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

# COOK ISLANDS
# COUNTRY REPORT:

# PROFILES AND RESULTS FROM SURVEY WORK AT AITUTAKI, PALMERSTON, MANGAIA AND RAROTONGA

(February and October 2007)

by

Silvia Pinca, Ribanataake Awira, Mecki Kronen, Lindsay Chapman, Ferral Lasi, Kalo Pakoa, Pierre Boblin, Kim Friedman, Franck Magron and Emmanuel Tardy

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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.

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## EXECUTIVE SUMMARY

The coastal component of the Pacific Regional Coastal Fisheries Development Programme (CoFish) conducted fieldwork in four locations around Cook Islands in February and October 2007. Cook Islands is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by CoFish or its associated programme PROCFish/C (Pacific Regional Oceanic and Coastal Fisheries Development Programme)[2].

The aim of the survey work was to provide baseline information on the status of reef fisheries, and to help fill the massive information gap that hinders the effective management of reef fisheries.

Other programme outputs include:

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

Survey work in Cook Islands covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with two teams of five programme scientists and several local counterparts from the Ministry of Marine Resources. The fieldwork included capacity building for the local counterparts through instruction on survey methodologies in all three disciplines, including the collection of data and inputting the data into the programme's database.

In Cook Islands, the four sites selected for the survey were Aitutaki, Palmerston, Mangaia and Rarotonga. These sites were selected based on specific criteria, which included:

- having active reef fisheries,
- being representative of the country,
- being relatively closed systems (people from the site fish in well-defined fishing grounds),
- being appropriate in size,
- possessing diverse habitat,
- presenting no major logistical problems,
- having been previously investigated, and
- presenting particular interest for the Cook Islands' Ministry of Marine Resources.

[2] 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.

***Results of fieldwork in Aitutaki***

The atoll of Aitutaki is located at around 18°53'S latitude, and 159°47'W longitude, roughly 250 km to the north of Rarotonga, the capital of Cook Islands. It is a triangular-shaped atoll with 15 small islets mainly located on the eastern reef, and a main volcanic island with a height of 119 m in the north. The lagoon is shallow, attaining a maximum depth of 11 m, and almost completely enclosed by a substantial barrier reef. There is only one main passage through the reef in the west, making the lagoon cut off from ocean influence, with the lagoon substrate composed of very fine sand and little reef. There were also several marine reserves, one at the northeast tip of the lagoon, one to the southeast, and two in the southwest where the Ministry also has a giant clam nursery area. The people of Aitutaki rely heavily on marine resources for subsistence needs, while there is also a market for fish to supply the restaurants and hotels on the island.

*Socioeconomics: Aitutaki*

Survey results suggest that the Aitutaki community is less dependent on fisheries than it may have traditionally been. The traditional dependency shows in a moderate-to-high fresh fish consumption (57.7 kg/person/year). However, canned fish consumption is significant (20.4 kg/person/year), which suggests a change in lifestyle from fresh fish to processed fish, and also a higher availability of cash to substitute purchased meals for seafood caught for subsistence. Consumption of invertebrates is very low (2.5 kg/person/year), and fishing activities are done by a few active fishers and focus on a few species only. Comparing our 2007 results with those from a 1995 survey, the total population on Aitutaki has decreased from 2300 to 1800, and so has the average household size, from 7 to 4 people, and the frequency and quantity of fresh fish from 4.7 to 3.3 meals/week and from 100 to ~58 kg/person/year. Salaries are the most important source of income, while fisheries supply only 7% of households with first and another 23% with second income. One reason for this change may be tourism, which brings at least 10 times as many visitors to Aitutaki as there are residents.

Finfish fishing is mostly done by gillnetting, which is held responsible for a decline in the lagoon’s finfish resources. The low average frequency of fishing trips indicates a major shift from subsistence and commercially driven fisheries to leisure and lifestyle fisheries. Most catch is taken by males, and is sourced from the lagoon rather than the passages or outer reef.

*Finfish resources: Aitutaki*

Fishing in Aitutaki is open access and targets very specific species due to the high presence of ciguatera, recorded especially in *Cephalopholis argus*, *Lethrinus xanthochilus*, *C. melampygus*, *C. ignobilis*, *Lutjanus fulvus* and *L. monostigma.* Ciguatera has always occurred; however, over recent years its occurrence has been more frequent, severe and spread over many species. As a result, more and more pelagic species are targeted, in particular to supply the tourist sector.

The finfish density at Aitutaki was low in terms of regional average, however similar to density in Palmerston. Size, size ratio, biomass and biodiversity were higher than those recorded in Palmerston Atoll. At a detailed analysis at family level, Scaridae displayed very low size in all habitats (from 34 to 38% of maximum recorded size for the species present). Catches from the Aitutaki lagoon and back-reef system were mainly composed of Scaridae (over 45% of the reported catches). The remaining catches were composed of Acanthuridae, Mullidae and Mugilidae families.

Resources were overall in average-to-poor condition. The inner reefs were poor in corals and finfish resources were not diverse nor particularly abundant. Density, biomass and diversity of fish were higher in the outer reefs but community composition was heavily dominated by Acanthuridae. Finfish abundance, size, biomass and biodiversity were lower in the internal reefs, where most fishing takes place. Sizes of Scaridae were much lower than the maximum size recorded for the relative species, indicating an impact from fishing these species.

*Invertebrate resources: Aitutaki*

The range of shallow-water reef habitats and areas of dynamic water movement across the barrier reef in Aitutaki provides extensive suitable areas for giant clams. However, a large proportion of reef area that was examined, both inside and outside the lagoon, was not in good condition, possibly due to the shallow and enclosed nature of the lagoon, recent cyclones, and crown-of-thorns starfish. Only one species of giant clam (*Tridacna maxima*) was noted; *T. squamosa* was also present at Aitutaki but was very rare (only two local specimens held at the MMR clam nursery) and not noted in outer-reef surveys. Introduced species, such as *T. gigas*, *T. derasa*, and *Hippopus hippopus*, are held in a suitable nursery area and in the reserve. In general, the status of giant clams at Aitutaki was noted as impacted, with wholesale changes in the composition and even structure of reefs open to fishing. Clam coverage, even from reefs open to fishing was still not critical, but density records and the 'missing' larger clam size classes, support the assumption that *T. maxima* stocks are greatly impacted by current levels of fishing.

The commercial topshell *Trochus niloticus* is common at Aitutaki and local reef conditions constitute excellent habitat for adult and juvenile trochus. Commercial stocks are most common at easily accessible, shallow-water reefs inside the lagoon and on the barrier-reef platforms, generally those influenced by passage water flows. There has been a moratorium of ~5–6 years on commercial fishing of trochus and, in 33–50% of survey stations, trochus stock density was found to be >500–600 /ha, which is the minimum density recommended before commercial fishing can be considered. However, commercial size classes are still relatively low in abundance, and no strong year class is currently visible below the commercial size class range. This is likely to be due both to environmental drivers affecting settlement and recruitment and possibly to the dominance of large-size shells. The blacklip pearl oyster, *Pinctada margaritifera* is relatively uncommon at Aitutaki.

Aitutaki has a diverse range of environments for sea cucumbers, including protected embayments near the main island and more exposed, oceanic-influenced areas at the southern edge of the lagoon. Medium-value species (e.g. leopardfish *Bohadschia argus*) were rare and high-value species that are easily targeted by fishers, e.g. black teatfish (*Holothuria nobilis*), were absent. Other species, such as the high-value white teatfish (*H. fuscogilva*), which is found in deeper water, was not present on searches near the passages. Only the low-value lollyfish (*H. atra*) was commonly recorded; *H. leucospilota*, which is targeted for the gonad, was easily found. There is no potential to develop a commercial sea cucumber fishery based on stocks at Aitutaki at this time.

*Recommendations for Aitutaki*

- Spearfishing be controlled and night spearfishing banned.

- The use of gillnets in the lagoon be regulated, with all fishers to comply with the existing restrictions.

- A monitoring system be set in place to follow further changes in finfish resources.

- The establishment of community-managed marine reserves be supported and followed by compliance and patrolling if results such as finfish recovery are to be expected. The discussion and trial of a surveillance and monitoring system that is tailored to meet the expectations and acceptance of the local population is advised.

- For successful stock management, clams be maintained at higher density, and include larger-sized individuals to ensure there is sufficient spawning taking place to produce new generations.

- Any proposed fishing plans for trochus consider the option of raising the maximum size limit, to harvest or sell some of the large adult trochus to markets or other communities that are trying to revitalise their reef fisheries by augmenting or introducing broodstock.

- MMR consider shortening the 5–6 year resting period currently adopted, as it may be too long to optimise productivity in the trochus fishery. If smaller, interim harvests could be made, this might actually benefit productivity. Any such approach should still take recruitment signals into account (by monitoring length frequency) and large trochus should be moved only from areas with dense aggregations (where density is >500 shells/ha).

- MMR consider monitoring trochus stocks in a few small areas of reef in the north of Aitutaki, in order to detect any signs of settlement/recruitment. This could be conducted at any rubble area situated in shallow water, preferably one that is subject to regular water movement and has both 'pink rock' (crustose coralline algae) and epiphyte algae cover.

- If there was potential to stock the lagoon with teatfish sea cucumbers from nearby populations, this might be considered as an 'experimental' development.

***Results of fieldwork in Palmerston***

Palmerston is a lozenge-shaped, enclosed atoll, located at 18°02'50"S latitude and 163°09'22"W longitude, roughly 500 km to the northwest of Rarotonga. It can only be reached by boat (no airstrip). The atoll is 12 km long and 9.5 km wide, with over one-half of the lagoon deeper than 20 m, with a maximum depth of 35 m. There are seven *motu* around the rim of the lagoon, with only one in the west-southwest being inhabited. At the time of the survey, fishing at Palmerston was open-access and there were no protected areas or reserves, although on occasion, the Island Council may declare a partial *ra'ui* (traditional community-based management system) for parrotfish. The islanders depended on fish and invertebrates for subsistence needs as well as income, and the Island Council had expressed concern about the future of the parrotfish fishery given the current fishing pressure.

*Socioeconomics: Palmerston*

The Palmerston community is highly dependent on its reef and lagoon resources due to the limited alternatives to gain income on this isolated atoll, as well as to its limited agricultural potential. This fact shows in a fresh-fish consumption of ~110 kg/person/year. Living costs on Palmerston are high because all goods must be imported by boat from Rarotonga, and all perishable food items require freezing facilities. However, modernisation in Palmerston is seen in the changes that have occurred in nutrition, education, income and lifestyle. Comparison of the data from the current CoFish survey (2007) with results from a 1988 survey shows that the population decreased from 140 (in 1980–1990) to 66 (in 1986) and 56 (in 2007); also, the total number of motorised boats decreased from 24 boats (reported in 1988) to 15 boats (9 motorised, 6 non-motorised) today.

The island's own subsistence demand for finfish is insignificant due to the small population; however, a major impact is imposed by commercial and non-commercial export to Rarotonga and elsewhere. Invertebrates are hardly targeted, consumed, commercialised or exported on a non-commercial basis, and the collection for commercial export, of *paua* (*Tridacna maxima*) in particular, is currently prohibited. In total, the current subsistence demand for invertebrates on Palmerston is low.

