trips used a boat.

Fishing on Vaitupu continued throughout the year. Apart from very rare cases targeting the outer reef, ice was not used on any fishing trip. Fishing in the lagoon was mainly done during the day, while intertidal reef flat and outer-reef fishing occurred either during the day or night, depending on the tides.

4.2.3 Catch composition and volume – finfish: Vaitupu

Catches from the intertidal reef flats were reported to mainly include *Valamugil seheli* (*kanase*, 38%), *Liza vaigiensis* (*kafakafa*, 14%) and *Kyphosus cinerascens* (*nanue*, 12%). Fishers targeting the lagoon mainly reported *Lethrinus* spp. (*noto*, *tanutanu*, 34%), *Liza vaigiensis* (*kafakafa*, 24%) and *Gerres* spp. (*matu*, 23%). By comparison, catches from the outer reef were more evenly distributed among more species, but the highest proportions (~10% of the total annual reported catch) were of Serranidae (*gatala*), *Cypselurus* spp. (*isave*) and *Myripristis violacea* (*malau*). Details on the estimated annual reported catch by vernacular species and scientific family are given in Appendix 2.3.1.

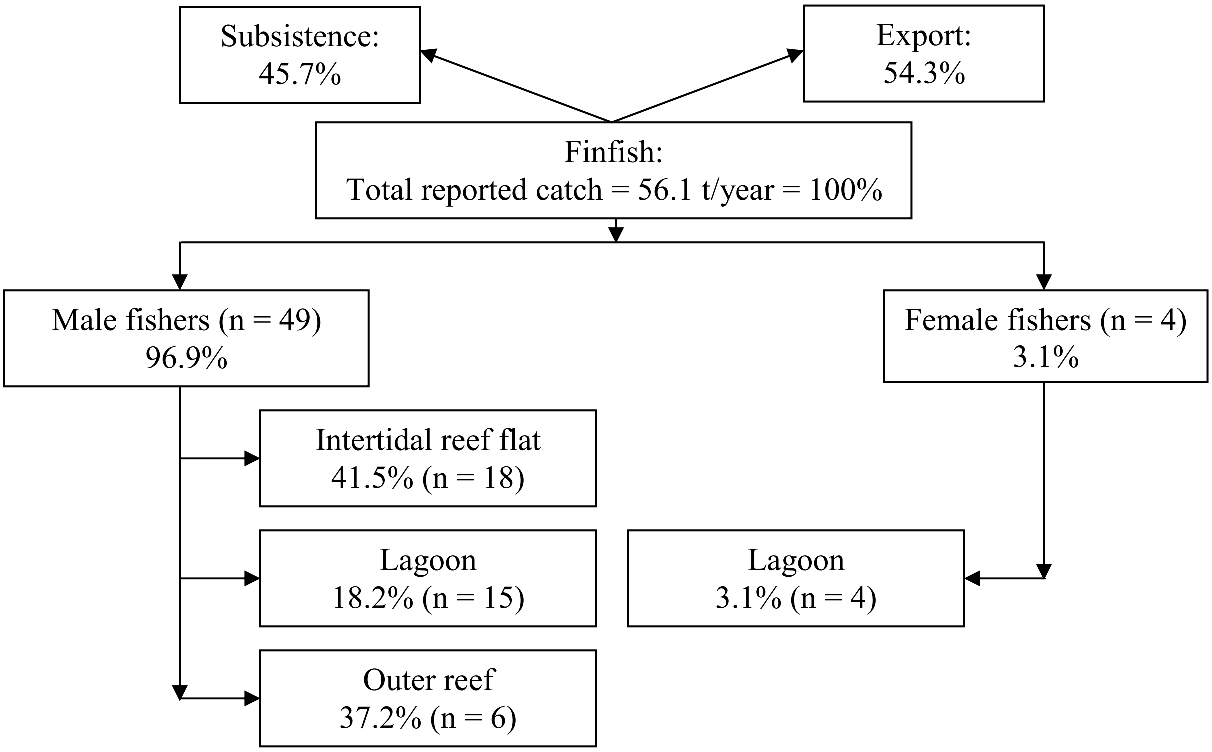

Figure 4.8: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Vaitupu.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The survey sample of finfish fishers interviewed represents about 7% of the projected total number of finfish fishers on Vaitupu only. Extrapolation of the survey data is therefore questionable. The reported and collected survey data summarised in Figure 4.8 show that most of the reported annual catch was sourced from the intertidal reef flats (42%) and outer reefs (37%). Catch from the lagoon accounted for 22% of the total annual catch. Females' contribution was low (3%).

In order to illustrate the possible total impact of fishing on Vaitupu, the reported survey data was extrapolated to cover the island's entire population. Accordingly, the total annual finfish catch amounted to 427.3 t/year. About 70% of the catch, i.e. 295.4 t/year, was consumed by the island's population, and the remaining 30% (131.9 t/year) was caught for supplying the school on Vaitupu, or for export to Funafuti.

The dominance of male fishers in Vaitupu's reef fishery is shown not only by the higher percentage of male fishers, but also in the higher average annual catch as compared to female fishers. However, this comparison is limited to lagoon catches only (Figure 4.9) and is unreliable due to the small number of female fishers sampled.

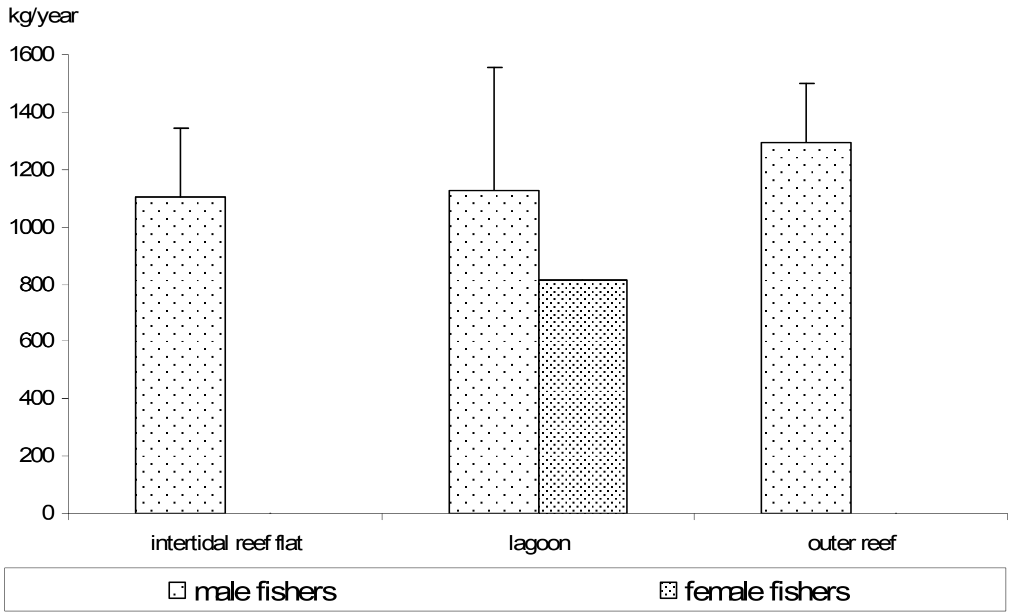

Figure 4.9: Average annual finfish catch (kg/year) per fisher by habitat and gender in Vaitupu.
Bars represent standard error (+SE).

The comparison of CPUE for males and females also suffered from the small sample size of female fishers. CPUE data for male fishers showed a progressive decline from the highest CPUE for intertidal reef flats to lagoon and lowest for outer-reef fishing. The few data entries available for female fishers targeting the intertidal reef flats suggested a lower CPUE than that for male fishers (Figure 4.10).

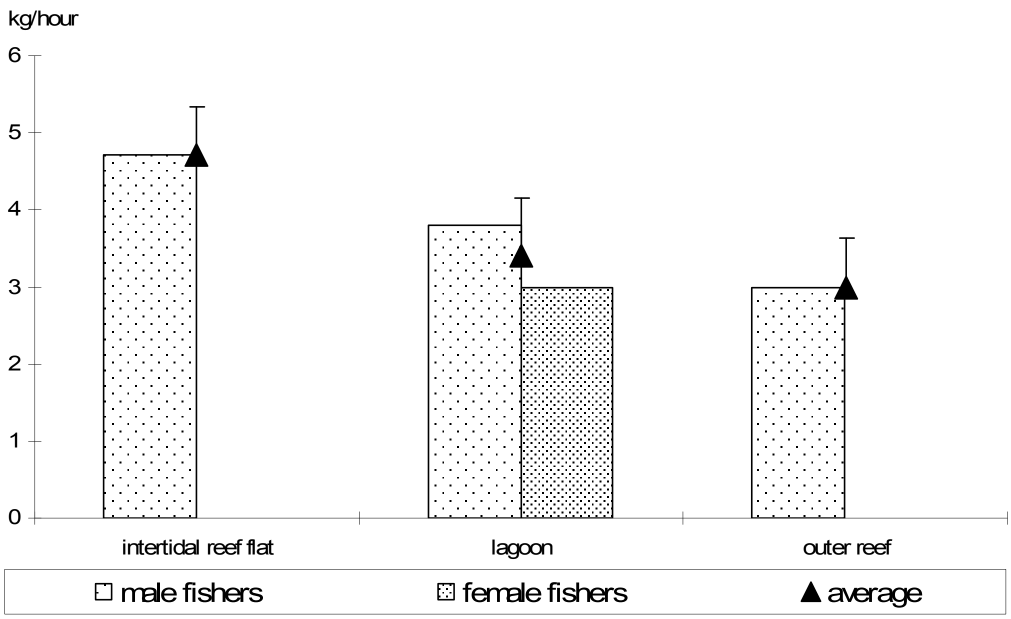

Figure 4.10: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Vaitupu.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Information provided by fishers on the proportion of catch per habitat that was used for subsistence and for sale (export to Funafuti) suggested that fishing in the lagoon and at the intertidal reef flats mainly served subsistence needs (Figure 4.11). Fishing trips targeting the outer reef served both subsistence and commercial interests equally. Fishing for catch to give away was not a priority, but did continue to play a role among Vaitupu's fishers.

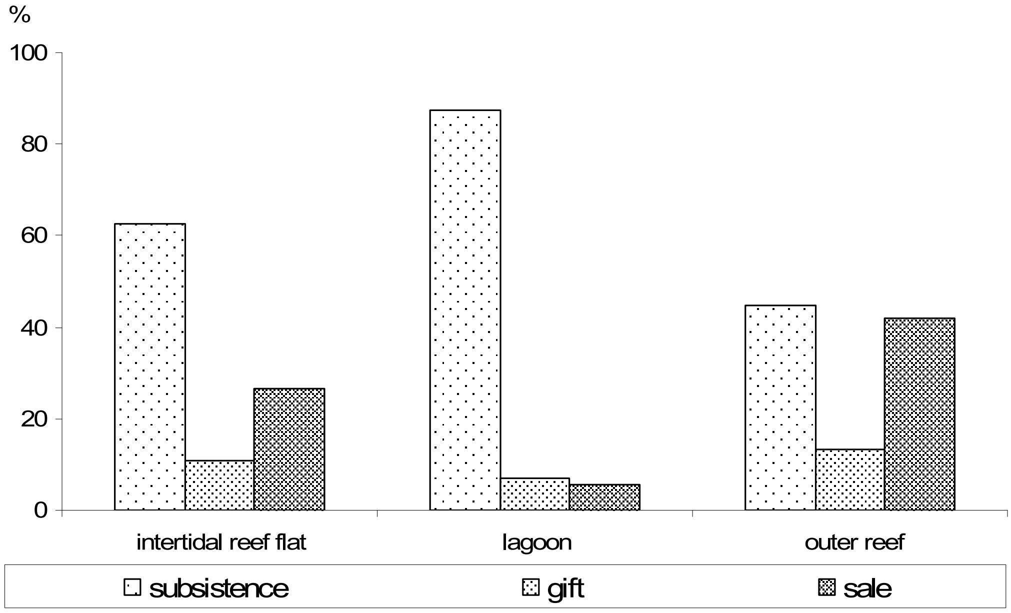

Figure 4.11: The use of finfish catches for subsistence, gift and sale, by habitat in Vaitupu.
Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and by habitat as shown in Figure 4.12, showed that, in most cases, the average size per fish family was larger for catches from the outer reef compared to the intertidal reef flats (Carangidae, Kyphosidae, Lethrinidae, Lutjanidae, Scaridae and Serranidae). There were indications that average fish sizes from catches in the lagoon were larger than or similar to those at the intertidal reef flats (Gerreidae, Lethrinidae, Lutjanidae and Mugilidae), and in two cases the largest as compared to both intertidal reef flats and outer-reef catches (Acanthuridae and Holocentridae). Mullidae were only reported from lagoon catches.

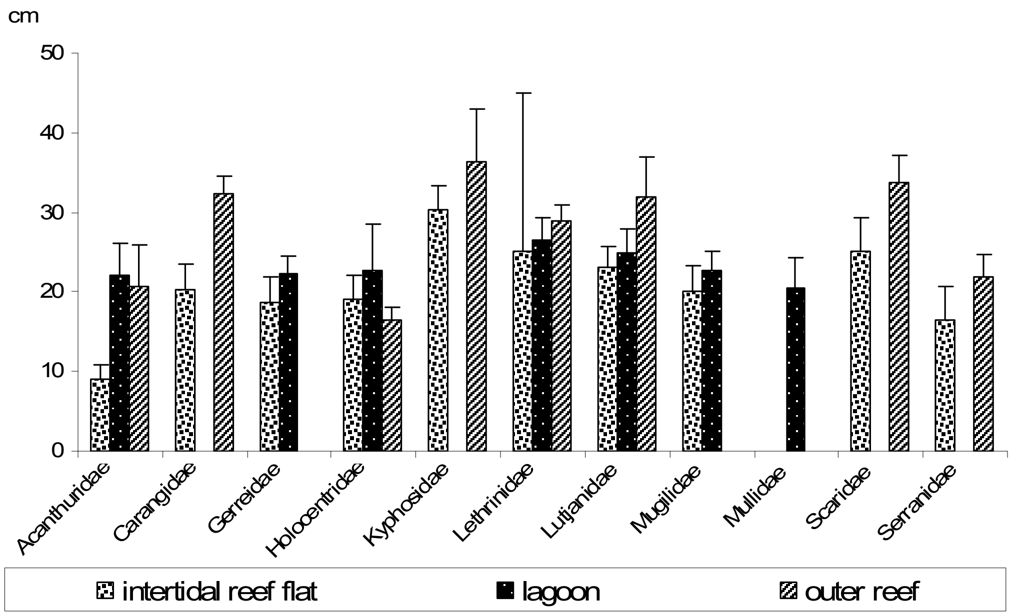

Figure 4.12: Average sizes (cm fork length) of fish caught by family and habitat in Vaitupu. Bars represent standard error (+SE).

As shown in Table 4.4 overall fisher density was relatively high, with 52 fishers/km² of Vaitupu's total fishing ground. Fisher density was highest in the small lagoon area where average annual catches per fisher were lowest. Lowest fisher density was at the outer reef (42 fishers/km²) and it coincided with highest average annual catches per fisher. Also, the calculated fishing pressure in terms of subsistence catch per reef and total fishing ground area was high, 27–30.5 t/km².

Table 4.4: Parameters used in assessing fishing pressure on finfish resources in Vaitupu

Parameters	Habitat				
	Intertidal reef flat	Lagoon	Outer reef	Total reef	Total fishing ground
Fishing ground area (km^2)	3.35	0.77	3.06	6.41	7.18
Density of fishers (number of fishers/km^2 fishing ground) (1)	48	111	42	59	52
Population density (people/km^2) (2)				227	203
Average annual finfish catch (kg/fisher/year) (3)	1104.3 (±237.6)	1094.5 (±383.6)	1223.3 (±211.5)		
Total fishing pressure of subsistence catches (t/km^2)				30.5	27.2

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 1455; total subsistence demand = 195.4 t/year; (3) catch figures are based on recorded data from survey respondents only.

4.2.4 Catch composition and volume – invertebrates: Vaitupu

Calculations of the reported annual catch rates per species groups are shown in Figure 4.13. The graph shows that the major impact by wet weight was focused on two species: *Asaphis violascens* (*kasi*) and *Turbo setosus* (*alili*). By comparison, there was very low impact on *Grapsus albolineatus* (*kamakama*), *Thais armigera* (*kivikivi*), *Anadara* spp. (*koki*), and octopus.

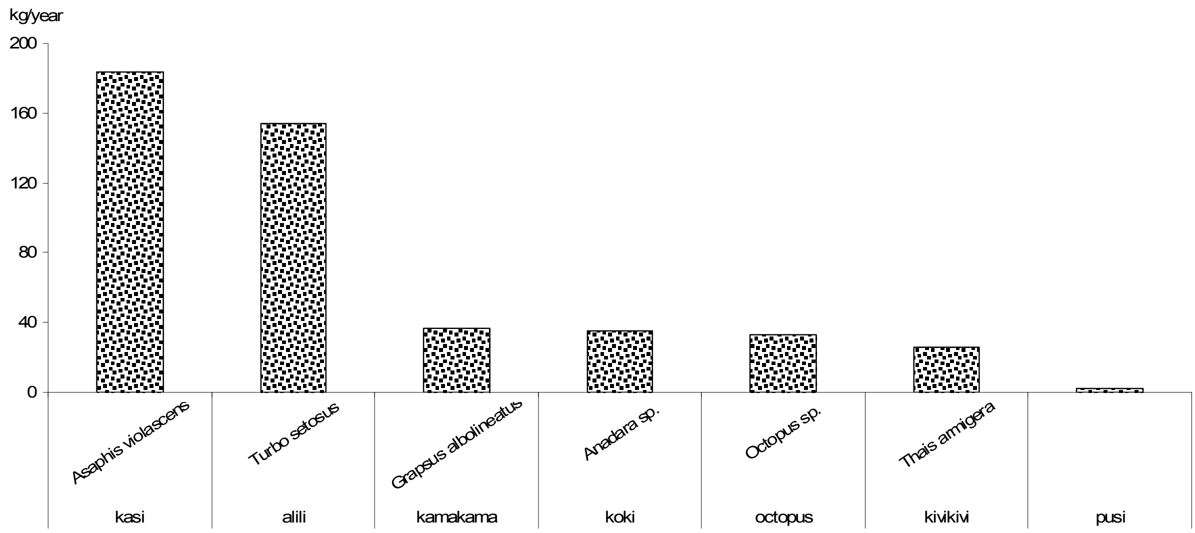

Figure 4.13: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Vaitupu.

Figure 4.14 shows that invertebrate fisheries at Vaitupu were very low in diversity. Only six species were reported for intertidal and reeftop fisheries.

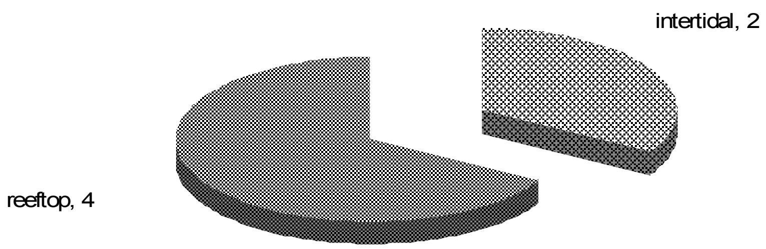

Figure 4.14: Number of vernacular names recorded for each invertebrate fishery in Vaitupu.

Details on the species distribution per habitat and on size distribution by species are provided in Appendices 2.3.2 and 2.3.3 respectively.

Comparison of the annual reported catch rates by fisher, gender and fisheries (Figure 4.15) shows that females' reeftop fisheries yielded the highest average catch weight per year. However, this data should not be considered representative due to the small sample size. Males' average catches were similar for both intertidal and reeftop fisheries. Males' average annual catch rates for intertidal gleaning slightly exceeded those of females.

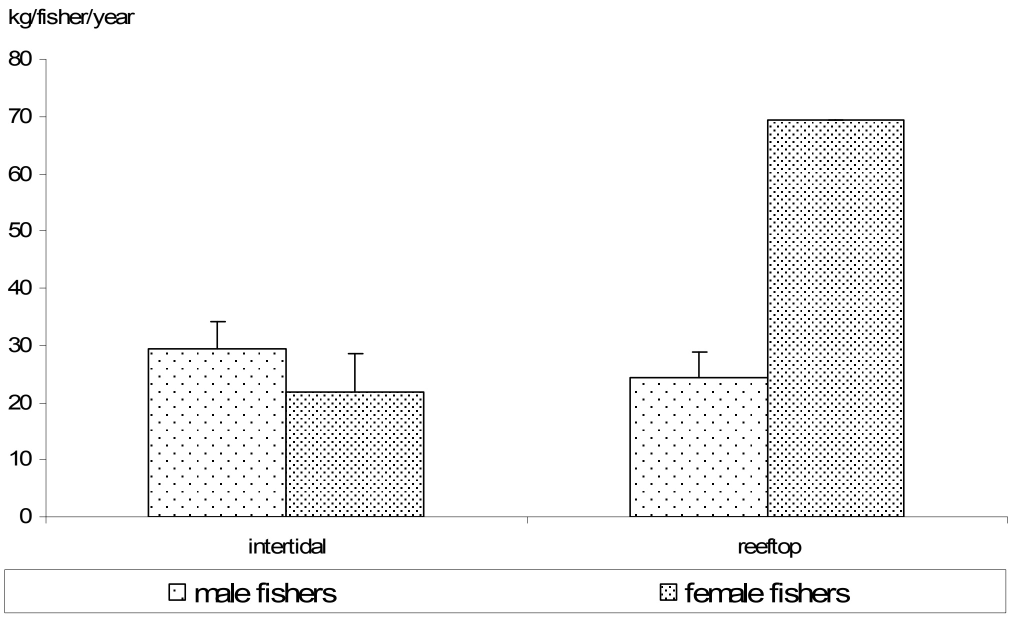

Figure 4.15: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Vaitupu.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 11 for males, n = 6 for females).

The ratio between invertebrates caught for subsistence and sale (Figure 4.16) shows that invertebrate fisheries on Vaitupu only served subsistence needs.

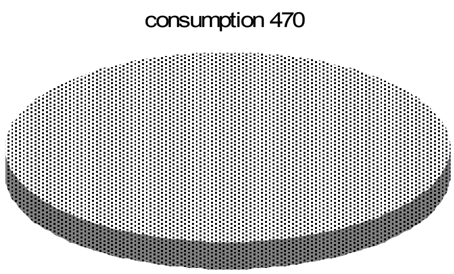

Figure 4.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Vaitupu.

The total annual catch volume expressed in wet weight based on the reported data from all respondents interviewed amounted to 0.5 t/year (= 100% – Figure 4.17). Catches from intertidal fisheries represented a slightly higher proportion (54%) of the total annual reported catch than those from reeftops (46%).

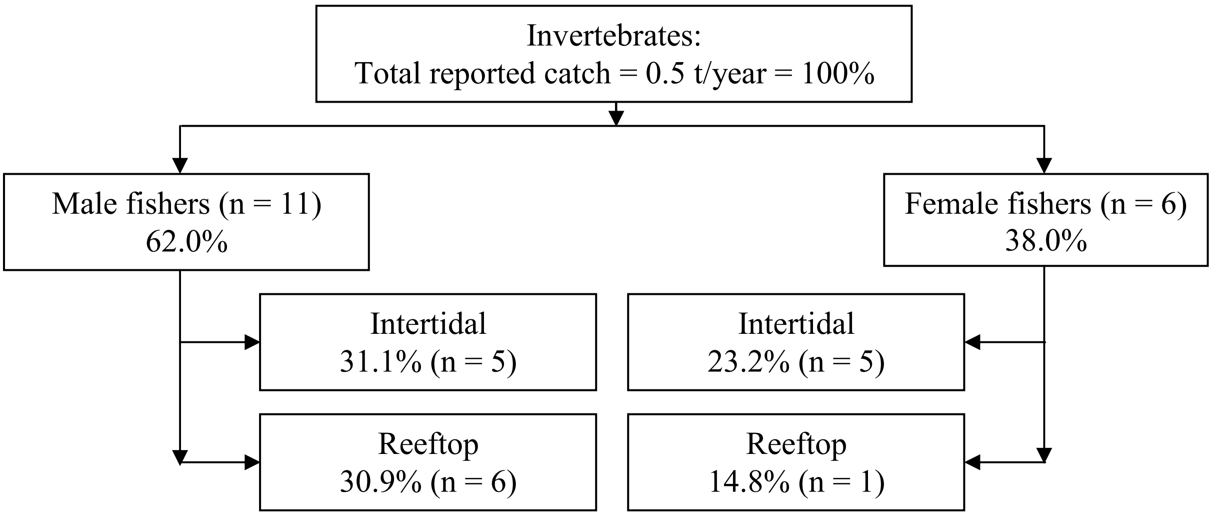

Figure 4.17: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Vaitupu.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The parameters presented in Table 4.5 show that both intertidal and reeftop habitats were relatively small, fisher density was relatively high and the average reported annual catch (biomass wet weight) per fisher was low for both fisheries.

Table 4.5: Parameters used in assessing fishing pressure on invertebrate resources in Vaitupu

Parameters	Fishery	
	Intertidal	Reeftop
Fishing ground area (km^2)	1.2	6.4
Number of fishers (per fishery) (1)	163	82
Density of fishers (number of fishers/km^2 fishing ground)	132	13
Average annual invertebrate catch (kg/fisher/year) (2)	25.53 (±4.07)	30.67 (±7.53)

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only.

4.2.5 Discussion and conclusions: socioeconomics in Vaitupu

- The Vaitupu community enjoyed a relatively low average household expenditure level, and a low proportion of its members received remittances. Salaries were the most important source of income. Fisheries were of low importance for the generation of cash income. A relatively low proportion of finfish was caught for export to Funafuti, and invertebrates were exclusively used for subsistence purposes. While invertebrates were not frequently consumed (0.4 times/week) and canned fish consumption was small, the consumption of finfish was high (163 kg/capita/year) and second highest across all PROCFish/C sites in Tuvalu.

- Fishing on Vaitupu was dominated by males. This was also true for invertebrates, although more females glean the intertidal reef flats, while more males glean the reeftops. The average number of fishers per household was moderate, and only a few owned a boat. The highest finfish fishing impact was almost equally accounted for by catches from the intertidal reef flats and the outer reef. Overall, fishing pressure was high (27–30.5

t/km²). However, CPUEs differed substantially; they were highest at the intertidal reef flats and decreased from lagoon to outer-reef fishing.

- Some of the variations in CPUE may be attributable to the use of different fishing techniques. Gillnets were mostly used at the intertidal reef flats; rod and lines in the lagoon; and a combination of handlines, speardiving and deep-bottom fishing at the outer reef. The use of different techniques may also explain some trends in the average finfish sizes reported. While sizes usually decreased from the intertidal reef flats to the outer reef, rod and line fishing techniques in the lagoon may have selected larger fish than did gillnets.

- Vaitupu's invertebrate fisheries were limited to reeftop and intertidal gleaning, with a total of six reported target species for subsistence purposes only. The total annual reported catch (biomass wet weight) of invertebrates was low and equally distributed over both reeftop and intertidal fisheries. In terms of impact on individual target species, however, most of the annual catch was accounted for by *Asaphis violascens* and *Turbo setosus*. By comparison, catches of the other five species were insignificant.

- The survey data suggests that the Vaitupu community had a very low dependency on finfish fisheries for income generation. The per capita consumption of finfish on Vaitupu was high and accounted for most of the catches from the sheltered coastal and outer-reef areas; less was sourced from the lagoon. Invertebrate fishing was exclusively for subsistence. In contrast to other sites surveyed in Tuvalu, pressure imposed by the island community's subsistence demand on their fishing resources was high. Possible explanations for the low commercial exploitation level may be resource limitations and/or marketing infrastructure.

4.3 Finfish resource surveys: Vaitupu

Finfish reef resources were surveyed in Vaitupu between March 28 and April 2 2005. In most sites, finfish resources and their associated habitats were assessed from 24 transects haphazardly placed and randomly distributed throughout all hard habitats accessible to divers (Figure 4.18), However, in Vaitupu, the main, larger lagoon is nearly enclosed. This, coupled with its mud–silt environment, makes the visibility relatively poor all the time. Therefore the lagoon was not surveyed, neither the fringing intertidal reefs. However, since the area these lagoon reefs cover is <1% of the total habitat, not much information is excluded by the lack of survey. Therefore only data from the outer reef (3.1 km^2) is discussed here. Appendix 3.3.1 provides the coordinates for the finfish surveys conducted around Vaitupu.

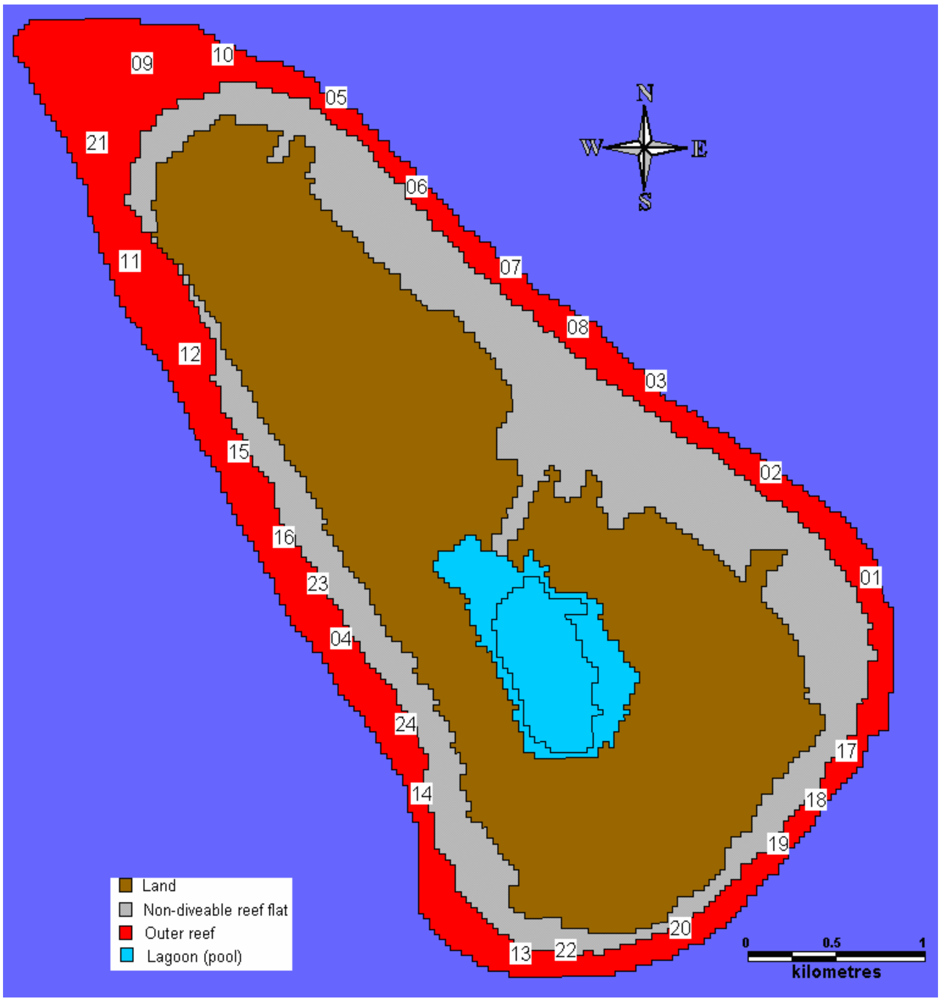

Figure 4.18: Habitat types and transect locations for finfish assessment in Vaitupu.
The smaller, northern lagoon does not appear here, due to the method of classification of the satellite image.

4.3.1 Finfish assessment results: Vaitupu

A total of 18 families, 50 genera, 138 species and 10,224 fishes were recorded in the 24 transects (Appendix 3.3.2). Data relating to the 14 most dominant families form the basis of this report, i.e. 43 genera, 128 species and 10,126 individuals. Of these, a mean of 11 fish families, 21 fish genera, 40 ±2 fish species and 426 ±30 individual fishes were observed and recorded in each transect on Vaitupu.

Table 4.6: Primary finfish habitat and resource parameters recorded in Vaitupu (average values ±SE)

Parameters	Habitat
	Outer reef [1]
Number of transects	24
Total habitat area (km^2)	3.1
Depth (m)	8 (0-14) [2]
Soft bottom (% cover)	2.5 ±0.6
Rubble & boulders (% cover)	5.9 ±1.7
Hard bottom (% cover)	73.0 ±1.8
Live coral (% cover)	18.5 ±1.3
Soft coral (% cover)	0
Biodiversity (species/transect)	39 ±2
Density (fish/m^2)	0.8 ±0.1
Size (cm FL) [3]	19.9 ±0.4
Size ratio (%)	60.5 ±1.2
Biomass (g/m^2)	179.2 ±19.8

[1] Unweighted average; [2] depth range; [3] FL = fork length.

The Vaitupu outer-reef system is 3.1 km² in area, spread around the island. The benthic communities of the outer reefs had a relatively low percentage of coral cover (18.5 ±1.3%, Table 4.6) and a high percentage of dead coral, slab and boulder cover (79%) and algae overgrowth (16.2 ±7.4%) compared to the other sites. These parameters described Vaitupu as the site with the poorest benthic communities of the four outer-reef sites in Tuvalu.

Fish density was the lowest among all outer reefs surveyed, including those of the two atoll sites. The most abundant fish families were Acanthuridae and Balistidae (Table 4.7, Figure 4.19), represented by the key species of *Ctenochaetus striatus*, *Acanthurus lineatus*, *A. nigricans*, *Naso lituratus*, *Melichthys niger* and *Melichthys vidua* (Table 4.7). The more targeted species of Lethrinidae, Lutjanidae and Serranidae were noticeably rare or absent during the surveys. Moreover, market-sized groupers (e.g. *Plectropomus* spp. and *Variola* spp.) were rarely observed during the survey.

The biomass composition of the main commercial fish species and genera differed when compared to outer reefs in the other Tuvalu survey sites (Figure. 4.19). Acanthuridae (100.3 ±12.7 g/m²) was the predominant family on the island, followed by Scaridae (26.2 ±5.1 g/m²), Balistidae (14.4 ±1.7 g/m²), Lutjanidae (11.6 ±2.5 g/m²) and Serranidae (8.2 ±1.3 g/m², Table 4.7). The two genera *Acanthurus* and *Naso* were predominant and contributed more than 45% of the biomass assemblage on Vaitupu. The most important species in terms of biomass were *A. lineatus*, *Naso lituratus*, *Ctenochaetus striatus*, *A. nigricans* and *Cephalopholis argus*.

We also recorded *Scarus tricolor* and *Chlorurus japanensis*, species which were previously only rarely recorded in Tuvalu. Two species of sharks (*Carcharhinus melanopterus* and *Triaenodon obesus*) were recorded in the surveys, however in alarmingly low numbers. Rare commercial and edible fish families recorded on Vaitupu were Pomacanthidae, Holocentridae and Zanclidae. There was no count of Nemipteridae, but the territorial and cryptic behaviour of these rare fishes makes them unsuitable for the UVC survey method used.

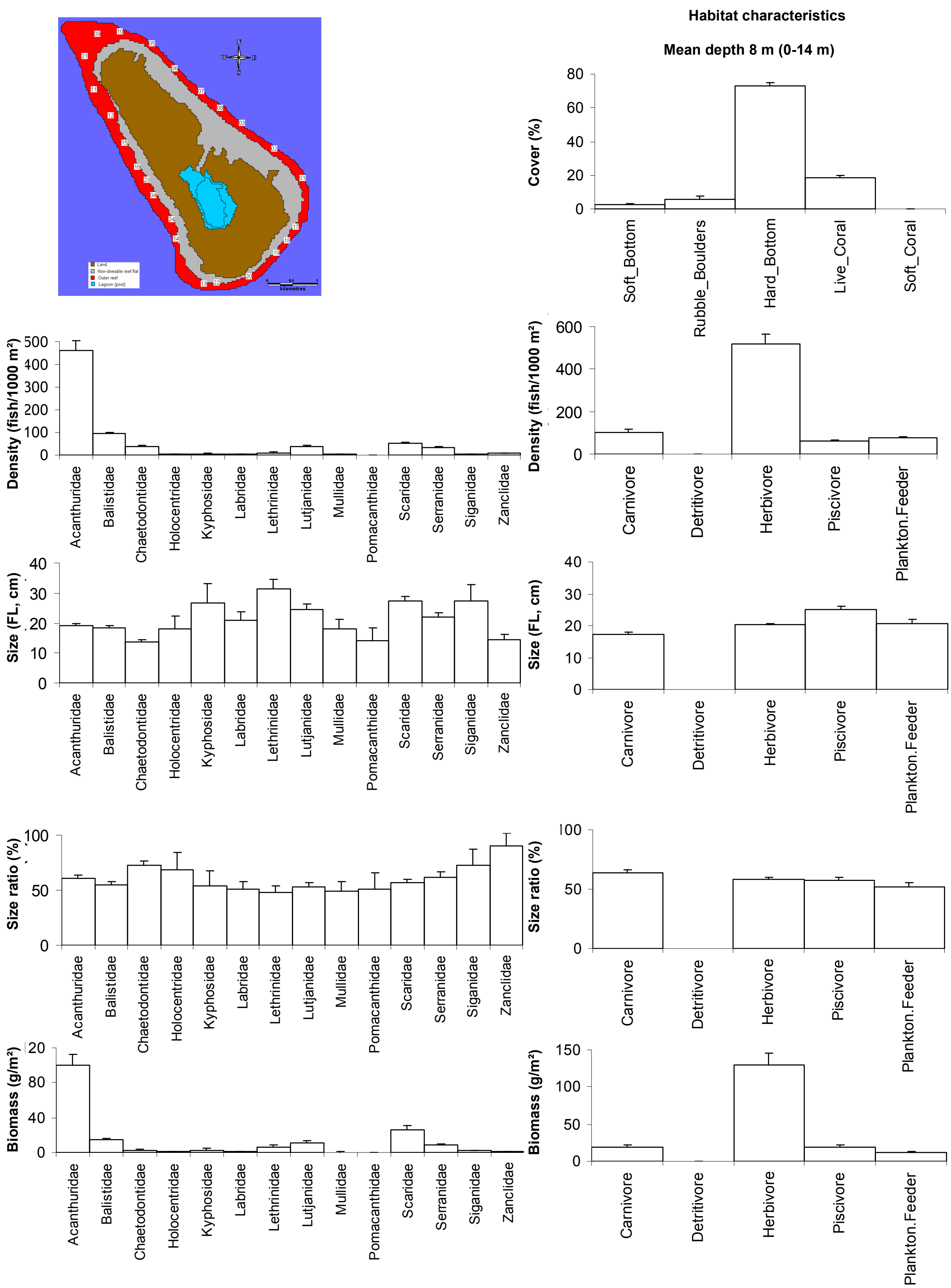

Figure 4.19: Profile of finfish resources in the outer-reef environment of Vaitupu.
Bars represent standard error (+SE); FL = fork length.

Table 4.7: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Vaitupu

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Lined bristletooth surgeonfish	0.13 ±0.02	14.0 ±2.2
	Acanthurus lineatus	Striped surgeonfish	0.12 ±0.01	34.3 ±8.0
	Acanthurus nigricans	Whitecheek surgeonfish	0.08 ±0.01	11.00 ±2.3
	Naso lituratus	Orangespine unicornfish	0.06 ±0.01	22.8 ±3.7
Balistidae	*Melichthys niger*	Black triggerfish	0.04 ±0.01	5.1 ±0.6
	Melichthys vidua	Pinktail triggerfish	0.03 ±0.01	2.7 ±0.4

4.3.2 Discussion and conclusions: finfish resources in Vaitupu

- Finfish resources were distributed uniformly around the island with slightly higher abundance and biomass along the windward side. However, there was a marked variation in fishing pressure between the leeward and windward sides of the island. The leeward side of the island is more protected and usually provides easy access, while the windward side is exposed to the predominant south easterly winds, and located far from the main passages and also from the main settlement. These characteristics make it naturally protected from fishing pressure compared to the leeward side. Similar to density and biomass, fish sizes showed differences between the two sides of the island, with relatively small fish at the leeward side of the island, most probably in response to the higher fishing pressure.

- When compared to the outer-reef values for all study sites, the finfish resources of Vaitupu Island displayed the lowest biodiversity, density and biomass. Like Niutao, Vaitupu did not have all the available habitats and reef types to allow a choice of fishing methods, gears and targets. Therefore, the level of fishing impact was expected to be intensive at Vaitupu compared to Funafuti and Nukufetau. Moreover, the high population density on the island appeared to increase fishing pressure to levels that might exceed sustainable limits in the outer reefs. In addition to the relatively large local population, the additional number of people at the secondary school situated on the island added even more fishing pressure on reef fish stocks. Fishing pressure, defined as fishers/km^2, was found to be the highest among the four survey sites, at both the intertidal reef flats and the outer reefs.