*Finfish resources: Palmerston*

Overall, the status of finfish resources in Palmerston was found to be moderate to low. This was due to the natural condition of the site, which is very remote, with relatively poor live-coral cover. The density and biomass of food-fish were the lowest recorded among the four sites surveyed in the country. Analysis at the reef habitat level showed that there was high spatial variability. The intermediate reefs (constituting only 1% of total reef area) showed the highest fish biomass as well as the largest average fish size and size ratio compared to the other habitats. The back-reefs (75% of the total reef area) displayed very low values of density, size, biomass and biodiversity, the lowest at this site as well as compared to the back-reefs at the other country sites. The outer reefs displayed intermediate values of size and biomass but highest density and biodiversity. Outer reefs provided the healthiest environment of the three, with high cover of live coral and diverse species composition, although poorer than all the other country sites surveyed. There is intensive fishing of parrotfish, caught both to feed the local population (consumption of fresh fish being very high) and for export to Rarotonga (75% of catches) for sale and family gifts. Increased targeting of parrotfish has occurred in the past 20 years due to major changes in fishing and preservation strategies (use of gillnets, more motorboats, easy refrigeration access).

Overall, Palmerston finfish resources appeared to be average to poor. The healthy status of the intermediate reefs was not mirrored by the condition of the outer and back-reefs. In these two habitats, density, biomass, biodiversity and average size were fairly low compared to the country and regional average. The dominance of Acanthuridae and Scaridae could be explained by the type of environment, which was mostly hard bottom, especially in the outer reef. The relative lack of carnivores, mainly Serranidae, is most probably to be attributed to natural conditions. The current status of resources appeared sustainable for subsistence use only. The pressure imposed by increased amounts of fish exported is damaging local resources. Certain species of parrotfish showed signs of impact from heavy fishing, especially in average sizes.

*Invertebrate resources: Palmerston*

The range of shallow-water reef habitats and areas of dynamic water movement across the atoll's barrier reef provides extensive suitable areas for giant clams at Palmerston. Both *Tridacna maxima* and *T. squamosa* were noted in general surveys. Only one *T. squamosa* specimen was noted on the outer-reef slope and this species is now endangered at Palmerston Atoll. However, the smaller *T. maxima* clam was relatively plentiful (found at all RBt stations at a density of 41.7–1708.3 clams/ha). Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the abundance of large-sized clams was low, supporting the assumption that stocks are impacted by fishing.

The local reef environment, with large, exposed reef platforms and extensive areas of lagoon and offshore reef, provided suitable habitat for both adult and juvenile trochus (*Trochus niloticus*). However, trochus were relatively uncommon at Palmerston. There has been a moratorium on commercial fishing of trochus for ~10 years, after a harvest of ~1.5 t of shell (~3500–4200 individuals). This harvest may well have been the bulk of the stock that existed on Palmerston as there are reports of >3000 shells being moved from Aitutaki to Palmerston in the 1980s. From the historical information available and the present low estimate of stock, the potential for developing a trochus fishery at Palmerston is marginal. The blacklip pearl oyster, *P. margaritifera*, was relatively uncommon at Palmerston, despite the enclosed nature of the atoll.

Palmerston had a diverse range of environments for sea cucumbers but was mostly exposed to oceanic influences and supported a limited range of sea cucumber species. Medium-value species (e.g. leopardfish *Bohadschia argus*) and high-value species that are easily targeted by fishers (e.g. black teatfish *Holothuria nobilis*) were rare and at low density. Other species, such as the high-value white teatfish (*H. fuscogilva*), were found in deeper water, but again the stocks were poor. Greenfish (*Stichopus chloronotus*) was an exception, with very high densities and widespread distribution around the lagoon. Even on broad-scale surveys, which cover a range of suitable and non-suitable habitats, the average density recorded was high (857 /ha). Surf redfish (*Actinopyga mauritiana*) was not at commercial density, but some areas undoubtedly have potential to produce small harvests of this species. Lollyfish (*H. atra*) was also common in the lagoon, but it may not be economically viable to harvest this lower-value species at this time. *H. leucospilota* was common and easy to find.

*Recommendations for Palmerston*

- Fisheries management interventions be implemented to restore today's resources, especially parrotfish, back to the reported previous levels and maintain them for sustainable use in the future. It may be more beneficial to focus on restoration and sustainable use, since opportunities to exploit alternative fishery options, such as aquaculture (e.g. pearl farming), seem to be rather limited.

- Given the particular social situation of the Palmerston community, the objective of developing and implementing an effective fisheries management plan can only be reached with full cooperation between the island's community and MMR at every step in the process, with a strong focus on ownership by the Palmerston community.

- For successful stock management, giant clams be maintained at higher density, and include larger-sized individuals to ensure there is sufficient spawning taking place to produce new generations.

- All fishing of *T. squamosa* be halted to allow numbers to recover, as the current numbers of this species are very low and this clam is now endangered at Palmerston Atoll.

- If possible, trochus broodstock be shipped to Palmerston and stocked in small patches of 20–30 shells in various areas on the north barrier and east reef slope. This may enable stocks to be increase to a level where harvesting is possible in the medium-term future.

***Results of fieldwork in Mangaia***

Mangaia is an upraised coral island surrounded by a narrow bench reef located at 21°54'30"S latitude and 157°59'40"W longitude. It is the southern-most island in the group, roughly 200 km southeast of Rarotonga. As a raised limestone island, Mangaia has only one reef type, which is the outer fringing reef surrounding the island. Mangaia has three main villages: Ivurua on the eastern side, Tamarua on the southern side and Oneroa, the administrative centre, covering the northwest side of the island.

*Socioeconomics: Mangaia*

The Mangaia community is highly dependent on its reef and lagoon resources for protein, complemented by agricultural produce from subsistence activities. A high degree of self-sufficiency for food is a necessity due to the limited alternatives for gaining income. Living costs on this isolated atoll are relatively high because all goods must be imported by boat from Rarotonga. The high dependency on marine resources for subsistence shows in the amount of seafood consumed (~66 kg/person/year of fresh fish; 7.5 kg/person/year of invertebrates). However, Mangaia is also subject to modernisation; changes in nutrition, education, income-earning and lifestyle are evident. Canned-fish consumption is relatively high (15 kg/person/year), and people now have access to water supply, electricity from a local power station, an ice-making plant, schools and medical facilities. However, many younger people migrate to Rarotonga and elsewhere for education and work.

There are few income-earning opportunities on the island and government jobs for highly educated people are limited. There is no marketing infrastructure to link with the Rarotonga or any other market. Also, the local reef and lagoon resources may not be sufficient to allow any significant increase in fishing if they are to be sustained for the future. Thus, the lack of transport and marketing access may actually help to maintain Mangaia's fishery resources for subsistence.

*Finfish resources: Mangaia*

The finfish resources in Mangaia were found to be rather poor. Only one type of habitat is present, an outer reef, where habitat is naturally poor and exposed to wind and erosion from sea urchins. The substrate was mainly composed of bare, hard bottom with very little live coral, especially on the western side of the island. The finfish community was almost homogeneous and composed almost uniquely of Acanthuridae. The dominance of herbivores, especially Acanthuridae, is partially explained by the hard-bottom substrate, which offers very limited niches for different fish. Overall fish density and diversity were low, especially in areas more accessible to spear fishing on the western side of the island. Fishing was mostly done by handline (mostly over grounds 60–100 m deep); however, some spear diving and gillnetting was also practised, even at night. The natural fish resources were not sufficient to allow any increase in fishing level for commercial purposes in a sustainable way. Local consumption is already imposing an impact on the natural resources.

*Invertebrate resources: Mangaia*

The scale and range of habitats in Mangaia suitable for giant clams were limited by the shallow-water reef-platform habitats and the dynamic water movement on the reef-front. Only two giant clam species were present: *Tridacna maxima* and *T. squamosa*. *T. maxima* was common on the reef platform and sparsely distributed on the reef slope. Larger, older clams were on the reef slopes. *T. squamosa* were only found at low density on the reef slope and may be in danger of declining to a point where spawning and the production of future generations becomes unsustainable. Giant clams stocks were impacted by fishing, due to the high fishing pressure on the reef platform frequented by gleaners. *T. maxima* density remained quite high on the reef platform, possibly due to the larger 'broodstock' clams on the reef slope, and this broodstock on the reef slope needs to be protected from fishing in order to maintain a source of gametes for future generations of clams.

Reef conditions constitute an adequate but small habitat for adult and juvenile trochus (*Trochus niloticus*). There is no commercial trochus stock at the moment, but a small broodstock of large, old individuals remains on the outer slope. Trochus are scarce, due to excessive gleaning; most of the recruitment is taken before reaching mature size.

The small area of fringing reef platform and steep reef slope that is exposed to swell at Mangaia Island is only suited to a small number of sea cucumber species. Only six commercial sea cucumber species were noted at Mangaia, which reflects the limited environment available. In addition, two subsistence species (*Holothuria cinerescens* and *H. pervicax*) were also noted in survey. Presence and density data collected suggested that sea cucumbers are not under significant fishing pressure, and even those species fished for subsistence purposes are not noticeably impacted. Surf redfish (*Actinopyga mauritiana*) and prickly redfish (*Thelenota ananas*) are relatively abundant and may be sufficient to allow periodic commercial harvesting at a low level, e.g. using a pulse-fishing strategy.

*Recommendations for Mangaia*

- Ecotourism be investigated as possibly the best option for future economic development on Mangaia.

- MMR work with the people of Mangaia to develop a joint management plan that engages all families on the island, that attempts to solve any property and land ownership disputes, and includes community-based fisheries resource management actions where needed.

- Strong management measures to protect the recruitment of clams and trochus be taken, with the larger clams in the deeper water protected from fishing.

- Small, no-take areas be established on the reef platform and protected from fishing to allow clam and trochus recruitment to occur.

- Stocks of surf redfish (*Actinopyga mauritiana*) and prickly redfish (*Thelenota ananas*) may be sufficient to allow periodic commercial harvesting at a low level. MMR may consider using a pulse-fishing strategy to control such a harvest, whereby a few days of fishing to reach a predetermined quota would be followed by an adequate period of rest.

***Results of fieldwork in Rarotonga***

Rarotonga is a high island and the capital of Cook Islands located at 21°14'30"S latitude and 159°46'33"W longitude. At 67 km$^2$, Rarotonga is the largest island in the group, with the highest point being 653 m above sea level. The oval-shaped island measures 11 km in length (east to west) and has a maximum width of 8 km (north to south). The fringing reef defines the lagoon, which is broad and sandy to the south and narrow and rocky to the north and east. The lagoon surrounding Rarotonga is quite small at 8 km$^2$ and in most areas is relatively shallow. Marine resources have been heavily impacted in the past both through fishing activity and other human activities including pollution, soil erosion and agriculture runoff (from farming and animals). Many reef fish species are now considered ciguatoxic, which has caused a change in subsistence activities. A system of *ra'ui* (traditional community-based management) has been implemented in the 2000s to safeguard marine resources around Rarotonga.

*Socioeconomics: Rarotonga*

Rarotongan people are currently much less dependent on their reef and lagoon resources than communities elsewhere in the country. Living standards and costs on Rarotonga are high. Most households depend on salaries for income and/or social and retirement payments. No households mentioned fisheries as providing any kind of income. Fresh fish and other seafood are eaten on average about twice per week. However, lack of availability and high prices may explain why Rarotonga people consume much less fresh fish than the average found across all sites surveyed in Cook Islands, i.e. ~32 kg/person/year as compared to ~52 kg/person/year. Also, invertebrate consumption is extremely low (~1.4 kg/person/year), and canned fish consumption is almost as high as the average across all sites (~11 kg/person/year as compared to ~13 kg/person/year). Reasons for the decrease in fresh-fish (and presumably also invertebrate) consumption are: the deterioration of the lagoon quality associated with a high risk of ciguatera fish poisoning, high prices and, perhaps, the change to a more urban lifestyle.

*Finfish resources: Rarotonga*

Most reef fish around Rarotonga are ciguatoxic, so almost no reef fish are eaten or fished for consumption. The most heavily affected area is the east and southeast part of the island. Fish density and biomass were higher than at similar sites in the country, surpassed only by the values in Aitutaki. However, biodiversity in Rarotonga was particularly low in both back-reefs and outer reefs, most probably due to the natural poverty of the reef substrate, made of coral slab and very little live coral.

Overall, Rarotonga finfish resources appeared to be in good condition. The reef habitat was very poor in the outer reef and supported primarily surgeonfish (Acanthuridae) in high abundance. The back-reef environment was slightly healthier and supported higher concentrations of fish; however, species diversity was low. The trophic community was mainly composed of herbivores but carnivores were more important in the back-reefs, where soft bottom was available and Mullidae were relatively abundant.

Ciguatera fish poisoning, which has become more serious in the past 10 years, is limiting fishing to a few species and for personal use only. This is the reason why fish abundance and biomass at this site are relatively high and fishing pressure, as well as impact, is low.

*Invertebrate resources: Rarotonga*

The range of reef habitats and the dynamic water-movement regime found at Rarotonga provided extensive suitable reef area for giant clams. Only one giant clam species was present (*Tridacna maxima*). *T. squamosa*, which has been recorded at the other CoFish sites in Cook Islands, was absent. *T. squamosa* can be considered as commercially extinct[3] in Rarotonga. In general, giant clams at Rarotonga were impacted by fishing, noted by the predominance of small size classes on the reef platform and the lack of larger clams on the reef slope. Despite the high level of fishing pressure, recruitment was still occurring and clams were still at reasonable density in some areas. However, the average clam size was small, and continued fishing at this level, without protection of parts of the fishery (and aggregations of 'broodstock') jeopardises sustainability and could result in a rapid decline of stocks in the medium term.

The back-reef, reef platforms and reef slope of Rarotonga constitute an extensive and suitable benthos for the commercial topshell (*Trochus niloticus*). Trochus were common at many easily accessible, shallow-water reefs on the extensive barrier platform. The most abundant aggregations of trochus were recorded along reef platform in the northwest and they occurred more sparsely along the reef slope. Trochus distribution was not common in the surf zones of the reef slope (depth 0–10 m) but at >10 m depths they were found at reasonable abundance and live shells were recorded down to 30 m depth. There was a good abundance of commercial size classes, with more than adequate numbers of 'broodstock'. There was no potential for commercial collection of the blacklip pearl oyster *Pinctada margaritifera* at Rarotonga and the green topshell *Tectus pyramis* was not recorded.

The large, high island of Rarotonga is surrounded by a full range of marine environments, although protected areas of inshore reef were limited in scale. The predominantly exposed reef was more suitable for a smaller range of sea cucumbers. Presence and density data collected in survey showed that sea cucumbers that were present locally were not under heavy fishing pressure, although previous fishing may have eliminated some species. In general, sea cucumber species fished for subsistence were also not impacted.

*Recommendations for Rarotonga*

- Protecting some areas of clams on the reef platform and designating some deeper-water locations as 'no-take' reserves to maintain high densities would be the best approach for successful stock management of giant clams.

- If small numbers of *T. squamosa* can be located around the reef slope of Rarotonga a recovery plan should be implemented. Identification of individuals may allow movement

[3] 'Commercially extinct' refers to a level of 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.

and aggregation of some remaining individuals to protected areas to assist successful sexual reproduction, or access for use in hatchery rearing of juveniles.

- Any proposed fishing plans for trochus (*Trochus niloticus*) may consider the option of partially raising the maximum size limit, so that large trochus can be harvested for specialist markets or some can be moved to replenish other areas by augmenting the existing broodstock or introducing new broodstock.

- Sea cucumber stocks of greenfish (*Stichopus chloronotus*) and potentially *Holothuria atra*, *Actinopyga mauritiana* and *Thelenota ananas* may offer limited potential for commercialisation if short, limited harvests (a few days) controlled by MMR could be interspersed between longer periods (several years) when the fishery remained protected from fishing, to allow stocks to recover from the harvest.

# RÉSUMÉ

Les agents de la composante côtière du projet régional de développement de la pêche côtière (CoFish/C) ont effectué des travaux de terrain sur quatre sites des Îles Cook, en février et octobre 2007. Les Îles Cook figurent parmi les 17 États et Territoires insulaires océaniens où des enquêtes ont été réalisées de manière échelonnée sur 5 à 6 ans, au titre de PROCFish ou de son programme connexe CoFish (Programme régional de développement de la pêche côtière dans le Pacifique)[4].

Les enquêtes visaient à réunir des informations de référence sur l'état des pêcheries récifales pour combler l'énorme déficit d'information qui fait obstacle à la bonne gestion de ces pêcheries.

D'autres réalisations sont à inscrire au crédit du programme :

- la mise en œuvre de la première évaluation comparative globale des ressources récifales (poissons, invertébrés et paramètres socio-économiques) jamais réalisée dans plusieurs États et Territoires insulaires océaniens au moyen de méthodes identiques sur chaque site ;
- la diffusion de rapports sur les pays qui comprennent un ensemble de « profils des pêcheries récifales » pour les différents sites de chaque pays afin de fournir les informations nécessaires à la planification de la gestion et du développement de la pêche côtière ;
- l'élaboration d'un ensemble d'indicateurs (ou de points de référence sur l'état des pêcheries) offrant des orientations pour l'élaboration de plans locaux et nationaux de gestion des pêcheries récifales et des programmes de suivi, et
- la mise au point de systèmes de gestion des données et de l'information, dont des bases de données régionales et nationales.

Les enquêtes conduites aux Îles Cook comprenaient trois volets (poissons, invertébrés et paramètres socio-économiques) pour chaque site. Deux équipes, composées de cinq chargés de recherche et d'agents du Ministère des resources marines des Îles Cook, ont été mobilisées. Au cours des travaux de terrain, l'équipe a formé ses homologues locaux aux méthodes d'enquête et de comptage employées dans chacun des trois volets, notamment à la collecte de données et à leur saisie dans la base de données du programme.

Aux Îles Cook, les quatre sites retenus étaient Aitutaki, Palmerston, Mangaia et Rarotonga. Chaque site a été sélectionné selon les critères suivants :

- la pêche récifale devait y être effectivement pratiquée ;
- le site devait être représentatif du pays ;
- le système devait être relativement fermé, c'est-à dire que les habitants du site pêchaient dans des zones bien définies ;
- la taille du site devait être appropriée ;

[4] Les projets CoFish et PROCFish/C font partie du même programme d'action, CoFish ciblant Niue, Nauru, les États fédérés de Micronésie, Palau, les Îles Marshall et les Îles Cook (pays ACP bénéficiant d'un financement au titre du 9e FED) et PROCFish/C les pays bénéficiant de fonds alloués au titre du 8e FED (pays ACP : Îles Fidji, Tonga, Papouasie-Nouvelle-Guinée, Îles Salomon, Vanuatu, Samoa, Tuvalu et Kiribati, et collectivités françaises d'outre-mer : Nouvelle-Calédonie, Polynésie française et Wallis et Futuna (PTOM). C'est pourquoi les termes CoFish et PROCFish/C sont employés indifféremment dans tous les rapports de pays.

- le site devait abriter des habitats divers ;
- il ne devait pas présenter de problèmes logistiques majeurs ;
- il devait avoir été étudié auparavant, et
- il devait présenter un intérêt particulier pour le Ministère des ressources marines des Îles Cook.

***Résultats des travaux de terrain effectués à Aitutaki***

L'atoll d'Aitutaki est situé par 18°53 de latitude sud et 159°47 de longitude ouest, à environ 250 km au nord de Rarotonga, la capitale des Îles Cook. Il s'agit d'un atoll de forme triangulaire, composé de quinze îlots, pour la plupart situés sur le récif oriental, et d'une île volcanique culminant à 119 m, au nord. Le lagon, peu profond (11 m de profondeur maximale), est presque entièrement ceinturé par un vaste récif barrière. La passe principale se trouve à l'ouest du récif, ce qui prive le lagon de toute influence océanique et explique que le substrat du lagon soit composé de sable très fin et que l'environnement récifal soit réduit. On trouve également plusieurs réserves marines, dont l'une est située à l'extrémité nord-est du lagon, une autre au sud-est et deux au sud-ouest. Il est à noter que ces deux dernières abritent une nourricerie de bénitiers administrée par le Ministère des ressources marines. La population est largement tributaire des ressources marines pour assurer ses besoins alimentaires et vend une partie des prises de poissons aux restaurants et hôtels de l'île.

*Données socioéconomiques : Aitutaki*

Les données recueillies pour Aitutaki laissent à penser que la communauté est moins tributaire de la pêche qu'autrefois. La dépendance traditionnelle à l'égard de la pêche est illustrée par la consommation modérée à élevée de poisson frais (57,7 kg/habitant/an). La consommation de poisson en conserve est toutefois importante (20,4 kg/habitant/an), ce qui témoigne d'une évolution du mode de vie et d'une plus grande disponibilité de liquidités. L'achat de plats préparés se substitue ainsi aux activités de pêche de subsistance. La consommation d'invertébrés est très faible (2,5 kg/habitant/an). Les pêcheurs sont peu nombreux et concentrent leurs activités sur quelques espèces seulement. Une comparaison des données recueillies en 2007 et de celles rapportées en 1995 montre que 1) la population totale d'Aitutaki a baissé de 2 300 à 1 800 habitants, 2) la taille moyenne des ménages a également diminué (de 7 à 4 personnes), et 3) la fréquence et la quantité de poisson frais a diminué de 4,7 à 3,3 repas/semaine et de 100 à 58 kg environ par habitant et par an. Les salaires sont la principale source de revenus, tandis que 7% seulement des ménages ont la pêche pour seule source de revenus principaux et que 23 % d'entre eux ont une source de revenus secondaire. L'une des raisons qui expliquerait ce changement de mode de vie est peut-être le tourisme, qui amène au moins dix fois plus de visiteurs à Aitutaki chaque année qu'il n'y a d'habitants.