- The benthic communities of the outer reefs of the four study sites shared similar habitat characteristics; however Vaitupu had the smallest percentage cover of live coral and the largest cover of dead coral. There was no apparent cause for this trend. However, it is perhaps possible to relate such poor live coral cover to factors other than those caused by humans. For instance, raised water temperature had resulted in a high level of coral bleaching. Also, frequent, strong storms and cyclones had impacted reefs in the recent past.

- The finfish resource survey indicated that Vaitupu had very low populations of the targeted and commercial species of Serranidae, Lutjanidae and Lethrinidae. Similarly to the case in Niutao, the relatively high abundance of Acanthuridae, Balistidae and, to a much lesser extent, Scaridae correlated well with the high cover of hard substrate and algae. Such herbivorous fishes are typical of an outer-reef environment, which was the only reef habitat surveyed in Vaitupu. Herbivores are often associated with coral slab and hard-bottom substrates, where they browse on their favourite food type, turf and small algae. The high abundance of Acanthuridae may also be explained by the frequent incidence of ciguatera on species like *Acanthurus lineatus*, *Ctenochaetus striatus* and *Naso lituratus* (Laurent *et al.* 2005). Similarly to density, the available stocks of Acanthuridae far exceeded those of the other remaining families: biomass was predominantly made up of Acanthuridae and Balistidae, while at all other sites, especially Nukufetau, there was evidence of a much higher importance of Lutjanidae and Lethrinidae, as well as Scaridae.

- Although biomass and density levels were average, mean size and size ratios were the highest and were similar to values in Niutao for most families, except Carangidae and Lutjanidae. Sizes of the commercially targeted Acanthuridae, Balistidae, Holocentridae, Scaridae, Serranidae and Siganidae were higher than 55% of their maximum known size. Therefore, even though fish population levels signalled that major carnivore stock sizes were low, they were not yet considered at a critically low level. It was not possible through the design of this study and preliminary analyses to state realistically whether the targeted reef fish populations were being fished below or above the optimum/maximum fishing yield. Relative comparisons of parameters across sites within and outside of Tuvalu will perhaps be able to generate a better overall picture of the state of the reef fish resources.

4.4 Invertebrate resource surveys: Vaitupu

The diversity and abundance of invertebrate species at Vaitupu Island were independently determined using a range of survey techniques (Table 4.8), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 4.20) and finer-scale assessment of specific reef and benthic habitats (Figures 4.21 and 4.22).

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 resources in those areas of naturally higher abundance and/or most suitable habitat.

Table 4.8: Number of stations and replicates completed at Vaitupu

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	12	72 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)	4 RFs 1 RFs_w	30 search periods
Sea cucumber night searches (Ns)	2	12 search periods
Sea cucumber day searches (Ds)	4	24 search periods

RFs_w = reef-front searches by walking.

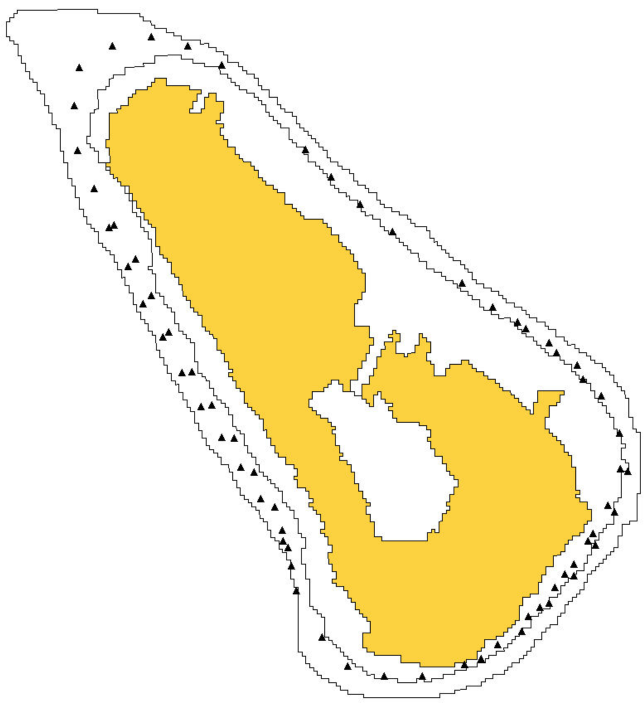

Figure 4.20: Broad-scale survey stations for invertebrates in Vaitupu.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

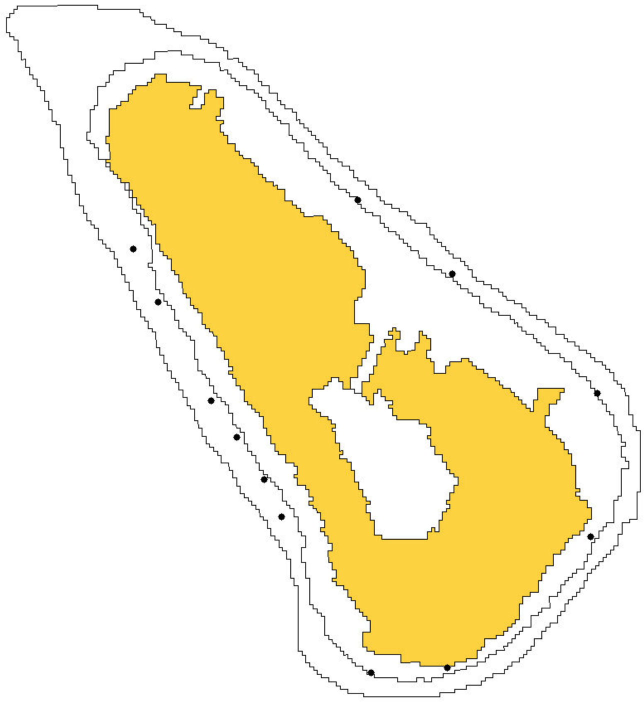

Figure 4.21: Fine-scale reef-benthos transect survey stations for invertebrates in Paunangisu.
Black circles: reef-benthos transect stations (RBt).

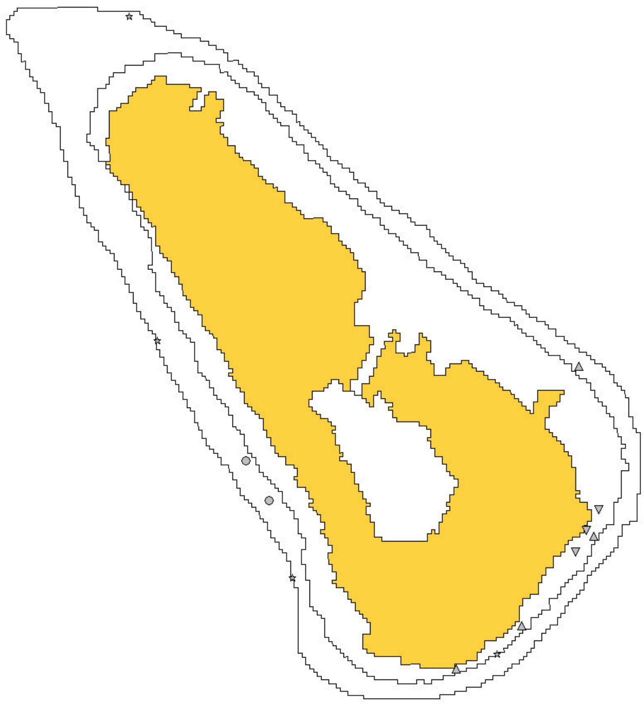

Figure 4.22: Fine-scale survey stations for invertebrates in Vaitupu.
Grey triangles: reef-front search stations (RFs);
inverted grey triangles: reef-front search stations by walking (RFs_w);
grey circles: sea cucumber night search stations (Ns);
grey stars: sea cucumber day search stations (Ds).

Twenty-five species or species groupings (groups of species within a genus) were recorded during invertebrate surveys at Vaitupu. Among these were 2 bivalves, 10 gastropods, 5 sea cucumbers, 3 urchins, 1 sea star and 1 lobster (Appendix 4.3.1). Information on key families and species are detailed below.

4.4.1 Giant clams: Vaitupu

There was little or no suitable lagoon or shallow-water reef that was protected from storm swell at Vaitupu (Major cyclones had affected the island in recent years: Bebe in 1972, and Oliwa and Keli in 1997). In El Niño years, cyclones are pushed towards Tuvalu and there is no extended offshore barrier reef to dissipate wave energy before it reaches coastal reefs.

Shallow-reef habitat that was suitable for clams was limited to approximately 4.5 km² of fringing reef, plus a further 1.2 km² of reeftop (reef platform), that was only submerged for short periods at high tides. There was also 0.7 km² of saline lagoon, which provided some marginal habitat. The most suitable reef was generally restricted to a shallow sloping reef in the lee of the island (west) and a narrow strip of submerged reef, which sloped steeply into deep water around the rest of the island.

Broad-scale sampling provided an overview of giant clam distribution around Vaitupu Island, and only one species of giant clam was recorded: elongate clam *Tridacna maxima* (recorded in 6 stations, 14 transects – Figure 4.23).

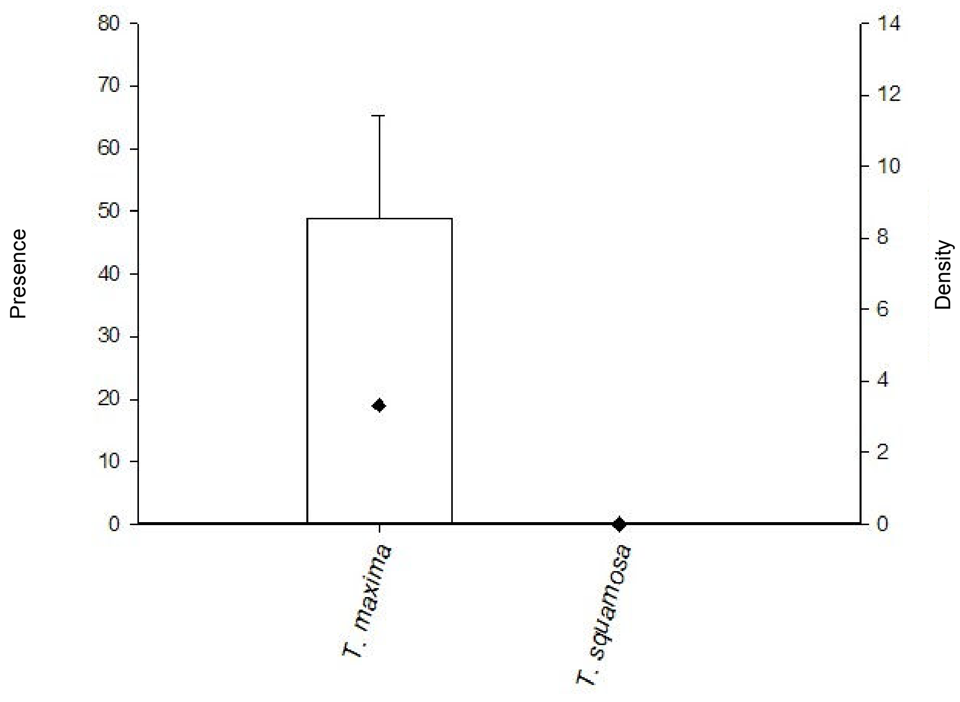

Figure 4.23: Presence and mean density of giant clam species at Vaitupu based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted more specific areas of clam habitat. Giant clam density was very low at Vaitupu and, although presence and density estimates were sought during fine-scale assessments of reef, no clams were recorded at the 12 reef-benthos transect stations and 4 sea cucumber day stations examined at Vaitupu.

The clams that were recorded in broad-scale surveys (n = 37) had an estimated average length of 11.2 ±0.5 cm. *T. maxima* matures after 3 to 5 years as males, but being a 'protandrous hermaphrodite' (It develops as a male first then later some stock becomes female.) it only starts to produce viable eggs later in its life, when shells reach about 12 cm in length (The asymptotic length (L_∞) is approximately >30 cm.). As can be seen from Figure 4.24, there were few recordings of large clams from Vaitupu assessments.

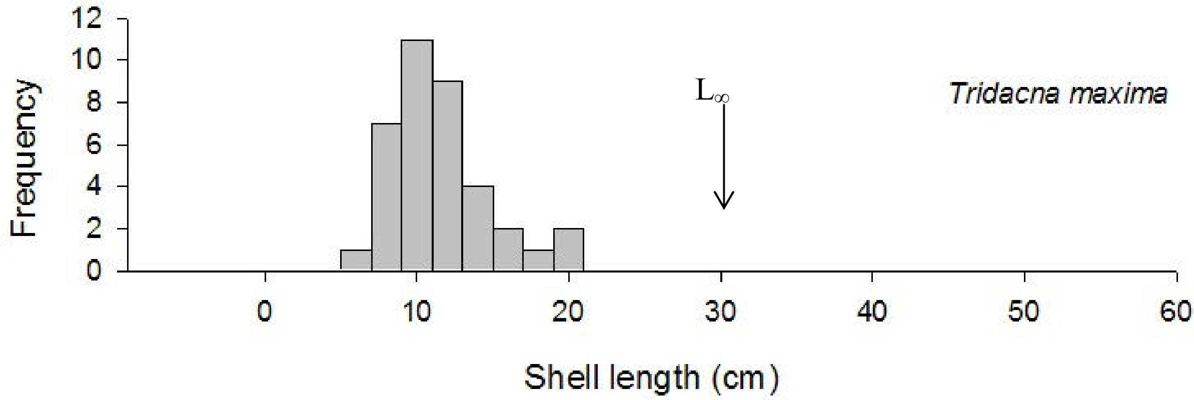

Figure 4.24: Size frequency histograms of giant clam *Tridacna maxima* in Vaitupu.

4.4.2 Mother-of-pearl species (MOP): trochus and pearl oysters – Vaitupu

Vaitupu Island is not large (outer perimeter of approximately 13.1 km), and submerged reef area was not extensive (4.5 km²) or particularly suitable for the commercial topshell *Trochus niloticus*, as most reef slopes steeply into deeper water. There was also very little habitat for juvenile trochus in the form of boulder fields and back-reef; Vaitupu would not support significant populations of this commercial species if it were introduced.

T. niloticus is not endemic in Tuvalu and has not been introduced to Vaitupu. Generally, the numbers of grazing gastropods were not found to be high in reef surveys, and the structure and exposure of the reef suggests Vaitupu would not present an attractive prospect for introduction of trochus. *Tectus pyramis*, the green topshell (of low commercial value), which has a similar life history to trochus, was present at Vaitupu at low density (Table 4.9). The four length recordings of *T. pyramis* had a mean basal width of 7 cm. Appendices 4.3.2 to 4.3.5 provide the results from broad-scale and fine-scale reef searches, while Appendix 4.3.8 details sizes of the invertebrate species surveyed.

Table 4.9: Presence and mean density of *Tectus pyramis* in Vaitupu
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Tectus pyramis				
B-S	0.7	0.4	2/12 = 17	3/72 = 4
RBt	10.4	5.4	3/12 = 25	3/72 = 4
RFs	0	0	0/4 = 0	0/24 = 0

B-S = broad-scale survey; RBt = reef-benthos transect; RFs = reef-front search.

The blacklip pearl oyster, *Pinctada margaritifera,* a normally cryptic and sparsely distributed species, was not recorded during the survey.

4.4.3 Infaunal species and groups: Vaitupu

No soft-benthos areas were found at Vaitupu, and therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made for this type of resource. The mission on Vaitupu was shorter than usual and did not allow significant investigation of the inland lagoons.

4.4.4 Other gastropods and bivalves: Vaitupu

Seba's spider conch, *Lambis truncata,* (the larger of the two common spider conchs) was detected in broad-scale, reef-front and sea cucumber day searches at low density (Appendices 4.3.1 to 4.3.7). *Turbo argyrostomus* and *T. setosus*, which are commonly collected along exposed reef fronts in the Pacific, were recorded at low density during reef-benthos surveys. Other gastropod species targeted by fishers (resource species, e.g. *Conus, Cymatium, Cypraea, Thais* and *Vasum*) were also recorded during independent survey (Appendices 4.3.1 to 4.3.7).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Spondylus*, are also in Appendices 4.3.1 to 4.3.7. No creel survey was conducted at Vaitupu Island.

4.4.5 Lobsters: Vaitupu

There was no dedicated night reef-front search (Ns) for lobsters (See Methods and Appendix 1.3.). However, despite the limited level of survey, one lobster was recorded in broad-scale surveys, and a further four lobsters noted in targeted surveys of reef (including night searches for sea cucumbers).

4.4.6 Sea cucumbers[9]: Vaitupu

The presence of valuable commercial species of sea cucumbers at this raised limestone island was lower than that recorded at both atoll lagoon sites in Tuvalu (Funafuti and Nukufetau). However, the land mass was large compared to the scale of the reef, and also held a semi-saline lagoon (<1 km^2), which was periodically linked to the ocean during spring tides. The

[9] 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.

restricted area of shallow-water reef (a total of 6.4 km^2; 4.5 km^2 of submerged fringing reef, 1.2 km^2 of reef platform and 0.7 km^2 of saline lagoon) was generally exposed and/or inhospitable for sea cucumbers (which are deposit feeders that eat organic matter in the upper few millimetres of bottom substrates).

Although the whole system provides little in the way of habitat for deposit feeders, which require sheltered reef margins and shallow, mixed hard- and soft-benthos habitat, the benthos around Vaitupu was characterised in areas by eutrophication (epiphyte-covered areas). In addition, sea cucumber fishing at Vaitupu had been under an extended moratorium. Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 4.10; Appendices 4.3.1 to 4.3.7), and five commercial species of sea cucumbers were recorded during in-water assessments (Table 4.10).

Sea cucumber species associated with reef, such as the high-value black teatfish (*Holothuria nobilis*) were present (found in only 1% of manta transects), but leopardfish (*Bohadschia argus*), and another common species associated with reef, greenfish (*Stichopus chloronotus*), were absent.

Surf redfish, *Actinopyga mauritiana,* a species that is characteristic of exposed locations, was recorded at exceptional abundances at Vaitupu, when compared to the other island and lagoon sites surveyed. The exposed offshore reef and surge zone present at Vaitupu was relatively extensive compared to the other non-lagoon site, Niutao (13 km compared to 7 km lineal distance), but small compared to the two atoll sites. Surf redfish at Vaitupu were concentrated in the south and southeastern sectors of the island, and were generally isolated to a narrow strip in front of the wave zone (and first 3 m of water depth). Surf redfish were not present on most of the exposed reef platforms, which tended to dry at low tide, as these platforms did not support many areas where water pooled or channelled. The density of this species was high for Tuvalu (an average of 241 per ha, RFs), but can only be considered as moderately high in commercial terms (Stocks can be found at 400–600 per ha at the better fishing locations.).

More protected areas of reef and soft benthos were rare in Vaitupu. Where they did exist, for example in the brackish-water lagoon, and in a limited number of back-reef pools on the reef platform, lower-value species were recorded. Brown sandfish (*Bohadschia vitiensis*) were noted at reasonably high density within the lagoon (No actual measurements were made.), and small lollyfish (*Holothuria atra*) were present on the back-reef at high density.

Deep dives on SCUBA (25–35 m) were also conducted to obtain a preliminary assessment of deep-water stocks, such as the high-value white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*) and the lower-value amberfish (*Thelenota anax*). In these assessments (average 27 m depth) white teatfish (*Holothuria fuscogilva*) and amberfish (*Thelenota anax*) were not recorded, although prickly redfish (*Thelenota ananas*) was found at low density.

Table 4.10: Sea cucumber species records for Vaitupu

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef-benthos stations n = 12			Other stations RFs = 4 RFs_w = 1			Other stations Ds = 4 Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	32.2	77.2	42	31.3	75.0	42	241.2 1.2	241.2 4.8	100 RFs 100 RFs_w	4.4	8.9	50 Ns
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M												
Bohadschia vitiensis	Brown sandfish	L										Observed in saline lagoon		
Holothuria atra	Lollyfish	L							156.0	624.0	100 RFs_w			
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M												
Holothuria nobilis [4]	Black teatfish	H	0.2	16.7	1									
Thelenota ananas	Prickly redfish	H										4.2	8.3	50 Ds
Thelenota anax	Amberfish	M												

[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; Ds = day search; Ns = night search.

4.4.7 Other echinoderms: Vaitupu

The edible slate urchin *Heterocentrotus mammillatus* was found at very low density, but no collector urchins *Tripneustes gratilla* were recorded. *Echinometra mathaei* was recorded at high density (100% of RBt stations), but *Echinothrix diadema* was rare.

Starfish apart from *Fromia* spp. were rare. No corallivorous starfish, such as the crown of thorns (*Acanthaster planci*) or blue starfish (*Linckia laevigata*), were recorded, although the pincushion star (*Culcita novaeguineae*) was present in low numbers (2 of 12 broad-scale stations).

4.4.8 Discussion and conclusions: invertebrate resources in Vaitupu

- Giant clams were rarely found at Vaitupu Island, despite the good coverage of the survey. At this low density, giant clams are past the critical threshold point where spawning and future recruitment is critically compromised. Therefore, the giant clam resource at Vaitupu is likely heavily depleted by past fishing. The open reef environment makes recruitment from these broadcast spawners more difficult than in more enclosed lagoon systems, thereby making an already fragile stock more susceptible to overfishing. The lack of large clams further decreases the possibility of a recovery, since only larger clams produce eggs.

- Based on the information collected on mother-of-pearl stocks, *Trochus niloticus* does not offer a promising prospect for introduction at Vaitupu, while *T. pyramis* and *Pinctada margaritifera* resources were poor. Although results suggest that fishing pressure on gastropods and bivalves was high, the rarity of these two species groups was mainly due to the somewhat harsh environmental conditions found at Vaitupu Island.

- Based on the information collected on sea cucumber stocks, there is a limited number of species available for commercial fishing, and stock densities are limited. The presence of medium-to-high-value surf redfish, *A. mauritiana*, and low-value brown sandfish (*B. vitiensis*) are of interest for commercialisation, but this preliminary survey needs to be upgraded before a fishery is considered. Further work will need to be completed to assess what level of commercial fishing can be allowed on such a small island, and to devise a management plan around such results.

4.5 Overall recommendations for Vaitupu

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomic, finfish and invertebrates), the following recommendations are made for Vaitupu:

- The Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* to establish a monitoring programme for marine resources, finfish and invertebrates, to monitor catch and landing to ensure that overfishing does not occur. Monitoring should include the level of fishing efforts (e.g. gear types, mesh sizes) and catches (e.g. size limits and landings by species).

- The strict control and successful management of the lagoons by the *Falekaupule* and *Kaupule* be extended to protect presently targeted species as well as controlling the mesh-size of nets used in the outer reefs. Also that Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* with developing management plans or arrangements for all inshore resources of Vaitupu to ensure the sustainable harvest of these resources, now and in the future.

- The local *Falekaupule* and *Kaupule* continue to support and encourage trolling for pelagic species outside the reef, to relieve fishing pressure on inshore resources and enable targeted species to be fished within sustainable levels.

- The Tuvalu Fisheries Department encourage the local *Falekaupule* and *Kaupule* to set up a protected area free of any fishing (shallow and deep water), which would have good potential for retaining broodstock of important invertebrate species, such as giant clams, which are depleted at present.

- The local *Falekaupule* and *Kaupule* be very cautious with any endeavour to open the sea cucumber fishery based on the two species that had reasonable densities. Further work is needed to assess what level of harvest can be allowed. This should all be done through a management plan for this fishery.

5. PROFILE AND RESULTS FOR NIUTAO

5.1 Site characteristics

Niutao is a single, small, coral-flat island with a narrow fringing reef (Figure 5.1) in the northern island group of the country, the third smallest (2.5 km²) island in Tuvalu. The island occupies over three quarters of the 3.1 km² reef platforms exposed at low tides. The entire island, which is basically a reef platform, consists of enclosed lagoon and land (2.4 km²), beaches (0.02 km²) and reef flat (0.7 km²) that gently drops off over the fringing reef (1.1 km², McLean and Hosking 1991). The three relatively shallow and small, fully enclosed lagoons are connected to the sea through subterranean passages and are surrounded by mangroves, which support a large population of crabs and one fish species (*Tilapia mossambica*) used by local people to feed pigs.

Figure 5.1: The island of Niutao.

On the fringing reef two good passages give access to the ocean fishing grounds. The other four passages can only be used during good weather. With a very narrow fringing reef (minimum width of about 40 m), reefs can be dangerous, particularly during the westerlies. Given its size, Niutao has the smallest reef areas in the country, while the highest land reaches only 3–5 m above sea level. Transportation by sea is only possible through the inter-island shipping service of Tuvalu passenger ships. Other than for visitors and travellers, inter-island transportation is particularly important for marketing or trading fresh and value-added fish products.

Opportunities for paid employment on the island are very limited, and are dominated by the public sector, particularly as positions with the national government and Island Council. The other sources of cash income are casual labour, sale of fish or produce, handicraft production and remittances from family members abroad. Remittances from overseas seafarers and relatives are the main source of income apart from employment and fishing. All households on the island are involved in traditional and subsistence economic activities. These activities are categorised into fishing, land work, handicraft making and housework. The estimated total population is about 660 (SPC 2005), although around another 200 live in Funafuti or overseas (Government of Tuvalu 1995b).

There are no formal commercial fishing or fisheries-related operations on Niutao and no structured fish market exists on the island, though male fishers often sell their catch at the landing site. There is a community fishing centre on the island, however, it was not operational at the time of the survey work. Therefore, fishing on the island is basically for family consumption. Common fishing practices include netting and rod fishing on the coastal reef and handlining and spearfishing on the outer reefs. Ciguatera fish poisoning is a serious concern of the island and is known to occur throughout the year but more frequently during the westerlies period (Government of Tuvalu 1995b). Pelagic fishing is very common and excess tuna catches are usually sold to the local community.

There are by-laws in existence at Niutao. All the fishing gear restrictions and other prohibitive measures endorsed by the Fisheries Department are observed on the island. These include prohibition of the use of: hookah and SCUBA gears for any form of fishing; dynamiting; and fish poisons. There are several females' groups on the island engaged in several projects; however, not many directly related to fish products.

5.2 Socioeconomic surveys: Niutao

PROCFish/C socioeconomic fieldwork was carried out on the island of Niutao, with 152 people interviewed from 26 households in the two major villages of Kulia and Teava. Thus, the survey covered about 18% of the island's total number of households (143) and of the total population (around 840 people).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. In total, 27 male finfish fishers and 11 male invertebrate fishers were individually interviewed. Each of these fishers belonged to one of the 26 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

5.2.1 The role of fisheries in the Niutao community: fishery demographics, income and seafood consumption patterns

Our survey results (Table 5.1) suggest an average of ~1.5 fishers per household. Combining the average number of fishers per household with our household survey data concerning the type of fisher (finfish fishers, invertebrate fishers) by gender, we can project a total of 88 fishers (males) who fished only for finfish, a total of 17 fishers who targeted invertebrates only (females; based on household surveys only as no finfish or invertebrate surveys were conducted with females) and 116 fishers (males only) who fished for both finfish and invertebrates.

The number and type of boats available to the households on Niutao varied between both villages. In Kulia, about half of all households owned a boat; most were canoes, fewer were motorised. In Teava, only 14% of the households surveyed had a boat, and all were non-motorised.

Table 5.1: Fishery demography, income and seafood consumption patterns in Niutao

Survey coverage	Niutao (n = 26 HH)	Average across sites (n = 113 HH)
Demography		
HH involved in reef fisheries (%)	100	100
Number of fishers per HH	1.5 (±0.2)	2.0 (±0.13)
Male finfish fishers per HH (%)	40.0	38.3
Female finfish fishers per HH (%)	0	0.4
Male invertebrate fishers per HH (%)	0	0
Female invertebrate fishers per HH (%)	7.5	14.1
Male finfish and invertebrate fishers per HH (%)	52.5	41.0
Female finfish and invertebrate fishers per HH (%)	0	6.2
Income		
HH with fisheries as 1st income (%)	35	24
HH with fisheries as 2nd income (%)	4	25
HH with agriculture as 1st income (%)	0	25
HH with agriculture as 2nd income (%)	0	1
HH with salary as 1st income (%)	50	52
HH with salary as 2nd income (%)	8	11
HH with other source as 1st income (%)	15	20
HH with other source as 2nd income (%)	8	14
Expenditure (USD/year/HH)	1827 (±240.78)	2102 (±155)
Remittance (USD/year/HH) (1)	2350 (±385.74)	1940 (±173.5)
Seafood consumption		
Quantity fresh fish consumed (kg/capita/year)	117.8 (±12.0)	151.0 (±6.30)
Frequency fresh fish consumed (times/week)	5.5 (±0.4)	6.1 (±0.17)
Quantity fresh invertebrate consumed (kg/capita/year)	n/a	n/a
Frequency fresh invertebrate consumed (times/week)	0.4 (±0.2)	0.4 (±0.07)
Quantity canned fish consumed (kg/capita/year)	3.0 (±0.9)	2.2 (±0.36)
Frequency canned fish consumed (times/week)	0.5 (±0.1)	0.5 (±0.07)
HH eat fresh fish (%)	100	99
HH eat invertebrates (%)	39	54
HH eat canned fish (%)	85	66
HH eat fresh fish they catch (%)	100	97
HH eat fresh fish they buy (%)	81	61
HH eat fresh fish they are given (%)	58	62
HH eat fresh invertebrates they catch (%)	31	50
HH eat fresh invertebrates they buy (%)	0	0
HH eat fresh invertebrates they are given (%)	8	11

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

Data shown in Figure 5.2 suggest that most households mainly relied on one source of income. Fisheries provided the first income for about 35% of all households surveyed, as compared to salaries, which supplied the first income to half of all households. Other income sources included the selling of toddy, handicrafts and shop ownership, and these activities provided the first income source for another 15% of all households.

Although fisheries played an important role for income generation, reported data from survey respondents show that only about 10% of the annual catch is marketed to generate income. Invertebrates are mostly caught for consumption. Thus, any impact caused by fisheries is mainly determined by subsistence rather than commercial needs.

Half of all households interviewed reported receiving remittances. The average amount these households received from external sources (USD 2350/year) was substantial and far exceeded the average household expenditure (USD 1827/year).

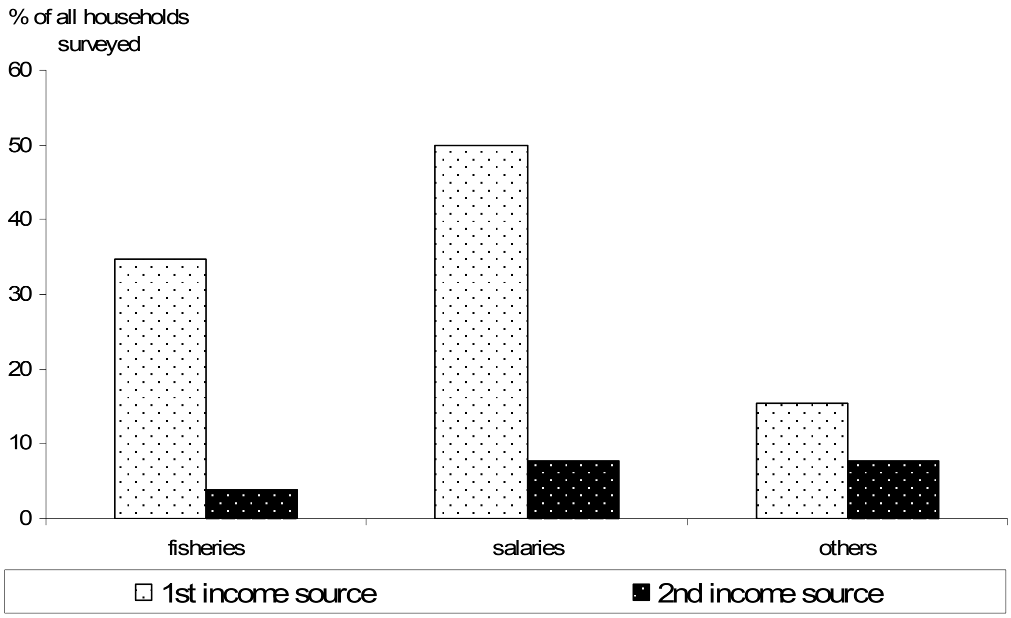

Figure 5.2: Ranked sources of income (%) in Niutao.
Total number of households = 26 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small businesses.

Average per capita fresh fish consumption (118 kg/year) was high compared to the regional average, and higher than the national average figure used here (98.4 kg/year – Figure 5.3). It was the lowest consumption though among all PROCFish/C sites in Tuvalu. Previous estimates for Tuvalu ranged between 60 kg/year (SPC 1997, cited in Gillett and Lightfoot 2001; page 206) and 146 kg/year (Fisheries Department 1994, cited in Gillett and Lightfoot 2001; page 209) with considerable variations among islands.

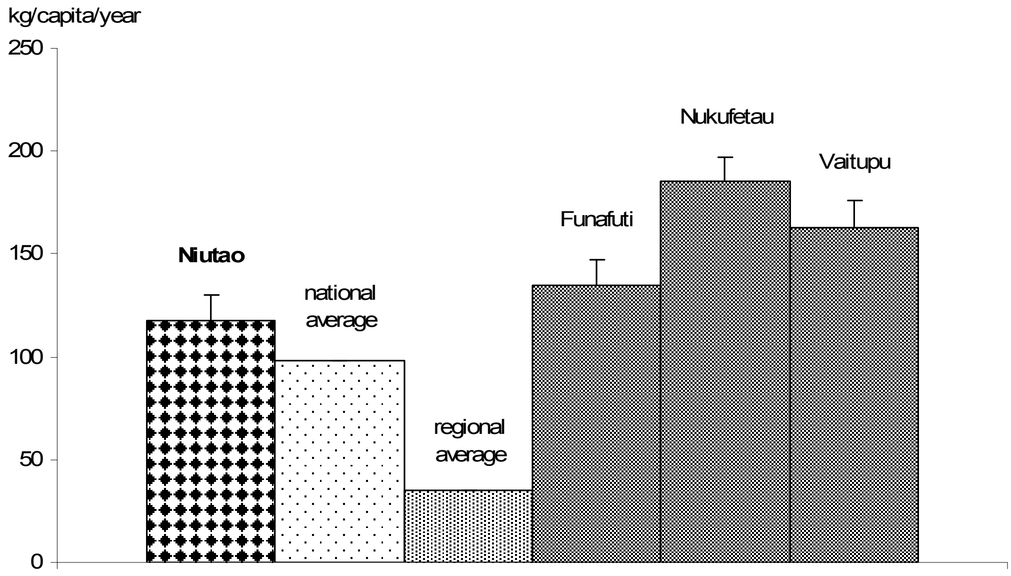

Figure 5.3: Per capita consumption (kg/year) of fresh fish in Niutao (n = 26) compared to national and regional averages (Gillett 2002b) and other PROCFish/C sites in Tuvalu.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The frequency and quantity of canned fish consumption per capita are low (0.5 times/week, 3 kg/year). Invertebrates were eaten by only one-third of all households interviewed and they were eaten less frequently, about once a fortnight (on average 0.4 times/week). While all respondents reported that they eat fish caught by a member of their household, about 80% of all households also sometimes bought finfish (from a neighbour, or at the roadside), and ~60% of all households were sometimes given finfish as a gift. Invertebrates consumed were mostly caught by a member of the household. They were not bought within the Niutao community and were rarely received as a gift.

By comparison with the average for all PROCFish/C sites in Tuvalu (Table 5.1), the Niutao community was more dependent on fisheries for income. Also the consumption values of canned fish and dependence on remittances (number of households receiving remittances, quantity of funds received) were higher than the average. However, the per capita consumption of fresh fish and the average household expenditure level on Niutao were below the average. Taking into account that the average number of fishers per household was comparatively low, and the number of boats owned was small, the social structure of Niutao may fall into two groups: one group that comprised households that benefited substantially from remittances and salaries and, as a result, consumed more canned fish but less invertebrate and fresh fish; and a second group of households that fished mainly for income.

5.2.2 Fishing strategies and gear: Niutao

Degree of specialisation in fishing

Fishing on Niutao was dominated by males: ~90% of all fishers were males, and only about 10% females (Figure 5.4). Less than half of the male fishers only caught finfish, most targeted both invertebrates and finfish. The few female fishers who emerged from the household survey reported that they were only involved in invertebrate fishing. Unfortunately, no individual surveys could be conducted so no details are available on female fishers in Niutao involved in invertebrate fishing.

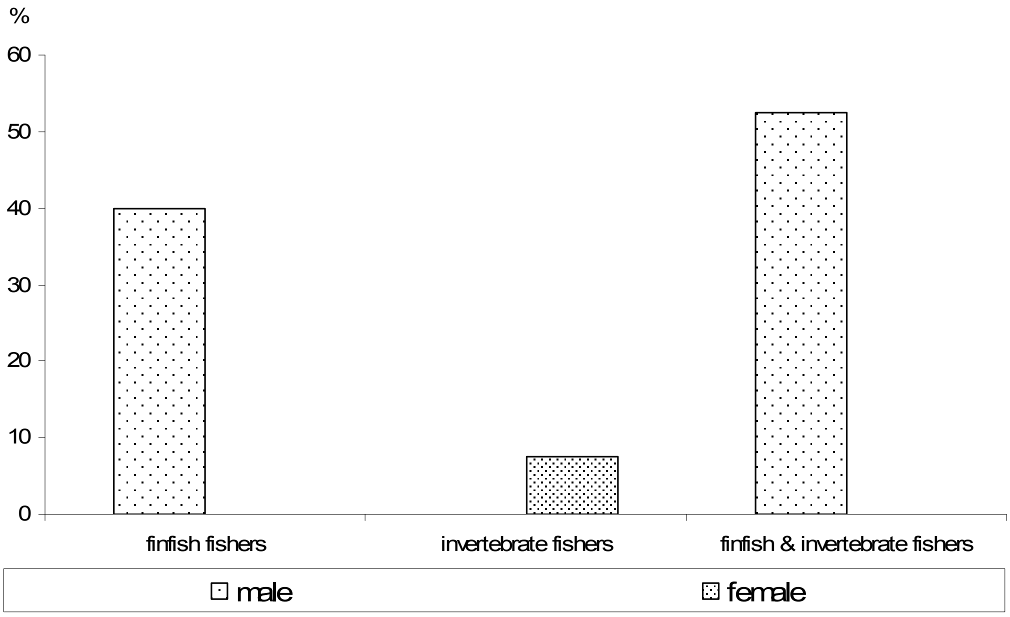

Figure 5.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Niutao.
All fishers = 100%.

Targeted stocks/habitats

Resources in Niutao fishing grounds are limited to reef areas. Invertebrate fishers may be separated into gleaners and divers, while finfish fishers targeted either the sheltered coastal or the outer-reef areas (Table 5.2).

Table 5.2: Proportion of interviewed finfish fishers and invertebrate fishers harvesting the various finfish and invertebrate stocks across a range of habitats in Niutao

Resource	Stock	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	74.1	0
	Outer reef	63.0	0
Invertebrate	Reeftop	45.5	0
	Other	36.4	0
	Lobster	45.5	0

'Other' refers to giant clams, *Lambis truncata* and lobster fishery.
Finfish fisher interviews, males: n = 27; females: n = 0. Invertebrate fisher interviews, males: n = 11; females, n = 0.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip was used to estimate the fishing pressure imposed by people from Niutao on their fishing grounds.

The island of Niutao is surrounded by a steeply sloping reef that is exposed to the open ocean and thus displays more features of an outer rather than a sheltered coastal reef. Intertidal reef flats, which may partly or completely dry during low tides, make up the transition between the land and the outer reef. Niutao's fishers targeted both the intertidal reef flats and the outer reef. Because there were significant differences in fishing either habitat, results from the socioeconomic survey are presented for these two habitats separately. However, from an ecological point of view, the existence of two distinct habitats is arguable.

Our survey results show that slightly more fishers (54%) targeted the intertidal reef flats than the outer reef (46%).

On Niutao, most invertebrates were caught by diving (~65% – Figure 5.5). Dive fisheries mainly targeted lobsters and, to a lesser extent, giant clams and *Lambis truncata*. Reeftop gleaning attracted about 36% of all invertebrate fishers.

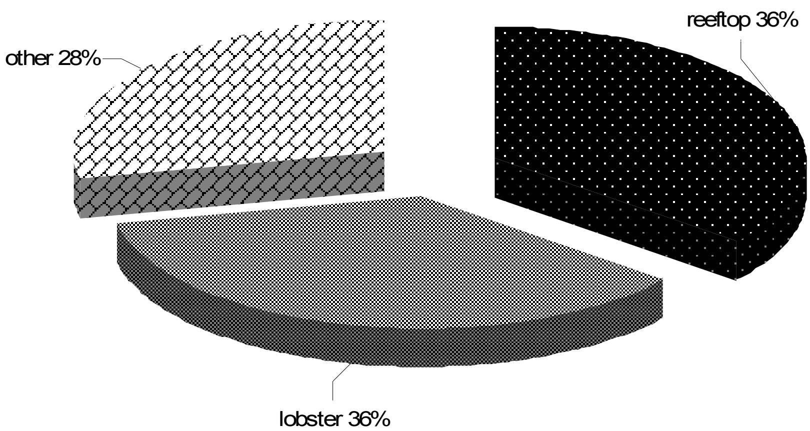

Figure 5.5: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Niutao.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to giant clams, *Lambis truncata* and lobster fishery.