Les poissons sont principalement pêchés au filet maillant, ce qui explique le déclin des ressources halieutiques du lagon. La faible fréquence des sorties de pêche témoigne de l'évolution d'une pêche axée sur la subsistance et le commerce vers une pêche récréative. Le poisson est surtout pêché par les hommes et provient davantage du lagon que des passes ou du tombant récifal externe.

*Ressources en poissons : Aitutaki*

La pêche à Aitutaki est ouverte à tous. Seules certaines espèces sont ciblées en raison d'une prévalence importante de la ciguatera, en particulier chez les populations de *Cephalopholis argus*, *Lethrinus xanthochilus*, *C. melampygus*, *C. ignobilis*, *Lutjanus fulvus* et *L. monostigma.* La ciguatera n'est pas un phénomène nouveau, mais la fréquence des flambées, leur gravité et leur portée ont récemment augmenté. En conséquence, les espèces pélagiques sont de plus en plus ciblées, notamment pour approvisionner le secteur touristique.

La densité de poisson est faible par rapport à la moyenne régionale mais équivaut à celle relevée à Palmerston. Les tailles, les rapports de tailles, la biomasse et la biodiversité de poissons sont supérieurs aux valeurs correspondantes enregistrées sur l'atoll de Palmerston. Une analyse détaillée, au niveau des familles, révèle que les Scaridae sont de très petite taille, tous habitats confondus, puisque l'on enregistre des tailles correspondant de 34 à 38% de la taille maximale enregistrée pour cette espèce. Les Scaridae constituent plus de 45% des prises déclarées, soit l'essentiel des prises réalisées dans le lagon et l'arrière-récif d'Aitutaki. On y trouve également, dans une moindre mesure, des Acanthuridae, des Mullidae et des Mugilidae.

Dans l'ensemble, les ressources sont dans un état satisfaisant à médiocre. Les zones récifales intérieures renferment peu de coraux. Les ressources halieutiques présentent une faible diversité et ne sont pas particulièrement abondantes. La densité, la biomasse et la diversité des poissons sont plus importantes sur les tombants récifaux externes. Les Acanthuridae sont toutefois prédominants. L'abondance, la taille, la biomasse et la biodiversité des poissons étaient moins importantes dans les zones récifales intérieures, les plus exploitées. Les tailles relevées chez les Scaridae étaient bien inférieures à la taille maximale observée pour les espèces de cette famille, ce qui tend à démontrer l'incidence de la pêche.

*Ressources en invertébrés : Aitutaki*

Aitutaki présente une large gamme d'habitats récifaux de faible profondeur et un hydrodynamisme important en plusieurs endroits du récif-barrière, autant de conditions convenant aux bénitiers. On observe néanmoins qu'une partie importante de la zone récifale étudiée, à l'intérieur comme à l'extérieur du lagon, n'est pas en bon état, peut-être en raison de la faible profondeur du lagon et de son caractère enclavé, des cyclones survenus récemment ou des infestations d'Acanthaster. On enregistre une seule espèce de bénitier (*Tridacna maxima*). *T. squamosa* est également présent mais très rare (seulement deux individus à la nourricerie de bénitiers administrée par le Ministère des ressources marines). Aucun individu n'a été recensé sur les tombants récifaux externes. Les espèces introduites, telles que *T. gigas*, *T. derasa* et *Hippopus hippopus* sont conservées dans une partie de la nourricerie prévue à cet effet et dans la réserve. En règle générale, il ressort des enquêtes menées à Aitutaki que les bénitiers sont affectés par la pêche. Par ailleurs, on note des modifications considérables dans la composition, voire la structure des récifs où la pêche est autorisée. Les stocks de bénitiers n'ont pas encore atteint un seuil critique, même dans les zones récifales où la pêche est autorisée, mais les données relatives à la densité et l'absence de bénitiers de grande taille confirment l'hypothèse que les stocks de *T. maxima* sont actuellement surexploités.

Le troca de valeur commerciale *Trochus niloticus* est une espèce commune à Aitutaki, dont les récifs constituent un habitat convenant parfaitement aux trocas juvéniles et adultes. Les stocks d'intérêt commercial sont les plus abondants sur les récifs de faible profondeur faciles d'accès situés à l'intérieur du lagon ou sur les plates-formes des récifs barrières, qui, généralement, subissent l'influence de la circulation de l'eau. Alors que la pêche commerciale du troca a été suspendue pendant cinq à six ans environ, les valeurs enregistrées dans 33 à 50 % des sites étudiés (>500–600 individus par hectare) correspondent à la densité minimale recommandée en vue d'une éventuelle pêche commerciale. Toutefois, les individus de taille commercialisable sont assez peu nombreux, et aucune classe d'âge n'est fortement représentée en dessous de la fourchette de tailles commercialisables. Ceci s'explique sans doute tant par des facteurs environnementaux, dont l'incidence se fait sentir sur l'installation et le recrutement des populations, que par la prédominance des trocas de grande taille. L'huître perlière à lèvres noires (*Pinctada margaritifera*) est assez peu commune à Aitutaki.

Aitutaki présente une grande diversité de milieux favorables aux holothuries, y compris des baies protégées situées non loin de l'île principale, et des zones plus exposées aux influences océaniques, à l'extrémité sud du lagon. Rares sont les espèces de valeur commerciale moyenne, telles que l'holothurie léopard (*Bohadschia argus*). On note l'absence d'espèces de grande valeur, particulièrement prisées des pêcheurs, telles que l'holothurie noire à mamelles (*Holothuria nobilis*). L'holothurie blanche à mamelles (*H. fuscogilva*), très recherchée et qui vit en eaux profondes, n'a pas été recensée dans les sites situés à proximité des passes. Seule *H. atra*, dont la valeur commerciale est faible, a été fréquemment observée ; *H. leucospilota*, ciblée pour ses gonades, s'est avérée assez présente. Pour l'heure, compte tenu de l'état des stocks vivant à Aitutaki, le potentiel de développement d'une pêcherie commerciale d'holothuries est inexistant.

*Recommandations pour Aitutaki*

- Il convient de restreindre la pêche au fusil-harpon et d'en interdire la pratique de nuit.

- L'emploi de filets maillants dans le lagon doit être règlementé et les pêcheurs devront respecter les restrictions en vigueur.

- Il est proposé de mettre en place un système de suivi permettant de surveiller l'évolution des ressources en poissons.

- Il faut aider à la création de réserves marines à gestion communautaire, mettre en place une réglementation et organiser des patrouilles si l'on tient à ce que les stocks se renouvellent. Il est recommandé d'organiser des consultations et d'effectuer des essais en vue de mettre en place un système de surveillance et de suivi permettant de répondre aux attentes de la population et d'être acceptée par cette dernière.

- Pour gérer au mieux les stocks de bénitiers, il faut augmenter et maintenir à un niveau de densité plus élevé les populations, lesquelles doivent comprendre des individus de grande taille afin d'assurer un niveau de reproduction suffisant pour renouveler les stocks.

- En ce qui concerne les trocas, tout plan de pêche devra dorénavant envisager la possibilité d'augmenter la limite de taille maximale, ce qui permettra de prélever ou de vendre des trocas adultes sur les marchés ou à d'autres communautés qui chercheraient à redynamiser le secteur des pêches récifales en introduisant des géniteurs ou en augmentant le stock existant.

- Le Ministère des ressources marines doit envisager de réduire la période d'interruption de la pêche, actuellement fixée à 5 ou 6 ans, car il se peut qu'elle soit trop longue pour optimiser la productivité de la pêche du troca. Des prélèvements de plus petite quantité, à intervalles plus fréquents, pourraient s'avérer bénéfiques pour la productivité. Les données de recrutement devront continuer à être prises en compte (en surveillant la fréquence de taille) et les trocas de grande taille devront être déplacés seulement s'ils se trouvent dans une zone de forte concentration (densité supérieure à 500 individus par hectare).

- Le Ministère des ressources marines doit envisager de surveiller les stocks de trocas sur plusieurs sites situés au nord d'Aitutaki afin de déceler d'éventuels signes d'installation ou de recrutement. Toute zone de débris située en eaux peu profondes, de préférence caractérisée par un hydrodynamisme régulier et la présence d'une couverture constituée à la fois de « rochers roses » (algues coralliennes croûteuses) et d'algues épiphytes, pourrait s'avérer propice.

- Il pourrait être envisagé, à titre expérimental, d'introduire dans le lagon des holothuries à mamelles prélevées parmi les populations environnantes.

***Résultats des travaux de terrain à Palmerston***

Palmerston est un atoll fermé en forme de losange, situé par 18°02'50'' de latitude sud et 163°09'22'' de longitude ouest, à quelque 500 km au nord ouest de Rarotonga. En l'absence de piste d'atterrissage, le bateau est le seul moyen d'y accéder. L'atoll s'étend sur 12 km de long et 9,5 km de large. Plus de la moitié du lagon est situé à une profondeur supérieure à 20 mètres, sans jamais dépasser 35 mètres. Sept îlots (*motu*) sont éparpillés le long de la ceinture du lagon. Seul celui situé dans la direction ouest-sud ouest est habité. Au moment de l'enquête, la pêche à Palmerston était ouverte à tous et il n'existait ni aires protégées ni réserves. Le Conseil insulaire avait toutefois la possibilité de décréter l'instauration d'un *ra'ui* partiel (système traditionnel de gestion communautaire de la pêche) pour le perroquet. Les habitants de l'île étant tributaires de la pêche de poissons et d'invertébrés pour assurer leur subsistance et tirer des revenus, le Conseil insulaire s'est déclaré préoccupé par l'avenir de la pêche du perroquet, compte tenu de la pression de pêche exercée actuellement sur cette espèce.

*Données socioéconomiques : Palmerston*

La communauté de Palmerston est en grande partie tributaire de ses ressources récifales et lagonaires. Elle n'a pas d'autre source de revenus sur cet atoll isolé, au potentiel agricole limité. C'est ce qui ressort du calcul de la consommation de poisson frais (environ 110 kg/habitant/an). Le coût de la vie à Palmerston est élevé, tous les produits étant importés de Rarotonga par bateau, et tous les produits alimentaires périssables nécessitant des congélateurs. Palmerston s'est toutefois modernisé, comme en témoigne l'évolution de l'alimentation, de l'éducation, des revenus et du mode de vie. En comparant les données recueillies à l'occasion d'une enquête menée en 1988 et de l'enquête CoFish de 2007, on constate que la population a reculé de 140 habitants (fin des années 80/début des années 90) à 66 (en 1996) et 56 (en 2007), et que le nombre total de bateaux à moteur a diminué de 24 bateaux déclarés (en 1988) à 15 bateaux recensés en 2007 (9 à moteur, 6 sans moteur).