As mentioned earlier, there were few female invertebrate fishers, and these were more likely to participate in reef gleaning rather than any dive fisheries. However, no female respondents were available during the survey. Proportions presented here are based on collected data, and hence represent male invertebrate fishers only.

Gear

Figure 5.6 shows that Niutao fishers used a variety of different gears. Castnets, gillnets and, to a lesser extent, rod and lines were used when fishing for finfish on the intertidal reef flats. Fish traps were hardly ever used. At the outer reef, speardiving was the main method, together with handlining; rod and lines, trolling and scoop nets were also sometimes used.

There was no clear pattern indicating whether day or night fishing was preferred; however, a few fishers only fished at night. Mostly, fishing was continuous throughout the year. Only about one-quarter of all fishing trips to the outer reef used a boat; all other fishing was done by walking.

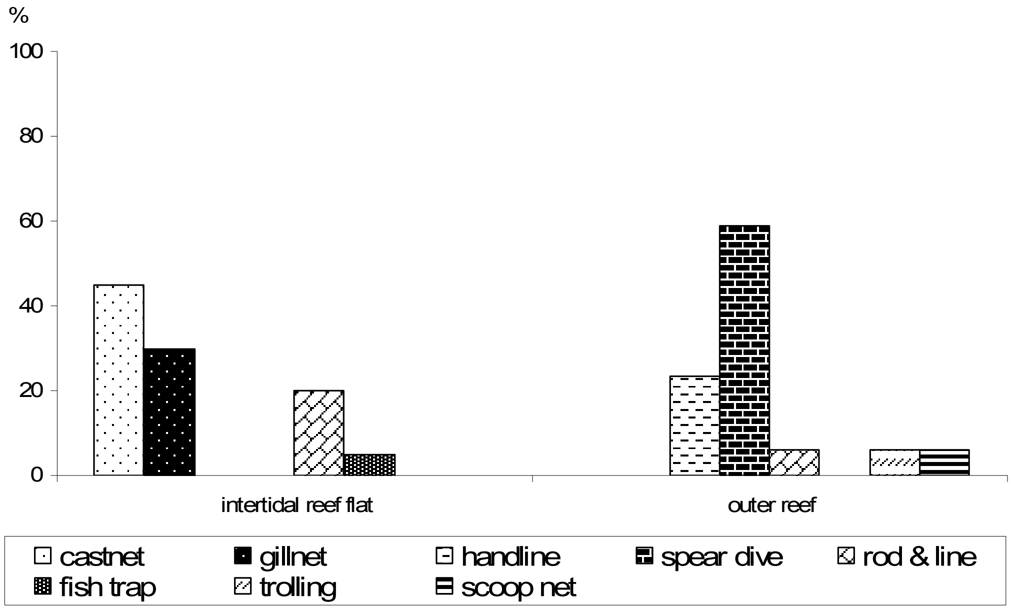

Figure 5.6: Fishing methods commonly used in different habitat types in Niutao.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Gleaning on Niutao was done by walking, using simple collection tools. Boats were not used for lobster nor any other dive fishery. As expected, lobster fishing was mostly done at night, and reeftop gleaning mostly during the day. Invertebrate fishing was performed throughout the year.

Frequency and duration of fishing trips

The frequency of fishing trips to the intertidal reef flats was higher (3 times/week) than trips to the outer reef (2.2 times/week – Table 5.3). However, an average fishing trip to the outer reef took longer (2.7 hours/trip) than a trip to the intertidal reef flats (2.1 hours/trip).

Dive fishing (other than targeting lobster) was the most frequently performed (~1 times/week), while lobster fishing and reeftop gleaning were done less than once a week (0.8 times/week). There was no significant difference in the duration of an average dive trip, whether for lobster or any other species. While dive trips lasted about 2 hours each, reeftop gleaning exceeded 2.5 hours per average trip.

Table 5.3: Average frequency and duration of fishing trips reported by male and female fishers in Niutao

Resource	Stock	Trip frequency (trip/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Intertidal reef flat	3.04 (±0.35)	0	2.13 (±0.26)	0
	Outer reef	2.24 (±0.21)	0	2.65 (±0.28)	0
Invertebrates	Reeftop	0.80 (±0.18)	0	2.60 (±0.24)	0
	Lobster	0.84 (±0.13)	0	2.00 (±0.00)	0
	Other	1.06 (±0.60)	0	1.88 (±0.31)	0

Figures in brackets denote standard error; 'other' refers to giant clams, *Lambis truncata* and lobster fishery.
Finfish fisher interviews, males: n = 27; females: n = 0. Invertebrate fisher interviews, males: n = 11; females: n = 0.

5.2.3 Catch composition and volume – finfish: Niutao

Reported catches from the sheltered coastal reef were dominated by *Kyphosus cinerascens* (*nanue*, 25%), *Acanthurus triostegus* (*manini*, 19%), *Acanthurus guttatus* (*maono*, 15%) and *Valamugil seheli* (*kanase*, 11%). There were more species reported in catches from the outer reef than from the sheltered coastal reef. Also, outer-reef catches were more uniformly distributed over a greater number of species, although there were two main species groups: *Myripristis violacea* (*malau*, 24%) and Serranidae (*gatala*, 11%). Details on the estimated annual reported catch by vernacular species names and scientific family names are given in Appendix 2.4.1.

The survey sample of finfish fishers interviewed represents about 13% of the projected total number of finfish fishers on Niutao. Extrapolation of our survey data is therefore limited. Regarding the reported survey data only (Figure 5.7), the majority of the reported annual catch was from intertidal reef flats.

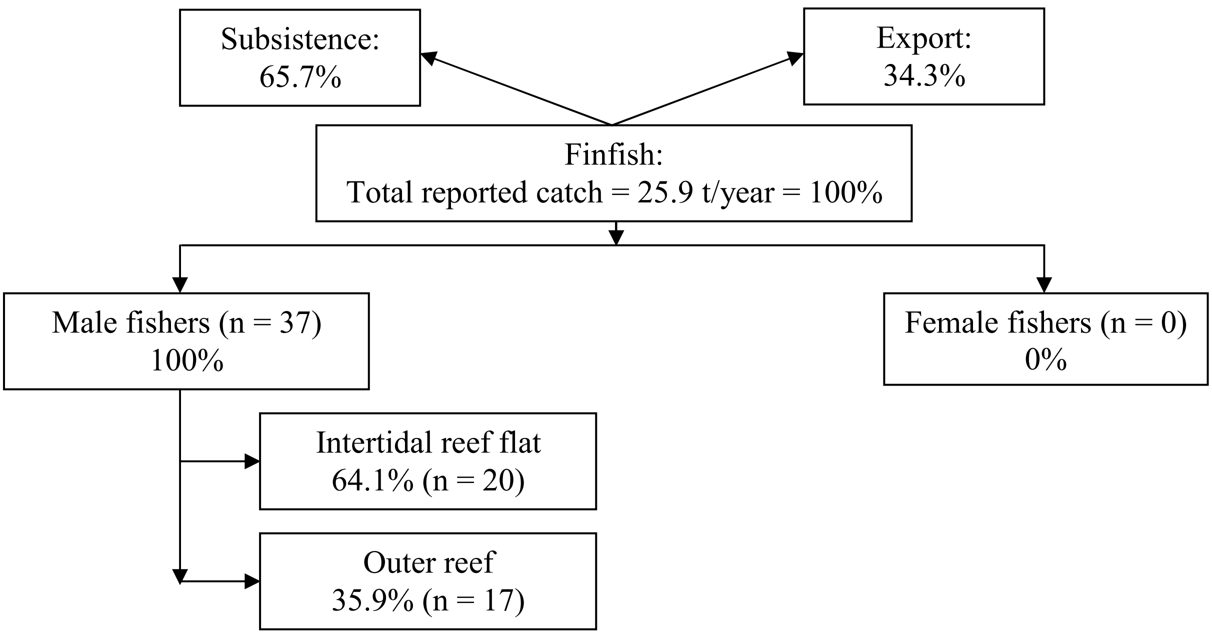

Figure 5.7: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Niutao.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey only.

Catches from the outer-reef area contributed to only about 36% (9.3 t/year) of the total catch (25.9 t/year). These figures correspond to the earlier observations that most fishers targeted the intertidal reef flats more frequently than the outer reef. Females do not participate in finfish fisheries on Niutao.

In order to estimate the total annual catch on Niutao, we calculated the total annual consumption figure which amounts to 123.1 t/year. About 5.5% and 14% of the reported catch from the intertidal reef flats and outer reef were sold, mainly to Funafuti. These proportions correspond to 4.3 t/year and 6.2 t/year respectively. Adding the sum of commercial catch (10.5 t/year) to the total subsistence needs (123.1 t/year), the estimated total annual impact amounted to 133.6 t. Taking into account that 64% of the total catch was sourced from intertidal reef flats, and 36% from the outer reef (Figure 5.8), the total fishing pressure imposed on intertidal reef flats was 85.5 t/year, and on the outer reef 48.1 t/year.

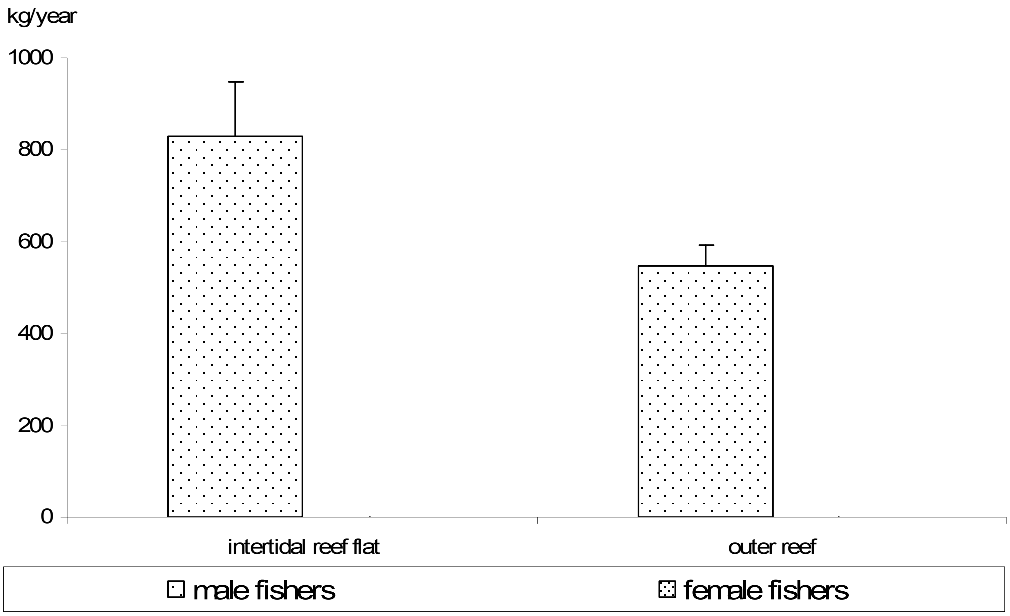

Figure 5.8: Average annual finfish catch (kg/year) per fisher by habitat and gender in Niutao. Bars represent standard error (+SE).

The survey data only allow comparison of male fishers' average annual catches by habitat. As shown in Figure 5.8, on average the annual catch of a fisher targeting the sheltered coastal reef exceeded that from the outer reef by a factor of 1.5. Thus, not only was the percentage of males fishing the intertidal reef flats higher but also their annual production was far higher as compared to the outer reef.

In contrast to most trends observed elsewhere in the region, but in agreement with the annual average catch data already presented for Niutao, the CPUE from the intertidal reef flats was substantially higher than the CPUE from the outer reef (Figure 5.9).

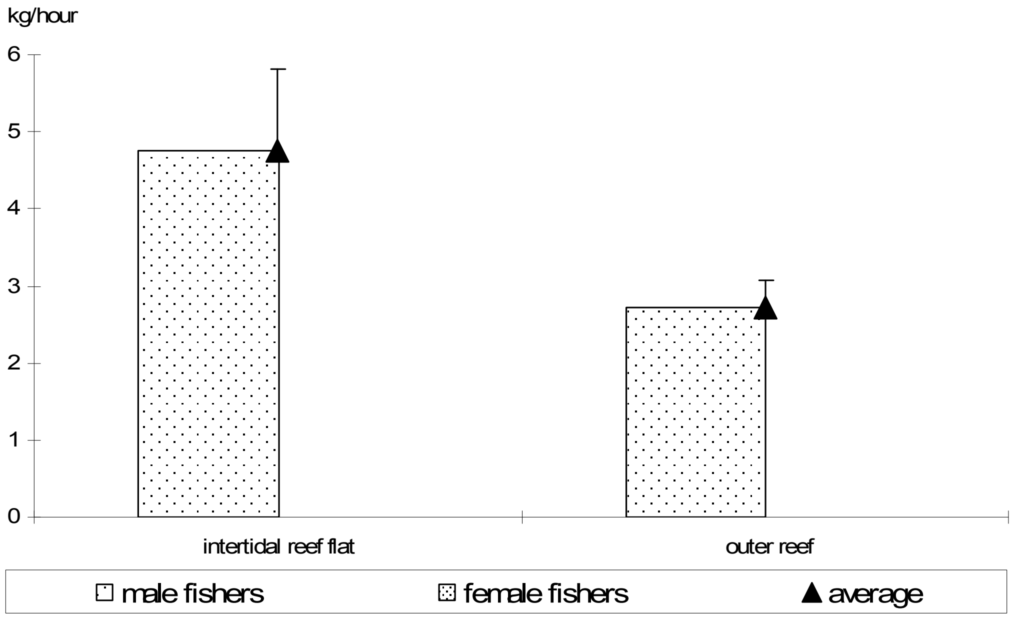

Figure 5.9: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Niutao.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data also show that only a small proportion of the total annual catch was distributed on a non-monetary basis among the Niutao community (Figure 5.10).

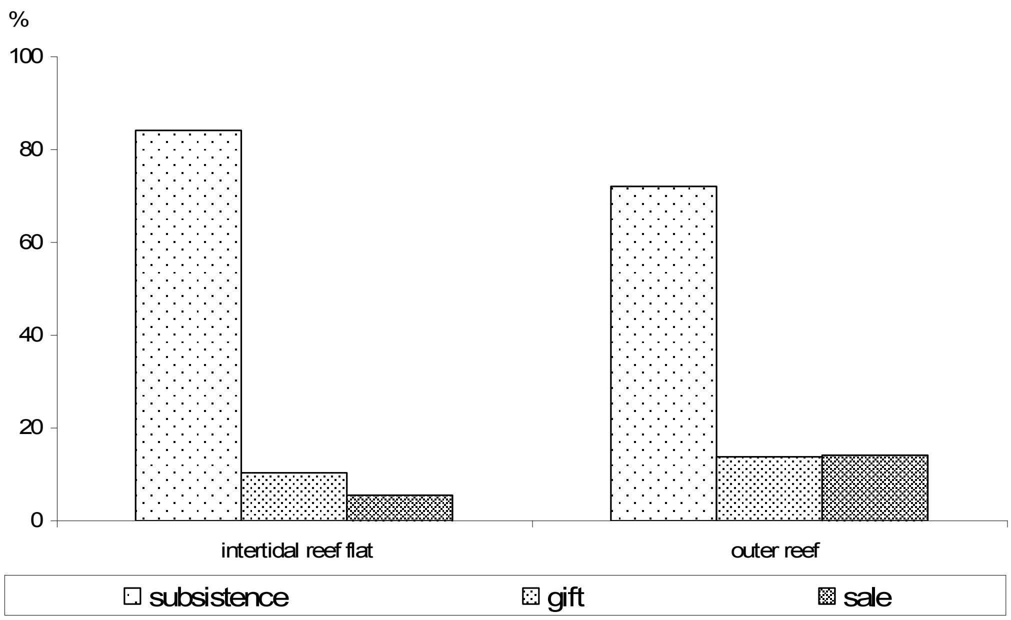

Figure 5.10: The use of finfish catches for subsistence, gift and sale, by habitat in Niutao.
Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and by habitat as shown in Figure 5.11 suggest that fish caught at the outer reef were generally larger in average size than the same fish families caught on the intertidal reef flats. This applies for Acanthuridae, Cirrhitidae, Kyphosidae, Lutjanidae and Serranidae. Little difference in fish size occurred for Holocentridae and Mugilidae but, on average and somewhat surprisingly, larger Carangidae were reported to be caught on the intertidal reef flats. Labridae and Pomacentridae were only reported in catches from the intertidal reef flat, and Priacanthidae and Scaridae for catches from the outer reef only.

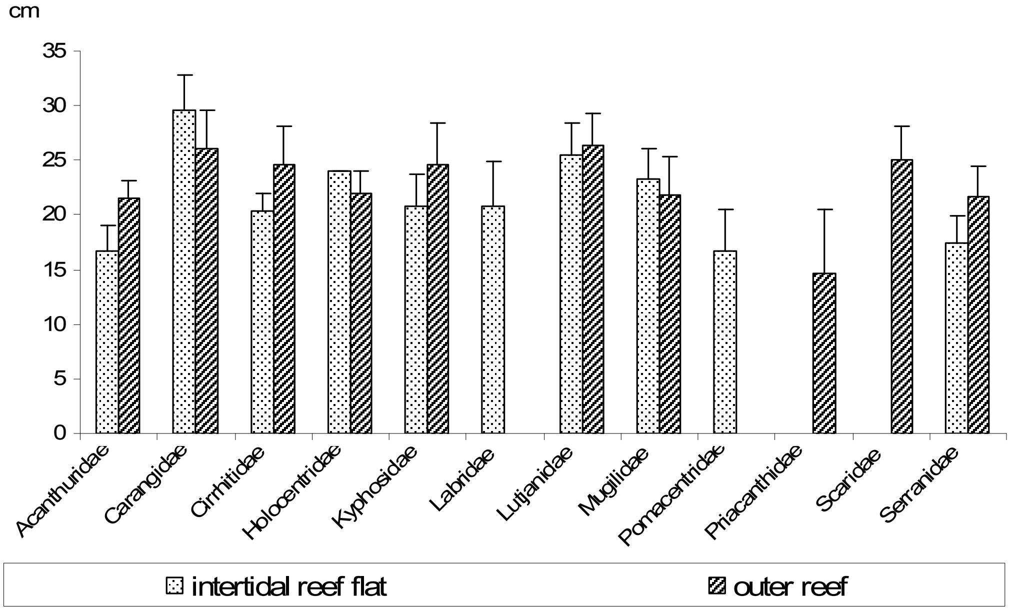

Figure 5.11: Average sizes (cm fork length) of fish caught by family and habitat in Niutao.
Bars represent standard error (+SE).

Fisher density, an indicator used to assess the level of current fishing pressure, was high: 103 fishers/km² of fishing ground (intertidal reef flats and outer-reef surface areas – Table 5.4). Surprisingly, although fisher density was higher on the intertidal reef flats (132 fishers/km²), the average annual catch per fisher was significantly higher for intertidal reef flats than for the outer reef. However, compared to other PROCFish/C sites in Tuvalu generally, the average annual catch per fisher was low, perhaps underlining the focus on subsistence rather than commercial fisheries. Fishing pressure expressed in subsistence catch per total reef and fishing ground areas was extremely high, at 47 t/km².

Table 5.4: Parameters used in assessing fishing pressure on finfish resources in Niutao

Parameters	Habitat			
	Intertidal reef flat	Outer reef	Total reef	Total fishing ground
Fishing ground area (km^2)	0.84	1.15	1.98	1.98
Density of fishers (number of fishers/km^2 fishing ground) (1)	132	82	103	103
Population density (people/km^2) (2)			421	421
Average annual finfish catch (kg/fisher/year) (3)	829.2 (±120.1)	545.4 (±46.8)		
Total fishing pressure of subsistence catches (t/km^2)			47.1	47.1

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 836; total subsistence demand = 93.45 t/year; (3) catch figures are based on recorded data from survey respondents only.

5.2.4 Catch composition and volume – invertebrates: Niutao

Calculations of the annual catch rates (reported) per species groups are shown in Figure 5.12. The graph shows that the major catch by wet weight was for one particular lobster species, *Panulirus penicillatus*. All other species listed, including *Parribacus antarcticus*, *Lambis truncata*, *Tridacna* spp. and *Turbo setosus*, contributed only a little.

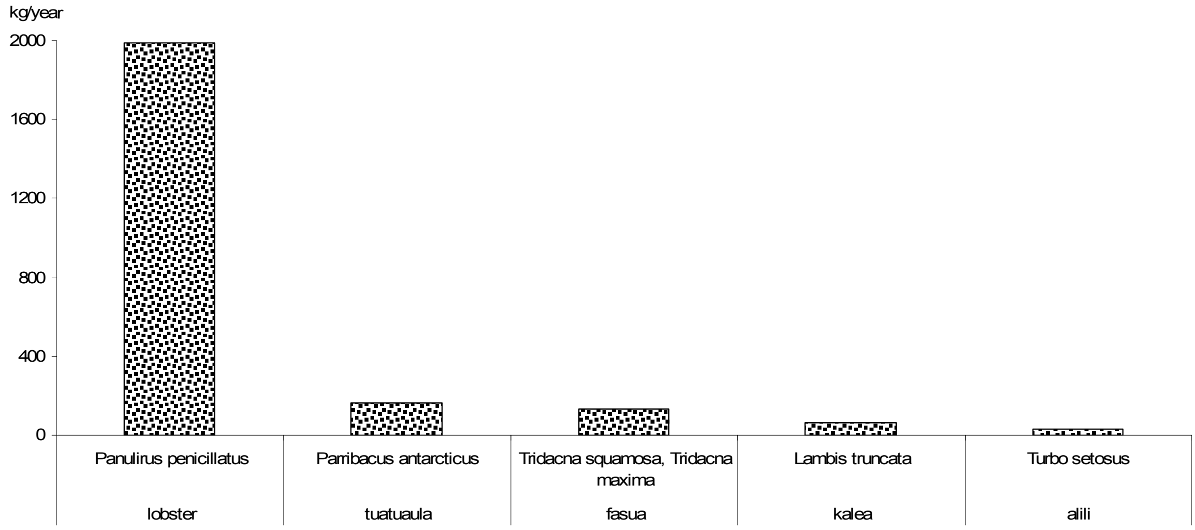

Figure 5.12: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Niutao.

Figure 5.13 reveals a low species diversity in all of the Niutao invertebrate fisheries. Reeftop gleaning and 'other' dive fisheries targeted three different groups (giant clams, *Lambis truncata*, lobsters), and the lobster fishery distinguished two lobster species by local names.

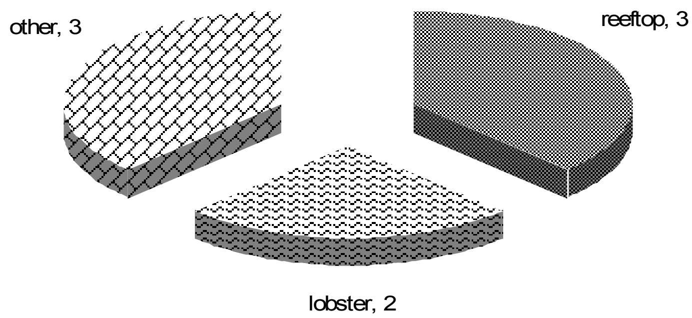

Figure 5.13: Number of vernacular names recorded for each invertebrate fishery in Niutao.
'Other' refers to giant clams, *Lambis truncata* and lobster fishery.

Details on species distribution by habitat and on size distribution by species are provided in Appendix 2.4.2 and Appendix 2.4.3 respectively.

Following the trends shown in Figure 5.12, annual reported catch rates by fisher and fishery (Figure 5.14) were highest for lobster and other dive fisheries, bearing in mind that the dive fishery also mainly comprised lobster catches. By comparison, reeftop catch rates were the lowest.

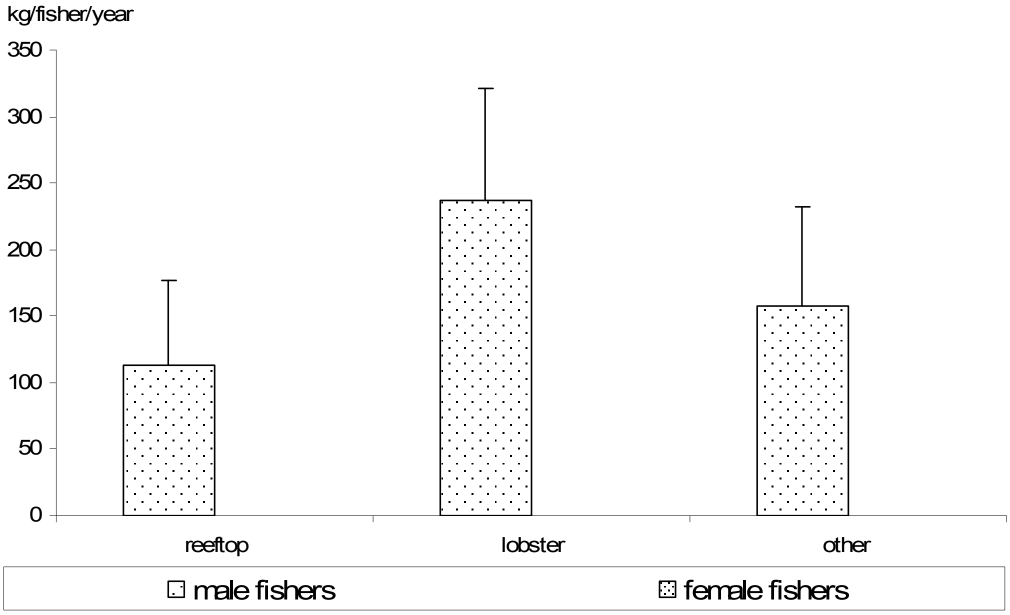

Figure 5.14: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Niutao.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 14 for males, n = 0 for females). 'Other' refers to giant clams, *Lambis truncata* and lobster fishery. Bars represent standard error (+SE).

The ratio between invertebrates caught for subsistence and sale as shown in Figure 5.15 highlights the high subsistence nature of the fisheries. No species or fishery was targeted only for commercial purposes. Assuming that consumption and sale each make up 50% of the combined category 'consumption & sale', then the share collected for commercial purposes did not exceed 10% of the annual reported catch. Bearing in mind that invertebrates consumed on Niutao were never bought, sale represents export to Funafuti only.

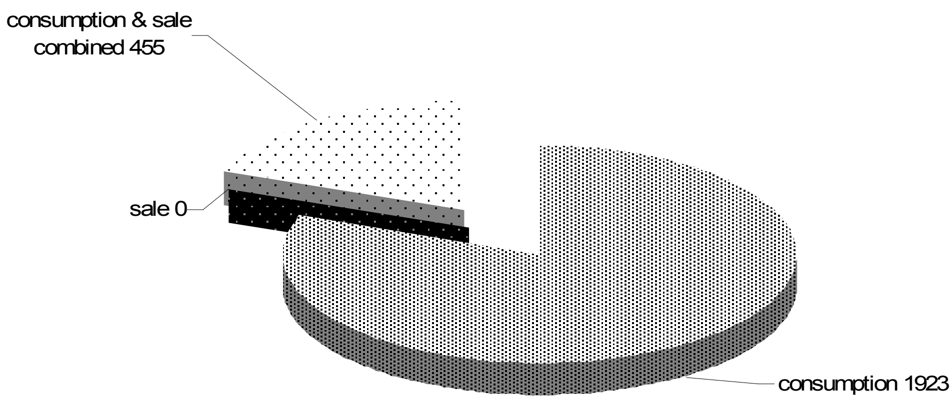

Figure 5.15: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Niutao.

The total annual catch volume expressed in wet weight based on the reported data from all respondents interviewed amounted to 2.4 t/year only (Figure 5.16). Catches from the lobster fishery represented the highest share: 1.2 t/year as compared to 0.6 t/year each for reeftop and 'other' dive fisheries (Figure 5.12 shows a catch of 2 t/year of lobster; this figure also includes lobsters caught when diving for other invertebrates as well.).

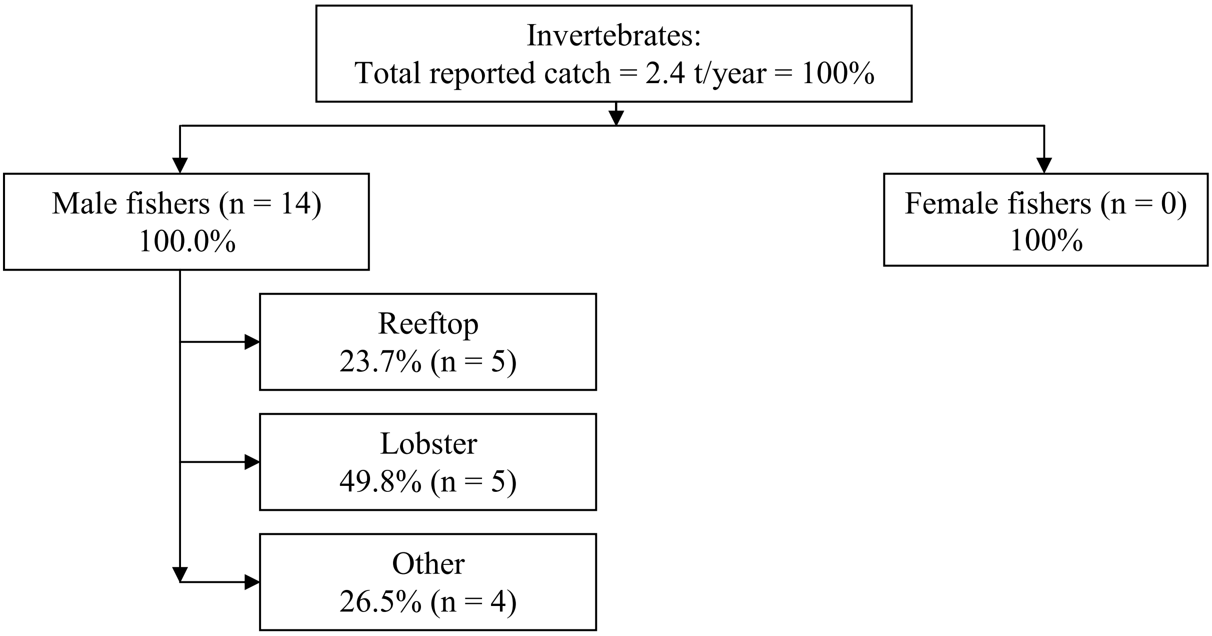

Figure 5.16: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Niutao.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey only. 'Other' refers to giant clams, *Lambis truncata* and lobster fishery.

The area of reeftop available for gleaners and divers targeting giant clams and Lambis truncata is limited (Table 5.5). Although fisher density (7 fishers/km reef length) was relatively low, an average reported catch of 240 kg of lobster/fisher/year is considerable. Furthermore, lobsters were also one of the main species groups targeted by general dive fishers, i.e. those who did not exclusively target crustaceans. By comparison, the average annual catch per reeftop gleaner was about half (112 kg/fisher/year).

Table 5.5: Parameters used in assessing fishing pressure on invertebrate resources in Niutao

Parameters	**Fishery**		
	Reeftop	**Lobster**	**Other**
Fishing ground area (km^2)	0.96	7.7 (1)	0.96
Number of fishers (per fishery) (2)	53	53	42
Density of fishers (number of fishers/km^2 fishing ground)	55	7 (1)	44
Average annual invertebrate catch (kg/fisher/year) (3)	112.69 (±63.98)	236.70 (±84.61)	157.74 (±73.81)

Figures in brackets denote standard error; 'other' refers to giant clams, *Lambis truncata* and lobster fishery; (1) reef length in km; number of fishers/km; (2) total number of fishers is extrapolated from household surveys; (3) catch figures are based on recorded data from survey respondents only.

5.2.5 Discussion and conclusions: socioeconomics in Niutao

- Although average household expenditures were lower than at other sites surveyed in Tuvalu, data collected suggest the importance of cash income on Niutao, mostly generated from salaries and also sourced from remittances. Finfish fisheries played an important role as first income source for 35% of all households as invertebrate fisheries were not commercial. The fact that a certain proportion of the community depended on fishing for income and that a high percentage of fish was bought for consumption may explain the overall low number of household members involved in fishing. However, in terms of fisheries impact, the quantity taken for local consumption far exceeded the proportion, and thus any possible impact, of commercial catches. Only 10% of the reported annual catch was marketed.

- People in Niutao eat a large amount of finfish (118 kg/capita/year), but this consumption figure was the lowest across all PROCFish/C sites in Tuvalu. Invertebrates and canned fish were eaten less frequently and the amount of canned fish eaten was very small. According to the survey data, overall fishing pressure was substantial; an annual catch of 47 t/km² was taken from the total reef and total fishing ground area. The highest fishing pressure was on the intertidal reef flats rather than on the outer reef. CPUE on the intertidal reef flats was almost double that on the outer-reef area.

- The main fishing methods used in the intertidal reef flats were mainly castnetting and gillnetting; at the outer reef, speardiving was the main method used. The fact that speardiving was used rather than castnetting and gillnetting may explain why, on average, fish caught at the outer reef were larger than those caught at the intertidal reef flats.

- Fishing on Niutao was mainly done by males; only a very few females were involved, and they fished only for invertebrates. An almost equal number of Niutao fishers targeted the three invertebrate fisheries. However, in terms of total annual biomass removed by wet weight, highest impact was reported for lobster diving. Reeftop gleaning and diving for *Lambis truncata* and giant clams (and lobster) combined only amounted to about half the total annual biomass as compared to the lobster fishery. Invertebrate fisheries on Niutao were very limited in terms of the number of target species.

- The role fisheries played in providing income and food on Niutao, the roles taken by males and females, and the fishing strategies used, all suggest that Niutao is a more traditional community where only the males go fishing, and only a certain proportion of the community fishes commercially. Finfish fishing was limited to the intertidal reef flats and outer reef, and invertebrate fisheries were dominated by lobster catches (*Panulirus penicillatus*). The fact that cash played an important role on Niutao, and that the proportion of the annual catches (both finfish and lobster) exported to the country's main market on Funafuti was low, may suggest that: the resource status of Niutao was not sufficient to support further exploitation; and/or the marketing capacity to export seafood from Niutao to Funafuti was limited. Limiting factors for export may include transport, demand, price, or any combination of the above.

5.3 Finfish resource surveys: Niutao

Finfish reef resources and associated habitats of Niutao Island were assessed between April 4 and April 8 2005. Surveys were conducted along 24 transects haphazardly placed and randomly distributed throughout all hard, diveable habitats (1.1 km^2) in the outer reefs around the island (Figure 5.17). The narrow, non-diveable intertidal reef flat (0.7 km^2) was relatively shallow and often dried up. The fully enclosed lagoons had a mud–silt environment, with relatively poor visibility all the time. Only one species of fish (*Tilapia mossambica*) inhabited the lagoons, plus large quantities of mangrove crabs. Therefore the fringing intertidal reefs were not surveyed. However, since the area they cover was <1% of the total habitat, not much information was excluded by the lack of survey.

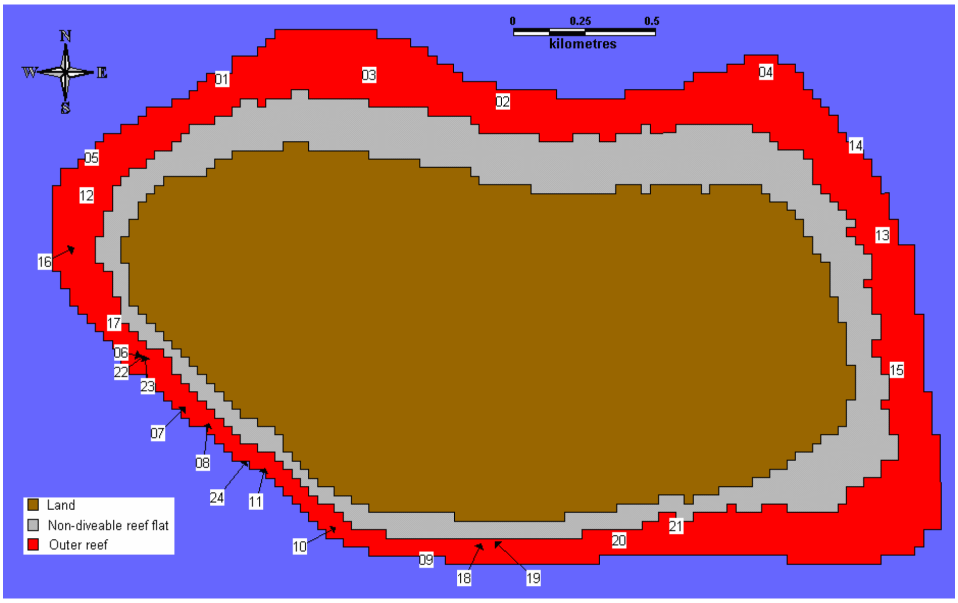

Figure 5.17: Habitat types and transect locations for finfish assessment in Niutao.

5.3.1 Finfish assessment results: Niutao

A total of 20 families, 51 genera, 140 species and 13,793 fishes were recorded in the 24 transects (Appendix 3.4.1). Data relating only to the 13 most dominant families form the basis of this report and the results presented below. These 13 families comprised 41 genera, 128 species and 13,450 individuals. Of this sample, a mean of 11 fish families, 22 fish genera, 41 fish species and 574 ±64 individual fishes were observed and recorded in each transect on Niutao (Appendix 3.4.2).

Table 5.6: Primary finfish habitat and resource parameters recorded on Niutao (average values ±SE)

Parameters	Habitat
	Outer reef [(1)]
Number of transects	24
Total habitat area (km^2)	1.1
Depth (m)	8 (4-12) [(2)]
Soft bottom (% cover)	1 ±0.5
Rubble & boulders (% cover)	1.4 ±0.5
Hard bottom (% cover)	76.6 ±1.4
Live coral (% cover)	19.4 ±1.5
Soft coral (% cover)	0.1 ±0.1
Biodiversity (species/transect)	41 ±3
Density (fish/m^2)	1.0 ±0.1
Size (cm FL) [(3)]	20.2 ±0.4
Size ratio (%)	57.9 ±1.1
Biomass (g/m^2)	258.7 ±41.3

[(1)] Unweighted average; [(2)] depth range; [(3)] FL = fork length.

Outer-reef environment: Niutao

The Niutao outer-reef system spreads across 1.1 km² around the island. Finfish resources were distributed uniformly around the island with slightly higher abundance and biomass along the windward side. The windward side is located far from the main passages and also at considerable distance from the main settlement. As such, there was a possibility of marked variation in fishing pressure between the windward and the leeward side of the island, which is more protected and accessible to fishing.

Nonetheless, fish density and biomass levels on Niutao were the highest (1.0 ±0.1 individuals/m², 258.7 ±41.3 g/m²) of the outer reefs of all the other study sites in the country.

Abundance of commercial fish was dominated by Acanthuridae and Balistidae, with the most important species: *Acanthurus lineatus*, *Naso lituratus*, *Ctenochaetus striatus*, *A. nigricans* and *Melichthys niger* (Table 5.7).

The biomass was composed predominantly of Acanthuridae and, to a much lower extent, Scaridae, Lutjanidae and Balistidae, with the species assemblages mostly made up of *Acanthurus lineatus*, *Naso lituratus*, *Chlorurus microrhinos*, *Acanthurus nigricans*, *Lutjanus bohar* and *Melichthys niger* (Table 5.7).

Rare commercial and edible fish families recorded on Niutao were Labridae, Pomacanthidae, Mullidae and Zanclidae. There was no record of Siganidae nor of Nemipteridae (Figure 5.18).

Compared to the other survey sites in Tuvalu, species diversity was lower only than in the outer reef of Funafuti, but fish density, size and biomass were the highest among the outer reefs of all survey sites. Densities of Acanthuridae and Balistidae were the highest among the four sites, while Scaridae had one of the lowest density values, along with Scaridae in Vaitupu.

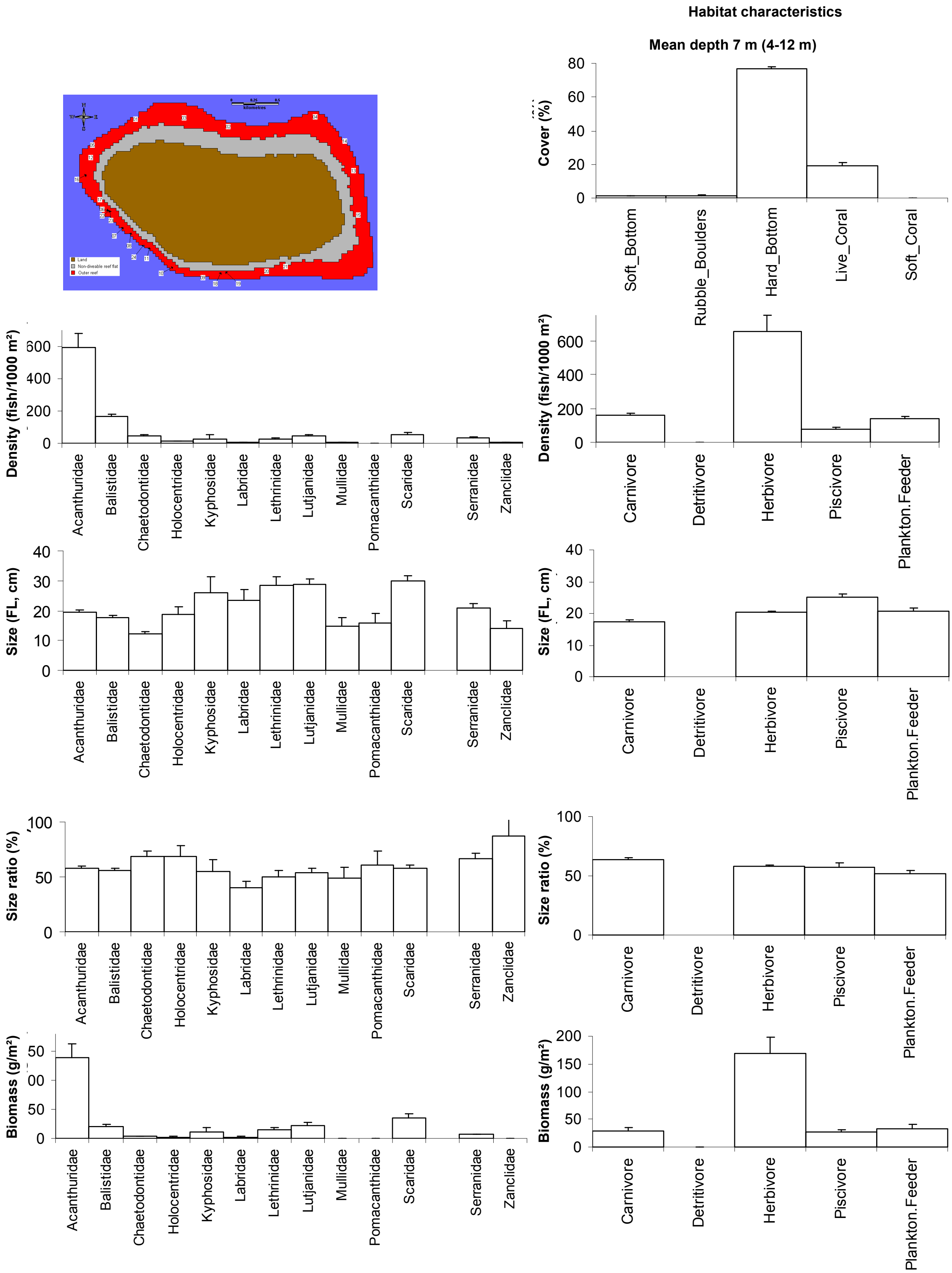

Figure 5.18: Profile of finfish resources in the outer-reef environment of Niutao.
Bars represent standard error (+SE); FL = fork length.

Table 5.7: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Niutao

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus lineatus*	Striped surgeonfish	0.17 ±0.02	41.5 ±6.9
	Naso lituratus	Orangespine unicornfish	0.10 ±0.03	41.3 ±11.1
	Ctenochaetus striatus	Lined bristletooth surgeonfish	0.09 ±0.03	8.1 ±2.8
	Acanthurus nigricans	Whitecheek surgeonfish	0.08 ±0.02	10.8 ±2.9
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.02 ±0.01	13.8 ±4.3
Balistidae	*Melichthys niger*	Black triggerfish	0.05 ±0.01	8.6 ±2.8
Lutjanidae	*Lutjanus bohar*	Red snapper	0.01 ±0.01	9.1 ±2.4

The biomass composition on Niutao was different to that of outer reefs in all other study sites. Biomass of Acanthuridae was higher than in all other study sites, close to 140 g/m^2. The reverse was true for Scaridae and Lutjanidae, which had the second lowest values after Vaitupu. Lutjanidae showed high biomass and average size values, although present in low numbers.

The hard substrate and live coral cover were comparable to the other sites, with 20% live coral cover, which is a relatively small amount for an outer-reef environment, and a large amount of hard-bottom cover (78%). The substrate in Niutao was also relatively high in algae growth (the highest of the four sites).

5.3.2 Discussion and conclusions: finfish resources in Niutao

- The benthic communities of the four study sites shared the same characteristics; however Niutao had the second highest amount of hard-rock cover and, together with Vaitupu, the smallest amount of live-coral cover among all the outer reefs studied. Niutao had also the highest algal cover of the four sites.

- Finfish resources were distributed uniformly around the island with slightly higher abundance and biomass along the windward side. The windward side of the island was located far from the main passages and also at considerable distance from the main settlement. As such, there was a possibility of marked variation in fishing pressure between leeward and windward side of the island.

- When compared to the average for Tuvalu PROCFish/C study sites, the finfish resources of Niutao Island displayed relatively low parameters of biodiversity, but the highest values of density and biomass among the four sites visited. Like Vaitupu, Niutao did not offer all the available habitats and reefs for a choice of fishing methods, gears and targets. Therefore, the level of fishing impact would be expected to be intensive here. However, the highest pressure was on the reef flat rather than on the outer reef, which is hard to access due to frequent poor weather conditions.

- The finfish resource assessment indicated that Niutao had low populations of the targeted and commercial species of Serranidae, Lutjanidae and Lethrinidae. These carnivorous fish were rare but relatively large in size, which suggests that these resources were not being overfished in the outer reef. The very high abundance of Acanthuridae and Balistidae correlates well with the high percentage cover of hard substrate and algae. Such herbivorous fishes are typical of an outer-reef environment (the only type of habitat surveyed in Niutao), and are often associated with coral slab and hard bottom, where they browse on turf and small algae, here very abundant. Their high abundance can also be related to the high incidence of ciguatera that predominantly hits *Acanthurus lineatus*, *Ctenochaetus striatus* and *Naso lituratus*, species that were all very abundant in Niutao. Available stock was made up predominantly of Acanthuridae, Balistidae and Scaridae. What differed from the similar island of Vaitupu was the relatively high biomass of *Lutjanus bohar* and *Monotaxis grandoculis*, which in Niutao also had the highest average sizes of the four sites. The large sizes of these species contributed to the large biomass of carnivorous fish, which was much greater than in Vaitupu.

- Average mean fish sizes were the largest among all sites, and had similar values to those in Vaitupu. They were the highest among the four outer-reef sites for Acanthuridae, Holocentridae and Scaridae. Sizes of the commercially targeted Lutjanidae, Lethrinidae, Scaridae and Serranidae were higher than the 55% of maximum known size for the relative families, which indicates that stocks were still healthy, even though numbers were low. Size ratios were very similar for all feeding guilds, suggesting a comparable use of the different trophic levels. There was a total absence of Siganidae in Niutao.

5.4 Invertebrate resource surveys: Niutao

The diversity and abundance of invertebrate species at Niutao Island were independently determined using a range of survey techniques (Table 5.8), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 5.19) and finer-scale assessment of specific reef and benthic habitats (Figures 5.20 and 5.21).

Table 5.8: Number of stations and replicates completed at Niutao

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	4	24 transects
Reef-benthos transects (RBt)	12	72 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)	4 RFs 4 RFs_w	48 search periods
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	3	18 search periods

RFs_w = reef-front search by walking.

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 the resources in those areas of naturally higher abundance and/or most suitable habitat.

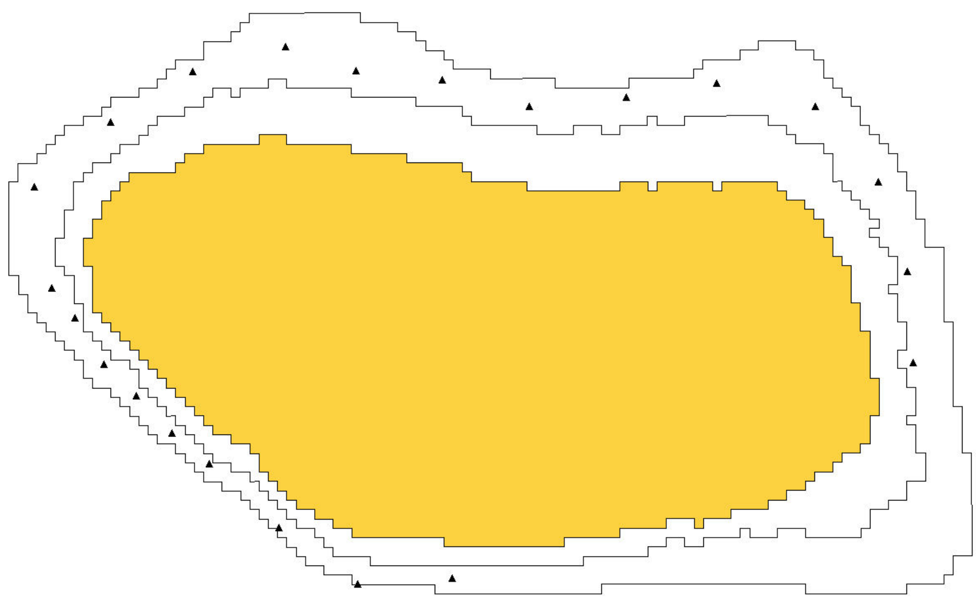

Figure 5.19: Broad-scale survey stations for invertebrates in Niutao.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

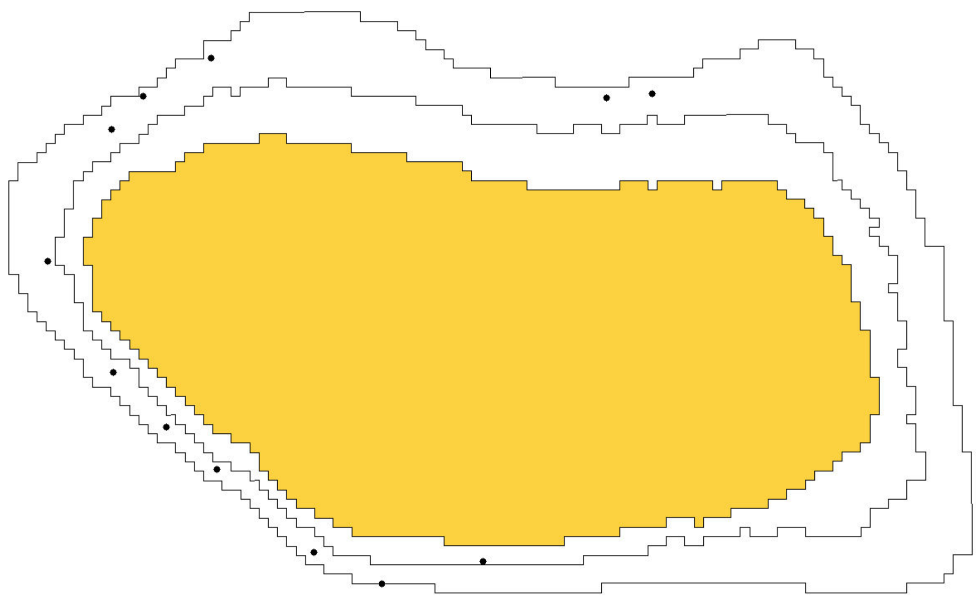

Figure 5.20: Fine-scale reef-benthos transect survey stations for invertebrates in Niutao.
Black circles: reef-benthos transect stations (RBt).

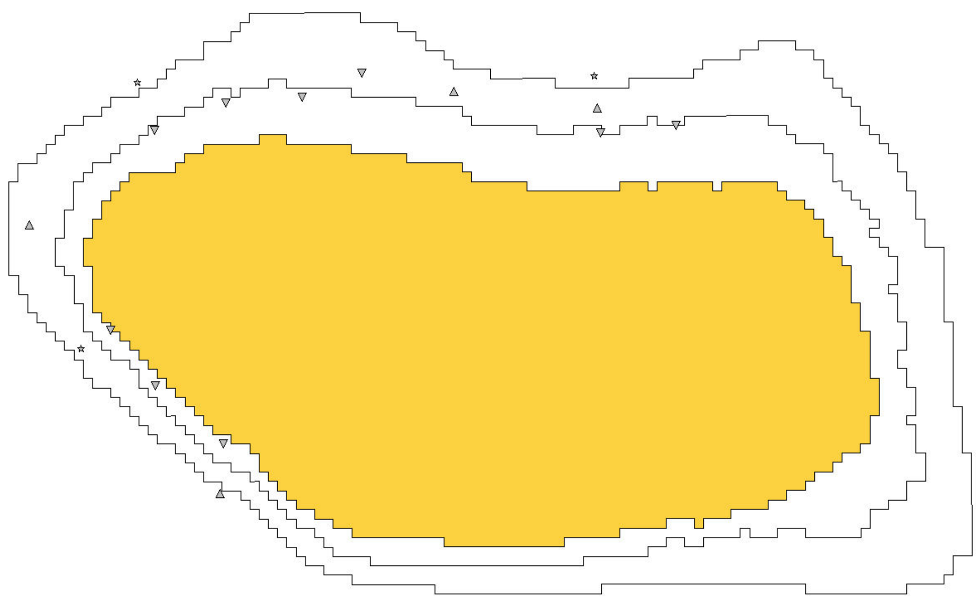

Figure 5.21: Fine-scale survey stations for invertebrates in Niutao.
Grey triangles: reef-front search stations (RFs);
inverted grey triangles: reef-front search stations by walking (RFs_w);
grey stars: sea cucumber day search stations (Ds).

Twenty species or species groupings (groups of species within a genus) were recorded within Niutao invertebrate surveys. Among these were 3 bivalves, 10 gastropods, 4 sea cucumbers, and 2 urchins (Appendix 4.4.1). Information on key families and species is detailed below.

5.4.1 Giant clams: Niutao

At Niutao, suitable reef habitat for giant clams was restricted to a narrow partially submerged reef flat and relatively steep fringing reef slope. Shallow reef was limited to a total of approximately 1 km^2 (7.7 km lineal perimeter). There was no lagoon or protected shallow-water reef habitat.

Broad-scale sampling provided an overview of giant clam distribution around Niutao Island. One species of giant clam was recorded in survey: elongate clam *Tridacna maxima* (found in 1 station and 1 transect – Figure 5.22).

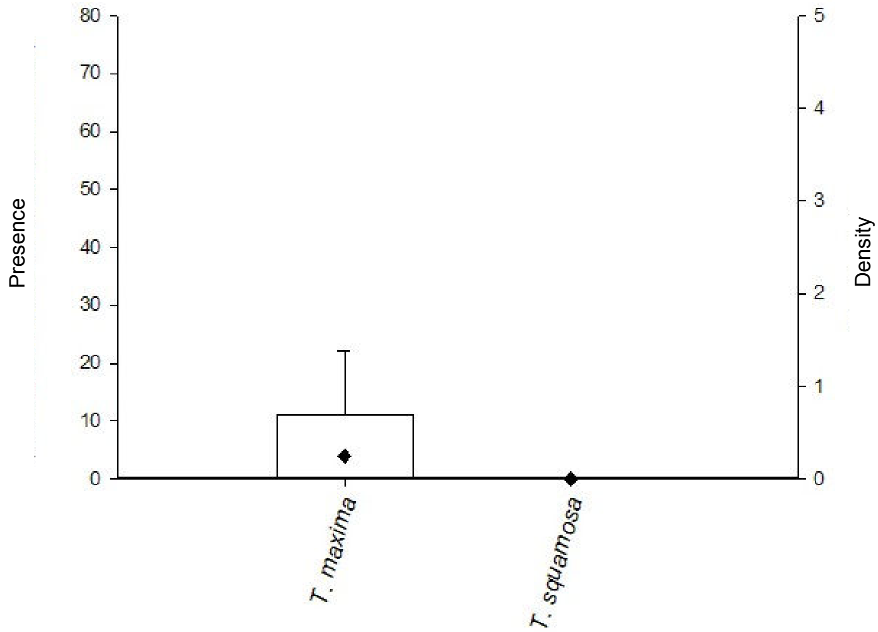

Figure 5.22: Presence and mean density of giant clam species at Niutao based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Finer-scale, reef-benthos assessments (RBt) allowed for a closer inspection of clam habitat (Appendix 4.4.2). *Tridacna maxima* was recorded within 17% of reef-benthos stations (2 clams from a total of 12 stations, 72 transects – Figure 5.23).

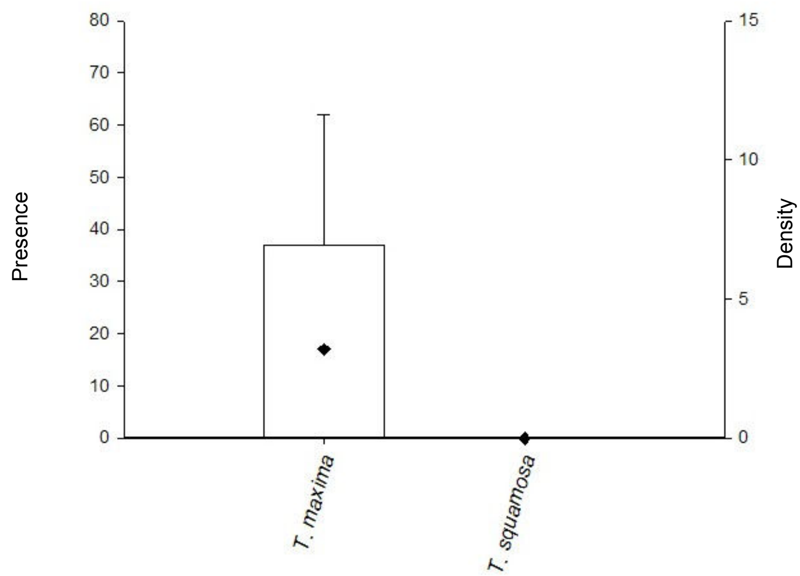

Figure 5.23: Presence and mean density of giant clam species at Niutao based on fine-scale reef-benthos survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Only two individual clams were recorded in these surveys, and both these *T. maxima* were mature clams near the asymptotic length (L_∞ >30 cm). The single clam recorded from broad-scale assessments was 15 cm in length, and no *T. maxima* was found in deeper-water searches (Ds stations).

T. squamosa, a species that is normally found at lower density than the elongate clam, and which was common elsewhere in Tuvalu, was not recorded here. This species is often found at refuge in deeper water, but was absent from all survey records collected in Niutao (Appendices 4.4.1 to 4.4.5).

5.4.2 Mother-of-pearl species (MOP): trochus and pearl oysters – Niutao

Niutao is not a large island, with an outer perimeter of <10 km and no nearby reef systems to act as a remote source of recruits. Reefs around Niutao Island do not constitute a good benthos for the commercial topshell, *Trochus niloticus*, as reef area is small, drops off steeply into deep water and is of low relief and complexity. Shallow-water reef with habitat suitable for juveniles was also limited; the area would not support significant populations of this commercial species.

Tectus pyramis, the green topshell (of low commercial value), was present at low density. Only three recordings of *T. pyramis* were made in reef-benthos transects. These had a mean size (basal width) of 7.7 ±0.5 cm.

As Tuvalu is not within the natural distribution of trochus, and Niutao has not received any translocations of trochus (unlike Funafuti and Nukufetau) no mother-of-pearl SCUBA assessments were made. It was also observed that the abundance of grazing gastropods on reefs was low, and the structure and exposure of reef did not offer an attractive site for the trochus (Table 5.9).

Table 5.9: Presence and mean density of *Tectus pyramis* in Niutao
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Tectus pyramis				
B-S	0	0	0/12 = 0	0/72 = 0
RBt	10.4	5.4	3/12 = 25	3/72 = 4
RFs	10.4	5.4	3/12 = 25	3/72 = 4

B-S = broad-scale survey; RBt = reef-benthos transect; RFs = reef-front search.

Pinctada margaritifera, a normally cryptic and sparsely distributed pearl oyster species was also not recorded during the survey.

5.4.3 Infaunal species and groups: Niutao

No soft-benthos areas were found on Niutao, and therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made for in-ground shell resources.

5.4.4 Other gastropods and bivalves: Niutao

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs) was detected at low density in broad-scale and sea cucumber day searches (Appendices 4.4.1 to

4.4.7). *Turbo* spp., which are commonly collected along exposed reef fronts in the Pacific, were not recorded during the survey. Other species targeted by fishers (resource species, e.g. *Australium, Charonia, Chicoreus, Conus, Cypraea, Thais* and *Vasum*) were recorded during independent survey (Appendices 4.4.1 to 4.4.7). Interestingly, a single triton shell, *Charonia tritonis* was recorded, although no crown of thorns starfish were noted (See Section 5.4.7: 'other echinoderms' for starfish data.).

Data on other bivalves in broad-scale and fine-scale benthos surveys (such as *Chama* and *Spondylus*) are also in Appendices 4.4.1 to 4.4.7. No creel survey was conducted at Niutao Island.

5.4.5 Lobsters: Niutao

There was no dedicated night reef-front search (Ns) for lobsters. No lobsters were recorded during the other surveys.

5.4.6 Sea cucumbers[10]: Niutao

Niutao Island had a restricted area of shallow-water reef (<1 km^2) in an exposed location, bordering a relatively small land mass. Sheltered reef margins and shallow, mixed hard- and soft-benthos habitat, suitable for sea cucumbers, was generally non-existent, and there was a high degree of wave action on exposed reef platforms which were emerged periodically at low tides. Reef slopes fell off quickly into deep water providing little buffer to the shallow-water fringing reef from storm swell. In general, the environment present at Niutao did not favour most deposit-feeding sea cucumber species (which eat organic matter in the upper few millimetres of bottom substrates).

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.10; Appendices 4.4.1 to 4.4.7). The presence of valuable commercial species at the raised limestone island of Niutao was lower than at Vaitupu, and significantly poorer than at both atoll lagoon sites surveyed in Tuvalu (Funafuti and Nukufetau). Because of the limited habitat available and the exposed conditions at Niutao, only four commercial species were recorded during in-water assessments (Table 5.10).

Sea cucumber species associated with reef, such as the high-value black teatfish (*Holothuria nobilis*), greenfish (*Stichopus chloronotus*) and leopardfish (*Bohadschia argus*) were all absent.

Surf redfish, *Actinopyga mauritiana*, a species characteristic of exposed conditions, were uncommon along the reef front in the first 6 m of water, but present at medium density along the exposed reef platforms (within the surge zone, 7 km lineal distance of perimeter reef platform). At these locations 'spurs' and pools of water held surf redfish at an estimated density of 40 per ha.

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[10] 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.

Table 5.10: Sea cucumber species records for Niutao

Species	Common name	Commercial value [5]	B-S transects n = 24			Reef-benthos stations n = 12			Other stations RFs = 4; RFs_w = 4			Other stations Ds = 3		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.7	16.7	4				39.3	78.6	50 RFs_w			
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M												
Bohadschia vitiensis	Brown sandfish	L												
Holothuria atra	Lollyfish	L				6.9	83.3	8	71.4	285.7	25 RFs_w	27.8	27.8	100
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M	0.7	16.7	4	3.5	41.7	8						
Holothuria nobilis [4]	Black teatfish	H												
Thelenota ananas	Prickly redfish	H										1.6	4.8	33
Thelenota anax	Amberfish	M												

[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; Ds = day search.

Interestingly, elephant trunkfish (*Holothuria fuscopunctata*) were recorded in broad-scale and reef-benthos transects. This species would be expected in more sheltered locations than is found at Niutao. More protected areas of reef and soft benthos were not generally found at Niutao, although small lollyfish (*Holothuria atra*) were present at low density at pools in the back sections of the reef platform.

Deep dives on SCUBA, sea cucumber day searches (25–35 m) were conducted to obtain a preliminary assessment of deep-water stocks such as the high-value white teatfish (*Holothuria fuscogilva*) and the lower-value amberfish (*Thelenota anax*). In these assessments (average 25 m), white teatfish (*Holothuria fuscogilva*) and amberfish (*Thelenota anax*) were not recorded, although prickly redfish (*Thelenota ananas*) were found at low density.

5.4.7 Other echinoderms: Niutao

No edible slate urchins *Heterocentrotus mammillatus* or collector urchins *Tripneustes gratilla* were recorded, although *Echinometra mathaei* and *Echinothrix diadema* were both present (in 33% of reef-benthos stations).

Starfish, apart from *Fromia* spp., were rare and no corallivorous starfish e.g. crown of thorns, (*Acanthaster planci*), blue starfish, (*Linckia laevigata*) or pincushion stars (*Culcita novaeguineae*) were recorded during assessments.

5.4.8 Discussion and conclusions: invertebrate resources in Niutao

- Despite the good coverage of the survey, clams were rare at Niutao Island (only three *T. maxima* found). At this density, giant clams are past the critical threshold point where spawning and future recruitment is critically compromised. The isolated nature of Niutao Island and the open-reef environment makes recruitment from these broadcast spawners less assured. The small scale of available reef for receiving incoming juveniles and holding adults makes an easily targeted stock, such as clams, more susceptible to overfishing.

- The small scale, high exposure and lack of suitable habitat affected the potential for mother-of-pearl resource species. Based on the information collected on mother-of-pearl stock, *T. niloticus* is not present and does not present a promising prospect for Niutao in the future. Populations of *T. pyramis*, a related species, were low in abundance and the black-lip pearl oyster, *P. margaritifera*, was not found. Fishing pressure, along with environmental conditions explains the paucity of these results.

- Based on the information collected on sea cucumber stocks, there is a limited number of species found on Niutao, and stock densities are very low. The presence of medium-high-value surf redfish, *A. mauritiana,* is of interest, but this preliminary survey suggests that occurrence and density is too low to consider commercial fishing. Commercial operation for this species relies on densities of approximately 400–600 per ha. Monitoring of this stock is suggested, as good recruitment could offer a small opportunity for periodic commercial harvests when conditions allow.

5.5 Overall recommendations for Niutao

Based on the survey work undertaken and the assessments made across all three disciplines (socioeconomics, finfish and invertebrates), the following recommendations are made for Niutao:

- In consultation with the local *Falekaupule* and *Kaupule*, the Tuvalu Fisheries Department conduct further in-water as well as socioeconomic surveys as perhaps the only means to further update trends in fish resources and resource use in the island.

- The local *Falekaupule* and *Kaupule* consider assisting the development of the immediate offshore pelagic fishery and investigate the use of the enclosed lagoons for milkfish farming. This may also contribute to the effective development of a small-scale subsistence or semi-commercial fishery on the island.

- The Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* to establish a monitoring programme for catch and landings to observe any decrease in fish stocks due to high fisher density and high catches. Effective ways of controlling fishing effort may include regulating fishing methods (e.g. gear types, mesh sizes) and catches (e.g. setting size limits, or total allowable catches of heavily exploited species) for marine resources, finfish and invertebrates.

- The Tuvalu Fisheries Department assist the local *Falekaupule* and *Kaupule* to develop management plans or arrangements for the inshore resources of Niutao to ensure the sustainable harvest of all marine resources, now and in the future. Ongoing assessments, including socioeconomic surveys, could be used to assess how management arrangements are working, with changes made as necessary.

- The local *Falekaupule* and *Kaupule* be very cautious in any endeavour to open the sea cucumber fishery at Niutao as the four species recorded have stocks at low to very low levels, and are not sufficient for commercial harvest at this time.

- The local *Falekaupule* and *Kaupule* consult with the Fisheries Department to look at options for increasing the numbers of giant clams, to allow a small breeding stock to be established at Niutao.

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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).

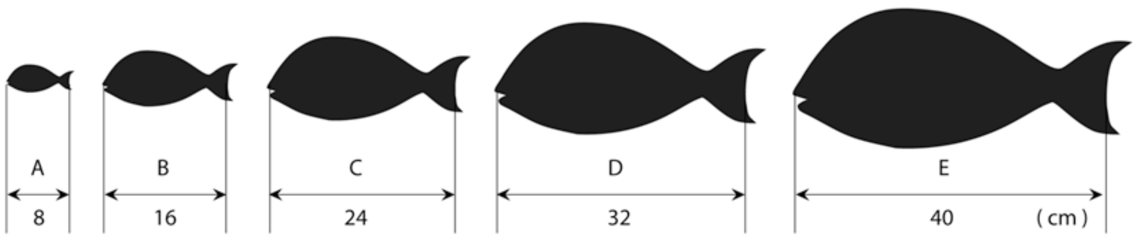


Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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.

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$_i$

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

<u>Total invertebrate consumption:</u>

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

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

<u>Total canned fish consumption:</u>

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

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

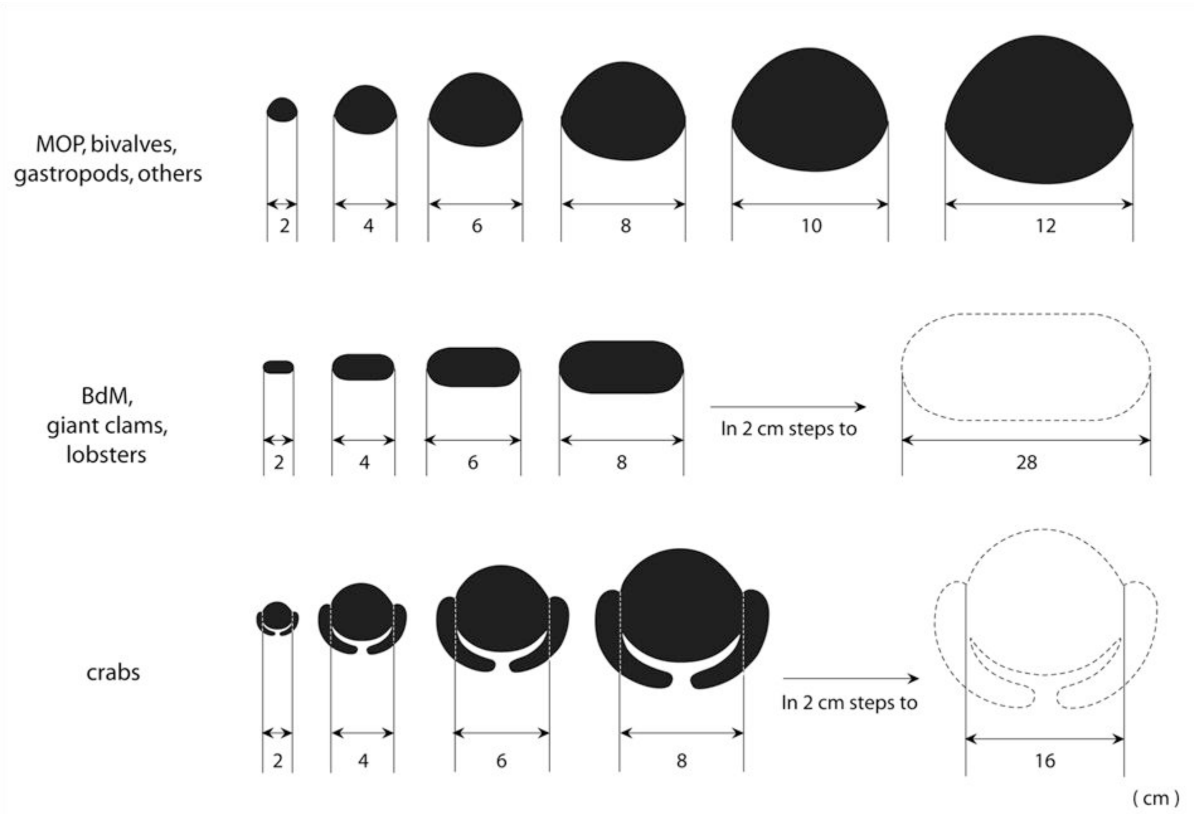


Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

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 <u>fishing strategies</u> 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).

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).

<u>Total annual finfish export:</u>

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

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 <u>fishing pressure</u>, 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.

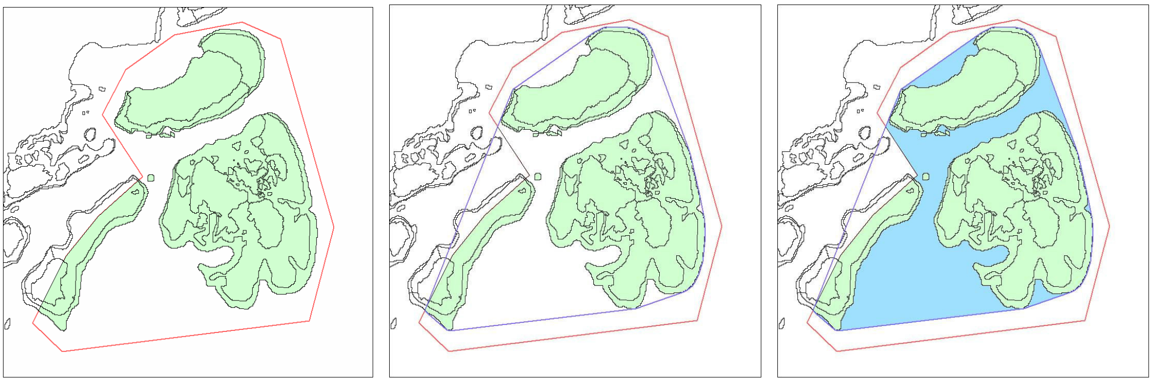


Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as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

(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).

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 $\mathrm{species}_j$
$F_{inv}f_h$ = total number of female invertebrate fishers for $\mathrm{habitat}_h$
$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for $\mathrm{habitat}_h$ and $\mathrm{species}_j$
$F_{inv}m_h$ = total number of male invertebrate fishers for $\mathrm{habitat}_h$
$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for $\mathrm{habitat}_h$ and $\mathrm{species}_j$
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 $\mathrm{habitat}_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for $\mathrm{habitat}_h$)
f_i = frequency of fishing trips (trips/week) as reported in $\mathrm{interview}_i$

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:____
____
____
____

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 <u>OR:</u>

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 ☐ <u>OR:</u>

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

and the rest you gift? yes ☐

how much? kg ☐ <u>OR:</u>

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

and/or sell? yes ☐

how much? kg ☐ <u>OR</u>:

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?

(if the fisher can't specify, tick the box)

	times/week		duration in hours < 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				

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				

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 cuccullata	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
Tellina sp.	20	35	65	7	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
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.

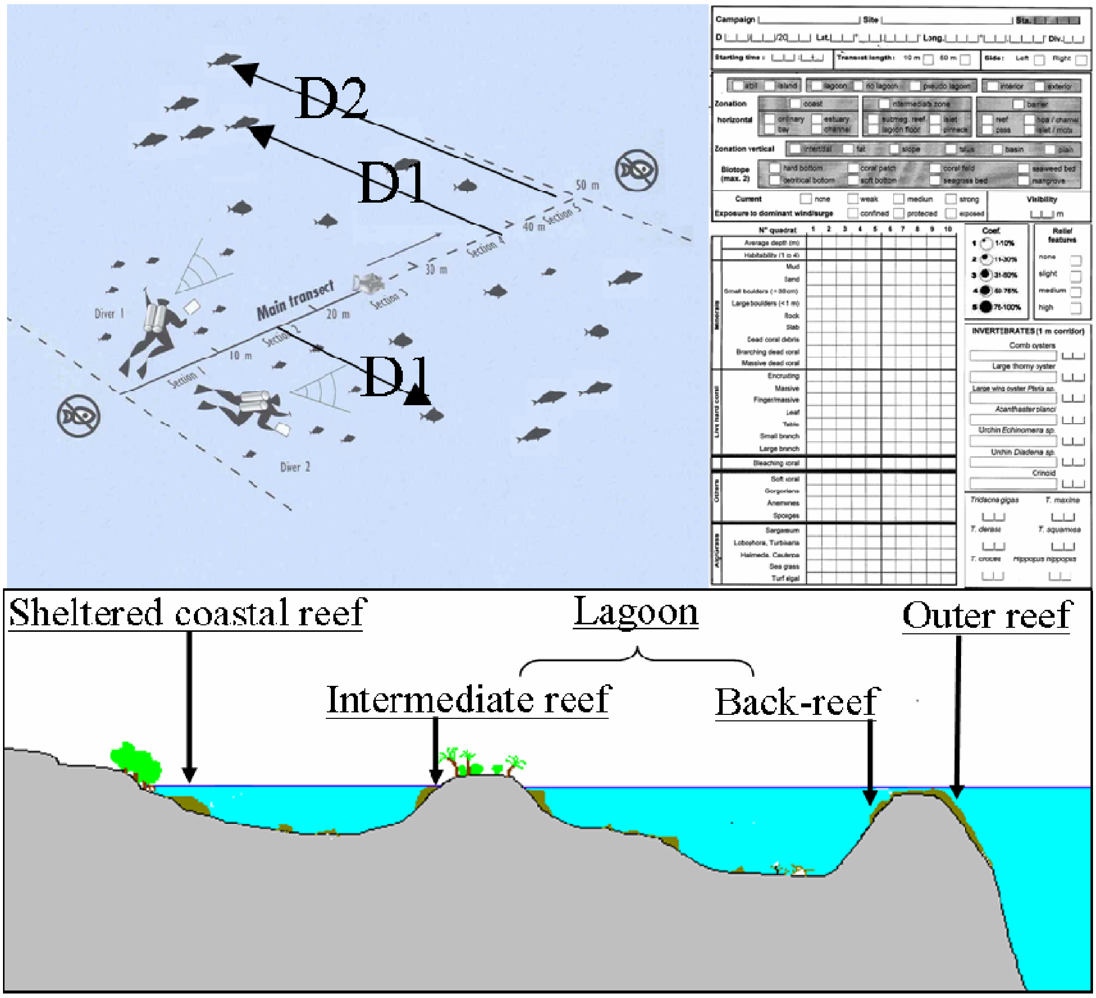


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys 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.

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.

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.

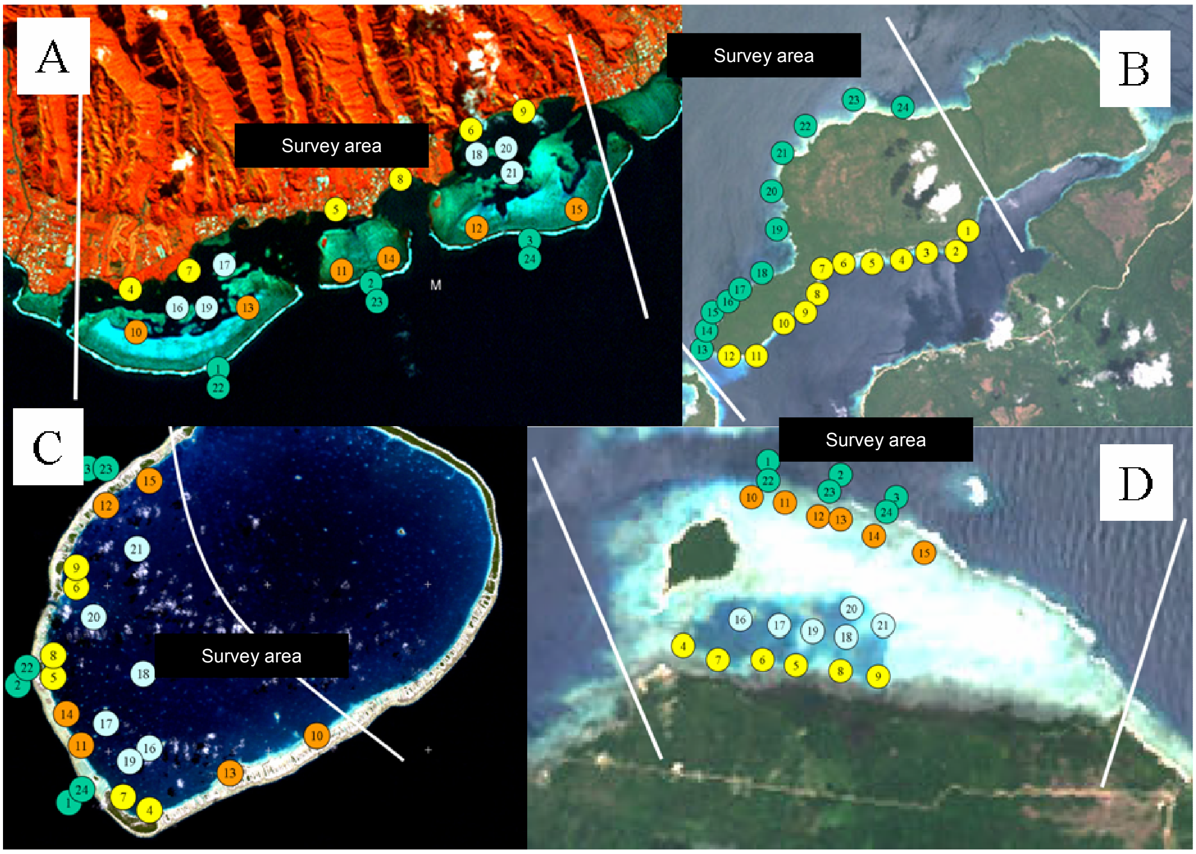


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon 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 ☐

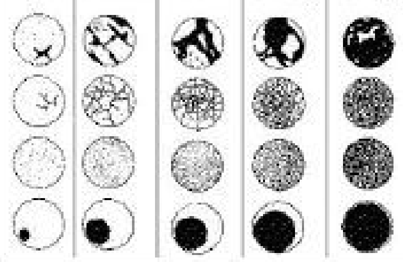
☐ coast		☐ intermediate zone		☐ barrier	
☐ linear	☐ cape	☐ submerg. reef	☐ pinnacle	☐ outer slope	☐ pass
☐ bay mouth	☐ back of bay	☐ near surf. reef	☐ islet lagoon	☐ reef crest	☐ hoa/channel
☐ estuary	☐ channel	☐ lagoon floor	☐ islet fringing reef	☐ back reef	☐ motu

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

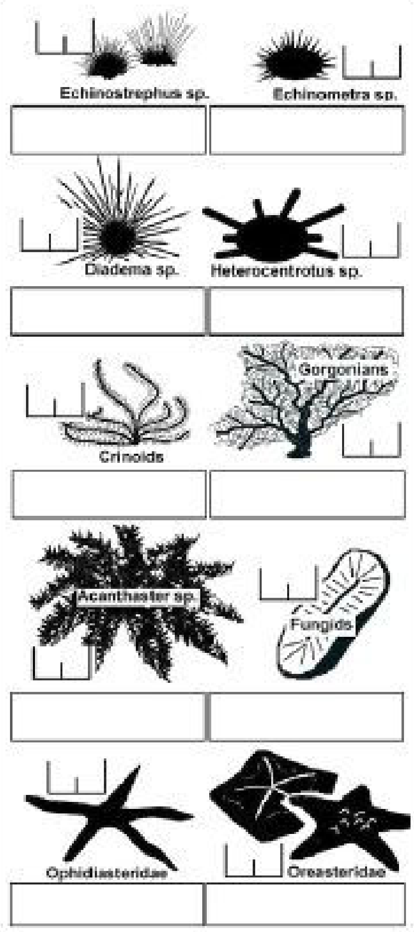
☐ hard bottom	☐ large coral patches	☐ small coral patches	☐ coral field	☐ seaweed bed
☐ detritical bottom	☐ soft bottom		☐ seagrass bed	☐ mangrove

	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	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	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 :										



Campaign |___________________| Site |_____________________________| Diver |__|__| Transect |__|__|__|

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

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

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.