La pression liée à la pêche vivrière de poisson est négligeable en raison de la taille réduite de la population. En revanche, les exportations à des fins commerciales ou autres vers Rarotonga et ailleurs ont une incidence considérable sur les stocks. Les invertébrés, eux, sont très peu ciblés, consommés, commercialisés ou exportés à des fins non commerciales. La pêche du *paua* (*Tridacna maxima*) à des fins d'exportation est actuellement interdite. Dans l'ensemble, la pression liée à la pêche vivrière d'invertébrés est faible.

*Ressources en poissons : Palmerston*

En règle générale, les ressources en poissons de Palmerston présentent des densités modérées à faibles. Ceci s'explique par la topographie du site, particulièrement isolé et relativement pauvre en coraux vivants. Les valeurs enregistrées en matière de densité et de biomasse de poissons destinés à la consommation sont les plus faibles des quatre sites étudiés. Une forte variabilité spatiale a été observée à l'échelon des habitats récifaux. Comparés à d'autres habitats, les récifs intermédiaires (seulement 1 % de la zone récifale totale) affichent les valeurs les plus élevées en ce qui concerne la biomasse, la taille moyenne et le rapport de tailles des poissons. Les arrière-récifs de Palmerston (75% de la zone récifale totale) enregistrent des valeurs très basses en matière de densité, de taille des poissons, de biomasse et de biodiversité, ce qui les place en dernière place des sites étudiés aux Îles Cook et des arrière-récifs étudiés, tous pays confondus. L'état des tombants récifaux externes se situe à un niveau intermédiaire pour ce qui est de la taille et de la biomasse des poissons, mais l'on y enregistre les valeurs les plus élevées en matière de densité et de biodiversité. Les tombants récifaux externes sont les mieux préservés des trois milieux étudiés : la couverture de coraux vivants est étendue et les espèces de poissons variées, bien que moins diversifiées que sur les autres sites étudiés. On constate une pêche intensive du perroquet, consommé par la population (consommation élevée de poisson frais) ou exporté vers Rarotonga (75 % des prises) pour y être vendu ou distribué à des proches. La pêche du perroquet s'est intensifiée au cours des 20 dernières années en raison de changements majeurs intervenus dans les techniques de pêche et de conservation (emploi de filets maillants, nombre accru de bateaux à moteur, accès plus facile aux congélateurs)

Dans l'ensemble, les densités de poissons relevées à Palmerston sont modérées à faibles. Le bon état des récifs intermédiaires est sans rapport avec l'état des tombants récifaux externes et des arrière-récifs, où les valeurs enregistrées en matière de densité, de biomasse, de biodiversité et de taille des poissons sont assez basses par rapport aux autres sites du pays et à la moyenne régionale. La prédominance des Acanthuridae et des Scaridae peut s'expliquer par le type de milieu, caractérisé par des fonds durs, notamment sur les tombants récifaux externes. L'absence relative de carnivores, et plus particulièrement de Serranidae, est vraisemblablement due à la topographie du site. Au vu de l'état actuel des ressources, seule la pêche vivrière paraît durable. La pression halieutique engendrée par l'augmentation des exportations de poisson est lourde de conséquences. Certaines espèces de perroquet présentent des signes de surexploitation, comme en témoigne le déclin des individus de taille moyenne.

*Ressources en invertébrés : Palmerston*

Palmerston présente une large gamme d'habitats récifaux de faible profondeur et un hydrodynamisme important en plusieurs endroits du récif-barrière, autant de conditions propices aux bénitiers. On enregistre la présence de *Tridacna maxima* et *T. squamosa* dans le cadre des enquêtes générales. S'agissant de *T. squamosa*, seul un individu a été recensé sur le tombant récifal externe et l'espèce est menacée d'extinction à Palmerston. *T. maxima*, de plus petite taille, affiche une présence assez forte (toutes les stations RBt signalent sa présence à une densité variant de 41,7 à 1 708,3 individus par hectare). *T. maxima* présente une gamme « complète » de classes de taille, puisqu'on observe des jeunes bénitiers, signe indicateur d'une bonne qualité de reproduction et de recrutement. Cependant, les bénitiers de grande taille sont peu abondants, ce qui tend à conforter l'hypothèse selon laquelle les stocks sont affectés par la pêche.

Le milieu récifal, composé de vastes récifs plate-formes exposés et de zones lagonaires et récifales étendues, offre des conditions propices aux trocas juvéniles et adultes (*Trochus niloticus*). Il n'en reste pas moins que les trocas sont assez peu abondants à Palmerston, après qu'un moratoire sur la pêche commerciale du troca a été imposé, dix années durant environ, suite au prélèvement d'environ une tonne et demie de trocas (~3 500–4 200 individus), soit probablement l'essentiel du stock vivant à Palmerston. Des rapports font état de la réinstallation de plus de 3 000 trocas d'Aitutaki à Palmerston, dans les années 1980. Pour l'heure, compte tenu des données historiques disponibles et du mauvais état des stocks, le potentiel de développement d'une pêcherie commerciale de trocas est négligeable. L'huître perlière à lèvres noires, *Pinctada margaritifera*, est assez peu commune à Palmerston, malgré le caractère enclavé de l'atoll.

Palmerston présente une grande diversité de milieux favorables aux holothuries. Toutefois, l'atoll subit essentiellement des influences océaniques et abrite une gamme limitée d'espèces d'holothuries. Les espèces de valeur commerciale moyenne, telles que l'holothurie léopard (*Bohadschia argus*) ou les espèces de grande valeur, particulièrement prisées des pêcheurs, telles que l'holothurie noire à mamelles (*Holothuria nobilis*), sont rares et présentes en faible densité. D'autres espèces, telles que l'holothurie blanche à mamelles (*H. fuscogilva*), très recherchée, ont été observées en eaux profondes, mais les stocks sont également en mauvais état. *Stichopus chloronotus*, qui enregistre de très fortes densités et dont la répartition est dispersée dans l'ensemble du lagon, fait figure d'exception. Il ressort des enquêtes à grande échelle, qui englobent divers habitats favorables et non favorables, que sa densité se situe à un niveau élevé (857 individus par hectare). L'holothurie de brisants (*Actinopyga mauritiana*) n'affiche pas une densité suffisante pour être intéressante au plan commercial. Il apparaît néanmoins que certaines zones pourraient servir à son exploitation à petite échelle. *H. atra* est répandue dans le lagon mais l'exploitation de cette espèce à faible valeur commerciale ne serait peut-être pas économiquement viable à l'heure actuelle. *H. leucospilota* est commune et facile à trouver.

*Recommandations pour Palmerston*

- Il convient de mettre en œuvre des mesures de gestion de la pêche visant à ce que les ressources, notamment en perroquets, reviennent à leur niveau antérieur et qu'elles s'y maintiennent de manière à pouvoir être exploitées durablement à l'avenir. Il serait peut-être plus constructif de mettre l'accent sur la reconstitution des ressources et leur exploitation durable, étant donné que les perspectives de recours à des solutions de remplacement, telles que l'aquaculture (p.ex. la perliculture), semblent assez limitées.

- Compte tenu de la situation sociale particulière des habitants de Palmerston, le seul moyen d'élaborer et de mettre en œuvre un plan de gestion de la pêche efficace consisterait à développer une collaboration étroite entre la population et le Ministère des ressources marines d'un bout à l'autre du processus, en veillant plus particulièrement à ce que les habitants de Palmerston se l'approprient.

- Pour gérer au mieux les stocks de bénitiers, il faut augmenter et maintenir à un niveau de densité stable les populations, lesquelles doivent comprendre des individus de grande taille afin d'assurer un niveau de reproduction suffisant pour renouveler les stocks.

- Il y a lieu d'interrompre l'exploitation de *T. squamosa* pour permettre aux stocks de se renouveler, car cette espèce est actuellement si peu présente qu'elle est considérée comme menacée d'extinction à Palmerston.

- Si possible, il serait recommandé d'introduire des stocks de trocas géniteurs à Palmerston et de les installer par petits groupes de 20 à 30 individus en divers endroits sur la partie nord du récif barrière et sur la pente orientale du récif. Ainsi, il est à espérer que les stocks pourront se renouveler jusqu'à atteindre un niveau permettant leur exploitation à moyen terme.

***Résultats des travaux de terrain à Mangaia***

Mangaia est une île corallienne surélevée, entourée d'une fine barrière récifale, qui est située par 21°54'30" de latitude sud et 157°59'40" de longitude ouest. De toutes les îles du groupe, il s'agit de l'île située le plus au sud, à 200 km environ au sud-est de Rarotonga. Mangaia, qui est une île calcaire haute, ne présente qu'un seul type de récif, à savoir un récif frangeant extérieur, qui s'étend sur son pourtour. Mangaia compte trois principaux villages : Ivurua sur la côte est, Tamarua sur la côte sud, et Oneroa, qui héberge le centre administratif, au nord-ouest de l'île.

*Données socioéconomiques : Mangaia*

La population de Mangaia est en grande partie tributaire de ses ressources récifales et lagonaires pour ses apports en protéines, auxquelles viennent s'ajouter les produits issus de l'agriculture vivrière. Une large autosuffisance alimentaire est nécessaire en raison des possibilités limitées de génération de revenus. Le coût de la vie à Mangaia est élevé, tous les produits étant importés de Rarotonga par bateau. La forte dépendance de la population à l'égard des ressources marines est illustrée par le calcul de la consommation de poisson frais (environ 66 kg/habitant/an) et d'invertébrés (7,5 kg/habitant/an). Mangaia s'est toutefois modernisée, comme en témoigne l'évolution de l'alimentation, de l'éducation, des revenus et du mode de vie. La consommation de poisson en conserve est relativement élevée (15 kg/habitant/an), et les habitants de Mangaia ont désormais accès à l'eau et à l'électricité (produite par une centrale électrique). Ils disposent également d'une installation frigorifique, d'établissements scolaires et d'infrastructures médicales. Nombreux sont les jeunes qui choisissent néanmoins de s'installer à Rarotonga ou ailleurs pour y suivre des études ou trouver du travail.

Il existe peu d'activités rémunératrices à Mangaia et les postes dans la fonction publique, réservés aux personnes ayant un niveau d'éducation élevé, sont en nombre limité. L'infrastructure commerciale qui permettrait d'assurer le transport des marchandises vers le marché de Rarotonga ou d'autres marchés est inexistante. Par ailleurs, les ressources récifales et lagonaires ne sont pas suffisantes pour permettre une augmentation de l'activité halieutique et doivent donc être préservées en vue de leur exploitation ultérieure. L'insuffisance des transports et des infrastructures commerciales peut contribuer à la préservation des ressources halieutiques dont la population de Mangaia est tributaire pour sa subsistance.