[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).

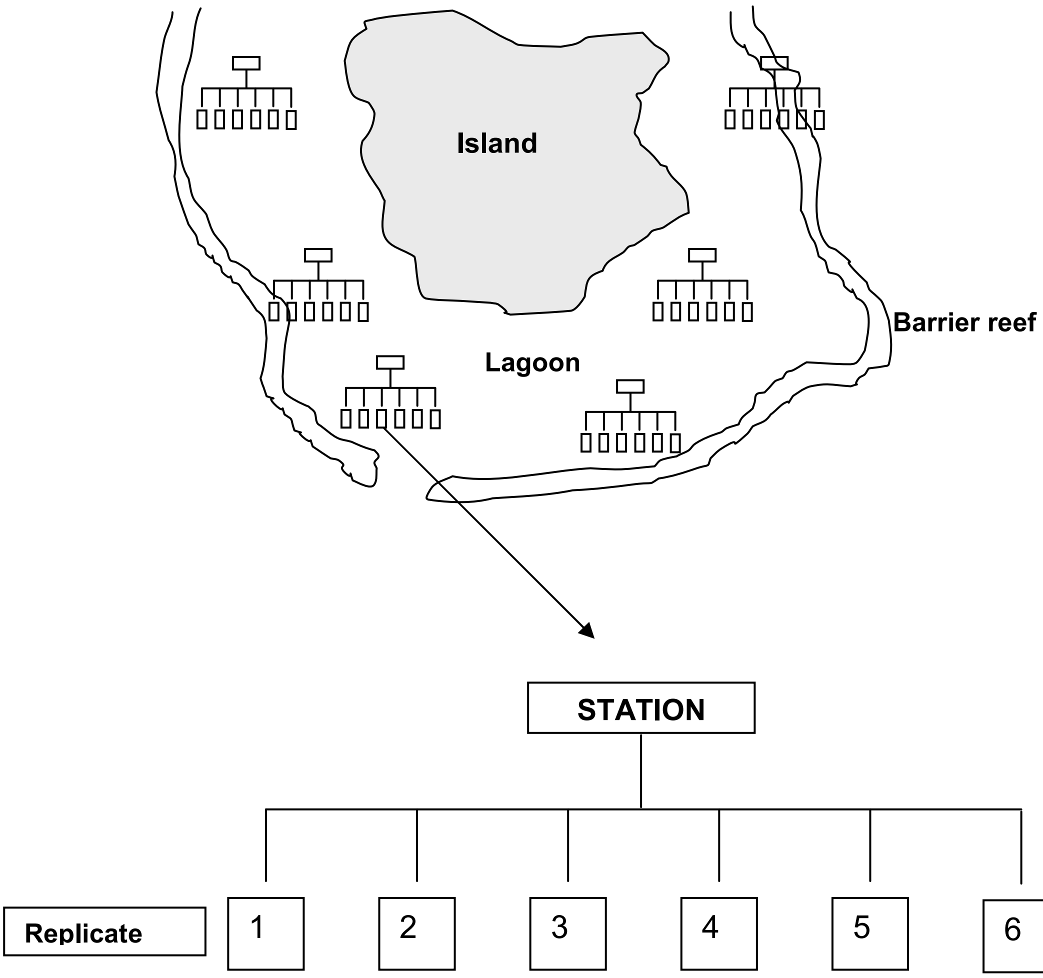


Figure A1.3.1: Stations and replicate measures at a given site.
A replicate measure could be a transect, search period or quadrat group.

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).

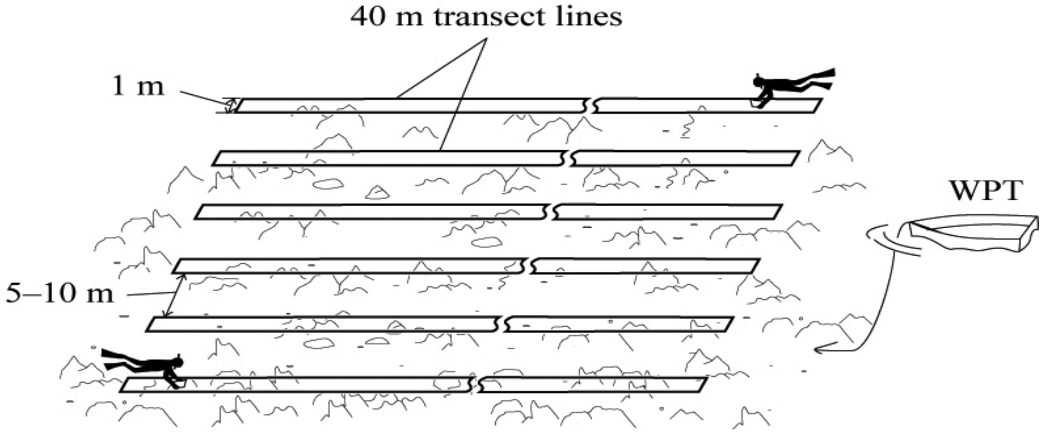


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

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.

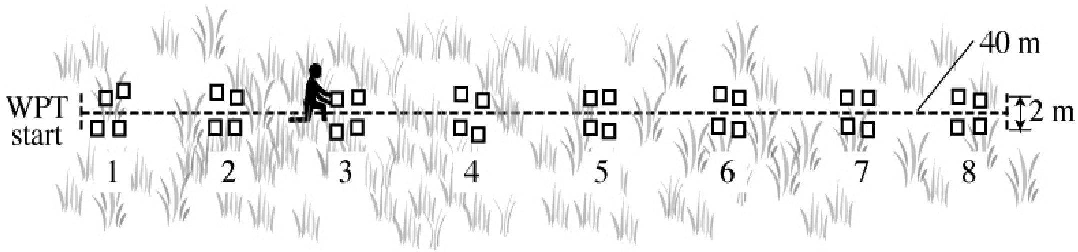


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<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).

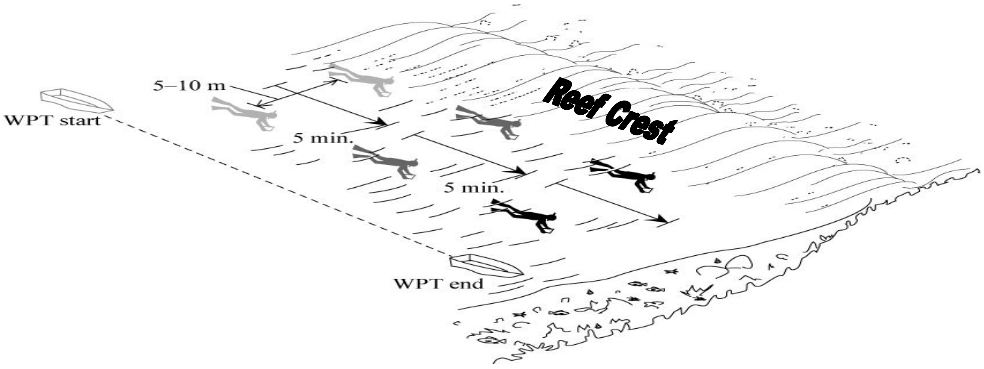


Figure A1.3.4: Reef-front search (RFs) station.

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.

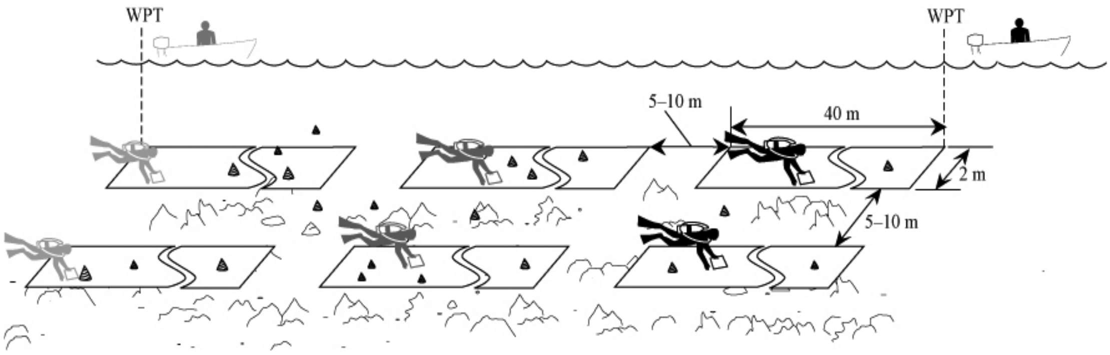


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

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.

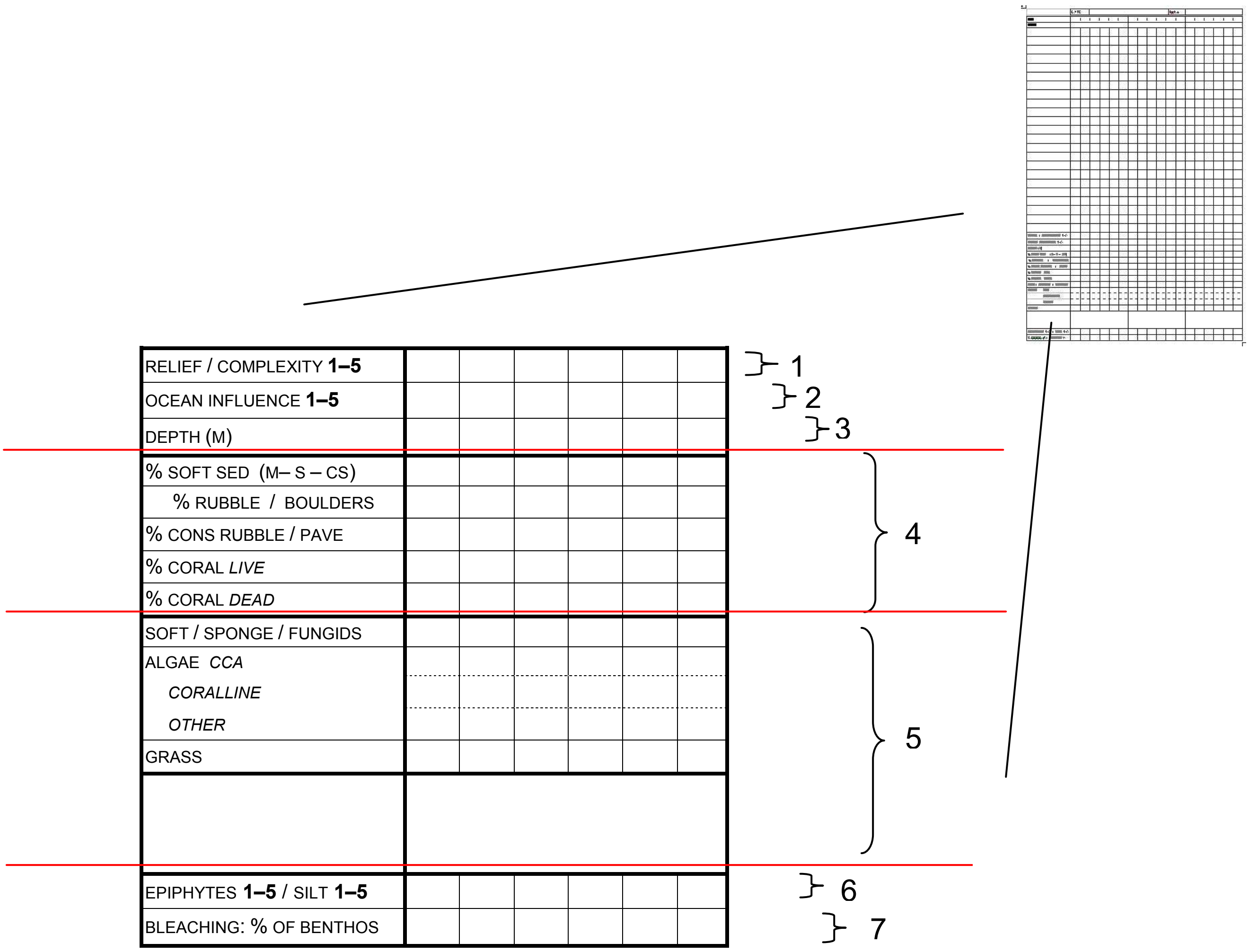


Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

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.

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 Funafuti socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Funafuti

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Sheltered coastal reef				
Kyphosidae	Nanue	*Kyphosus cinerascens*	4029	16
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	3289	13
Acanthuridae	Manini	*Acanthurus triostegus*	3161	13
Acanthuridae	Manini lakau	*Naso lituratus*	1713	7
Lujanidae	Savane	*Lutjanus kasmira*	1492	6
Siganidae	Maiava	*Siganus vermiculatus*	1387	6
Mugilidae	Kafakafa	*Liza vaigiensis*	1355	5
Mugilidae	Kanase	*Valamugil seheli*	1317	5
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	1146	5
Caesionidae	Ulia	*Caesio caerulaurea*	825	3
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	600	2
Lujanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	573	2
Gerreidae	Matu	*Gerres* spp.	573	2
Serranidae	Fapuku	*Epinephelus polyphekadion*	530	2
Scaridae	Ulafi	*Scarus ghobban*	523	2
Acanthuridae	Ume	*Naso unicornis*	460	2
Acanthuridae	Ponelolo	*Acanthurus lineatus*	429	2
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	414	2
Acanthuridae	Maono	*Acanthurus guttatus*	244	1
Carangidea	Lalaufou	*Alectis ciliaris*	198	1
Lethrinidae	Muu	*Monotaxis grandoculis*	195	1
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	191	1
Serranidae	Gatala liki	*Epinephelus merra*	155	1

2.1.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Funafuti (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Sheltered coastal reef (continued)				
Scaridae	Laea	*Scarus* spp.	117	0
Carangidea	Teu	*Caranx sexfasciatus*	37	0
Carangidea	Ata	*Scomberoides lysan*	31	0
Holocentridae	Malau	*Myripristis violacea*	24	0
Lujanidae	Taea	*Lutjanus gibbus*	12	0
Total:			**25,023**	**100**
Lagoon				
Lujanidae	Taea	*Lutjanus gibbus*	5172	23
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	5162	23
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	5021	23
Acanthuridae	Ume	*Naso unicornis*	851	4
Acanthuridae	Manini lakau	*Naso lituratus*	809	4
Kyphosidae	Nanue	*Kyphosus cinerascens*	783	4
Lethrinidae	Gutula	*Lethrinus xanthochilus*	462	2
Acanthuridae	Manini	*Acanthurus triostegus*	447	2
Acanthuridae	Pokapoka	*Naso vlamingii, Naso brevirostris, Naso caesius*	402	2
Siganidae	Maiava	*Siganus vermiculatus*	396	2
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	337	2
Gerreidae	Matu	*Gerres* spp.	305	1
Lethrinidae	Muu	*Monotaxis grandoculis*	294	1
Carangidea	Kamai	*Elagatis bipinnulata*	277	1
Sphyranidae	Taotao	*Sphyraena forsteri*	277	1
Lutjanidae	Kapatiko	*Aprion* spp.	260	1
Serranidae	Tonu gatala	*Plectropomus laevis*	214	1
Lujanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	169	1
Sphyranidae	Pauea	*Sphyraena forsteri*	150	1
Serranidae	Gatala liki	*Epinephelus merra*	149	1
Acanthuridae	Ponelolo	*Acanthurus lineatus*	107	0

2.1.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Funafuti (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Lagoon (continued)				
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	89	0
Balistidae	Umu	*Pseudobalistes flavimarginatus*	81	0
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	37	0
Scombridae	Valu	*Gymnosarda unicolor*	37	0
Total:			**22,287**	**100**
Lagoon and outer reef				
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	885	36
Lujanidae	Taea	*Lutjanus gibbus*	850	34
Lethrinidae	noto / tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	305	12
Lethrinidae	Saabutu	*Lethrinus erythracanthus*	216	9
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	216	9
Lujanidae	Savane	*Lutjanus kasmira*	20	1
Total:			**2491**	**100**

Appendix 2: Socioeconomic survey data
Funafuti

2.1.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Funafuti (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Outer reef				
Exocoetidae	Isave	*Cypselurus* spp.	2770	22
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	1604	13
Carangidea	Tafauli	*Caranx lugubris*	1219	10
Lujanidae	Taea	*Lutjanus gibbus*	1045	8
Lutjanidae	Palu malau	*Etelis coruscans, Etelis carbunculus*	595	5
Acanthuridae	Ume	*Naso unicornis*	562	4
Gempylidae	Palu	*Ruvettus pretiosus*	531	4
Lutjanidae	Palu sega	*Aphareus rutilans*	524	4
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	503	4
Acanthuridae	Manini lakau	*Naso lituratus*	484	4
Kyphosidae	Nanue	*Kyphosus cinerascens*	422	3
Lethrinidae	Muu	*Monotaxis grandoculis*	338	3
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	328	3
Holocentridae	Malau	*Myripristis violacea*	316	2
Acanthuridae	Ponelolo	*Acanthurus lineatus*	312	2
Serranidae	Fapuku	*Epinephelus polyphekadion*	230	2
Carangidea	Atule	*Selar crumenophthalmus*	171	1
Serranidae	Eve	*Epinephelus hexagonatus*	153	1
Scaridae	Ulafi	*Scarus ghobban*	135	1
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	129	1
Acanthuridae	Manini	*Acanthurus triostegus*	111	1
Carangidea	Ulua	*Caranx melampygus*	104	1
Lujanidae	Savane	*Lutjanus kasmira*	64	0
Scaridae	Laea	*Scarus* spp.	54	0
Lujanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	36	0
Carangidea	Aseu	*Caranx melampygus, Caranx ignobilis*	7	0
Total:			**12,744**	**100**

2.1.2 Annual catch of invertebrate species groups in Funafuti (number, total weight wet biomass and % of total annual catch by weight from reported and extrapolated data by fisheries)

Fishery	Vernacular name	Scientific name	Reported data		Extrapolated data		% annual catch (weight)
			no/year	kg/year	no/year	kg/year	
Reeftop	Kamakama	*Grapsus albolineatus*	1048	37	70,547	2469	0.5
	Alili	*Turbo setosus*	2533	51	114,788	2296	0.5
	Matamea	*Eriphia sebana*	1436	50	55,932	1958	0.4
	Kivikivi	*Thais armigera*	1693	34	87,863	1757	0.3
	Sibo	*Nerita albicilla, Nerita polita*	1618	8	85,350	427	0.1
Sand	Misa		119,934	600	8,315,434	41,577	8.2
	Kasi	*Asaphis violascens*	28,790	432	1,882,485	28,237	5.6
Lobster	Lobster	*Panulirus penicillatus*	1359	1359	45,567	45,567	9.0
Seagrass	Panea	*Strombus luhuanus*	358,179	8954	13,209,029	330,226	65.3
	Tio	*Dendropoma maximum*	875	13	60,633	910	0.2
Other	Kalea	*Lambis truncata*	771	386	25,859	12,930	2.6
	Fasua	*Tridacna squamosa, Tridacna maxima*	2251	1125	75,447	37,724	7.5
Total:						**506,077**	**100**

'Other' refers to giant clam and *Lambis truncata* fishery.

2.1.3 Size class distribution of invertebrate species groups in Funafuti (% of total numbers per species from reported catch data)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Alili	*Turbo setosus*	04-06 cm	100.0
Fasua	*Tridacna squamosa, Tridacna maxima*	10-15 cm	17.8
		15-40 cm	26.6
		18-24 cm	55.6
Kalea	*Lambis truncata*	18-22 cm	92.2
		20-30 cm	7.8
Kamakama	*Grapsus albolineatus*	04-06 cm	5.7
		06-08 cm	11.4
		08 cm	82.8
Kasi	*Asaphis violascens*	04-06 cm	1.2
		06-08 cm	98.8
Kivikivi	*Thais armigera*	04 cm	100.0
Lobster	*Panulirus penicillatus*	18-24 cm	27.6
		18-28 cm	25.4
		20-22 cm	11.0
		20-28 cm	2.9
		20-40 cm	18.4
Matamea	*Eriphia sebana*	04 cm	31.3
		04-06 cm	8.3
		06-08 cm	60.3
Misa		00-01 cm	100.0
Panea	*Strombus luhuanus*	03-04 cm	62.7
		04 cm	13.7
		04-06 cm	23.6
Sibo	*Nerita albicilla, Nerita polita*	02 cm	100.0
Tio	*Dendropoma maximum*	01-02 cm	100.0

2.2 Nukufetau socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Nukufetau

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Sheltered coastal reef				
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	24	n/a
Acanthuridae	Manini	*Acanthurus triostegus*	652	4
Acanthuridae	Manini lakau	*Naso lituratus*	883	5
Carangidae	Kata	*Carangoides ferdau*	502	3
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	14	n/a
Gerreidae	Matu	*Gerres* spp.	944	6
Holocentridae	Malau	*Myripristis violacea*	68	n/a
Kyphosidae	Nanue	*Kyphosus cinerascens*	615	4
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	351	2
Lethrinidae	Muu	*Monotaxis grandoculis*	438	3
Lutjanidae	Kapatiko	*Aprion* spp.	161	1
Lutjanidae	Taea	*Lutjanus gibbus*	1346	8
Mugilidae	Kafakafa	*Liza vaigiensis*	2784	17
Mugilidae	Kanase	*Valamugil seheli*	5399	32
Mullidae	Kaivete	*Mulloidichthys flavolineatus*	234	1
Scaridae	Ulafi	*Scarus ghobban*	1262	8
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	550	3
Serranidae	Sumu	*Plectropomus* spp.	105	1
Siganidae	Maiava	*Siganus vermiculatus*	284	2
Total:			**16,616**	**100**

n/a = no information available.

2.2.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Nukufetau (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Sheltered coastal reef and outer reef				
Acanthuridae	Manini lakau	*Naso lituratus*	107	10
Acanthuridae	Ume	*Naso unicornis*	387	37
Scaridae	Ulafi	*Scarus ghobban*	287	27
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	277	26
Total:			**1058**	**100**

2.2.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Nukufetau (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Lagoon				
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	45	n/a
Acanthuridae	Manini lakau	*Naso lituratus*	92	n/a
Acanthuridae	Ume	*Naso unicornis*	311	1
Carangidae	Tafauli	*Caranx lugubris*	1729	8
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	98	n/a
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	685	3
Gerreidae	Matu	*Gerres* spp.	212	1
Holocentridae	Malau	*Myripristis violacea*	619	3
Kyphosidae	Nanue	*Kyphosus cinerascens*	75	n/a
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	303	1
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	2537	12
Lethrinidae	Muu	*Monotaxis grandoculis*	23	n/a
Lutjanidae	Kapatiko	*Aprion* spp.	2208	11
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	53	n/a
Lutjanidae	Taea	*Lutjanus gibbus*	7144	34
Lutjanidae	Savane	*Lutjanus kasmira*	284	1
Mugilidae	Kanase	*Valamugil seheli*	265	1
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	54	n/a
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	4015	19
Serranidae	Fapuku	*Epinephelus polyphekadion*	188	1
Total:			**20,960**	**100**

n/a = no information available.

2.2.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Nukufetau (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Lagoon and outer reef				
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	162	1
Acanthuridae	Manini	*Acanthurus triostegus*	63	1
Acanthuridae	Manini lakau	*Naso lituratus*	1148	10
Acanthuridae	Ume	*Naso unicornis*	752	7
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	215	2
Carangidae	Atule	*Selar crumenophthalmus*	1468	13
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	313	3
Holocentridae	Malau	*Myripristis violacea*	529	5
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	38	n/a
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	1688	15
Lethrinidae	Muu	*Monotaxis grandoculis*		4
Lutjanidae	Kapatiko	*Aprion* spp.	414	23
Lutjanidae	Taea	*Lutjanus gibbus*	2654	1
Lutjanidae	Savane	*Lutjanus kasmira*	118	n/a
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	1814	16
Total:			**11,376**	**100**

n/a = no information available.

2.2.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Nukufetau (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total annual reported catch
Outer reef				
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	46	1
Acanthuridae	Manini	*Acanthurus triostegus*	186	4
Acanthuridae	Manini lakau	*Naso lituratus*	392	9
Carangidae	Kata	*Carangoides ferdau*	54	1
Carangidae	Tafauli	*Caranx lugubris*	107	2
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	417	9
Holocentridae	Malau	*Myripristis violacea*	466	10
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	132	3
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	35	1
Lutjanidae	Taea	*Lutjanus gibbus*	1251	28
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	133	3
Scaridae	Ulafi	*Scarus ghobban*	161	4
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	1098	25
Total:			**4478**	**100**

2.2.2 Annual catch of invertebrate species groups in Nukufetau (number, total weight wet biomass and % of total annual catch by weight from reported and extrapolated data by fisheries)

Fishery	Vernacular name	Scientific name	Reported data		Extrapolated data		% annual catch (weight)
			no/year	kg/year	no/year	kg/year	
Reeftop	Lobster	*Panulirus penicillatus*	825	825	7217	7217	9.5
	Pule uli	*Cypraea caputserpensis*	32,766	491	317,326	4760	6.3
	Alili	*Turbo setosus*	2240	45	22,342	447	0.6
	Kivikivi	*Thais armigera*	2274	45	19,902	398	0.5
	Tuatuaula	*Parribacus antarcticus*	50	37	437	328	0.4
	Pule uli lasi	*Cypraea mauritiana*	315	6	2756	55	0.1
Sand	Misa		9162	46	102,959	515	0.7
	Kasi	*Asaphis violascens*	550	8	6178	93	0.1
Reeftop, Sand	Octopus	*Octopus* spp.	835	459	8882	4885	6.4
	Pule kena	*Cypraea annulus, Cypraea moneta*	402,504	4025	4,085,017	40,850	53.9
Seagrass	Panea	*Strombus luhuanus*	183	5	1604	40	0.1
Other	Kalea	*Lambis truncata*	849	424	7430	3715	4.9
	Fasua	*Tridacna squamosa, Tridacna maxima*	2842	1421	24,880	12,440	16.4
Total:						**75,742**	**100.0**

'Other' refers to giant clam and *Lambis truncata* fishery.

2.2.3 Size class distribution of invertebrate species groups in Nukufetau (% of total numbers per species from reported catch data)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Alili	*Turbo setosus*	06-08 cm	49.1
		06-10 cm	28.6
		08 cm	22.3
Fasua	*Tridacna squamosa, Tridacna maxima*	10-28 cm	10.5
		12-40 cm	30.6
		16-22 cm	17.6
		16-24 cm	15.8
		20-25 cm	7.0
Kalea	*Lambis truncata*	20-24 cm	83.8
		26-28 cm	16.2
Kasi	*Asaphis violascens*	08-10 cm	100.0
Kivikivi	*Thais armigera*	04-06 cm	100.0
Lobster	*Panulirus penicillatus*	18-22 cm	30.3
		18-30 cm	16.7
		20-24 cm	24.2
		20-28 cm	12.1
		24-28 cm	16.7
Misa		01 cm	100.0
Octopus	*Octopus* spp.	02-04 cm	13.2
		02-06 cm	24.0
		04-05 cm	62.9
Panea	*Strombus luhuanus*	04 cm	100.0
Pule kena	*Cypraea annulus, Cypraea moneta*	00-01 cm	85.8
		00-02 cm	13.7
		01-02 cm	0.5
Pule uli	*Cypraea caputserpensis*	01 cm	15.3
		01-02 cm	68.6
		02 cm	0.9
		02-03 cm	15.3
Pule uli lasi	*Cypraea mauritiana*	05-06 cm	77.8
		06 cm	22.2
Tuatuaula	*Parribacus antarcticus*	20-24 cm	100.0

2.3 Vaitupu socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Vaitupu

Family	Vernacular name	Scientific name	Total weight (kg)	% of total catch
Intertidal reef flat				
Acanthuridae	Maono	*Acanthurus guttatus*	23	n/a
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	41	n/a
Acanthuridae	Manini	*Acanthurus triostegus*	949	4
Acanthuridae	Kapalagi	*Acanthurus xanthopterus*	298	1
Acanthuridae	Manini lakau	*Naso lituratus*	145	1
Albulidae	Kiokio	*Albula neoguinaica*	300	1
Apogonidae	Manifi	*Archamia* spp.	59	n/a
Carangidae	Teu	*Caranx sexfasciatus*	906	4
Chanidae	Paneava	*Chanos chanos*	23	n/a
Gereidae	Matu	*Gerres* spp.	1551	7
Holocentridae	Malau	*Myripristis violacea*	386	2
Kyphosidae	Nanue	*Kyphosus cinerascens*	2763	12
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	362	2
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	100	n/a
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	2074	9
Mugilidae	Kafakafa	*Liza vaigiensis*	3323	14
Mugilidae	Kanase	*Valamugil seheli*	8876	38
Mullidae	Kaivete	*Mulloidichthys flavolineatus*	59	n/a
Scaridae	Ulafi	*Scarus ghobban*	750	3
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	566	2
Total:			**23,554**	**100**

n/a = no information available.

2.3.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Vaitupu (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total catch
Lagoon				
Albulidae	Kiokio	*Albula neoguinaica*	35	n/a
Gereidae	Matu	*Gerres* spp.	2454	23
Holocentridae	Malau	*Myripristis violacea*	16	n/a
Holocentridae	Ta malau	*Sargocentron spiniferum*	241	2
Lethrinidae	Noto / Tanutanu	*Lethrinus erythracanthus, Lethrinus harak*	3558	34
Lutjanidae	Kapatiko	*Aprion* spp.	28	n/a
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	596	6
Mugilidae	Kafakafa	*Liza vaigiensis*	2552	24
Mugilidae	Kanase	*Valamugil seheli*	72	1
Mullidae	Kaivete	*Mulloidichthys flavolineatus*	994	9
Total:			**10,546**	**100**
Outer reef				
Acanthuridae	Ponelolo	*Acanthurus lineatus*	155	1
Acanthuridae	Manini	*Acanthurus triostegus*	45	n/a
Acanthuridae	Kapalagi	*Acanthurus xanthopterus*	1834	8
Acanthuridae	Manini lakau	*Naso lituratus*	929	4
Acanthuridae	Pokapoka	*Naso vlamingii, Naso brevirostris, Naso caesius*	48	n/a
Carangidae	Tafauli	*Caranx lugubris*	1320	6
Carangidae	Ulua	*Caranx melampygus*	955	4
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	242	1
Exocoetidae	Isave	*Cypselurus* spp.	2170	10
Gempylidae	Palu	*Ruvettus pretiosus*	372	2
Gereidae	Matu	*Gerres* spp.	48	n/a
Holocentridae	Malau	*Myripristis violacea*	2021	9
Kyphosidae	Nanue	*Kyphosus cinerascens*	1632	8
Lethrinidae	Saabutu	*Lethrinus erythracanthus*	514	2
Lethrinidae	Filoa	*Lethrinus olivaceus, Lethrinus atkinsoni, Lethrinus xanthochilus, Lethrinus obsoletus*	744	3
Lethrinidae	Gutula	*Lethrinus xanthochilus*	96	n/a
Lutjanidae	Palu sega	*Aphareus rutilans*	653	3
Lutjanidae	Palu malau	*Etelis coruscans, Etelis carbunculus*	1250	6
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	79	n/a
Lutjanidae	Taea	*Lutjanus gibbus*	211	1
Lutjanidae	Savane	*Lutjanus kasmira*	270	1
Lutjanidae	Palu savane	*Pristipomoides zonatus*	640	3
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	312	1
Scaridae	Ulafi	*Scarus ghobban*	659	3
Scaridae	Laea	*Scarus* spp.	452	2
Scombridae	Takua	*Thunnus albacares*	1032	5

n/a = no information available.

2.3.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Vaitupu (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total catch
Outer reef (continued)				
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	2355	11
Serranidae	Tonu gatala	*Plectropomus laevis*	232	1
Serranidae	Pula	*Variola albimarginata*	364	2
Total:			**21,634**	**100**

2.3.2 Annual catch of invertebrate species groups in Vaitupu (number, total weight wet biomass and % of total annual catch by weight from reported and extrapolated data by fisheries)

Fishery	Vernacular name	Scientific name	Reported data		Extrapolated data		% annual catch (weight)
			no/year	kg/year	no/year	kg/year	
Reeftop	Alili	*Turbo setosus*	7689	154	103,801	2076	29.9
	Kivikivi	*Thais armigera*	1303	26	29,813	596	8.6
	Octopus	*Octopus* spp.	60	33	588	323	4.7
	Pusi		37	2	368	18	0.3
Sand	Kasi	*Asaphis violascens*	12,242	184	183,129	2747	39.6
	Kamakama	*Grapsus albolineatus*	1049	37	24,014	840	12.1
Other	Koki	*Anadara* spp.	1666	35	16,336	343	4.9
Total:						**6945**	**100.0**

2.3.3 Size class distribution of invertebrate species groups in Vaitupu (% of total numbers per species from reported catch data)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Alili	*Turbo setosus*	04-06 cm	28.2
		06 cm	19.5
		06-08 cm	32.5
		10 cm	19.8
Kamakama	*Grapsus albolineatus*	06-08 cm	100.0
Kasi	*Asaphis violascens*	04 cm	2.9
		06-08 cm	74.7
		06-10 cm	22.5
Kivikivi	*Thais armigera*	06-08 cm	100.0
Koki	*Anadara* spp.	06-08 cm	100.0
Octopus	*Octopus* spp.	08-12 cm	100.0

2.4 Niutao socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Niutao

Family	Vernacular name	Scientific name	Total weight (kg)	% of total catch
Intertidal reef flat				
Kyphosidae	Nanue	*Kyphosus cinerascens*	4528	25
Acanthuridae	Manini	*Acanthurus triostegus*	3358	19
Acanthuridae	Maono	*Acanthurus guttatus*	2689	15
Mugilidae	Kanase	*Valamugil seheli*	1911	11
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	1466	8
Acanthuridae	Ponelolo	*Acanthurus lineatus*	864	5
Holocentridae	Malau	*Myripristis violacea*	673	4
Carangidae	Fua ika (Fua ulua)	*Caranx lugubris*	605	3
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	498	3
Pomacentridae	Mutumutu	*Abudefduf septemfasciatus*	356	2
Lutjanidae	Tagau / Taiva	*Lutjanus fulviflammus, Lutjanus fulvus*	345	2
Bleniidae	Manoko	*Istiblennius meleagris*	155	1
Mugilidae	Kafakafa	*Liza vaigiensis*	155	1
Labridae	Uloulo	*Thalassoma trilobatum*	119	1
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	106	1
Scaridae	Laea	*Scarus* spp.	87	0
Carangidae	Sokelau	*Trachinotus baillonii*	52	0
Total:			**17,966**	**100**

2.4.1 Annual catch (kg) of fish groups per habitat (includes only reported catch data by interviewed finfish fishers) – Niutao (continued)

Family	Vernacular name	Scientific name	Total weight (kg)	% of total catch
Outer reef				
Holocentridae	Malau	*Myripristis violacea*	2751	24
Serranidae	Gatala	*Cephalopholis sexmaculata, Cephalopholis igarashiensis, Cephalopholis aurantia, Cephalopholis miniata, Cephalopholis argus, Epinephelus socialis, Epinephelus miliaris, Epinephelus merra, Epinephelus polyphekadion, Epinephelus lanceolatus, Epinephelus morrhua, Epinephelus maculatus, Epinephelus chlorostigma, Epinephelus hexagonatus, Gracila albomarginata, Plectropomus areolatus, Saloptia powelli, Variola albimarginata, Variola louti*	1218	11
Exocoetidae	Isave	*Cypselurus* spp.	776	7
Cirrhitidae	Patuki	*Cirrhitus pinnulatus*	760	7
Scaridae	Laea	*Scarus* spp.	725	6
Holocentridae	Ta malau	*Sargocentron spiniferum*	712	6
Kyphosidae	Nanue	*Kyphosus cinerascens*	641	6
Acanthuridae	Manini lakau	*Naso lituratus*	623	6
Acanthuridae	Maono	*Acanthurus guttatus*	527	5
Mugilidae	Kanase	*Valamugil seheli*	345	3
Scaridae	Ulafi	*Scarus ghobban*	298	3
Acanthuridae	Pone	*Acanthurus nigrofuscus, Acanthurus nigroris, Acanthurus olivaceus*	237	2
Acanthuridae	Pokapoka	*Naso vlamingii, Naso brevirostris, Naso caesius*	221	2
Lutjanidae	Savane	*Lutjanus kasmira*	220	2
Acanthuridae	Kapalagi	*Acanthurus xanthopterus*	216	2
Serranidae	Pula	*Variola albimarginata*	186	2
Acanthuridae	Ponelolo	*Acanthurus lineatus*	173	2
Acanthuridae	Ume	*Naso unicornis*	134	1
Lutjanidae	Palu sega	*Aphareus rutilans*	129	1
Carangidae	Aseu	*Caranx melampygus, Caranx ignobilis*	103	1
Priacanthidae	Matapa	*Priacanthus hamrur*	90	1
Carangidae	Tafauli	*Caranx lugubris*	82	1
Carangidae	Kamai	*Elagatis bipinnulata*	51	0
Sphyranidae	Pauea	*Sphyraena forsteri*	51	0
Carangidae	Ulua	*Caranx melampygus*	26	0
Serranidae	Sumu	*Plectropomus* spp.	26	0
Total:			**11,321**	**100**

2.4.2 Annual catch of invertebrate species groups in Niutao (number, total weight wet biomass and % of total annual catch by weight from reported and extrapolated data by fisheries)

Fishery	Vernacular name	Scientific name	Reported data		Extrapolated data		% annual catch (weight)
			no/year	kg/year	no/year	kg/year	
Reeftop	Alili	*Turbo setosus*	1688	34	17,725	355	1.4
	Tuatuaula	*Parribacus antarcticus*	40	30	420	315	1.3
Lobster	Tuatuaula	*Parribacus antarcticus*	178	134	1873	1405	5.6
Other	Fasua	*Tridacna squamosa, Tridacna maxima*	262	131	2752	1376	5.5
	Kalea	*Lambis truncata*	130	65	1368	684	2.7
Lobster, Reeftop, Other	Lobster	*Panulirus penicillatus*	1984	1984	20,834	20,834	83.4
Total:						**24,968**	**100.0**

2.4.3 Size class distribution of invertebrate species groups in Niutao (% of total numbers per species from reported catch data)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Alili	*Turbo setosus*	04 cm	2.4
		06 cm	46.2
		06-10 cm	51.5
Fasua	*Tridacna squamosa, Tridacna maxima*	10-15 cm	5.7
		12-40 cm	82.8
		16-20 cm	11.4
Kalea	*Lambis truncata*	20-22 cm	100.0
Lobster	*Panulirus penicillatus*	16-18 cm	15.1
		18-20 cm	40.8
		18-22 cm	7.9
		20-24 cm	28.5
		24-28 cm	7.7
Tuatuaula	*Parribacus antarcticus*	20 cm	38.2
		22-24 cm	61.8

APPENDIX 3: FINFISH SURVEY DATA

3.1 Funafuti finfish survey data

3.1.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Funafuti

Station name	Habitat	Latitude	Longitude
TRA01	Lagoon	8°30'36.9612" S	179°10'47.0388" E
TRA02	Coastal reef	8°30'20.0412" S	179°11'45.1212" E
TRA03	Coastal reef	8°26'22.4412" S	179°10'08.3388" E
TRA04	Outer reef	8°25'26.1012" S	179°07'07.0788" E
TRA05	Back-reef	8°26'11.6412" S	179°05'41.2188" E
TRA06	Lagoon	8°28'56.2188" S	179°09'24.5988" E
TRA07	Outer reef	8°31'13.9188" S	179°12'16.8588" E
TRA08	Outer reef	8°32'44.6388" S	179°10'04.98" E
TRA09	Back-reef	8°33'52.02" S	179°07'53.4" E
TRA10	Lagoon	8°33'04.32" S	179°08'24.4788" E
TRA11	Back-reef	8°32'35.88" S	179°09'58.0788" E
TRA12	Outer reef	8°37'09.3612" S	179°05'55.0788" E
TRA13	Outer reef	8°36'14.94" S	179°04'12.8388" E
TRA14	Back-reef	8°33'36.9" S	179°03'13.0788" E
TRA15	Back-reef	8°36'00.6012" S	179°04'26.22" E
TRA16	Coastal reef	8°36'07.6788" S	179°05'58.4412" E
TRA17	Outer reef	8°29'20.04" S	179°03'06.0588" E
TRA18	Back-reef	8°30'51.2388" S	179°02'33" E
TRA19	Back-reef	8°29'39.9012" S	179°03'47.7" E
TRA20	Lagoon	8°30'01.1412" S	179°07'12.54" E
TRA21	Coastal reef	8°31'53.8212" S	179°11'11.22" E
TRA22	Lagoon	8°30'36.36" S	179°09'03.06" E
TRA23	Lagoon	8°29'28.14" S	179°08'06.9612" E
TRA24	Back-reef	8°25'46.3188" S	179°08'48.1812" E

Appendix 3: Finfish survey data
Funafuti

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0575	13.62
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0579	3.99
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0028	4.50
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0003	0.01
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0085	0.33
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0551	2.12
Back-reef	Acanthuridae	*Acanthurus xanthopterus*	0.0008	0.81
Back-reef	Acanthuridae	*Ctenochaetus binotatus*	0.0023	0.03
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.1090	5.81
Back-reef	Acanthuridae	*Naso annulatus*	0.0003	0.23
Back-reef	Acanthuridae	*Naso lituratus*	0.0248	10.93
Back-reef	Acanthuridae	*Naso vlamingii*	0.0005	0.58
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0413	0.91
Back-reef	Balistidae	*Balistapus undulatus*	0.0043	0.51
Back-reef	Balistidae	*Melichthys niger*	0.0003	0.00
Back-reef	Balistidae	*Melichthys vidua*	0.0028	0.06
Back-reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0003	0.79
Back-reef	Balistidae	*Rhinecanthus aculeatus*	0.0015	0.08
Back-reef	Balistidae	*Rhinecanthus rectangulus*	0.0018	0.21
Back-reef	Balistidae	*Sufflamen chrysopterus*	0.0033	0.17
Back-reef	Caesionidae	*Caesio caerulaurea*	0.0103	0.11
Back-reef	Caesionidae	*Pterocaesio trilineata*	0.0355	0.60
Back-reef	Carangidae	*Caranx melampygus*	0.0015	1.94
Back-reef	Carangidae	*Elagatis bipinnulata*	0.0003	0.37
Back-reef	Carangidae	*Scomberoides* spp.	0.0003	0.23
Back-reef	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0003	9.80
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0030	0.11
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0015	0.03
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0025	0.10
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0015	0.05
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0085	0.21
Back-reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0005	0.01
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0040	0.11
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0209	0.53
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0005	0.01
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0045	0.09
Back-reef	Holocentridae	*Myripristis violacea*	0.0013	0.02
Back-reef	Holocentridae	*Neoniphon sammara*	0.0030	0.26
Back-reef	Holocentridae	*Sargocentron diadema*	0.0003	0.02
Back-reef	Labridae	*Cheilinus chlorourus*	0.0033	0.31
Back-reef	Labridae	*Cheilinus fasciatus*	0.0033	0.52
Back-reef	Labridae	*Cheilinus undulatus*	0.0008	3.33
Back-reef	Labridae	*Coris aygula*	0.0003	0.02
Back-reef	Labridae	*Hemigymnus fasciatus*	0.0013	0.15
Back-reef	Labridae	*Oxycheilinus digrammus*	0.0015	0.05
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0035	0.71
Back-reef	Lethrinidae	*Lethrinus obsoletus*	0.0003	0.17
Back-reef	Lethrinidae	*Lethrinus olivaceus*	0.0003	0.31

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Lethrinidae	*Lethrinus ornatus*	0.0003	0.13
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0008	0.67
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0415	15.90
Back-reef	Lutjanidae	*Aphareus furca*	0.0008	0.43
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0028	1.13
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0003	0.01
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0253	16.26
Back-reef	Lutjanidae	*Lutjanus monostigma*	0.0003	0.30
Back-reef	Mullidae	*Mulloidichthys flavolineatus*	0.0178	0.39
Back-reef	Mullidae	*Mulloidichthys vanicolensis*	0.0028	0.06
Back-reef	Mullidae	*Parupeneus barberinus*	0.0015	0.13
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0023	0.18
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0035	0.27
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0188	0.56
Back-reef	Mullidae	*Parupeneus pleurostigma*	0.0008	0.05
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0005	0.07
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0010	1.31
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0028	3.25
Back-reef	Scaridae	*Chlorurus sordidus*	0.0643	12.08
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0075	4.96
Back-reef	Scaridae	*Scarus altipinnis*	0.0003	0.24
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0003	0.11
Back-reef	Scaridae	*Scarus forsteni*	0.0008	0.05
Back-reef	Scaridae	*Scarus frenatus*	0.0003	0.01
Back-reef	Scaridae	*Scarus ghobban*	0.0003	0.16
Back-reef	Scaridae	*Scarus globiceps*	0.0033	0.81
Back-reef	Scaridae	*Scarus niger*	0.0523	1.23
Back-reef	Scaridae	*Scarus oviceps*	0.0088	1.93
Back-reef	Scaridae	*Scarus psittacus*	0.0025	1.03
Back-reef	Scaridae	*Scarus rubroviolaceus*	0.0005	0.47
Back-reef	Scaridae	*Scarus schlegeli*	0.0048	1.46
Back-reef	Scaridae	*Scarus spinus*	0.0003	0.05
Back-reef	Serranidae	*Aethaloperca rogaa*	0.0008	0.03
Back-reef	Serranidae	*Cephalopholis argus*	0.0073	2.35
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0010	0.12
Back-reef	Serranidae	*Epinephelus hexagonatus*	0.0003	0.00
Back-reef	Serranidae	*Epinephelus merra*	0.0093	0.38
Back-reef	Serranidae	*Epinephelus spilotoceps*	0.0023	0.14
Back-reef	Serranidae	*Plectropomus areolatus*	0.0005	0.57
Back-reef	Serranidae	*Plectropomus laevis*	0.0003	0.41
Back-reef	Serranidae	*Plectropomus leopardus*	0.0003	0.23
Back-reef	Siganidae	*Siganus argenteus*	0.0038	0.34
Back-reef	Siganidae	*Siganus punctatus*	0.0010	0.81
Back-reef	Siganidae	*Siganus spinus*	0.0165	0.57
Back-reef	Siganidae	*Siganus vermiculatus*	0.0008	0.01
Back-reef	Zanclidae	*Zanclus cornutus*	0.0025	0.17

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Acanthuridae	*Acanthurus blochii*	0.0010	0.07
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.0150	2.32
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0035	0.37
Coastal reef	Acanthuridae	*Acanthurus nigricauda*	0.0005	0.01
Coastal reef	Acanthuridae	*Acanthurus pyroferus*	0.0010	0.04
Coastal reef	Acanthuridae	*Acanthurus triostegus*	0.0240	0.81
Coastal reef	Acanthuridae	*Ctenochaetus binotatus*	0.0010	0.02
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.0930	5.64
Coastal reef	Acanthuridae	*Naso lituratus*	0.0025	0.11
Coastal reef	Acanthuridae	*Naso unicornis*	0.0025	0.21
Coastal reef	Acanthuridae	*Zebrasoma scopas*	0.0145	0.46
Coastal reef	Balistidae	*Rhinecanthus aculeatus*	0.0005	0.01
Coastal reef	Balistidae	*Sufflamen chrysopterus*	0.0005	0.08
Coastal reef	Caesionidae	*Caesio caerulaurea*	0.0140	0.16
Coastal reef	Caesionidae	*Pterocaesio trilineata*	0.0100	0.08
Coastal reef	Carangidae	*Caranx melampygus*	0.0015	1.12
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0175	0.48
Coastal reef	Chaetodontidae	*Chaetodon citrinellus*	0.0110	0.18
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0030	0.08
Coastal reef	Chaetodontidae	*Chaetodon kleinii*	0.0005	0.01
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0040	0.13
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0135	0.39
Coastal reef	Chaetodontidae	*Chaetodon meyeri*	0.0010	0.05
Coastal reef	Chaetodontidae	*Chaetodon reticulatus*	0.0025	0.08
Coastal reef	Chaetodontidae	*Chaetodon trifascialis*	0.0140	0.44
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0020	0.06
Coastal reef	Chaetodontidae	*Chaetodon vagabundus*	0.0075	0.10
Coastal reef	Holocentridae	*Myripristis berndti*	0.0045	0.18
Coastal reef	Holocentridae	*Neoniphon sammara*	0.0015	0.09
Coastal reef	Holocentridae	*Sargocentron caudimaculatum*	0.0015	0.22
Coastal reef	Holocentridae	*Sargocentron microstoma*	0.0005	0.02
Coastal reef	Labridae	*Cheilinus chlorourus*	0.0055	0.21
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0020	0.33
Coastal reef	Labridae	*Cheilinus undulatus*	0.0005	0.00
Coastal reef	Lethrinidae	*Lethrinus obsoletus*	0.0025	0.13
Coastal reef	Lethrinidae	*Lethrinus variegatus*	0.0040	0.22
Coastal reef	Lethrinidae	*Lethrinus xanthochilus*	0.0025	0.06
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0325	6.99
Coastal reef	Lutjanidae	*Aphareus furca*	0.0015	0.02
Coastal reef	Lutjanidae	*Aprion virescens*	0.0005	0.82
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0015	0.40
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0005	0.02
Coastal reef	Lutjanidae	*Lutjanus monostigma*	0.0020	0.67
Coastal reef	Mullidae	*Mulloidichthys flavolineatus*	0.0500	0.75
Coastal reef	Mullidae	*Mulloidichthys vanicolensis*	0.0005	0.02
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0080	0.22
Coastal reef	Mullidae	*Parupeneus bifasciatus*	0.0030	0.07
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0060	0.29

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Mullidae	*Parupeneus multifasciatus*	0.0470	1.38
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0555	7.81
Coastal reef	Scaridae	*Hipposcarus longiceps*	0.0110	0.63
Coastal reef	Scaridae	*Scarus forsteni*	0.0025	0.20
Coastal reef	Scaridae	*Scarus ghobban*	0.0005	0.45
Coastal reef	Scaridae	*Scarus niger*	0.0510	1.08
Coastal reef	Scaridae	*Scarus oviceps*	0.0115	1.29
Coastal reef	Scaridae	*Scarus psittacus*	0.0035	0.54
Coastal reef	Scaridae	*Scarus rivulatus*	0.0005	0.41
Coastal reef	Scaridae	*Scarus schlegeli*	0.0005	0.48
Coastal reef	Scaridae	*Scarus spinus*	0.0005	0.04
Coastal reef	Serranidae	*Aethaloperca rogaa*	0.0025	0.06
Coastal reef	Serranidae	*Cephalopholis argus*	0.0005	0.01
Coastal reef	Serranidae	*Epinephelus merra*	0.0250	0.82
Coastal reef	Siganidae	*Siganus argenteus*	0.0275	1.45
Coastal reef	Siganidae	*Siganus punctatus*	0.0010	0.08
Coastal reef	Siganidae	*Siganus spinus*	0.0190	1.76
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0170	0.73
Lagoon	Acanthuridae	*Acanthurus achilles*	0.0020	0.09
Lagoon	Acanthuridae	*Acanthurus albipectoralis*	0.0033	1.94
Lagoon	Acanthuridae	*Acanthurus blochii*	0.0067	2.89
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0377	20.70
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0498	3.57
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0007	0.79
Lagoon	Acanthuridae	*Acanthurus olivaceus*	0.0073	1.44
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.0053	0.81
Lagoon	Acanthuridae	*Acanthurus triostegus*	0.0067	0.23
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.0007	0.01
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1010	5.93
Lagoon	Acanthuridae	*Naso annulatus*	0.0003	0.21
Lagoon	Acanthuridae	*Naso caesius*	0.0173	25.19
Lagoon	Acanthuridae	*Naso lituratus*	0.0367	19.27
Lagoon	Acanthuridae	*Naso lopezi*	0.0020	2.34
Lagoon	Acanthuridae	*Naso unicornis*	0.0040	2.55
Lagoon	Acanthuridae	*Naso vlamingii*	0.0007	0.77
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0777	1.61
Lagoon	Balistidae	*Balistapus undulatus*	0.0053	1.07
Lagoon	Balistidae	*Balistoides conspicillum*	0.0003	0.73
Lagoon	Balistidae	*Pseudobalistes flavimarginatus*	0.0007	1.28
Lagoon	Caesionidae	*Caesio caerulaurea*	0.1400	22.61
Lagoon	Caesionidae	*Caesio teres*	0.0200	0.63
Lagoon	Caesionidae	*Pterocaesio tile*	0.0643	12.48
Lagoon	Caesionidae	*Pterocaesio trilineata*	0.0133	0.49
Lagoon	Carangidae	*Caranx melampygus*	0.0043	5.70
Lagoon	Carangidae	*Elagatis bipinnulata*	0.0067	9.98
Lagoon	Carangidae	*Scomberoides* spp.	0.0007	0.44
Lagoon	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0003	8.92
Lagoon	Carcharhinidae	*Triaenodon obesus*	0.0003	3.78

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0027	0.09
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0040	0.17
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0047	0.12
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0083	0.23
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0183	0.53
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0020	0.05
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0063	0.17
Lagoon	Holocentridae	*Myripristis murdjan*	0.0013	0.01
Lagoon	Holocentridae	*Myripristis vittata*	0.0007	0.07
Lagoon	Holocentridae	*Neoniphon sammara*	0.0033	0.14
Lagoon	Holocentridae	*Neoniphon* spp.	0.0007	0.02
Lagoon	Holocentridae	*Sargocentron caudimaculatum*	0.0003	0.01
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0007	0.68
Lagoon	Holocentridae	*Sargocentron tiere*	0.0010	0.04
Lagoon	Labridae	*Cheilinus chlorourus*	0.0033	0.32
Lagoon	Labridae	*Cheilinus fasciatus*	0.0137	0.81
Lagoon	Labridae	*Cheilinus undulatus*	0.0013	0.23
Lagoon	Labridae	*Hemigymnus fasciatus*	0.0050	0.57
Lagoon	Labridae	*Oxycheilinus digrammus*	0.0013	0.06
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0137	3.86
Lagoon	Lethrinidae	*Lethrinus erythracanthus*	0.0010	0.56
Lagoon	Lethrinidae	*Lethrinus harak*	0.0003	0.22
Lagoon	Lethrinidae	*Lethrinus olivaceus*	0.0007	1.46
Lagoon	Lethrinidae	*Lethrinus xanthochilus*	0.0003	0.05
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0273	9.90
Lagoon	Lutjanidae	*Aphareus furca*	0.0017	0.97
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0062	5.21
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.0017	0.94
Lagoon	Lutjanidae	*Lutjanus monostigma*	0.0050	3.11
Lagoon	Mullidae	*Mulloidichthys flavolineatus*	0.0380	1.08
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0450	0.18
Lagoon	Mullidae	*Parupeneus barberinus*	0.0013	0.24
Lagoon	Mullidae	*Parupeneus bifasciatus*	0.0007	0.01
Lagoon	Mullidae	*Parupeneus cyclostomus*	0.0023	0.08
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0120	0.28
Lagoon	Mullidae	*Parupeneus spilurus*	0.0007	0.34
Lagoon	Myliobatidae	*Aetobatus narinari*	0.0003	0.38
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0043	0.56
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0013	1.20
Lagoon	Scaridae	*Chlorurus japanensis*	0.0003	0.09
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0050	2.85
Lagoon	Scaridae	*Chlorurus sordidus*	0.0183	3.52
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0027	0.93
Lagoon	Scaridae	*Scarus frenatus*	0.0010	0.33
Lagoon	Scaridae	*Scarus ghobban*	0.0013	0.75
Lagoon	Scaridae	*Scarus globiceps*	0.0063	1.12
Lagoon	Scaridae	*Scarus niger*	0.0267	0.64
Lagoon	Scaridae	*Scarus oviceps*	0.0060	0.63

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Scaridae	*Scarus rubroviolaceus*	0.0017	0.68
Lagoon	Scaridae	*Scarus schlegeli*	0.0073	2.65
Lagoon	Scombridae	*Gymnosarda unicolor*	0.0007	3.01
Lagoon	Scombridae	*Scomberomorus commerson*	0.0003	3.65
Lagoon	Serranidae	*Aethaloperca rogaa*	0.0027	0.14
Lagoon	Serranidae	*Cephalopholis argus*	0.0023	1.77
Lagoon	Serranidae	*Cephalopholis urodeta*	0.0013	0.12
Lagoon	Serranidae	*Epinephelus fuscoguttatus*	0.0007	0.51
Lagoon	Serranidae	*Epinephelus hexagonatus*	0.0003	0.01
Lagoon	Serranidae	*Epinephelus merra*	0.0063	0.30
Lagoon	Serranidae	*Epinephelus polyphekadion*	0.0017	0.86
Lagoon	Serranidae	*Epinephelus* spp.	0.0003	0.02
Lagoon	Serranidae	*Plectropomus areolatus*	0.0020	1.61
Lagoon	Serranidae	*Plectropomus laevis*	0.0003	0.18
Lagoon	Serranidae	*Plectropomus leopardus*	0.0003	0.17
Lagoon	Serranidae	*Plectropomus maculatus*	0.0007	0.51
Lagoon	Siganidae	*Siganus argenteus*	0.0190	1.36
Lagoon	Siganidae	*Siganus spinus*	0.0463	4.20
Lagoon	Sphyraenidae	*Sphyraena qenie*	0.0003	1.34
Lagoon	Zanclidae	*Zanclus cornutus*	0.0157	0.71
Outer reef	Acanthuridae	*Acanthurus achilles*	0.0063	0.28
Outer reef	Acanthuridae	*Acanthurus blochii*	0.0027	0.37
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0027	2.31
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.1040	6.24
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0013	0.49
Outer reef	Acanthuridae	*Acanthurus olivaceus*	0.0050	0.33
Outer reef	Acanthuridae	*Acanthurus pyroferus*	0.0040	0.23
Outer reef	Acanthuridae	*Acanthurus thompsoni*	0.0003	0.01
Outer reef	Acanthuridae	*Acanthurus triostegus*	0.0093	0.38
Outer reef	Acanthuridae	*Ctenochaetus binotatus*	0.0091	0.09
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.1660	7.18
Outer reef	Acanthuridae	*Naso caesius*	0.0020	0.83
Outer reef	Acanthuridae	*Naso lituratus*	0.0314	21.19
Outer reef	Acanthuridae	*Naso unicornis*	0.0027	3.22
Outer reef	Acanthuridae	*Naso vlamingii*	0.0067	7.44
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0132	0.23
Outer reef	Balistidae	*Balistapus undulatus*	0.0243	3.08
Outer reef	Balistidae	*Melichthys niger*	0.0157	0.49
Outer reef	Balistidae	*Melichthys vidua*	0.0385	2.30
Outer reef	Balistidae	*Sufflamen bursa*	0.0023	0.11
Outer reef	Balistidae	*Xanthichthys auromarginatus*	0.0013	0.20
Outer reef	Caesionidae	*Caesio caerulaurea*	0.0518	9.86
Outer reef	Caesionidae	*Caesio teres*	0.0293	7.78
Outer reef	Caesionidae	*Pterocaesio tile*	0.0127	3.72
Outer reef	Carangidae	*Caranx melampygus*	0.0007	0.64
Outer reef	Carangidae	*Scomberoides* spp.	0.0003	0.17
Outer reef	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0003	2.95
Outer reef	Carcharhinidae	*Carcharhinus melanopterus*	0.0003	3.75

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0017	0.05
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0023	0.04
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0027	0.08
Outer reef	Chaetodontidae	*Chaetodon lineolatus*	0.0003	0.01
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0003	0.01
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0033	0.11
Outer reef	Chaetodontidae	*Chaetodon meyeri*	0.0003	0.01
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0047	0.14
Outer reef	Chaetodontidae	*Chaetodon pelewensis*	0.0020	0.04
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0317	0.87
Outer reef	Chaetodontidae	*Chaetodon semeion*	0.0007	0.03
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0110	0.25
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0040	0.10
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0037	0.06
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0007	0.02
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0007	0.03
Outer reef	Ephippidae	*Platax* spp.	0.0033	2.69
Outer reef	Holocentridae	*Myripristis murdjan*	0.0070	0.11
Outer reef	Holocentridae	*Myripristis vittata*	0.0003	0.07
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0003	0.43
Outer reef	Holocentridae	*Sargocentron tiere*	0.0007	0.06
Outer reef	Labridae	*Cheilinus chlorourus*	0.0020	0.40
Outer reef	Labridae	*Cheilinus fasciatus*	0.0040	0.08
Outer reef	Labridae	*Cheilinus undulatus*	0.0027	13.46
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0033	0.47
Outer reef	Labridae	*Oxycheilinus digrammus*	0.0013	0.08
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0037	0.43
Outer reef	Lethrinidae	*Lethrinus erythracanthus*	0.0010	0.93
Outer reef	Lethrinidae	*Lethrinus genivittatus*	0.0003	0.07
Outer reef	Lethrinidae	*Lethrinus olivaceus*	0.0007	0.67
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0217	12.48
Outer reef	Lutjanidae	*Aphareus furca*	0.0113	5.64
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0075	5.65
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0007	0.35
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0070	5.45
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0040	2.04
Outer reef	Lutjanidae	*Macolor macularis*	0.0180	16.85
Outer reef	Lutjanidae	*Macolor niger*	0.0010	0.22
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0027	0.17
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0013	0.06
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0093	0.31
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0003	0.03
Outer reef	Scaridae	*Calotomus carolinus*	0.0007	0.73
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0007	0.65
Outer reef	Scaridae	*Chlorurus japanensis*	0.0003	0.18
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0113	12.53
Outer reef	Scaridae	*Chlorurus sordidus*	0.0667	13.70
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0082	9.32

3.1.2 Weighted average density and biomass of all finfish species recorded in Funafuti using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Scaridae	*Scarus altipinnis*	0.0237	28.72
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0020	0.91
Outer reef	Scaridae	*Scarus forsteni*	0.0007	0.19
Outer reef	Scaridae	*Scarus frenatus*	0.0023	0.68
Outer reef	Scaridae	*Scarus globiceps*	0.0003	0.03
Outer reef	Scaridae	*Scarus niger*	0.0565	1.28
Outer reef	Scaridae	*Scarus oviceps*	0.0223	4.42
Outer reef	Scaridae	*Scarus psittacus*	0.0033	1.38
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0010	1.00
Outer reef	Scaridae	*Scarus schlegeli*	0.0053	0.78
Outer reef	Scaridae	*Scarus spinus*	0.0040	1.50
Outer reef	Scaridae	*Scarus tricolor*	0.0017	1.57
Outer reef	Serranidae	*Aethaloperca rogaa*	0.0010	0.04
Outer reef	Serranidae	*Cephalopholis argus*	0.0170	10.32
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0083	1.18
Outer reef	Serranidae	*Epinephelus fuscoguttatus*	0.0003	0.33
Outer reef	Serranidae	*Epinephelus macrospilos*	0.0007	0.03
Outer reef	Serranidae	*Epinephelus polyphekadion*	0.0010	0.87
Outer reef	Serranidae	*Plectropomus areolatus*	0.0013	1.94
Outer reef	Siganidae	*Siganus argenteus*	0.0040	0.55
Outer reef	Siganidae	*Siganus niger*	0.0007	0.02
Outer reef	Siganidae	*Siganus spinus*	0.0020	0.43
Outer reef	Zanclidae	*Zanclus cornutus*	0.0057	0.31

3.2 Nukufetau finfish survey data

3.2.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Nukufetau

Station name	Habitat	Latitude	Longitude
TRA01	Coastal reef	8°02'12.66" S	178°19'44.58" E
TRA02	Back-reef	8°02'51.1188" S	178°21'03.8988" E
TRA03	Back-reef	7°57'59.4612" S	178°21'43.2" E
TRA04	Back-reef	7°56'56.5188" S	178°21'20.4588" E
TRA05	Back-reef	7°56'07.98" S	178°22'51.06" E
TRA06	Back-reef	7°56'21.7788" S	178°23'25.1412" E
TRA07	Outer reef	7°59'18.7188" S	178°19'47.2188" E
TRA08	Outer reef	8°01'57.54" S	178°18'10.62" E
TRA09	Outer reef	8°02'49.74" S	178°20'24.54" E
TRA10	Outer reef	8°04'16.32" S	178°22'18.9012" E
TRA11	Back-reef	8°03'20.2788" S	178°22'03.18" E
TRA12	Coastal reef	8°03'13.7988" S	178°22'38.5212" E
TRA13	Coastal reef	8°01'07.7412" S	178°23'44.4588" E
TRA14	Coastal reef	7°58'21.2412" S	178°25'45.4188" E
TRA15	Lagoon	7°59'12.66" S	178°23'37.2012" E
TRA16	Back-reef	7°59'45.42" S	178°21'10.5588" E
TRA17	Outer reef	7°56'12.66" S	178°23'38.94" E
TRA18	Outer reef	7°56'36.1212" S	178°21'20.34" E
TRA19	Lagoon	7°59'19.7412" S	178°21'16.1388" E
TRA20	Lagoon	8°01'50.9412" S	178°21'57.6" E
TRA21	Back-reef	8°00'45.9" S	178°19'18.7788" E
TRA22	Back-reef	7°58'44.1588" S	178°20'36.6" E
TRA23	Coastal reef	8°01'40.3788" S	178°19'26.2812" E
TRA24	Coastal reef	8°01'25.7412" S	178°19'12.0612" E

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0113	5.46
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0018	0.11
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0078	0.28
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0098	7.69
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0029	0.23
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0078	0.21
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0096	0.33
Back-reef	Acanthuridae	*Ctenochaetus binotatus*	0.0013	0.02
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.0669	2.84
Back-reef	Acanthuridae	*Ctenochaetus strigosus*	0.0007	0.01
Back-reef	Acanthuridae	*Naso annulatus*	0.0016	0.83
Back-reef	Acanthuridae	*Naso brevirostris*	0.0003	0.11
Back-reef	Acanthuridae	*Naso caesius*	0.0107	3.37
Back-reef	Acanthuridae	*Naso lituratus*	0.0093	5.29
Back-reef	Acanthuridae	*Naso tuberosus*	0.0004	0.12
Back-reef	Acanthuridae	*Naso unicornis*	0.0042	4.72
Back-reef	Acanthuridae	*Naso vlamingii*	0.0047	4.84
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0273	0.84
Back-reef	Acanthuridae	*Zebrasoma veliferum*	0.0009	0.08
Back-reef	Balistidae	*Balistapus undulatus*	0.0089	1.56
Back-reef	Balistidae	*Melichthys niger*	0.0004	0.03
Back-reef	Balistidae	*Melichthys vidua*	0.0048	0.11
Back-reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0009	1.21
Back-reef	Balistidae	*Rhinecanthus aculeatus*	0.0024	0.28
Back-reef	Balistidae	*Rhinecanthus rectangulus*	0.0004	0.09
Back-reef	Balistidae	*Sufflamen chrysopterus*	0.0024	0.08
Back-reef	Caesionidae	*Caesio caerulaurea*	0.0258	1.35
Back-reef	Caesionidae	*Caesio teres*	0.0120	1.26
Back-reef	Caesionidae	*Pterocaesio* spp.	0.0222	0.25
Back-reef	Caesionidae	*Pterocaesio trilineata*	0.0378	0.76
Back-reef	Carangidae	*Caranx melampygus*	0.0040	1.78
Back-reef	Carangidae	*Elagatis bipinnulata*	0.0020	1.63
Back-reef	Carangidae	*Gnathanodon speciosus*	0.0002	0.12
Back-reef	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0002	3.30
Back-reef	Carcharhinidae	*Carcharhinus melanopterus*	0.0007	12.57
Back-reef	Carcharhinidae	*Triaenodon obesus*	0.0004	1.18
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0053	0.24
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0018	0.03
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0011	0.05
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0027	0.10
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0111	0.30
Back-reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0027	0.05
Back-reef	Chaetodontidae	*Chaetodon plebeius*	0.0002	0.00
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0009	0.02
Back-reef	Chaetodontidae	*Chaetodon semeion*	0.0007	0.01
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0253	0.62
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0013	0.04
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0011	0.03
Back-reef	Chaetodontidae	*Forcipiger longirostris*	0.0009	0.05

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Back-reef	Chaetodontidae	*Heniochus monoceros*	0.0007	0.12
Back-reef	Holocentridae	*Myripristis berndti*	0.0002	0.07
Back-reef	Holocentridae	*Myripristis kuntee*	0.0002	0.06
Back-reef	Holocentridae	*Myripristis* spp.	0.0007	0.01
Back-reef	Holocentridae	*Neoniphon sammara*	0.0053	0.27
Back-reef	Holocentridae	*Sargocentron caudimaculatum*	0.0002	0.05
Back-reef	Holocentridae	*Sargocentron spiniferum*	0.0009	1.01
Back-reef	Holocentridae	*Sargocentron tiere*	0.0009	0.09
Back-reef	Kyphosidae	*Kyphosus cinerascens*	0.0044	4.18
Back-reef	Kyphosidae	*Kyphosus vaigiensis*	0.0378	21.69
Back-reef	Labridae	*Cheilinus chlorourus*	0.0058	0.49
Back-reef	Labridae	*Cheilinus fasciatus*	0.0040	0.38
Back-reef	Labridae	*Cheilinus trilobatus*	0.0004	0.01
Back-reef	Labridae	*Cheilinus undulatus*	0.0007	5.49
Back-reef	Labridae	*Oxycheilinus* spp.	0.0002	0.01
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0313	3.18
Back-reef	Lethrinidae	*Lethrinus erythracanthus*	0.0002	0.17
Back-reef	Lethrinidae	*Lethrinus obsoletus*	0.0020	0.79
Back-reef	Lethrinidae	*Lethrinus olivaceus*	0.0038	3.18
Back-reef	Lethrinidae	*Lethrinus ornatus*	0.0002	0.09
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0047	1.87
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0758	20.28
Back-reef	Lutjanidae	*Aphareus furca*	0.0091	4.31
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0107	8.49
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0053	1.50
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0436	26.81
Back-reef	Lutjanidae	*Lutjanus monostigma*	0.0273	6.65
Back-reef	Lutjanidae	*Macolor macularis*	0.0013	0.65
Back-reef	Mullidae	*Mulloidichthys flavolineatus*	0.0040	0.07
Back-reef	Mullidae	*Parupeneus barberinus*	0.0020	0.17
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0084	1.25
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0062	0.37
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0222	0.61
Back-reef	Muraenidae	*Gymnothorax javanicus*	0.0002	0.22
Back-reef	Myliobatidae	*Aetobatus narinari*	0.0002	9.41
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0020	0.32
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0004	0.60
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0013	1.36
Back-reef	Scaridae	*Chlorurus sordidus*	0.0291	4.78
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0029	2.02
Back-reef	Scaridae	*Scarus altipinnis*	0.0002	0.10
Back-reef	Scaridae	*Scarus forsteni*	0.0004	0.07
Back-reef	Scaridae	*Scarus frenatus*	0.0007	0.28
Back-reef	Scaridae	*Scarus ghobban*	0.0004	0.45
Back-reef	Scaridae	*Scarus globiceps*	0.0022	0.79
Back-reef	Scaridae	*Scarus niger*	0.0386	5.34
Back-reef	Scaridae	*Scarus oviceps*	0.0067	0.89
Back-reef	Scaridae	*Scarus psittacus*	0.0047	0.85
Back-reef	Scaridae	*Scarus rivulatus*	0.0002	0.09

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Back-reef	Scaridae	*Scarus rubroviolaceus*	0.0024	2.14
Back-reef	Scaridae	*Scarus schlegeli*	0.0049	1.41
Back-reef	Serranidae	*Aethaloperca rogaa*	0.0011	0.07
Back-reef	Serranidae	*Anyperodon leucogrammicus*	0.0013	0.10
Back-reef	Serranidae	*Cephalopholis argus*	0.0120	5.01
Back-reef	Serranidae	*Cephalopholis miniata*	0.0002	0.09
Back-reef	Serranidae	*Epinephelus areolatus*	0.0018	0.05
Back-reef	Serranidae	*Epinephelus fasciatus*	0.0002	0.04
Back-reef	Serranidae	*Epinephelus fuscoguttatus*	0.0011	3.05
Back-reef	Serranidae	*Epinephelus merra*	0.0082	0.30
Back-reef	Serranidae	*Epinephelus polyphekadion*	0.0027	2.32
Back-reef	Serranidae	*Epinephelus spilotoceps*	0.0020	0.24
Back-reef	Serranidae	*Gracila albomarginata*	0.0002	0.03
Back-reef	Serranidae	*Plectropomus areolatus*	0.0013	1.22
Back-reef	Serranidae	*Plectropomus leopardus*	0.0004	0.32
Back-reef	Serranidae	*Plectropomus maculatus*	0.0004	0.24
Back-reef	Siganidae	*Siganus argenteus*	0.0033	1.24
Back-reef	Siganidae	*Siganus vermiculatus*	0.0004	0.03
Back-reef	Zanclidae	*Zanclus cornutus*	0.0027	0.24
Coastal reef	Acanthuridae	*Acanthurus blochii*	0.0063	4.60
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.0110	0.78
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0090	0.41
Coastal reef	Acanthuridae	*Acanthurus nigricauda*	0.0023	1.20
Coastal reef	Acanthuridae	*Acanthurus triostegus*	0.0097	0.26
Coastal reef	Acanthuridae	*Acanthurus xanthopterus*	0.0027	2.21
Coastal reef	Acanthuridae	*Ctenochaetus binotatus*	0.0007	0.01
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.0940	3.73
Coastal reef	Acanthuridae	*Naso caesius*	0.0010	0.32
Coastal reef	Acanthuridae	*Naso lituratus*	0.0062	0.56
Coastal reef	Acanthuridae	*Naso unicornis*	0.0030	0.85
Coastal reef	Acanthuridae	*Zebrasoma scopas*	0.0160	0.33
Coastal reef	Balistidae	*Balistapus undulatus*	0.0020	0.66
Coastal reef	Balistidae	*Melichthys vidua*	0.0010	0.04
Coastal reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0003	0.52
Coastal reef	Balistidae	*Rhinecanthus aculeatus*	0.0003	0.07
Coastal reef	Balistidae	*Sufflamen chrysopterus*	0.0003	0.05
Coastal reef	Caesionidae	*Pterocaesio trilineata*	0.0100	0.08
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0043	0.15
Coastal reef	Chaetodontidae	*Chaetodon citrinellus*	0.0020	0.04
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0073	0.29
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0213	0.70
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0100	0.25
Coastal reef	Chaetodontidae	*Chaetodon meyeri*	0.0007	0.01
Coastal reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0013	0.02
Coastal reef	Chaetodontidae	*Chaetodon reticulatus*	0.0007	0.03
Coastal reef	Chaetodontidae	*Chaetodon semeion*	0.0003	0.01
Coastal reef	Chaetodontidae	*Chaetodon trifascialis*	0.0147	0.32
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0033	0.09
Coastal reef	Chaetodontidae	*Chaetodon vagabundus*	0.0050	0.13

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Coastal reef	Holocentridae	*Myripristis vittata*	0.0023	0.29
Coastal reef	Holocentridae	*Neoniphon sammara*	0.0090	0.50
Coastal reef	Holocentridae	*Sargocentron spiniferum*	0.0027	2.59
Coastal reef	Holocentridae	*Sargocentron tiere*	0.0033	0.25
Coastal reef	Kyphosidae	*Kyphosus vaigiensis*	0.0007	0.04
Coastal reef	Labridae	*Cheilinus chlorourus*	0.0020	0.12
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0023	0.07
Coastal reef	Labridae	*Cheilinus undulatus*	0.0003	0.22
Coastal reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0003	0.00
Coastal reef	Lethrinidae	*Lethrinus ornatus*	0.0003	0.11
Coastal reef	Lethrinidae	*Lethrinus variegatus*	0.0003	0.00
Coastal reef	Lethrinidae	*Lethrinus xanthochilus*	0.0017	0.03
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0953	21.27
Coastal reef	Lutjanidae	*Aphareus furca*	0.0040	1.80
Coastal reef	Lutjanidae	*Lutjanus bohar*	0.0003	0.00
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0483	10.33
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0733	21.18
Coastal reef	Lutjanidae	*Lutjanus kasmira*	0.0003	0.00
Coastal reef	Lutjanidae	*Lutjanus monostigma*	0.0053	2.76
Coastal reef	Mullidae	*Mulloidichthys flavolineatus*	0.0203	0.32
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0030	0.28
Coastal reef	Mullidae	*Parupeneus bifasciatus*	0.0053	0.10
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0007	0.02
Coastal reef	Mullidae	*Parupeneus multifasciatus*	0.0210	0.47
Coastal reef	Muraenidae	*Gymnothorax javanicus*	0.0003	0.21
Coastal reef	Pomacanthidae	*Pygoplites diacanthus*	0.0010	0.11
Coastal reef	Scaridae	*Chlorurus microrhinos*	0.0043	3.15
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0377	6.75
Coastal reef	Scaridae	*Hipposcarus longiceps*	0.0020	1.22
Coastal reef	Scaridae	*Scarus flavipectoralis*	0.0003	0.11
Coastal reef	Scaridae	*Scarus forsteni*	0.0007	0.15
Coastal reef	Scaridae	*Scarus ghobban*	0.0003	0.59
Coastal reef	Scaridae	*Scarus globiceps*	0.0007	0.20
Coastal reef	Scaridae	*Scarus niger*	0.0183	0.85
Coastal reef	Scaridae	*Scarus oviceps*	0.0187	3.33
Coastal reef	Scaridae	*Scarus psittacus*	0.0027	0.32
Coastal reef	Scaridae	*Scarus rivulatus*	0.0083	3.03
Coastal reef	Scaridae	*Scarus rubroviolaceus*	0.0003	0.11
Coastal reef	Scaridae	*Scarus schlegeli*	0.0007	0.05
Coastal reef	Scaridae	*Scarus spinus*	0.0003	0.16
Coastal reef	Serranidae	*Aethaloperca rogaa*	0.0030	0.23
Coastal reef	Serranidae	*Cephalopholis argus*	0.0040	0.68
Coastal reef	Serranidae	*Epinephelus merra*	0.0217	0.48
Coastal reef	Serranidae	*Plectropomus areolatus*	0.0003	0.00
Coastal reef	Siganidae	*Siganus argenteus*	0.0040	0.48
Coastal reef	Siganidae	*Siganus spinus*	0.0063	1.37
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0020	0.04
Lagoon	Acanthuridae	*Acanthurus blochii*	0.0007	0.15
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0120	1.55

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0200	1.23
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0033	3.63
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.0007	0.14
Lagoon	Acanthuridae	*Ctenochaetus binotatus*	0.0040	0.06
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.0857	4.04
Lagoon	Acanthuridae	*Naso caesius*	0.0020	0.17
Lagoon	Acanthuridae	*Naso lituratus*	0.0287	12.75
Lagoon	Acanthuridae	*Naso unicornis*	0.0073	7.89
Lagoon	Acanthuridae	*Naso vlamingii*	0.0180	15.05
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0160	0.55
Lagoon	Balistidae	*Balistapus undulatus*	0.0067	1.40
Lagoon	Balistidae	*Balistoides conspicillum*	0.0007	1.55
Lagoon	Balistidae	*Melichthys vidua*	0.0020	0.03
Lagoon	Caesionidae	*Caesio caerulaurea*	0.1140	12.55
Lagoon	Caesionidae	*Caesio lunaris*	0.0133	0.16
Lagoon	Caesionidae	*Caesio teres*	0.0467	2.29
Lagoon	Caesionidae	*Pterocaesio tile*	0.0900	24.60
Lagoon	Caesionidae	*Pterocaesio trilineata*	0.2880	3.54
Lagoon	Carangidae	*Caranx ignobilis*	0.0007	1.52
Lagoon	Carangidae	*Caranx melampygus*	0.0200	16.25
Lagoon	Carangidae	*Elagatis bipinnulata*	0.0027	4.00
Lagoon	Carangidae	*Scomberoides lysan*	0.0007	0.67
Lagoon	Carangidae	*Scomberoides* spp.	0.0047	1.83
Lagoon	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0033	111.28
Lagoon	Carcharhinidae	*Triaenodon obesus*	0.0007	1.06
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0027	0.18
Lagoon	Chaetodontidae	*Chaetodon lineolatus*	0.0020	0.04
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0027	0.09
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0140	0.38
Lagoon	Chaetodontidae	*Chaetodon melannotus*	0.0013	0.04
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0107	0.28
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0027	0.07
Lagoon	Holocentridae	*Myripristis violacea*	0.0007	0.01
Lagoon	Holocentridae	*Neoniphon sammara*	0.0007	0.01
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0007	0.03
Lagoon	Kyphosidae	*Kyphosus vaigiensis*	0.0173	12.35
Lagoon	Labridae	*Cheilinus fasciatus*	0.0140	1.54
Lagoon	Labridae	*Cheilinus undulatus*	0.0013	0.30
Lagoon	Labridae	*Hemigymnus fasciatus*	0.0013	0.10
Lagoon	Labridae	*Oxycheilinus digrammus*	0.0027	0.14
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0027	1.07
Lagoon	Lethrinidae	*Lethrinus amboinensis*	0.0027	1.31
Lagoon	Lethrinidae	*Lethrinus erythracanthus*	0.0013	0.72
Lagoon	Lethrinidae	*Lethrinus variegatus*	0.0007	0.01
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0260	10.44
Lagoon	Lutjanidae	*Aprion virescens*	0.0007	0.64
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0213	17.47
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.0140	12.27
Lagoon	Lutjanidae	*Lutjanus monostigma*	0.0100	6.07