*Ressources en poissons : Mangaia*

Les ressources en poissons semblent en assez mauvais état. Le tombant récifal externe, seul type d'habitat à Mangaia, est naturellement pauvre en ressources. De plus, il est exposé au vent et au risque d'érosion lié à la présence d'oursins. Le substrat est majoritairement composé de fonds durs et dénudés. Les coraux vivants sont quasi-absents, en particulier sur la partie ouest de l'île. La communauté de poissons est homogène dans l'ensemble et composée presque exclusivement d'Acanthuridae. La prédominance des herbivores, notamment des Acanthuridae, s'explique en partie par la nature du substrat, constitué pour l'essentiel de fonds durs, ce qui limite la diversité des lieux où les poissons peuvent trouver refuge. Dans l'ensemble, la densité et la diversité des poissons enregistrent des valeurs faibles, en particulier à l'ouest de l'île, dans les zones accessibles aux pêcheurs munis de fusils-harpons. La pêche à la palangrotte est la plus pratiquée (par des profondeurs de 60 à 100 mètres). Sont également pratiquées la pêche au fusil-harpon et la pêche au filet maillant, y compris de nuit. Pour l'heure, l'état des stocks ne permet pas d'augmenter la pêche commerciale tout en assurant la gestion durable des ressources, l'incidence de la consommation de poisson par la population se faisant d'ores et déjà sentir.

*Ressources en invertébrés : Mangaia*

À Mangaia, la diversité des habitats propices aux bénitiers est limitée par les récifs plate-formes situés en eaux peu profondes et par l'hydrodynamisme observé sur le front récifal. Seuls deux espèces de bénitiers, *Tridacna maxima* et *T. squamosa,* ont été recensées. *T. maxima* est communément répandu sur le récif plate-forme et réparti de façon clairsemée sur la pente du récif, où l'on note également la présence de bénitiers de taille et d'âge supérieures. *T. squamosa* a été enregistré à faible densité sur la pente du récif et le stock risque de diminuer au point de compromettre la reproduction et le renouvellement des populations. Les stocks de bénitiers sont affectés par la pêche, la pression halieutique exercée par les personnes ramassant les bénitiers sur les récifs plate-formes étant particulièrement élevée. *T. maxima* affiche une densité assez élevée sur le récif plate-forme, ce qui peut s'expliquer par la présence de bénitiers « reproducteurs » de plus grande taille sur la pente du récif. Il est important de protéger ce stock de reproducteurs afin de conserver une source de gamètes assurant l'avenir des futures générations de bénitiers.

Les récifs de Mangaia offrent un habitat adapté mais limité aux trocas (*Trochus niloticus*), adultes ou juvéniles. À l'heure actuelle, le stock de trocas n'est pas exploitable à des fins commerciales, mais on note la présence sur la pente externe d'un petit stock de reproducteurs, composé d'individus de taille et d'âge supérieures. Les trocas sont rares en raison d'un ramassage excessif. La plupart des individus nécessaires au recrutement sont pêchés avant même d'atteindre leur taille de maturité.

Compte tenu de la faible étendue du récif plate-forme frangeant et de la présence d'une pente récifale abrupte exposée à la houle, Mangaia n'offre des conditions propices qu'à un nombre limité d'espèces d'holothuries. Seules six espèces commerciales ont été recensées, ce qui témoigne des limites imposées par le milieu. On note également la présence de deux espèces ciblées par la pêche vivrière : *Holothuria cinerescens* et *H. pervicax.* Les données de présence et de densité semblent indiquer que les holothuries ne sont pas soumises à une pression halieutique importante. Même les espèces récoltées à des fins de subsistance ne sont pas particulièrement affectées par la pêche. L'holothurie de brisant (*Actinopyga mauritiana*) et l'holothurie ananas (*Thelenota ananas*) sont assez abondantes et les stocks peuvent être suffisants pour permettre des récoltes périodiques à des fins commerciales, pour autant que l'exploitation se situe à un faible niveau d'intensité (p.ex. pêche intensive ponctuelle).

*Recommandations pour Mangaia*

- Il faut examiner les possibilités liées à l'écotourisme, qui pourrait être la solution la mieux adaptée au développement économique de Mangaia.

- Le Ministère des ressources marines doit s'attacher, en collaboration avec la population de Mangaia, à élaborer un plan de gestion conjoint, auquel seront associées toutes les familles de l'île. Ce plan visera notamment à résoudre les litiges fonciers et à prévoir, le cas échéant, des mesures de gestion communautaire des ressources halieutiques.

- Il faut prendre des mesures de gestion strictes afin de protéger le recrutement des bénitiers et des trocas, notamment en interdisant la pêche des bénitiers de grande taille en eaux profondes.

- Il convient d'envisager l'aménagement de zones interdites à la pêche sur le récif plate-forme, et la mise en place de conditions favorisant le recrutement des bénitiers et des trocas.

- Les stocks d'holothuries de brisant (*Actinopyga mauritiana*) et d'holothuries ananas (*Thelenota ananas*) peuvent être suffisants pour permettre des récoltes périodiques à des fins commerciales, pour autant que l'exploitation se situe à un faible niveau d'intensité. Afin d'en contrôler les modalités, le Ministère des ressources marines peut envisager d'adopter une stratégie en faveur de la pêche intensive ponctuelle. La pêche d'holothuries serait ainsi autorisée pendant quelques jours et jusqu'à une certaine limite. S'ensuivrait une période d'interdiction de la pêche, dont la durée permettrait aux stocks de se reconstituer.

***Résultats des travaux de terrain à Rarotonga***

L'île de Rarotonga, capitale des Îles Cook, est une île haute située par 21°14'30" de latitude sud et 159°46'33" de longitude ouest. Avec une superficie de 67 $km^2$, Rarotonga est l'île la plus vaste des Îles Cook. Elle culmine à 653 m. De forme ovale, Rarotonga s'étend sur 11 km de long d'est en ouest, pour une largeur maximale de 8 km du nord au sud. Le récif frangeant borde le lagon, vaste et sableux au sud, étroit et rocheux au nord et à l'est. Le lagon entourant Rarotonga est peu étendu (8 $km^2$) et souvent peu profond. Les ressources marines ont été fortement affectées par les campagnes de pêche et d'autres activités humaines (pollution, érosion des sols et ruissellements d'origine agricole liés à la culture et à l'élevage). Nombre de poissons de récif sont aujourd'hui considérés comme étant ciguatoxiques, ce qui a entraîné une évolution des activités de subsistance. Un *ra'ui* (système traditionnel de gestion communautaire de la pêche) a été mis en place dans les années 2000 afin de protéger les ressources marines de Rarotonga.

*Données socioéconomiques : Rarotonga*

À l'heure actuelle, la population de Rarotonga est moins tributaire des ressources récifales et lagonaires que les autres communautés du pays. Le niveau et le coût de la vie sont élevés. Les salaires ainsi que les retraites et les allocations sociales constituent les principales sources de revenus. Aucun des ménages interrogés n'a cité la pêche comme source de revenus. Les habitants de Rarotonga consomment du poisson frais et d'autres produits de la mer deux fois par semaine en moyenne. L'insuffisance du poisson frais et les prix élevés justifient peut-être que la consommation de poisson frais (~32 kg/habitant/an) soit bien inférieure à celle observée sur les autres sites (~52 kg/habitant/an). Par ailleurs, la consommation d'invertébrés est extrêmement faible (1,4 kg/habitant/an), tandis que la consommation de poisson en conserve (~11 kg/habitant/an) avoisine la moyenne relevée sur les autres sites (~13 kg/habitant/an). La diminution de la consommation de poisson frais (et sans doute également celle d'invertébrés) peut s'expliquer par la détérioration de la qualité des eaux lagonaires (et l'augmentation connexe du risque d'intoxication ciguatérique), les coûts élevés et, peut-être, l'adoption d'un mode de vie de type urbain.

*Ressources en poissons : Rarotonga*

La plupart des poissons de récif autour de Rarotonga sont porteurs de ciguatoxines, et ne sont donc ni consommés, ni pêchés. La zone la plus touchée s'étend à l'est et au sud-est de l'île. La densité et la biomasse des poissons y enregistrent des valeurs plus élevées que sur d'autres sites comparables, à l'exception d'Aitutaki. On note cependant une biodiversité particulièrement faible sur les arrière-récifs et les tombants récifaux externes, le substrat récifal étant naturellement pauvre (dalles coralliennes présentant très peu de corail vivant).

Les ressources en poissons de Rarotonga semblent globalement en bon état. L'habitat récifal est très limité sur le tombant récifal externe. On y observe essentiellement des chirurgiens (Acanthuridae), particulièrement abondants. L'arrière-récif se porte légèrement mieux et abrite des concentrations plus importantes de poissons. La diversité des espèces est néanmoins faible. La structure trophique est pour l'essentiel composée d'herbivores, mais les carnivores sont plus présents dans les arrière-récifs, caractérisés par des fonds meubles et l'abondance de Mullidae.

Les cas d'intoxication ciguatérique ont augmenté au cours des dix dernières années. La pêche se limite désormais à certaines espèces, uniquement destinées à la consommation personnelle. Ces facteurs expliquent les valeurs assez élevées enregistrées en termes d'abondance et de biomasse de poissons, assez importantes sur ce site, et le fait que la pression halieutique et l'impact de la pêche soient faibles.

*Ressources en invertébrés : Rarotonga*

Rarotonga présente une large gamme d'habitats récifaux et un bon hydrodynamisme, autant de conditions convenant aux bénitiers. On enregistre une seule espèce de bénitier (*Tridacna maxima*). *T. squamosa*, dont la présence a été observée sur les autres sites du projet CoFish aux Îles Cook, est absent et peut-être considéré comme une espèce disparue d'un point de vue commercial[5] à Rarotonga. De manière générale, on constate que les bénitiers sont affectés par

[5] L'expression « espèce disparue d'un point de vue commercial » renvoie à une rareté de l'espèce telle que les prélèvements ne suffiraient pas à satisfaire une pêche de rente ou de subsistance, bien que l'espèce soit toujours présente à très faible densité.

la pêche, comme en témoigne la prédominance des individus de petite taille sur le récif plate-forme et l'absence d'individus de grande taille sur la pente récifale. En dépit d'une forte pression halieutique, le recrutement se poursuit et les bénitiers affichent une densité raisonnable par endroits. Il n'en reste pas moins que la taille moyenne des bénitiers reste petite et que la poursuite des activités de pêche au niveau d'intensité actuel, sans protection d'une partie des ressources et sans constitution de stocks reproducteurs, compromettrait la viabilité de la filière et risquerait d'aboutir à un déclin rapide des stocks à moyen terme.

L'arrière-récif, les récifs plate-formes et la pente récifale de Rarotonga offrent un benthos étendu et favorable au troca d'intérêt commercial (*Trochus niloticus*). Les trocas sont répandus sur de nombreux récifs faciles d'accès et de faible profondeur, au niveau de la vaste plate-forme du récif barrière. Les plus fortes concentrations de trocas ont été observées le long du récif plate-forme, au nord ouest, et, dans une moindre mesure, le long de la pente récifale. Les trocas sont peu nombreux dans la zone de déferlement de la pente récifale (entre 0 et 10 m de profondeur) mais assez abondants à partir de 10 m de profondeur. Des trocas vivants ont même été recensés à 30 m de profondeur. On note une abondance satisfaisante d'individus de taille commercialisable et un nombre tout à fait honorable de géniteurs. S'agissant de l'huître perlière à lèvres noires (*Pinctada margaritifera*), les perspectives commerciales à Rarotonga sont inexistantes. Aucun burgau (*Tectus pyramis*) n'a été observé.