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Lagoon	Mullidae	*Parupeneus barberinus*	0.0033	0.18
Lagoon	Mullidae	*Parupeneus bifasciatus*	0.0013	0.01
Lagoon	Mullidae	*Parupeneus cyclostomus*	0.0033	0.29
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0313	0.70
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0033	0.35
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0147	10.04
Lagoon	Scaridae	*Chlorurus sordidus*	0.0273	3.30
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0173	8.36
Lagoon	Scaridae	*Scarus altipinnis*	0.0013	0.59
Lagoon	Scaridae	*Scarus ghobban*	0.0027	1.63
Lagoon	Scaridae	*Scarus niger*	0.0067	0.08
Lagoon	Scaridae	*Scarus psittacus*	0.0007	0.20
Lagoon	Scaridae	*Scarus rubroviolaceus*	0.0235	7.46
Lagoon	Scaridae	*Scarus schlegeli*	0.0027	0.50
Lagoon	Serranidae	*Aethaloperca rogaa*	0.0027	0.15
Lagoon	Serranidae	*Anyperodon leucogrammicus*	0.0007	0.13
Lagoon	Serranidae	*Cephalopholis argus*	0.0127	10.37
Lagoon	Serranidae	*Epinephelus hexagonatus*	0.0007	0.24
Lagoon	Serranidae	*Epinephelus maculatus*	0.0007	0.25
Lagoon	Serranidae	*Epinephelus merra*	0.0247	0.81
Lagoon	Serranidae	*Epinephelus polyphekadion*	0.0067	4.12
Lagoon	Serranidae	*Plectropomus areolatus*	0.0040	3.22
Lagoon	Siganidae	*Siganus argenteus*	0.0100	4.77
Lagoon	Siganidae	*Siganus punctatus*	0.0027	2.16
Lagoon	Siganidae	*Siganus spinus*	0.0013	0.02
Outer reef	Acanthuridae	*Acanthurus achilles*	0.0157	1.17
Outer reef	Acanthuridae	*Acanthurus dussumieri*	0.0003	0.56
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0588	5.69
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.0691	3.54
Outer reef	Acanthuridae	*Acanthurus olivaceus*	0.0007	0.04
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.1440	5.78
Outer reef	Acanthuridae	*Ctenochaetus strigosus*	0.0040	0.15
Outer reef	Acanthuridae	*Naso annulatus*	0.0007	0.42
Outer reef	Acanthuridae	*Naso caesius*	0.0027	0.79
Outer reef	Acanthuridae	*Naso lituratus*	0.0192	10.47
Outer reef	Acanthuridae	*Naso unicornis*	0.0057	7.98
Outer reef	Acanthuridae	*Naso vlamingii*	0.0070	5.92
Outer reef	Balistidae	*Balistapus undulatus*	0.0203	2.22
Outer reef	Balistidae	*Balistoides conspicillum*	0.0003	0.78
Outer reef	Balistidae	*Balistoides viridescens*	0.0003	0.56
Outer reef	Balistidae	*Melichthys niger*	0.0749	1.70
Outer reef	Balistidae	*Melichthys vidua*	0.0432	2.42
Outer reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0017	3.18
Outer reef	Balistidae	*Rhinecanthus rectangulus*	0.0003	0.00
Outer reef	Balistidae	*Sufflamen bursa*	0.0090	1.24
Outer reef	Balistidae	*Sufflamen chrysopterus*	0.0053	0.18
Outer reef	Balistidae	*Xanthichthys auromarginatus*	0.0013	0.20
Outer reef	Caesionidae	*Caesio teres*	0.0138	1.60
Outer reef	Carangidae	*Caranx melampygus*	0.0060	6.29

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Outer reef	Carangidae	*Elagatis bipinnulata*	0.0017	1.70
Outer reef	Carangidae	*Scomberoides* spp.	0.0017	0.77
Outer reef	Carcharhinidae	*Carcharhinus amblyrhynchos*	0.0003	13.07
Outer reef	Carcharhinidae	*Carcharhinus melanopterus*	0.0013	27.28
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0018	0.05
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0020	0.04
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0013	0.05
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0067	0.16
Outer reef	Chaetodontidae	*Chaetodon meyeri*	0.0010	0.03
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0037	0.16
Outer reef	Chaetodontidae	*Chaetodon pelewensis*	0.0043	0.08
Outer reef	Chaetodontidae	*Chaetodon quadrimaculatus*	0.0023	0.05
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0147	0.56
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0107	0.28
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0007	0.01
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0007	0.02
Outer reef	Chaetodontidae	*Forcipiger flavissimus*	0.0027	0.09
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0057	0.17
Outer reef	Cirrhitidae	*Paracirrhites hemistictus*	0.0057	0.10
Outer reef	Cirrhitidae	*Paracirrhites* spp.	0.0007	0.02
Outer reef	Holocentridae	*Myripristis adusta*	0.0003	0.06
Outer reef	Holocentridae	*Myripristis berndti*	0.0003	0.11
Outer reef	Holocentridae	*Myripristis murdjan*	0.0007	0.01
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0003	0.00
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0003	0.02
Outer reef	Labridae	*Cheilinus chlorourus*	0.0007	0.13
Outer reef	Labridae	*Cheilinus fasciatus*	0.0027	0.51
Outer reef	Labridae	*Cheilinus undulatus*	0.0003	4.24
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0007	0.03
Outer reef	Labridae	*Oxycheilinus digrammus*	0.0037	0.14
Outer reef	Lethrinidae	*Lethrinus erythracanthus*	0.0003	0.11
Outer reef	Lethrinidae	*Lethrinus olivaceus*	0.0057	4.97
Outer reef	Lethrinidae	*Lethrinus xanthochilus*	0.0020	1.83
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0167	5.69
Outer reef	Lutjanidae	*Aphareus furca*	0.0047	2.24
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0277	20.06
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0597	37.11
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0075	0.59
Outer reef	Lutjanidae	*Macolor macularis*	0.0143	13.77
Outer reef	Lutjanidae	*Macolor niger*	0.0070	4.13
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0060	0.37
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0020	0.09
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0070	0.34
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0003	0.04
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0067	10.64
Outer reef	Scaridae	*Chlorurus sordidus*	0.0460	14.49
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0063	5.68
Outer reef	Scaridae	*Scarus altipinnis*	0.0027	3.09
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0047	1.66

3.2.2 Weighted average density and biomass of all finfish species recorded in Nukufetau using distance-sampling underwater visual censuses (D-UVC) (continued)

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Outer reef	Scaridae	*Scarus forsteni*	0.0007	0.37
Outer reef	Scaridae	*Scarus globiceps*	0.0003	0.13
Outer reef	Scaridae	*Scarus niger*	0.0316	11.40
Outer reef	Scaridae	*Scarus oviceps*	0.0003	0.05
Outer reef	Scaridae	*Scarus psittacus*	0.0050	1.37
Outer reef	Scaridae	*Scarus rivulatus*	0.0007	0.06
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0030	2.07
Outer reef	Scaridae	*Scarus schlegeli*	0.0040	1.20
Outer reef	Scaridae	*Scarus tricolor*	0.0013	1.14
Outer reef	Serranidae	*Aethaloperca rogaa*	0.0033	0.11
Outer reef	Serranidae	*Cephalopholis argus*	0.0217	7.49
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0177	0.80
Outer reef	Serranidae	*Epinephelus hexagonatus*	0.0007	0.00
Outer reef	Serranidae	*Epinephelus polyphekadion*	0.0007	0.99
Outer reef	Serranidae	*Plectropomus areolatus*	0.0003	1.09
Outer reef	Siganidae	*Siganus argenteus*	0.0013	0.81
Outer reef	Siganidae	*Siganus punctatus*	0.0037	2.39
Outer reef	Siganidae	*Siganus spinus*	0.0097	2.69
Outer reef	Zanclidae	*Zanclus cornutus*	0.0007	0.09

3.3 Vaitupu finfish survey data

3.3.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Vaitupu

Station name	Latitute	Longitude
TRA01	7°28'54.4188" S	178°41'57.3612" E
TRA02	7°28'35.3388" S	178°41'38.94" E
TRA03	7°28'18.5412" S	178°41'17.5812" E
TRA04	7°29'05.82" S	178°40'19.4412" E
TRA05	7°27'28.08" S	178°40'21.36" E
TRA06	7°27'42.4188" S	178°40'35.1588" E
TRA07	7°27'57.78" S	178°40'50.88" E
TRA08	7°28'08.6412" S	178°41'03.3" E
TRA09	7°27'19.8612" S	178°39'44.3412" E
TRA10	7°27'19.08" S	178°40'00.3612" E
TRA11	7°27'56.4588" S	178°39'40.32" E
TRA12	7°28'13.5012" S	178°39'51.3612" E
TRA13	7°30'03.5388" S	178°40'52.5612" E
TRA14	7°29'34.1412" S	178°40'34.2588" E
TRA15	7°28'31.5588" S	178°40'00.4188" E
TRA16	7°28'47.2188" S	178°40'08.8788" E
TRA17	7°29'26.34" S	178°41'52.9188" E
TRA18	7°29'35.2788" S	178°41'47.22" E
TRA19	7°29'43.1988" S	178°41'40.1388" E
TRA20	7°29'58.8588" S	178°41'22.1388" E
TRA21	7°27'35.1" S	178°39'36.9" E
TRA22	7°30'02.8188" S	178°41'01.0212" E
TRA23	7°28'55.6212" S	178°40'15.06" E
TRA24	7°29'21.4188" S	178°40'31.3788" E

Appendix 3: Finfish survey data
Vaitupu

3.3.2 Weighted average density and biomass of all finfish species recorded in Vaitupu using distance-sampling underwater visual censuses (D-UVC)

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus achilles*	0.0043	0.58
Acanthuridae	*Acanthurus blochii*	0.0033	1.31
Acanthuridae	*Acanthurus dussumieri*	0.0005	0.27
Acanthuridae	*Acanthurus guttatus*	0.0089	0.85
Acanthuridae	*Acanthurus lineatus*	0.1220	34.30
Acanthuridae	*Acanthurus nigricans*	0.0789	11.00
Acanthuridae	*Acanthurus nigricauda*	0.0033	1.95
Acanthuridae	*Acanthurus olivaceus*	0.0123	2.37
Acanthuridae	*Acanthurus pyroferus*	0.0028	0.34
Acanthuridae	*Acanthurus* spp.	0.0023	0.51
Acanthuridae	*Acanthurus thompsoni*	0.0033	0.05
Acanthuridae	*Acanthurus triostegus*	0.0239	1.98
Acanthuridae	*Acanthurus xanthopterus*	0.0046	3.65
Acanthuridae	*Ctenochaetus binotatus*	0.0003	0.01
Acanthuridae	*Ctenochaetus striatus*	0.1250	14.03
Acanthuridae	*Ctenochaetus strigosus*	0.0007	0.02
Acanthuridae	*Naso annulatus*	0.0003	0.11
Acanthuridae	*Naso caesius*	0.0003	0.14
Acanthuridae	*Naso lituratus*	0.0561	22.80
Acanthuridae	*Naso unicornis*	0.0022	1.48
Acanthuridae	*Naso vlamingii*	0.0029	2.40
Acanthuridae	*Zebrasoma scopas*	0.0028	0.20
Acanthuridae	*Zebrasoma veliferum*	0.0003	0.03
Balistidae	*Balistapus undulatus*	0.0136	1.96
Balistidae	*Melichthys niger*	0.0366	5.05
Balistidae	*Melichthys vidua*	0.0288	2.68
Balistidae	*Odonus niger*	0.0002	0.02
Balistidae	*Pseudobalistes flavimarginatus*	0.0021	3.10
Balistidae	*Pseudobalistes fuscus*	0.0004	0.36
Balistidae	*Rhinecanthus aculeatus*	0.0001	0.03
Balistidae	*Rhinecanthus rectangulus*	0.0027	0.31
Balistidae	*Sufflamen bursa*	0.0073	0.75
Balistidae	*Sufflamen chrysopterus*	0.0015	0.21
Caesionidae	*Caesio caerulaurea*	0.0009	0.32
Caesionidae	*Caesio teres*	0.0025	0.58
Carangidae	*Carangoides ferdau*	0.0003	0.29
Carangidae	*Carangoides orthogrammus*	0.0003	0.15
Carangidae	*Caranx melampygus*	0.0023	1.23
Carangidae	*Elagatis bipinnulata*	0.0003	0.08
Carcharhinidae	*Triaenodon obesus*	0.0002	2.48
Chaetodontidae	*Chaetodon auriga*	0.0053	0.68
Chaetodontidae	*Chaetodon bennetti*	0.0002	0.00
Chaetodontidae	*Chaetodon citrinellus*	0.0024	0.09
Chaetodontidae	*Chaetodon ephippium*	0.0049	0.49
Chaetodontidae	*Chaetodon flavirostris*	0.0001	0.00
Chaetodontidae	*Chaetodon lunula*	0.0076	0.65
Chaetodontidae	*Chaetodon ornatissimus*	0.0010	0.05
Chaetodontidae	*Chaetodon pelewensis*	0.0010	0.04
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0009	0.06

Appendix 3: Finfish survey data
Vaitupu

3.3.2 Weighted average density and biomass of all finfish species recorded in Vaitupu using distance-sampling underwater visual censuses (D-UVC) (continued)

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Chaetodontidae	*Chaetodon rafflesii*	0.0002	0.02
Chaetodontidae	*Chaetodon reticulatus*	0.0066	0.46
Chaetodontidae	*Chaetodon semeion*	0.0018	0.14
Chaetodontidae	*Chaetodon* spp.	0.0001	0.01
Chaetodontidae	*Chaetodon trifascialis*	0.0008	0.03
Chaetodontidae	*Chaetodon ulietensis*	0.0002	0.00
Chaetodontidae	*Chaetodon vagabundus*	0.0013	0.09
Chaetodontidae	*Forcipiger flavissimus*	0.0005	0.05
Chaetodontidae	*Forcipiger longirostris*	0.0028	0.11
Chaetodontidae	*Heniochus monoceros*	0.0002	0.01
Chaetodontidae	*Heniochus varius*	0.0005	0.04
Holocentridae	*Myripristis berndti*	0.0004	0.10
Holocentridae	*Myripristis vittata*	0.0017	0.25
Holocentridae	*Sargocentron caudimaculatum*	0.0002	0.02
Holocentridae	*Sargocentron diadema*	0.0002	0.01
Holocentridae	*Sargocentron* spp.	0.0001	0.01
Holocentridae	*Sargocentron spiniferum*	0.0003	0.10
Holocentridae	*Sargocentron tiere*	0.0015	0.26
Kyphosidae	*Kyphosus cinerascens*	0.0051	1.57
Kyphosidae	*Kyphosus vaigiensis*	0.0019	1.47
Labridae	*Cheilinus chlorourus*	0.0011	0.16
Labridae	*Cheilinus fasciatus*	0.0013	0.26
Labridae	*Cheilinus trilobatus*	0.0002	0.03
Labridae	*Cheilinus undulatus*	0.0004	0.41
Labridae	*Coris aygula*	0.0002	0.06
Labridae	*Oxycheilinus digrammus*	0.0014	0.13
Lethrinidae	*Gnathodentex aureolineatus*	0.0010	0.47
Lethrinidae	*Lethrinus erythracanthus*	0.0004	0.17
Lethrinidae	*Lethrinus obsoletus*	0.0004	0.28
Lethrinidae	*Lethrinus olivaceus*	0.0041	2.99
Lethrinidae	*Lethrinus* spp.	0.0001	0.03
Lethrinidae	*Lethrinus xanthochilus*	0.0017	1.40
Lethrinidae	*Monotaxis grandoculis*	0.0031	1.41
Lutjanidae	*Aphareus furca*	0.0069	2.32
Lutjanidae	*Lutjanus bohar*	0.0043	1.66
Lutjanidae	*Lutjanus fulvus*	0.0113	2.47
Lutjanidae	*Lutjanus gibbus*	0.0008	0.50
Lutjanidae	*Lutjanus kasmira*	0.0010	0.17
Lutjanidae	*Lutjanus monostigma*	0.0087	2.87
Lutjanidae	*Lutjanus semicinctus*	0.0012	0.56
Lutjanidae	*Lutjanus* spp.	0.0004	0.12
Lutjanidae	*Macolor macularis*	0.0009	0.63
Lutjanidae	*Macolor niger*	0.0008	0.28
Lutjanidae	*Paracaesio* spp.	0.0004	0.06
Mullidae	*Mulloidichthys vanicolensis*	0.0001	0.01
Mullidae	*Parupeneus bifasciatus*	0.0057	0.86
Mullidae	*Parupeneus cyclostomus*	0.0016	0.29
Mullidae	*Parupeneus multifasciatus*	0.0023	0.23
Mullidae	*Parupeneus spilurus*	0.0001	0.03

3.3.2 Weighted average density and biomass of all finfish species recorded in Vaitupu using distance-sampling underwater visual censuses (D-UVC) (continued)

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Pomacanthidae	*Pomacanthus sexstriatus*	0.0002	0.02
Pomacanthidae	*Pygoplites diacanthus*	0.0011	0.08
Scaridae	*Cetoscarus bicolor*	0.0001	0.09
Scaridae	*Chlorurus frontalis*	0.0001	0.05
Scaridae	*Chlorurus japanensis*	0.0013	0.64
Scaridae	*Chlorurus microrhinos*	0.0052	4.76
Scaridae	*Chlorurus sordidus*	0.0108	3.92
Scaridae	*Hipposcarus longiceps*	0.0084	6.20
Scaridae	*Scarus altipinnis*	0.0001	0.09
Scaridae	*Scarus chameleon*	0.0001	0.04
Scaridae	*Scarus flavipectoralis*	0.0028	1.04
Scaridae	*Scarus forsteni*	0.0016	0.59
Scaridae	*Scarus frenatus*	0.0014	0.45
Scaridae	*Scarus ghobban*	0.0003	0.24
Scaridae	*Scarus globiceps*	0.0014	0.46
Scaridae	*Scarus niger*	0.0008	0.59
Scaridae	*Scarus oviceps*	0.0005	0.13
Scaridae	*Scarus psittacus*	0.0026	1.14
Scaridae	*Scarus rubroviolaceus*	0.0075	2.96
Scaridae	*Scarus* spp.	0.0004	0.23
Scaridae	*Scarus spinus*	0.0004	0.11
Scaridae	*Scarus tricolor*	0.0040	2.10
Scaridae	*Scarus xanthopleura*	0.0005	0.38
Serranidae	*Aethaloperca rogaa*	0.0005	0.05
Serranidae	*Cephalopholis argus*	0.0204	6.68
Serranidae	*Cephalopholis urodeta*	0.0115	1.13
Serranidae	*Epinephelus areolatus*	0.0001	0.01
Serranidae	*Epinephelus coioides*	0.0001	0.06
Serranidae	*Epinephelus spilotoceps*	0.0003	0.06
Serranidae	*Gracila albomarginata*	0.0001	0.06
Serranidae	*Variola louti*	0.0002	0.13
Siganidae	*Siganus argenteus*	0.0037	1.52
Siganidae	*Siganus punctatus*	0.0011	0.55
Sphyraenidae	*Sphyraena barracuda*	0.0001	2.23
Sphyraenidae	*Sphyraena qenie*	0.0001	0.26
Zanclidae	*Zanclus cornutus*	0.0083	1.02

3.4 Niutao finfish survey data

3.4.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Niutao

Station name	Latitude	Longitude
TRA01	6°06'03.6612" S	177°20'00.7188" E
TRA02	6°06'06.12" S	177°20'32.7588" E
TRA03	6°06'03.1788" S	177°20'17.5812" E
TRA04	6°06'03.1788" S	177°21'04.0212" E
TRA05	6°06'12.42" S	177°19'46.6788" E
TRA06	6°06'34.9812" S	177°19'52.4388" E
TRA07	6°06'40.7412" S	177°19'57.6012" E
TRA08	6°06'42.5412" S	177°20'00.24" E
TRA09	6°06'58.0788" S	177°20'24.0612" E
TRA10	6°06'54.36" S	177°20'14.7012" E
TRA11	6°06'47.6388" S	177°20'06.6588" E
TRA12	6°06'16.56" S	177°19'46.2612" E
TRA13	6°06'20.9988" S	177°21'16.8588" E
TRA14	6°06'11.2788" S	177°21'15.2388" E
TRA15	6°06'36.8388" S	177°21'18.9612" E
TRA16	6°06'22.7412" S	177°19'44.8212" E
TRA17	6°06'31.3812" S	177°19'50.4588" E
TRA18	6°06'56.2212" S	177°20'31.4412" E
TRA19	6°06'55.98" S	177°20'33.0612" E
TRA20	6°06'55.9188" S	177°20'46.0788" E
TRA21	6°06'54.2412" S	177°20'52.62" E
TRA22	6°06'34.92" S	177°19'52.9212" E
TRA23	6°06'34.92" S	177°19'52.9212" E
TRA24	6°06'46.8612" S	177°20'04.6212" E

3.4.2 Weighted average density and biomass of all finfish species recorded in Niutao using distance-sampling underwater visual censuses (D-UVC)

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus achilles*	0.0001	0.004
Acanthuridae	*Acanthurus albipectoralis*	0.0003	0.127
Acanthuridae	*Acanthurus blochii*	0.0025	0.378
Acanthuridae	*Acanthurus dussumieri*	0.0008	0.563
Acanthuridae	*Acanthurus guttatus*	0.0004	0.043
Acanthuridae	*Acanthurus leucocheilus*	0.0027	0.823
Acanthuridae	*Acanthurus lineatus*	0.1740	41.507
Acanthuridae	*Acanthurus nigricans*	0.0847	10.813
Acanthuridae	*Acanthurus nigricauda*	0.0002	0.075
Acanthuridae	*Acanthurus nigroris*	0.0025	0.246
Acanthuridae	*Acanthurus olivaceus*	0.0179	3.751
Acanthuridae	*Acanthurus pyroferus*	0.0118	1.952
Acanthuridae	*Acanthurus* spp.	0.0006	0.230
Acanthuridae	*Acanthurus thompsoni*	0.0014	0.080
Acanthuridae	*Acanthurus triostegus*	0.0463	3.438
Acanthuridae	*Acanthurus xanthopterus*	0.0082	5.761
Acanthuridae	*Ctenochaetus marginatus*	0.0014	0.287
Acanthuridae	*Ctenochaetus striatus*	0.0899	8.085
Acanthuridae	*Ctenochaetus strigosus*	0.0022	0.090
Acanthuridae	*Ctenochaetus tominiensis*	0.0007	0.040
Acanthuridae	*Naso annulatus*	0.0041	2.086
Acanthuridae	*Naso brachycentron*	0.0024	1.121
Acanthuridae	*Naso brevirostris*	0.0009	1.045
Acanthuridae	*Naso caesius*	0.0047	4.027
Acanthuridae	*Naso hexacanthus*	0.0038	3.136
Acanthuridae	*Naso lituratus*	0.1040	41.334
Acanthuridae	*Naso lopezi*	0.0004	0.368
Acanthuridae	*Naso* spp.	0.0003	0.704
Acanthuridae	*Naso unicornis*	0.0008	0.584
Acanthuridae	*Naso vlamingii*	0.0086	6.351
Acanthuridae	*Paracanthurus hepatus*	0.0004	0.117
Acanthuridae	*Zebrasoma scopas*	0.0149	0.677
Acanthuridae	*Zebrasoma veliferum*	0.0008	0.060
Balistidae	*Balistapus undulatus*	0.0208	2.243
Balistidae	*Balistoides conspicillum*	0.0001	0.125
Balistidae	*Balistoides viridescens*	0.0002	0.239
Balistidae	*Melichthys niger*	0.0531	8.629
Balistidae	*Melichthys vidua*	0.0443	3.998
Balistidae	*Odonus niger*	0.0083	0.346
Balistidae	*Pseudobalistes flavimarginatus*	0.0003	0.321
Balistidae	*Pseudobalistes fuscus*	0.0003	0.217
Balistidae	*Rhinecanthus aculeatus*	0.0003	0.056
Balistidae	*Rhinecanthus rectangulus*	0.0148	1.688
Balistidae	*Sufflamen bursa*	0.0191	1.995
Balistidae	*Sufflamen chrysopterus*	0.0067	0.753
Caesionidae	*Caesio caerulaurea*	0.0017	0.394
Caesionidae	*Caesio teres*	0.0123	5.109
Carangidae	*Carangoides orthogrammus*	0.0003	0.050
Carangidae	*Caranx ignobilis*	0.0001	0.055

3.4.2 Weighted average density and biomass of all finfish species recorded in Niutao using distance-sampling underwater visual censuses (D-UVC) (continued)

Family	Species	Density (fish/m²)	Biomass (g/m²)
Carangidae	*Caranx melampygus*	0.0045	2.766
Carangidae	*Elagatis bipinnulata*	0.0046	3.056
Carangidae	*Scomberoides* spp.	0.0002	0.060
Chaetodontidae	*Chaetodon auriga*	0.0013	0.091
Chaetodontidae	*Chaetodon citrinellus*	0.0062	0.183
Chaetodontidae	*Chaetodon ephippium*	0.0010	0.088
Chaetodontidae	*Chaetodon flavirostris*	0.0002	0.019
Chaetodontidae	*Chaetodon lunula*	0.0082	0.778
Chaetodontidae	*Chaetodon lunulatus*	0.0003	0.010
Chaetodontidae	*Chaetodon ornatissimus*	0.0015	0.096
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0088	0.360
Chaetodontidae	*Chaetodon reticulatus*	0.0069	0.392
Chaetodontidae	*Chaetodon semeion*	0.0018	0.101
Chaetodontidae	*Chaetodon ulietensis*	0.0023	0.057
Chaetodontidae	*Chaetodon unimaculatus*	0.0002	0.004
Chaetodontidae	*Forcipiger flavissimus*	0.0043	0.460
Chaetodontidae	*Forcipiger longirostris*	0.0040	0.146
Chaetodontidae	*Heniochus chrysostomus*	0.0002	0.015
Chaetodontidae	*Heniochus varius*	0.0002	0.014
Chanidae	*Chanos chanos*	0.0001	0.097
Cirrhitidae	*Paracirrhites hemistictus*	0.0048	0.511
Diodontidae	*Diodon hystrix*	0.0002	0.094
Holocentridae	*Myripristis berndti*	0.0032	0.682
Holocentridae	*Myripristis violacea*	0.0003	0.055
Holocentridae	*Myripristis vittata*	0.0013	0.221
Holocentridae	*Sargocentron caudimaculatum*	0.0019	0.225
Holocentridae	*Sargocentron spiniferum*	0.0003	0.105
Holocentridae	*Sargocentron tiere*	0.0035	0.634
Kyphosidae	*Kyphosus cinerascens*	0.0248	8.254
Kyphosidae	*Kyphosus* spp.	0.0001	0.039
Kyphosidae	*Kyphosus vaigiensis*	0.0050	3.076
Labridae	*Cheilinus fasciatus*	0.0002	0.051
Labridae	*Cheilinus undulatus*	0.0003	1.952
Labridae	*Coris aygula*	0.0018	0.450
Labridae	*Hemigymnus fasciatus*	0.0003	0.032
Labridae	*Hemigymnus melapterus*	0.0002	0.069
Labridae	*Oxycheilinus digrammus*	0.0020	0.130
Lethrinidae	*Gnathodentex aureolineatus*	0.0034	1.564
Lethrinidae	*Lethrinus erythracanthus*	0.0001	0.052
Lethrinidae	*Lethrinus olivaceus*	0.0033	3.687
Lethrinidae	*Lethrinus* spp.	0.0001	0.006
Lethrinidae	*Lethrinus xanthochilus*	0.0003	0.278
Lethrinidae	*Monotaxis grandoculis*	0.0169	8.943
Lutjanidae	*Aphareus furca*	0.0074	2.462
Lutjanidae	*Aprion virescens*	0.0001	0.405
Lutjanidae	*Lutjanus bohar*	0.0149	9.108
Lutjanidae	*Lutjanus fulvus*	0.0062	2.020
Lutjanidae	*Lutjanus gibbus*	0.0013	0.913
Lutjanidae	*Lutjanus kasmira*	0.0005	0.112

3.4.2 Weighted average density and biomass of all finfish species recorded in Niutao using distance-sampling underwater visual censuses (D-UVC) (continued)

Family	Species	Density (fish/m²)	Biomass (g/m²)
Lutjanidae	*Lutjanus monostigma*	0.0114	4.218
Lutjanidae	*Macolor macularis*	0.0018	1.478
Lutjanidae	*Macolor niger*	0.0015	1.443
Monacanthidae	*Aluterus scriptus*	0.0001	0.021
Mullidae	*Parupeneus bifasciatus*	0.0041	0.472
Mullidae	*Parupeneus multifasciatus*	0.0039	0.344
Pomacanthidae	*Pygoplites diacanthus*	0.0025	0.271
Scaridae	*Calotomus carolinus*	0.0001	0.055
Scaridae	*Chlorurus japanensis*	0.0018	0.900
Scaridae	*Chlorurus microrhinos*	0.0167	13.794
Scaridae	*Chlorurus sordidus*	0.0029	1.244
Scaridae	*Hipposcarus longiceps*	0.0003	0.250
Scaridae	*Scarus altipinnis*	0.0002	0.111
Scaridae	*Scarus chameleon*	0.0005	0.247
Scaridae	*Scarus flavipectoralis*	0.0041	1.715
Scaridae	*Scarus forsteni*	0.0088	4.331
Scaridae	*Scarus frenatus*	0.0012	0.628
Scaridae	*Scarus ghobban*	0.0002	0.125
Scaridae	*Scarus globiceps*	0.0018	0.315
Scaridae	*Scarus niger*	0.0007	0.339
Scaridae	*Scarus oviceps*	0.0002	0.040
Scaridae	*Scarus psittacus*	0.0009	0.408
Scaridae	*Scarus quoyi*	0.0002	0.032
Scaridae	*Scarus rivulatus*	0.0002	0.101
Scaridae	*Scarus rubroviolaceus*	0.0057	5.053
Scaridae	*Scarus* spp.	0.0002	0.082
Scaridae	*Scarus spinus*	0.0001	0.026
Scaridae	*Scarus tricolor*	0.0090	4.929
Scaridae	*Scarus xanthopleura*	0.0004	0.379
Serranidae	*Aethaloperca rogaa*	0.0003	0.012
Serranidae	*Cephalopholis argus*	0.0076	3.360
Serranidae	*Cephalopholis* spp.	0.0001	0.004
Serranidae	*Cephalopholis urodeta*	0.0234	2.263
Serranidae	*Epinephelus fuscoguttatus*	0.0003	0.063
Serranidae	*Epinephelus hexagonatus*	0.0003	0.047
Serranidae	*Epinephelus spilotoceps*	0.0014	0.129
Serranidae	*Gracila albomarginata*	0.0017	0.669
Serranidae	*Variola albimarginata*	0.0001	0.044
Sphyraenidae	*Sphyraena qenie*	0.0013	0.501
Zanclidae	*Zanclus cornutus*	0.0039	0.423

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Funafuti invertebrate survey data

4.1.1 Invertebrate species recorded in different assessments in Funafuti

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*			+
Bêche-de-mer	*Actinopyga miliaris*	+		+
Bêche-de-mer	*Bohadschia argus*	+		+
Bêche-de-mer	*Bohadschia vitiensis*	+		
Bêche-de-mer	*Holothuria atra*	+		
Bêche-de-mer	*Holothuria fuscogilva*			+
Bêche-de-mer	*Holothuria fuscopunctata*	+		+
Bêche-de-mer	*Holothuria nobilis*	+		
Bêche-de-mer	*Thelenota ananas*	+		+
Bêche-de-mer	*Thelenota anax*	+		+
Bivalve	*Chama* spp.	+		
Bivalve	*Spondylus* spp.	+		+
Bivalve	*Tridacna maxima*	+	+	+
Bivalve	*Tridacna squamosa*	+	+	+
Cnidarians	*Stichodactyla* spp.	+		+
Crustacean	*Lysiosquillina* spp.	+		
Crustacean	*Penaeus* spp.			+
Gastropod	*Cerithium nodulosum*		+	
Gastropod	*Chicoreus ramosus*		+	
Gastropod	*Conus miles*		+	
Gastropod	*Conus* spp.	+	+	
Gastropod	*Coralliophila* spp.		+	
Gastropod	*Cypraea moneta*		+	
Gastropod	*Cypraea* spp.		+	
Gastropod	*Cypraea talpa*		+	
Gastropod	*Lambis chiragra*	+		
Gastropod	*Lambis truncata*	+	+	+
Gastropod	*Strombus luhuanus*	+	+	+
Gastropod	*Tectus pyramis*	+	+	+
Gastropod	*Tectus* spp.		+	
Gastropod	*Thais* spp.		+	
Gastropod	*Trochus maculata*			+
Gastropod	*Trochus niloticus*	+		+
Gastropod	*Trochus* spp.		+	
Gastropod	*Turbo argyrostomus*		+	+
Gastropod	*Turbo setosus*			+
Gastropod	*Turbo* spp.			+
Star	*Culcita novaeguineae*	+		+
Urchin	*Echinometra mathaei*	+	+	+
Urchin	*Echinothrix diadema*	+	+	+

+ = presence of the species.

4.1.2 Funafuti 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 miliaris	1.00	0.44	83	16.67	0.00	5	0.99	0.47	14	3.47	0.69	4
Bohadschia argus	4.00	1.20	83	25.57	4.07	13	3.66	2.08	14	10.25	4.73	5
Bohadschia vitiensis	0.40	0.40	83	33.33		1	0.40	0.40	14	5.56		1
Chama spp.	3.21	2.82	83	88.89	72.22	3	3.17	2.97	14	22.22	19.44	2
Conus spp.	0.40	0.28	83	16.67	0.00	2	0.79	0.79	14	11.11		1
Culcita novaeguineae	1.80	0.57	83	16.61	0.04	9	1.78	0.69	14	4.15	0.95	6
Echinometra mathaei	14.03	6.50	83	232.89	40.56	5	19.81	13.78	14	138.70	27.96	2
Echinothrix diadema	0.40	0.28	83	16.67	0.00	2	0.60	0.43	14	4.17	1.39	2
Holothuria atra	10.64	6.80	83	147.19	80.45	6	10.41	10.10	14	72.90	68.76	2
Holothuria fuscopunctata	2.00	0.77	83	23.75	3.34	7	1.78	0.85	14	6.24	1.32	4
Holothuria nobilis	1.20	0.68	83	24.90	8.31	4	1.19	0.99	14	8.30	5.52	2
Lambis truncata	3.81	1.04	83	22.59	2.83	14	3.67	1.21	14	5.70	1.51	9
Lysiosquillina spp.	0.80	0.80	83	66.67		1	0.79	0.79	14	11.11		1
Spondylus spp.	4.02	2.11	83	47.62	19.39	7	3.97	3.34	14	13.89	11.11	4
Stichodactyla spp.	0.20	0.20	83	16.67		1	0.20	0.20	14	2.78		1
Strombus luhuanus	15.86	7.72	83	219.44	67.69	6	15.67	11.27	14	73.15	41.83	3
Tectus pyramis	3.41	0.94	83	21.78	2.22	13	3.57	1.14	14	5.55	1.39	9
Thelenota ananas	3.41	1.17	83	25.70	5.18	11	3.37	1.24	14	6.73	1.69	7
Thelenota anax	7.03	2.22	83	44.87	8.52	13	6.30	2.61	14	17.64	3.48	5
Tridacna maxima	22.67	5.54	83	69.70	13.08	27	23.20	10.17	14	40.59	15.33	8
Tridacna squamosa	1.00	0.44	83	16.62	0.03	5	0.99	0.47	14	3.46	0.69	4
Trochus niloticus	0.20	0.20	83	16.23		1	0.19	0.19	14	2.71		1

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.

4.1.3 Funafuti reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Cerithium nodulosum	6.94	5.16	108	375.00	125.00	2	6.94	5.05	18	62.50	20.83	2
Conus miles	2.31	2.31	108	250.00		1	2.31	2.31	18	41.67		1
Conus spp.	18.52	9.13	108	400.00	100.00	5	18.52	10.23	18	83.33	29.46	4
Coralliophila spp.	254.63	127.12	108	6875.00	625.00	4	254.63	187.22	18	2291.67	833.33	2
Cypraea moneta	2.31	2.31	108	250.00		1	2.31	2.31	18	41.67		1
Cypraea spp.	2.31	2.31	108	250.00		1	2.31	2.31	18	41.67		1
Cypraea talpa	4.63	3.26	108	250.00	0.00	2	4.63	3.18	18	41.67	0.00	2
Echinometra mathaei	370.37	79.10	108	1600.00	196.32	25	370.37	156.88	18	1111.11	293.97	6
Echinothrix diadema	11.57	6.05	108	312.50	62.50	4	11.57	5.64	18	52.08	10.42	4
Lambis truncata	20.83	6.68	108	250.00	0.00	9	20.83	6.07	18	46.88	5.21	8
Strombus luhuanus	39.35	26.75	108	1062.50	571.68	4	39.35	27.26	18	236.11	121.08	3
Tectus pyramis	57.87	12.57	108	312.50	24.83	20	57.87	16.89	18	94.70	21.09	11
Tectus spp.	2.31	2.31	108	250.00		1	2.31	2.31	18	41.67		1
Thais spp.	2.31	2.31	108	250.00		1	2.31	2.31	18	41.67		1
Tridacna maxima	118.06	22.89	108	411.29	49.93	31	118.06	33.56	18	163.46	39.88	13
Tridacna squamosa	25.46	9.27	108	305.56	55.56	9	25.46	10.73	18	76.39	19.89	6
Trochus spp.	6.94	3.97	108	250.00	0.00	3	6.94	3.77	18	41.67	0.00	3
Turbo argyrostomus	4.63	3.26	108	250.00	0.00	2	4.63	3.18	18	41.67	0.00	2

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.

4.1.4 Funafuti 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	2.61	1.34	54	35.29	6.79	4	2.61	1.46	9	7.84	2.26	3
Echinometra mathaei	5661.00	1271.25	54	16,983.01	1950.46	18	5661.00	3000.75	9	16,983.01	3451.58	3
Lambis truncata	0.87	0.61	54	23.53	0.00	2	0.87	0.58	9	3.92		1
Tectus pyramis	3.05	1.09	54	23.53	0.00	7	3.05	1.09	9	5.88	1.13	4
Tridacna maxima	3.49	1.45	54	31.37	4.96	6	3.49	1.66	9	7.84	3.92	2
Tridacna squamosa	0.87	0.61	54	23.53	0.00	2	0.87	0.58	9	3.92		1
Trochus niloticus	0.44	0.44	54	23.53		1	0.44	0.44	9	3.92		1
Turbo argyrostomus	0.44	0.44	54	23.53		1	0.44	0.44	9	3.92		1
Turbo setosus	0.44	0.44	54	23.53		1	0.44	0.44	9	3.92		1

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.

4.1.5 Funafuti mother-of-pearl search (MOPs) 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	16.67	7.70	30	83.33	24.66	6	16.67	9.40	5	20.83	10.88	4
Echinothrix diadema	1.52	1.52	30	45.45		1	1.52	1.52	5	7.58		1
Lambis truncata	1.52	1.52	30	45.45		1	1.52	1.52	5	7.58		1
Turbo argyrostomus	1.52	1.52	30	45.45		1	1.52	1.52	5	7.58		1
Turbo spp.	1.52	1.52	30	45.45		1	1.52	1.52	5	7.58		1

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.

4.1.6 Funafuti sea cucumber night search (Ns) 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 miliaris	4.44	4.44	12	53.33		1	4.44	4.44	2	8.89		1
Bohadschia argus	26.67	12.28	12	80.00	15.40	4	26.67	17.78	2	26.67	17.78	2
Holothuria fuscopunctata	35.56	13.67	12	85.33	13.06	5	35.56	26.67	2	35.56	26.67	2
Thelenota anax	4.44	4.44	12	53.33		1	4.44	4.44	2	8.89		1

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.

4.1.7 Funafuti sea cucumber day search (Ds) 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 miliaris	0.48	0.48	30	14.29		1	0.48	0.48	5	2.38		1
Culcita novaeguineae	3.81	1.80	30	22.86	5.71	5	3.81	1.93	5	6.35	2.10	3
Holothuria fuscogilva	23.81	6.62	30	59.52	9.76	12	23.81	15.95	5	39.68	23.10	3
Holothuria fuscopunctata	0.48	0.48	30	14.29		1	0.48	0.48	5	2.38		1
Lambis truncata	1.43	0.80	30	14.29	0.00	3	1.43	0.58	5	2.38	0.00	3
Spondylus spp.	6.19	4.83	30	61.90	40.69	3	6.19	6.19	5	30.95		1
Stichodactyla spp.	0.48	0.48	30	14.29		1	0.48	0.48	5	2.38		1
Tectus pyramis	0.48	0.48	30	14.29		1	0.48	0.48	5	2.38		1
Thelenota ananas	5.71	2.01	30	21.43	3.82	8	5.71	2.21	5	7.14	2.17	4
Thelenota anax	8.57	2.33	30	23.38	2.90	11	8.57	2.21	5	8.57	2.21	5
Tridacna maxima	2.38	0.99	30	14.29	0.00	5	2.38	1.06	5	3.97	0.79	3
Tridacna squamosa	0.95	0.66	30	14.29	0.00	2	0.95	0.58	5	2.38	0.00	2

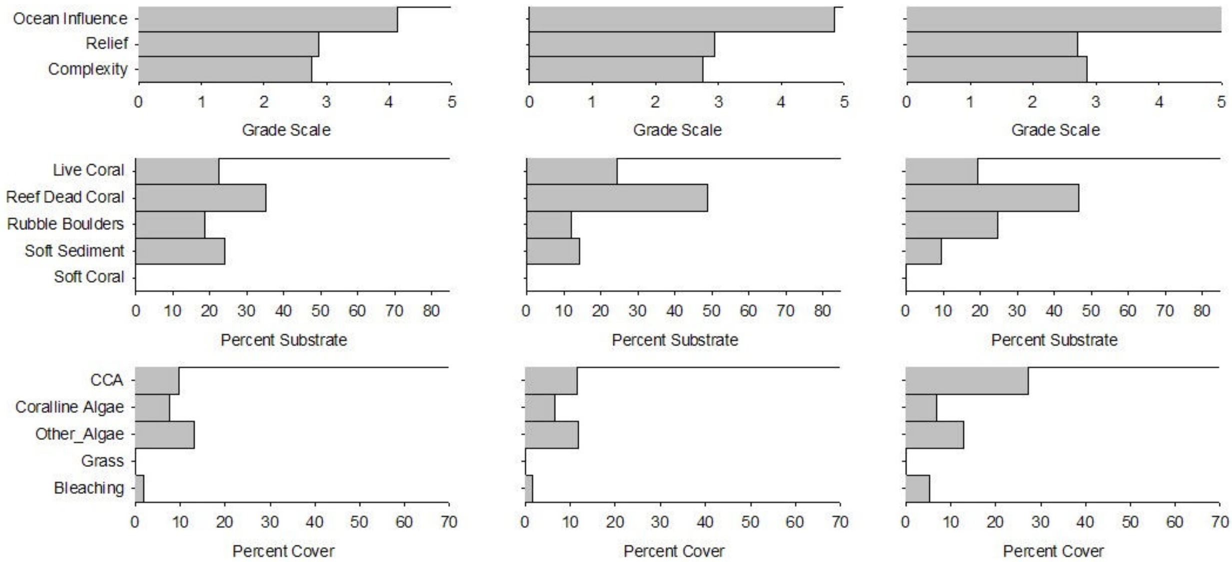
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.1.8 Funafuti species size review – all survey methods

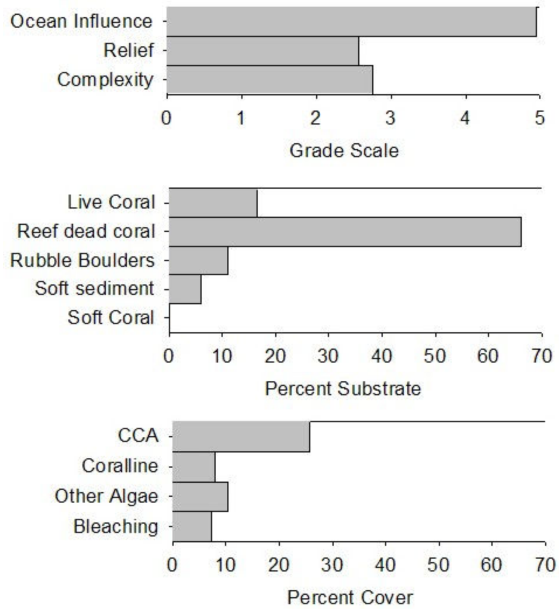
Species	Mean length (cm)	SE	n
Tridacna maxima	10.9	0.3	180
Strombus luhuanus	4.2	0.0	107
Thelenota anax	48.1	0.9	54
Holothuria atra	38.0	0.0	53
Holothuria fuscogilva	36.4	0.6	50
Tectus pyramis	6.1	0.1	50
Lambis truncata	24.3	0.9	35
Thelenota ananas	45.4	1.4	29
Bohadschia argus	34.9	1.4	26
Tridacna squamosa	19.1	2.1	20
Holothuria fuscopunctata	36.2	1.0	19
Actinopyga mauritiana	18.9	0.4	17
Conus spp.	5.5	1.1	10
Actinopyga miliaris	32.2	2.2	7
Holothuria nobilis	31.7	1.5	6
Turbo argyrostomus	6.7	0.1	4
Cerithium nodulosum	8.7	0.4	3
Trochus spp.	4.0		3
Lambis chiragra	1.8		3
Bohadschia vitiensis	25.0		2
Trochus niloticus	12.1	0.1	2
Trochus maculata	6.5	0.5	2
Cypraea talpa	4.8	0.8	2
Turbo spp.	35.0		1
Thais spp.	6.5		1
Chicoreus ramosus	6.2		1
Tectus spp.	6.0		1
Cypraea spp.	4.0		1
Conus miles	2.5		1

4.1.9 Habitat descriptors for independent assessments – Funafuti

Broad-scale inner, middle and outer assessments of habitat



Reef-benthos assessment of habitat



4.2 Nukufetau invertebrate survey data

4.2.1 Invertebrate species recorded in different assessments in Nukufetau

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*			+
Bêche-de-mer	*Bohadschia argus*	+	+	+
Bêche-de-mer	*Bohadschia vitiensis*	+		
Bêche-de-mer	*Holothuria atra*		+	+
Bêche-de-mer	*Holothuria fuscogilva*	+		+
Bêche-de-mer	*Holothuria fuscopunctata*	+		+
Bêche-de-mer	*Holothuria nobilis*	+		+
Bêche-de-mer	*Thelenota ananas*	+		+
Bêche-de-mer	*Thelenota anax*			+
Bivalve	*Chama* spp.	+		
Bivalve	*Pinctada margaritifera*			+
Bivalve	*Spondylus* spp.	+	+	+
Bivalve	*Tridacna maxima*	+	+	+
Bivalve	*Tridacna squamosa*	+		+
Crustacean	*Panulirus* spp.			+
Gastropod	*Chicoreus ramosus*		+	
Gastropod	*Conus miles*		+	
Gastropod	*Conus* spp.		+	
Gastropod	*Cypraea moneta*		+	
Gastropod	*Cypraea tigris*	+	+	
Gastropod	*Lambis chiragra*	+	+	
Gastropod	*Lambis truncata*	+	+	+
Gastropod	*Strombus luhuanus*	+	+	
Gastropod	*Tectus pyramis*	+	+	+
Gastropod	*Turbo* spp.	+		
Gastropod	*Tutufa* spp.		+	
Octopus	*Octopus cyanea*	+	+	
Star	*Culcita novaeguineae*	+	+	+
Star	*Linckia laevigata*	+		
Urchin	*Echinometra mathaei*	+	+	+
Urchin	*Echinothrix diadema*		+	+

+ = presence of the species.

4.2.2 Nukufetau 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
Bohadschia argus	5.09	1.73	72	28.21	6.64	13	5.09	2.90	12	8.73	4.59	7
Bohadschia vitiensis	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Chama spp.	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Culcita novaeguineae	1.64	0.68	72	19.64	2.74	6	1.64	0.80	12	4.91	1.30	4
Cypraea tigris	0.46	0.33	72	16.67	0.00	2	0.46	0.31	12	2.78	0.00	2
Echinometra mathaei	3.01	1.69	72	54.17	17.18	4	3.01	3.01	12	36.11		1
Holothuria fuscogilva	0.46	0.46	72	33.33		1	0.46	0.46	12	5.56		1
Holothuria fuscopunctata	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Holothuria nobilis	1.16	0.76	72	27.78	11.11	3	1.16	0.72	12	4.63	1.85	3
Lambis truncata	3.49	1.28	72	25.12	5.67	10	3.49	1.19	12	5.98	1.40	7
Linckia laevigata	0.46	0.46	72	33.33		1	0.46	0.46	12	5.56		1
Octopus cyanea	0.69	0.40	72	16.67	0.00	3	0.69	0.36	12	2.78	0.00	3
Spondylus spp.	5.09	1.64	72	28.21	5.78	13	5.09	1.80	12	7.64	2.21	8
Strombus luhuanus	38.43	23.38	72	153.70	89.96	18	38.43	25.52	12	57.64	37.11	8
Tectus pyramis	2.33	0.69	72	16.79	0.12	10	2.33	0.83	12	4.66	0.93	6
Thelenota ananas	0.93	0.73	72	33.33	16.67	2	0.93	0.93	12	11.11		1
Tridacna maxima	17.43	2.81	72	35.85	3.80	35	17.43	3.89	12	17.43	3.89	12
Tridacna squamosa	1.16	0.50	72	16.67	0.00	5	1.16	0.41	12	2.78	0.00	5
Turbo spp.	0.48	0.34	72	17.26	0.60	2	0.48	0.32	12	2.88	0.10	2

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.

4.2.3 Nukufetau reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	3.21	3.21	78	250.00		1	3.21	3.21	13	41.67		1
Conus miles	9.62	5.48	78	250.00	0.00	3	9.62	6.92	13	62.50	20.83	2
Conus spp.	38.46	11.25	78	272.73	22.73	11	38.46	11.03	13	62.50	11.14	8
Culcita novaeguineae	22.44	8.14	78	250.00	0.00	7	22.44	6.00	13	41.67	0.00	7
Cypraea moneta	32.05	17.88	78	500.00	193.65	5	32.05	16.45	13	83.33	32.27	5
Cypraea tigris	3.21	3.21	78	250.00		1	3.21	3.21	13	41.67		1
Echinometra mathaei	60.90	18.91	78	431.82	59.27	11	60.90	22.93	13	158.33	15.59	5
Echinothrix diadema	9.62	7.13	78	375.00	125.00	2	9.62	9.62	13	125.00		1
Holothuria atra	67.31	52.15	78	1312.50	903.55	4	67.31	67.31	13	875.00		1
Lambis truncata	6.41	4.50	78	250.00	0.00	2	6.41	6.41	13	83.33		1
Octopus cyanea	3.21	3.21	78	250.00		1	3.21	3.21	13	41.67		1
Spondylus spp.	12.82	6.28	78	250.00	0.00	4	12.82	7.29	13	55.56	13.89	3
Strombus luhuanus	201.92	120.71	78	2625.00	1282.49	6	201.92	137.62	13	656.25	383.16	4
Tectus pyramis	57.69	14.37	78	300.00	26.73	15	57.69	13.79	13	93.75	6.82	8
Tridacna maxima	160.26	27.36	78	390.63	40.38	32	160.26	42.42	13	189.39	44.72	11
Tutufa spp.	3.21	3.21	78	250.00		1	3.21	3.21	13	41.67		1

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.

4.2.4 Nukufetau 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	1.31	1.31	18	23.53		1	1.31	1.31	3	3.9		1
Echinometra mathaei	2359.48	6.54	18	2359.48	6.54	18	2359.48	6.54	3	2359.48	6.54	3
Echinothrix diadema	6.54	6.54	18	117.65		1	6.54	6.54	3	19.61		1

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.

4.2.5 Nukufetau 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
Holothuria atra	122.2	64.9	18	366.7	158.3	6	122.2	122.2	3	366.7		1

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.

4.2.6 Nukufetau sea cucumber night search (Ns) 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
Bohadschia argus	13.33	9.57	12	80	26.67	2	13.33	13.33	2	26.67		1
Culcita novaeguineae	17.78	10.03	12	71.11	17.78	3	17.78	17.78	2	35.56		1
Holothuria fuscogilva	8.89	5.99	12	53.33	0	2	8.89	8.89	2	17.78		1

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.

4.2.7 Nukufetau sea cucumber day search (Ds) 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
Bohadschia argus	1.49	0.77	48	17.86	3.57	4	1.49	0.89	8	3.97	1.59	3
Culcita novaeguineae	4.02	1.66	48	24.11	6.46	8	4.02	1.78	8	6.43	2.25	5
Echinometra mathaei	0.60	0.60	48	28.57		1	0.60	0.60	8	4.76		1
Holothuria fuscogilva	55.33	15.42	48	139.79	30.20	19	55.33	30.06	8	73.78	37.62	6
Holothuria fuscopunctata	0.60	0.42	48	14.29	0.00	2	0.60	0.39	8	2.38	0.00	2
Holothuria nobilis	0.30	0.30	48	14.29		1	0.30	0.30	8	2.38		1
Lambis truncata	0.89	0.50	48	14.29	0.00	3	0.89	0.44	8	2.38	0.00	3
Panulirus spp.	0.30	0.30	48	14.29		1	0.30	0.30	8	2.38		1
Pinctada margaritifera	0.60	0.60	48	28.57		1	0.60	0.60	8	4.76		1
Spondylus spp.	8.63	4.01	48	59.18	19.07	7	8.63	5.65	8	34.52	1.19	2
Tectus pyramis	0.30	0.30	48	14.29		1	0.30	0.30	8	2.38		1
Thelenota ananas	3.72	1.53	48	25.51	5.80	7	3.72	1.41	8	5.95	1.51	5
Thelenota anax	13.24	5.02	48	42.38	13.53	15	13.24	6.06	8	17.66	7.28	6
Tridacna maxima	5.06	2.35	48	30.36	10.61	8	5.06	2.27	8	10.12	2.64	4
Tridacna squamosa	2.98	1.34	48	23.81	6.02	6	2.98	2.05	8	7.94	4.42	3

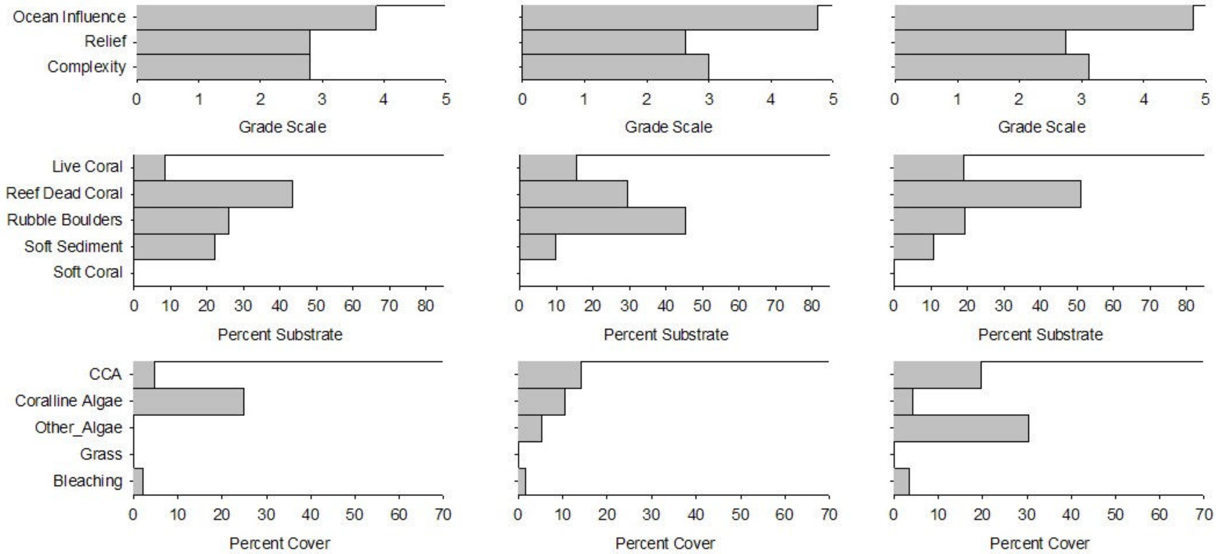
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.2.8 Nukufetau species size review – all survey methods

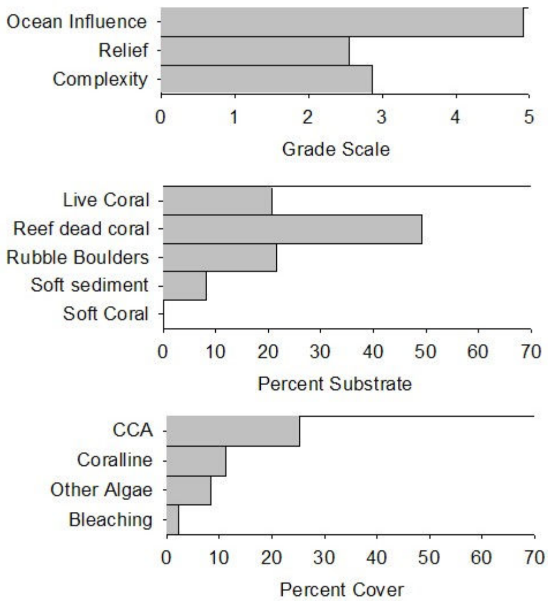
Species	Mean length (cm)	SE	n
Strombus luhuanus	3.8	0.1	229
Holothuria atra	15.7	0.3	175
Holothuria fuscogilva	34.6	0.6	148
Tridacna maxima	9.9	0.4	137
Thelenota anax	54.2	0.7	43
Bohadschia argus	38.9	0.4	31
Tectus pyramis	6.1	0.2	29
Lambis truncata	26.8	0.9	20
Tridacna squamosa	32.4	3.1	15
Thelenota ananas	53.2	2.6	14
Lambis chiragra	13.1	0.4	13
Conus spp.	4.0	0.5	12
Cypraea moneta	2.0	0.0	10
Holothuria nobilis	30.8	2.0	6
Holothuria fuscopunctata	44.3	5.4	3
Cypraea tigris	8.2	0.0	3
Conus miles	3.4	0.4	3
Pinctada margaritifera	16.0		2
Bohadschia vitiensis	38.0		1
Tutufa spp.	6.7		1
Chicoreus ramosus	5.5		1
Echinometra mathaei			1839
Spondylus spp.			55
Culcita novaeguineae			29
Echinothrix diadema			8
Octopus cyanea			4
Linckia laevigata			2
Turbo spp.			2
Actinopyga mauritiana			1
Chama spp.			1
Panulirus spp.			1

4.2.9 Habitat descriptors for independent assessments – Nukufetau

Broad-scale inner, middle and outer assessments of habitat



Reef-benthos assessment of habitat



4.3 Vaitupu invertebrate survey data

4.3.1 Invertebrate species recorded in different assessments in Vaitupu

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+	+
Bêche-de-mer	*Holothuria atra*			+
Bêche-de-mer	*Holothuria nobilis*	+		
Bêche-de-mer	*Thelenota ananas*			+
Bivalve	*Spondylus* spp.			+
Bivalve	*Tridacna maxima*	+		
Crustacean	*Eriphia sebana*		+	
Crustacean	*Panulirus* spp.		+	+
Gastropod	*Conus* spp.	+	+	
Gastropod	*Cymatium* spp.		+	
Gastropod	*Cypraea caputserpensis*		+	
Gastropod	*Cypraea moneta*		+	
Gastropod	*Cypraea talpa*		+	
Gastropod	*Cypraea tigris*		+	
Gastropod	*Lambis truncata*	+		+
Gastropod	*Tectus pyramis*	+	+	
Gastropod	*Tectus* spp.	+		
Gastropod	*Thais* spp.		+	
Gastropod	*Trochus* spp.		+	+
Gastropod	*Turbo argyrostomus*	+	+	
Gastropod	*Turbo setosus*		+	
Gastropod	*Vasum ceramicum*		+	
Octopus	*Octopus cyanea*		+	
Star	*Culcita novaeguineae*	+		+
Urchin	*Echinometra mathaei*	+	+	
Urchin	*Echinometra* spp.	+		
Urchin	*Echinothrix diadema*		+	
Urchin	*Heterocentrotus mammillatus*		+	

+ = presence of the species.

4.3.2 Vaitupu 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	32.18	7.71	72	77.22	15.15	30	32.18	13.10	12	48.26	17.14	8
Conus spp.	0.46	0.33	72	16.67	0.00	2	0.46	0.31	12	2.78	0.00	2
Culcita novaeguineae	1.16	0.69	72	27.78	5.56	3	1.16	0.93	12	6.94	4.17	2
Echinometra mathaei	349.54	257.31	72	8388.89	4763.22	3	349.54	349.54	12	4194.44		1
Echinometra spp.	798.61	398.14	72	9583.33	3189.61	6	798.61	798.61	12	9583.33		1
Holothuria nobilis	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Lambis truncata	0.46	0.33	72	16.67	0.00	2	0.46	0.31	12	2.78	0.00	2
Panulirus spp.	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Tectus pyramis	0.23	0.23	72	16.67		1	0.23	0.23	12	2.78		1
Tectus spp.	0.46	0.33	72	16.67	0.00	2	0.46	0.46	12	5.56		1
All *Tectus*	0.69	0.40	72	16.67	0.00	3	0.69	0.50	12	4.17	1.39	2
Tridacna maxima	8.56	2.87	72	44.05	10.57	14	8.56	5.49	12	17.13	10.15	6
Turbo argyrostomus	0.46	0.33	72	16.67	0.00	2	0.46	0.46	12	5.56		1

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.

4.3.3 Vaitupu reef-benthos transect (RBt) 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	31.25	13.93	72	375.00	85.39	6	31.25	14.62	12	75.00	24.30	5
Conus spp.	34.72	13.37	72	312.50	62.50	8	34.72	12.39	12	69.44	13.89	6
Cymatium spp.	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67	-	1
Cypraea caputserpensis	76.39	21.91	72	423.08	59.27	13	76.39	28.48	12	130.95	36.85	7
Cypraea moneta	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Cypraea talpa	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Cypraea tigris	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Echinometra mathaei	10,489.58	1885.32	72	11,619.23	2040.28	65	10,489.58	2796.31	12	10,489.58	2796.31	12
Echinothrix diadema	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Heterocentrotus mammillatus	6.94	4.88	72	250.00	0.00	2	6.94	4.68	12	41.67	0.00	2
Octopus cyanea	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Panulirus spp.	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Tectus pyramis	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Thais spp.	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Trochus spp.	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Turbo argyrostomus	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1
Turbo setosus	13.89	8.40	72	333.33	83.33	3	13.89	7.83	12	55.56	13.89	3
Vasum ceramicum	3.47	3.47	72	250.00		1	3.47	3.47	12	41.67		1

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.

4.3.4 Vaitupu 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	241.18	43.31	24	304.64	44.20	19	241.18	96.99	4	241.18	96.99	4
Lambis truncata	0.98	0.98	24	23.53		1	0.98	0.98	4	3.92		1

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.

4.3.5 Vaitupu 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	4.8	4.8	6	28.6		1	1.2	1.2	1	4.8		1
Holothuria atra	623.8	281.1	6	935.7	316.6	4	156.0	156.0	1	623.8		1

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.

4.3.6 Vaitupu sea cucumber night search (Ns) 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	4.44	4.44	12	53.33		1	4.44	4.44	2	8.89		1
Panulirus spp.	8.89	5.99	12	53.33	0.00	2	8.89	8.89	2	17.78		1

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.

4.3.7 Vaitupu sea cucumber day search (Ds) 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
Culcita novaeguineae	2.98	1.21	24	14.29	0.00	5	2.98	1.79	4	5.95	1.19	2
Lambis truncata	2.98	2.10	24	35.71	7.14	2	2.98	2.98	4	11.90		1
Panulirus spp.	0.60	0.60	24	14.29		1	0.60	0.60	4	2.38		1
Spondylus spp.	1.79	0.99	24	14.29	0.00	3	1.79	1.14	4	3.57	1.19	2
Thelenota ananas	4.17	2.50	24	25.00	10.71	4	4.17	3.42	4	8.33	5.95	2
Trochus spp.	0.60	0.60	24	14.29		1	0.60	0.60	4	2.38		1

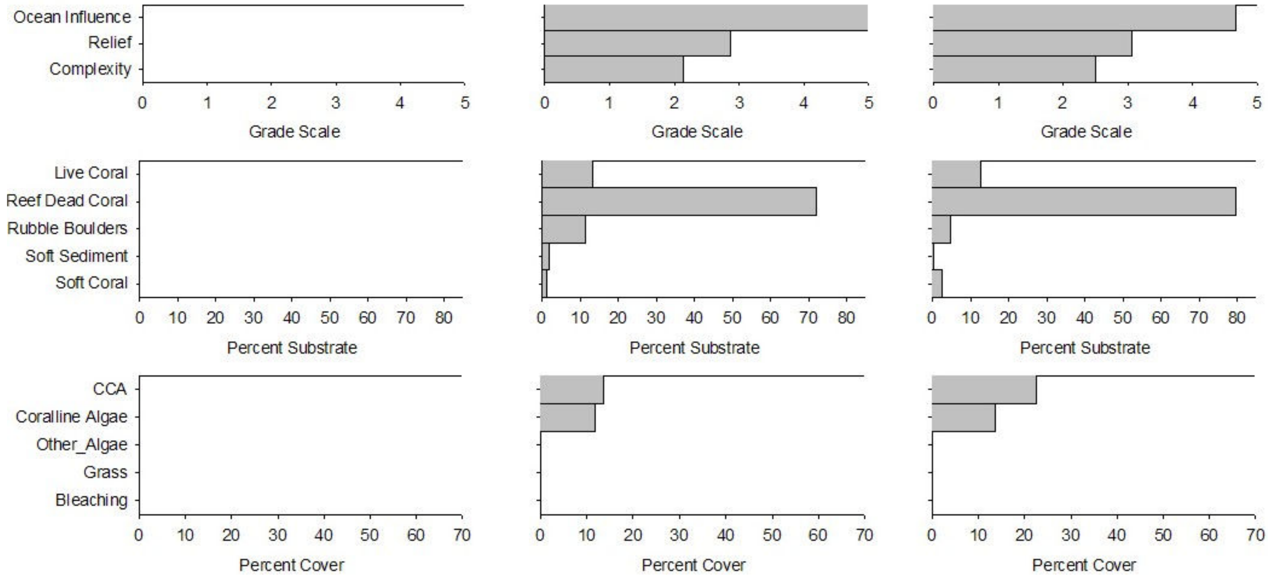
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.8 Vaitupu species size review – all survey methods

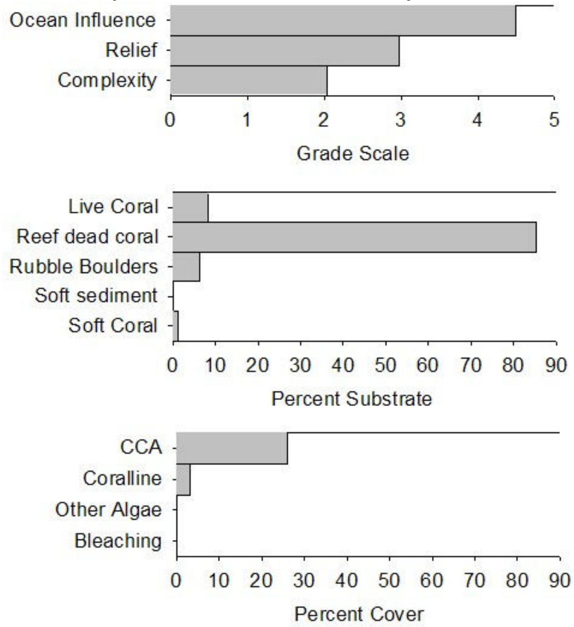
Species	Mean length (cm)	SE	n
Actinopyga mauritiana	21.4	0.2	397
Tridacna maxima	11.2	0.5	37
Cypraea caputserpensis	3.6	0.0	22
Conus spp.	6.1	0.4	12
Lambis truncata	22.9	0.5	8
Thelenota ananas	52.4	4.5	7
Turbo setosus	5.0	0.7	4
Panulirus spp.	15.0		4
Turbo argyrostomus	6.8		3
Trochus spp.	4.3	1.4	2
Tectus pyramis	7.0		2
Cymatium spp.	4.5		1
Eriphia sebana	4.5		1
Thais spp.	4.9		1
Cypraea talpa	5.0		1
Cypraea tigris	7.0		1
Vasum ceramicum	8.0		1
Holothuria nobilis	32.0		1
Echinometra mathaei			4531
Echinometra spp.			3450
Holothuria atra			262
Culcita novaeguineae			10
Spondylus spp.			3
Stichopus chloronotus			3
Heterocentrotus mammillatus			2
Tectus spp.			2
Cypraea moneta			1
Echinothrix diadema			1
Octopus cyanea			1

4.3.9 Habitat descriptors for independent assessments – Vaitupu

Broad-scale inner (absent), middle and outer assessments of habitat



Reef-benthos assessment of habitat



4.4 Niutao invertebrate survey data

4.4.1 Invertebrate species recorded in different assessments in Niutao

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+		+
Bêche-de-mer	*Holothuria atra*		+	+
Bêche-de-mer	*Holothuria fuscopunctata*	+	+	
Bêche-de-mer	*Thelenota ananas*			+
Bivalve	*Chama* spp.	+	+	
Bivalve	*Spondylus* spp.			+
Bivalve	*Tridacna maxima*	+	+	
Gastropod	*Astralium* spp.		+	
Gastropod	*Charonia tritonis*			+
Gastropod	*Conus* spp.		+	
Gastropod	*Cypraea caputserpensis*		+	+
Gastropod	*Drupa morum*		+	
Gastropod	*Drupa* spp.		+	
Gastropod	*Lambis truncata*	+		+
Gastropod	*Tectus pyramis*		+	
Gastropod	*Thais armigera*		+	
Gastropod	*Thais* spp.		+	
Gastropod	*Trochus* spp.			+
Gastropod	*Turbo argyrostomus*		+	
Gastropod	*Vasum ceramicum*		+	
Octopus	*Octopus cyanea*	+	+	+
Star	*Fromia* spp.		+	
Urchin	*Echinometra mathaei*		+	+
Urchin	*Echinothrix diadema*		+	+

+ = presence of the species.

4.4.2 Niutao 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	0.69	0.69	24	16.67		1	0.69	0.69	4	2.78		1
Chama spp.	0.69	0.69	24	16.67		1	0.69	0.69	4	2.78		1
Holothuria fuscopunctata	0.69	0.69	24	16.67		1	0.69	0.69	4	2.78		1
Lambis truncata	2.07	1.14	24	16.59	0.07	3	2.07	0.69	4	2.77	0.01	3
Octopus cyanea	0.69	0.69	24	16.67		1	0.69	0.69	4	2.78		1
Tridacna maxima	0.69	0.69	24	16.67		1	0.69	0.69	4	2.78		1

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.

4.4.3 Niutao reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Astralium spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Chama spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus spp.	107.6	31.6	72	484.4	95.4	16	107.6	35.0	12	161.5	40.5	8
Cypraea caputserpensis	149.3	35.5	72	537.5	77.5	20	149.3	57.2	12	224.0	73.0	8
Drupa morum	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Drupa spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Echinometra mathaei	52.1	18.5	72	468.8	56.6	8	52.1	26.2	12	156.3	46.2	4
Echinothrix diadema	27.8	12.7	72	333.3	83.3	6	27.8	17.3	12	83.3	41.7	4
Fromia spp.	295.1	68.8	72	923.9	146.1	23	295.1	152.9	12	590.3	260.7	6
Holothuria atra	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Holothuria fuscopunctata	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Octopus cyanea	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Tectus pyramis	10.4	5.9	72	250.0	0.0	3	10.4	5.4	12	41.7	0.0	3
Thais armigera	24.3	13.2	72	437.5	119.7	4	24.3	20.8	12	145.8	104.2	2
Thais spp.	24.3	13.2	72	437.5	119.7	4	24.3	16.6	12	145.8	20.8	2
Tridacna maxima	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Turbo argyrostomus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Vasum ceramicum	20.8	9.6	72	300.0	50.0	5	20.8	10.9	12	62.5	20.8	4

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.

4.4.4 Niutao 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
Cypraea caputserpensis	28.43	13.66	24	113.73	38.62	6	28.43	28.43	4	113.73		1
Echinometra mathaei	5.88	2.55	24	28.24	4.71	5	5.88	1.13	4	5.88	1.13	4
Echinothrix diadema	7.84	2.71	24	26.89	3.36	7	7.84	2.77	4	7.84	2.77	4
Octopus cyanea	0.98	0.98	24	23.53		1	0.98	0.98	4	3.92		1

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 present.

4.4.5 Niutao 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	39.29	10.36	24	85.71	11.87	11	39.29	22.87	4	78.57	7.14	2
Holothuria atra	71.43	41.76	24	428.57	170.93	4	71.43	71.43	4	285.71		1

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.

4.4.6 Niutao sea cucumber day search (Ds) 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
Charonia tritonis	0.79	0.79	18	14.29		1	0.79	0.79	3	2.38		1
Echinothrix diadema	2.38	2.38	18	42.86		1	2.38	2.38	3	7.14		1
Holothuria atra	27.78	12.52	18	55.56	21.75	9	27.78	20.68	3	27.78	20.68	3
Lambis truncata	2.38	1.29	18	14.29	0.00	3	2.38	1.37	3	3.57	1.19	2
Spondylus spp.	0.79	0.79	18	14.29		1	0.79	0.79	3	2.38		1
Thelenota ananas	1.59	1.09	18	14.29	0.00	2	1.59	1.59	3	4.76		1
Trochus spp.	0.79	0.79	18	14.29		1	0.79	0.79	3	2.38		1

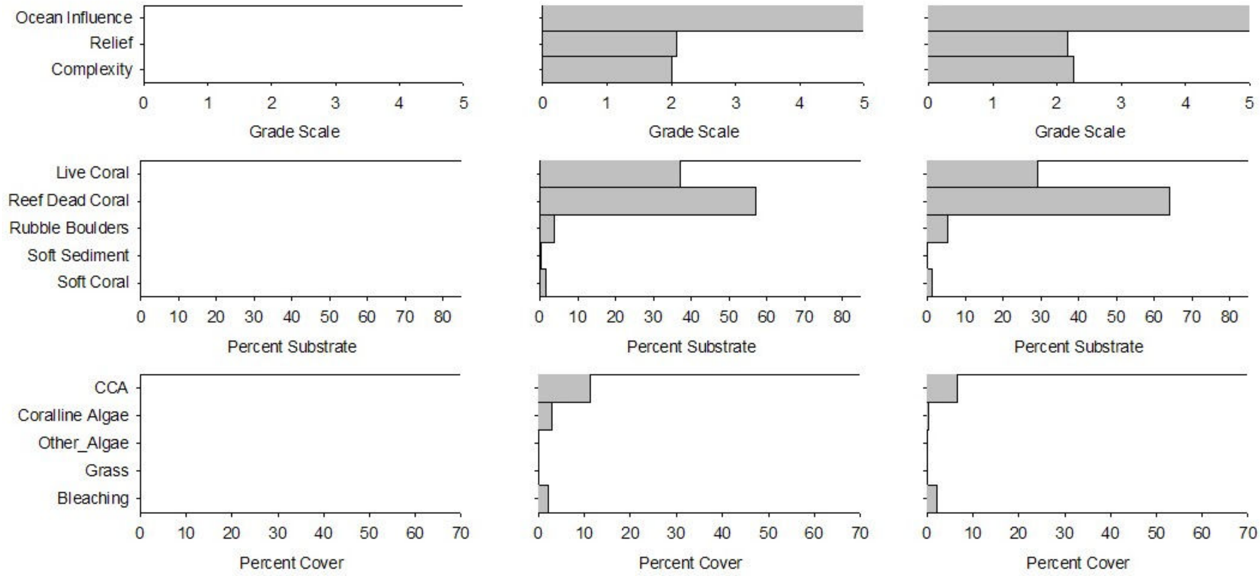
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.7 Niutao species size review – all survey methods

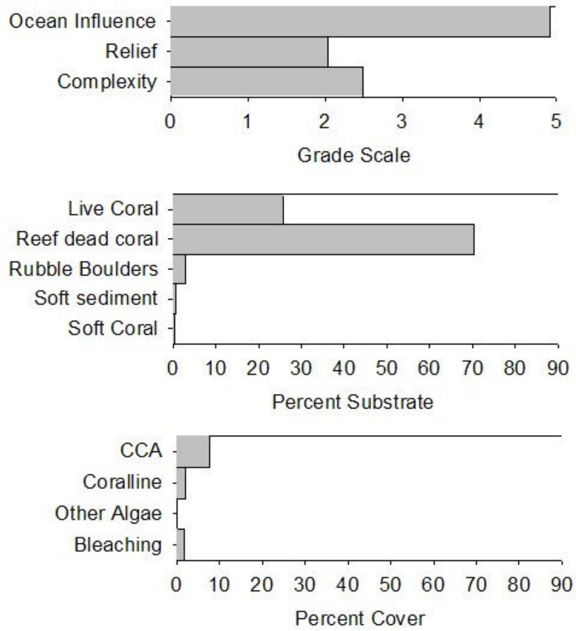
Species	Mean length (cm)	SE	n
Holothuria atra	48.3	0.2	157
Conus spp.	4.6	0.3	31
Thais armigera	5.1	0.2	7
Thais spp.	5.3	0.8	7
Vasum ceramicum	8.0	0.5	6
Lambis truncata	23.0	0.9	6
Tectus pyramis	7.7	0.5	3
Tridacna maxima	26.5	9.4	3
Holothuria fuscopunctata	36.0	0.0	2
Thelenota ananas	52.5	2.5	2
Turbo argyrostomus	7.1	0.0	1
Charonia tritonis	32.0	0.0	1

4.4.8 Habitat descriptors for independent assessments – Niutao

Broad-scale inner (absent), middle and outer assessments of habitat



Reef-benthos assessment of habitat

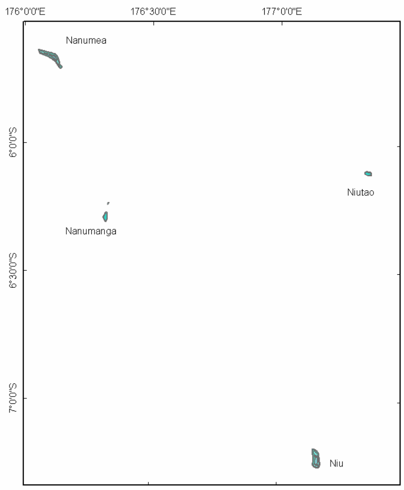


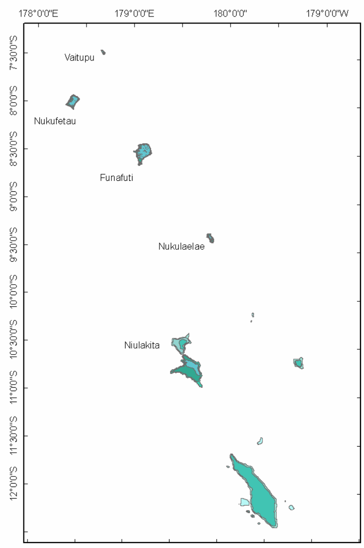
APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT, TUVALU

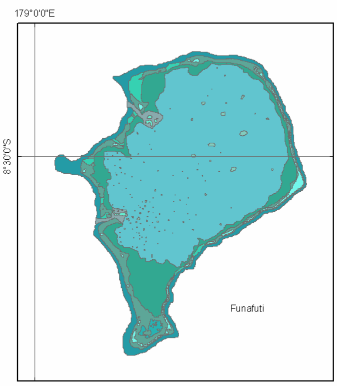
Institut de Recherche pour le Développement, UR 128 (France)
Institute for Marine Remote Sensing, University of South Florida (USA)
National Aeronautics and Space Administration (USA)

Millennium Coral Reef Mapping Project
Tuvalu

(July 2007)







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, Tuvalu coral reefs were mapped. Tuvalu is composed of atolls, drowned atolls and banks. The figures on the left column show the available Tuvalu Millennium product. Millennium products are maps at geomorphological level. An enlargement is provided for Funafuti Atoll to illustrate the level of detail that is achieved for each individual atoll.

The PROCFish/C project who is reporting on the present document on Tuvalu fishery status has been using Millennium products in the last four 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 generally 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 Tuvalu 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.