Rarotonga est une île vaste et haute, entourée d'un large éventail d'environnements marins. Les zones récifales côtières abritées sont néanmoins peu étendues. Le récif, largement exposé, convient à une gamme restreinte d'holothuries. Les données relatives à leur présence et à leur densité, recueillies dans le cadre de l'enquête, indiquent que la pression exercée sur les stocks est modérée. Il est néanmoins possible que les campagnes de pêche antérieures aient abouti à la disparition de certaines espèces. D'une manière générale, les espèces d'holothuries prélevées à des fins de subsistance n'ont pas été affectées.

*Recommandations pour Rarotonga*

- Il faut protéger certaines zones de prédilection des bénitiers situées sur le récif plate-forme et créer des réserves interdites aux pêcheurs en eaux plus profondes, ce qui permettra de préserver de fortes densités de populations et de gérer au mieux les stocks de bénitiers.

- Dans l'éventualité où il serait possible d'installer une petite quantité de *T. squamosa* à proximité de la pente récifale, il serait opportun de mettre en œuvre un plan de reconstitution des stocks. On peut envisager de déplacer et de concentrer un certain nombre d'individus dans des zones protégées afin de favoriser la reproduction ou de les utiliser dans le cadre de l'élevage de juvéniles en écloserie.

- En ce qui concerne les trocas (*Trochus niloticus*), tout plan de pêche devrait dorénavant envisager la possibilité de relever la limite de taille maximale, ce qui permettra de prélever ou de vendre des trocas adultes sur les marchés ou à d'autres communautés qui chercheraient à redynamiser le secteur des pêches récifales en introduisant des géniteurs ou en augmentant le stock existant.

- Les stocks d'holothuries scissipares (*Stichopus chloronotus*) et ceux de *Holothuria atra*, *Actinopyga mauritiana* et *Thelenota ananas* peuvent offrir des perspectives commerciales limitées, pour autant que le Ministère des ressources marines en autorise et contrôle la pêche pendant de courtes périodes (quelques jours), espacées entre elles de longues périodes (quelques années) durant lesquelles les populations ne pourront être pêchées et auront la possibilité de se reconstituer.

## ACRONYMS

| | |
|---|---|
| ACIAR | Australian Centre for International Agricultural Research |
| 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) |
| CIDDP | Cook Island Department of Development and Planning |
| CIMMR | Cook Island Ministry of Marine Resources |
| CIMOPED | Cook Island Ministry of Planning and Economic Development |
| CIMRIS | Cook Islands Marine Resource Institutional Strengthening |
| 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 |
| GDP | gross domestic product |
| GIS | Geographic Information Systems |
| GPS | global positioning system |
| GRT | gross registered tonnage |
| ha | hectare |
| HH | household |
| ITQ | Individual Transferable Quotas |
| JCU | James Cook University |
| JICA | Japan's International Cooperation Agency |
| MCRMP | Millennium Coral Reef Mapping Project |
| MIRAB | Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations) |
| MMR | Ministry of Marine Resources |
| MOP | mother-of-pearl |
| MOPt | mother-of-pearl transect |

| | |
|---|---|
| MPA | marine protected area |
| MRM | marine resource management |
| MSA | medium-scale approach |
| MSY | maximum sustainable yield |
| NASA | National Aeronautics and Space Administration (USA) |
| NCA | nongeniculate coralline algae |
| Ns | night search |
| NZAID | New Zealand Agency for International Development |
| NZD | New Zealand dollar(s) |
| OCT | Overseas Countries and Territories |
| PICTs | Pacific Island countries and territories |
| PROCFish | Pacific Regional Oceanic and Coastal Fisheries Development programme |
| PROCFish/C | Pacific Regional Oceanic and Coastal Fisheries Development programme (coastal component) |
| RBt | reef-benthos transect |
| RFID | Reef Fisheries Integrated Database |
| RFs | reef-front search |
| RFs_w | reef-front search: walking |
| RoN | Republic of Nauru |
| SBq | soft-benthos quadrat |
| SCUBA | self-contained underwater breathing apparatus |
| SE | standard error |
| SO | southern oscillation |
| SOPAC | Pacific Islands Applied Geoscience Commission |
| SPC | Secretariat of the Pacific Community |
| 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 Programme (PROCFish); and
2. The Coastal Fisheries Development Programme (CoFish)

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

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

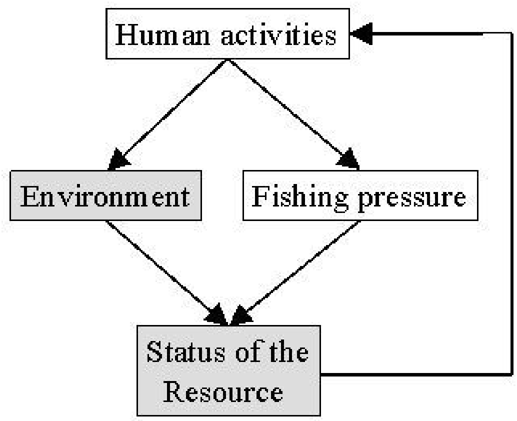



**Figure 1.1: Synopsis of the CoFish* multidisciplinary approach.**
CoFIsh conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the basis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

Expected outputs of the project include:

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

## 1.2 PROCFish/C and CoFish methodologies

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

### *1.2.1 Socioeconomic assessment*

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

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

Socioeconomic assessments also relied on additional complementary data, including:

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

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

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

### *1.2.2 Finfish resource assessment*

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

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

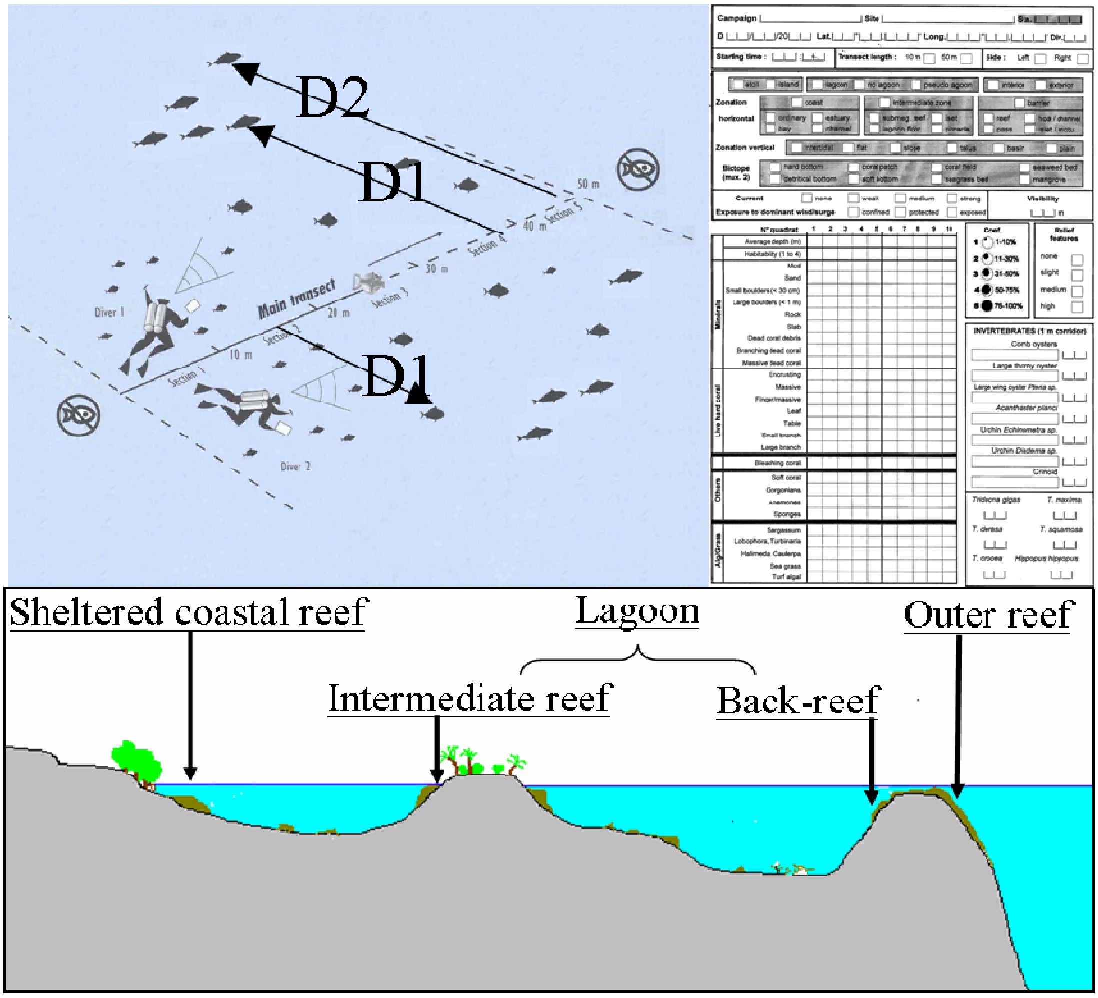



**Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).**
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

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

### *1.2.3 Invertebrate resource assessment*

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

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

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

The main objective of the broad-scale assessment was to describe the large-scale distribution pattern of invertebrates (i.e. their relative rarity and patchiness) and, importantly, to identify target areas for further fine-scale assessment. Broad-scale assessments were used to record large sedentary invertebrates; transects were 300 m long × 2 m wide, across inshore, midshore and more exposed oceanic habitats (See Figure 1.3 (1).).[6]

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.).

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

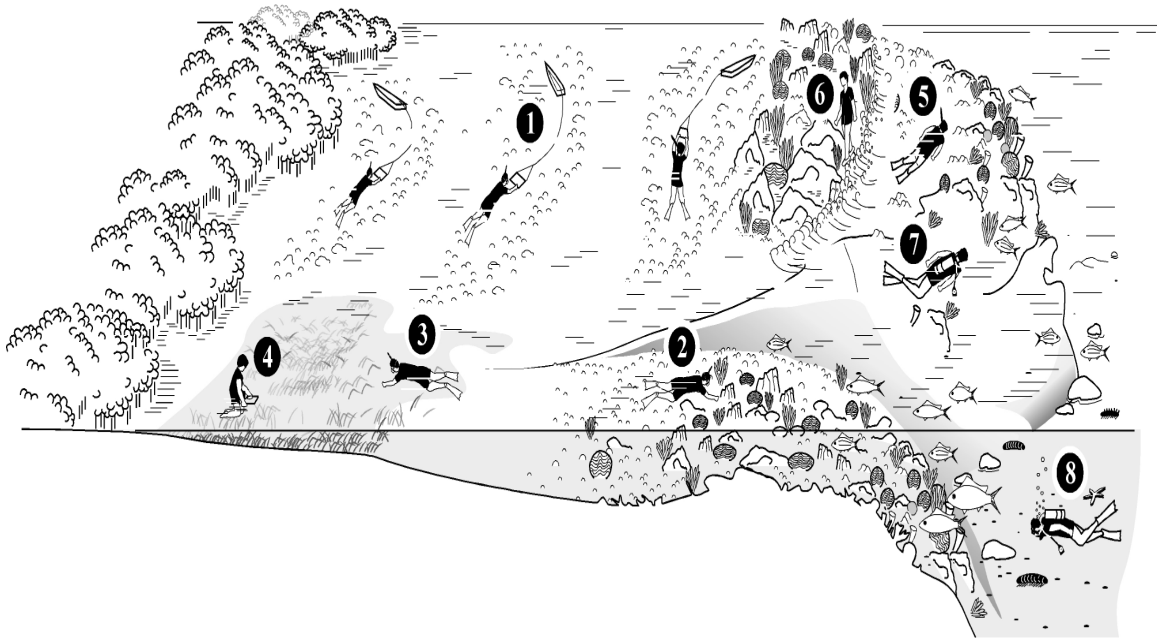



**Figure 1.3: Assessment of invertebrate resources and associated environments.**
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted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

### *1.3.1 General*

Cook Islands lies between 8° and 23°S latitude and 156° to 167°W longitude (Turner 2007). The neighbouring countries are Niue, Tokelau and American Samoa to the west, French Polynesia to the southeast, and Kiribati to the northeast (Figure 1.4). Cook Islands is made up of 15 islands, a southern group of eight islands and a northern group of seven islands over 1000 km to the north. The southern Cook Islands are Rarotonga (the capital), Aitutaki, Atiu, Mangaia, Mauke, Mitiaro, Manuae and Takutea. These islands are primarily high volcanic islands with lush vegetation. Mauke, Mitiaro, Mangaia, and Atiu are raised islands with encircling reef platforms adjacent to the coast. Aitutaki is part volcanic island and part atoll, with an enclosed lagoon, while Rarotonga is a volcanic island with a narrow fringing reef (CIMMR 2001). The northern Cook Islands include Pukapuka, Tongareva (also known as Penrhyn), Manihiki, Palmerston, Rakahanga, Suwarrow and Nassau. These islands, and Manuae in the south, are (with the exception of Nassau, a sandy cay), all low lying coral atolls with coconut trees being the primary vegetation (Liew 1980). With the passing of the 1977 Territorial Sea and Exclusive Economic Zone (EEZ) Act, jurisdiction was assumed over 1.83 million km$^2$ of ocean. In contrast, the total land area of Cook Islands is only 237 km$^2$ or 0.01% of the sea area (CIDDP 1984; Lewis 1986).

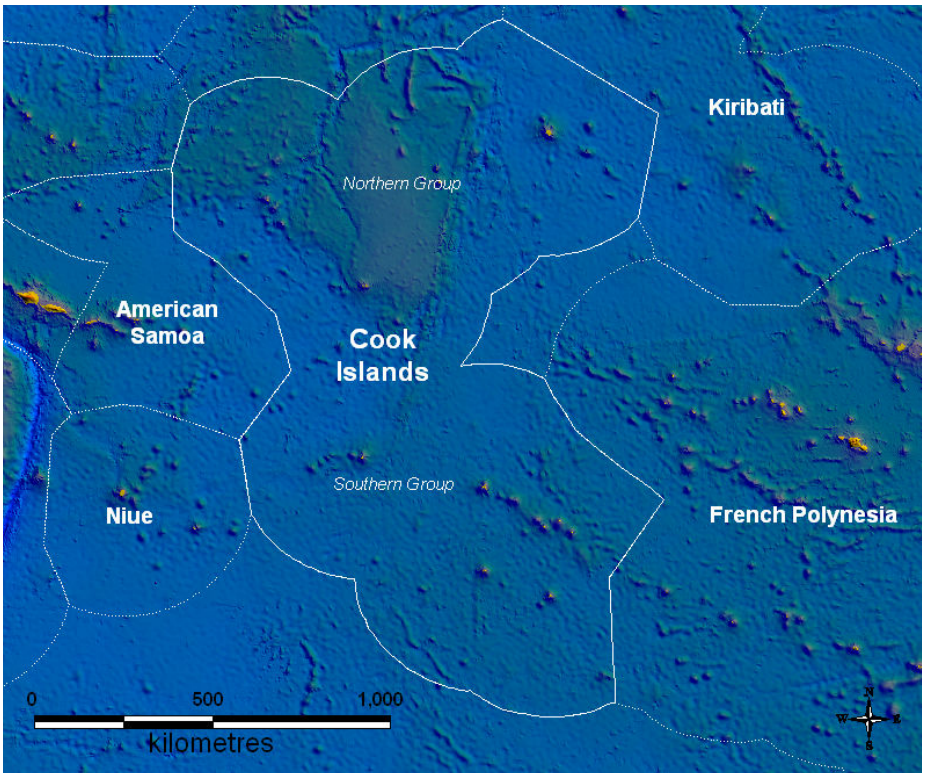



**Figure 1.4: Map of Cook Islands.**

Cook Islands has a tropical oceanic climate with two seasons. The drier months, from April to November, have an average maximum temperature of about 26°C and an average minimum temperature of about 20°C. The wetter, more humid months, from December to March, have an average maximum temperature of 28°C and an average minimum of 22°C. During the latter season, Cook Islands can experience occasionally severe tropical storms and even hurricanes (Cook Islands Government 2008). The mean annual temperature in Rarotonga is 24°C and the average annual rainfall is 2,030 mm (Liew 1980, Smith 1993).

From the turn of the century until 1971, the population of Cook Islands showed a steady growth. From 1971 to 1976 population figures dropped with the steady exodus of Cook Islanders to New Zealand in search of employment opportunities. This decline continues today and is most marked in the outer islands where the people move to Rarotonga or overseas. The 2006 census provisional figures give a total population of 19,569 with an increase of 8.6% from the 2001 figures (Cook Islands Statistics Office 2007). The northern group atolls show a 24.2% decline since 2001, while the southern group islands show a 0.5% increase. Note that these general figures can be deceiving. In the southern group, Mangaia's population declined by 12.1% (744 to 644 people). The southern islands that have increased in population are Palmerston 31.3% (48 to 63 people), Rarotonga 16.1% (12,188 to 14,153 people) and Aitutaki 12.7% (1946 to 2194 people). Of the total population, 72.3% reside in Rarotonga, while 20.6% live in the rest of the southern group islands, and 7.1% live in the northern group atolls. The group's average density is 83 inhabitants/km$^2$ (Cook Islands Statistics Office 2007).

Since 1965, constitutionally Cook Islands is a self-governing state in free association with New Zealand. The government is based on the Westminster parliamentary system with lower levels of government comprising the island, district and village councils. In addition, there is the House of Ariki and the Koutu Nui, an assembly of hereditary traditional leaders representing all inhabited islands, which meets to advise the government on matters of land use and traditional custom. Although Cook Islands is fully responsible for internal affairs, New Zealand retains responsibility for external affairs and defence, in consultation with Cook Islands. Cook Islanders are citizens of both Cook Islands and New Zealand (Commission for Political Review 1998, FAO 2008).

The leading producers of income within Cook Islands are tourism, fishing, agriculture and financial services (offshore banking). Approximately 50,000 tourists visit Cook Islands each year, bringing revenues of over NZD 33.5 million (CIMMR 2001). Exports, worth NZD 5.22 million in 2005, were copra, papaya, fresh and canned citrus fruit, coffee, fish, pearls and pearl shells, and clothing. The main export partners in 2006 were Australia (34%), Japan (27%), New Zealand (25%), and the United States (8%). Imports worth NZD 81.04 million in 2005 were dominated by foodstuffs, textiles, fuels, timber and capital goods. The main import partners in 2006 were New Zealand (61%), Fiji (19%), the US (9%), and Australia (6%) (Central Intellogence Agency 2008). Donor aid and remittances from families working overseas provide additional financial support to the country.

According to a 1999 report, marine resources are rated as a primary economic sector, with marine products accounting for an average of 72% of total exports. Cultured black pearls are the main export earner. Other marine exports include the live ornamental fish trade, mother-of-pearl shell (which includes trochus) and the fresh fish trade. A relatively modest amount of revenue is received on behalf of the crown for licensing offshore fishing. Closer to shore, the small local fishing industry trades mainly pelagic fish almost exclusively on the domestic market. In addition, marine resources are a fundamental source of food. Subsistence fishing (ranging from reef gleaning to near-shore fishing) is practised widely throughout Cook Islands. In a 1996 national census it was reported that 67% of households engaged in this activity (Anon. 1999).

### *1.3.2 The fisheries sector*

Since 1982, fisheries development in Cook Islands has been classified into three main areas. The first area is subsistence fishing comprising shellfish and seaweed harvesting, reef fishing and netting, spear fishing, handlining for reef fish, trolling, and drop lining for tuna from small boats. The second area is lagoon fisheries comprising mainly trochus, pearls and pearl shell development, and giant clams. The third area is commercial fishing, subdivided into artisanal and industrial fisheries (CIDDP 1984, CIMOPED 1988).

#### *Offshore fisheries*

Traditionally, Cook Island fishers have fished outside the reef for a range of pelagic species using different small-scale fishing techniques for different species. More recently, medium-scale tuna fishing activities have commenced with some fishers also catching deep-water snappers from time to time.

*Offshore tuna fishery*

The involvement of Cook Islanders in the offshore tuna fishery, specifically tuna longlining, is fairly recent, although trials were undertaken in 1966 by a New Zealand vessel that landed 25 mt of fish before the vessel was lost in a cyclone (Hinds 1970). In 1970 a locally-constructed vessel conducted some tuna longline trials; however, the lack of suitable and affordable bait limited the longline operations of this vessel. The vessel also conducted some poling of tuna while the longline soaked, with an average of 100 skipjack poled daily (Hinds 1970). Also during this period, offshore tuna fishing was done by foreign fleets with records covering the periods 1962 to 1995 for Japanese longline vessels, 1967 to 1995 for Taiwanese vessels and 1975 to 1993 for Korean vessels (Lawson and Lewis 1996).

The SPC's Skipjack Survey and Assessment Programme conducted tagging cruises in the waters of Cook Islands with one cruise in late 1978, two cruises in 1979 and one cruise in early 1980. The first cruise focused fishing in the northern group, mainly around Penrhyn, where 1226 skipjack tuna were tagged and another 4128 retained. The second cruise was in the southern group around Rarotonga and Aitutaki, with a mere nine skipjack tagged and another 41 retained for sampling (Kearney *et al.* 1979). The third cruise was back in the northern group, where 83 skipjack were caught, but none tagged. The final cruise back in the southern group resulted in 142 skipjack caught with 39 of these tagged and released (Lawson and Kearney 1982).

Domestic tuna longline trials commenced again in 1986, from the atoll of Penrhyn in the northern Cook Islands; however the export trials were unsuccessful (Chapman 2004). It was not until the later 1980s/early 1990s that domestic longlining commenced in the southern group. The Government of Cook Islands purchased a small 8.8 m vessel from the boatyard in Tonga in 1989 and commenced longline fishing trials off the coast. In 1991, 22 fishing trips were made, with albacore being the target species. In 1992 the fishing operation ceased and the vessel was pulled out of the water (Bertram 1993). Also during 1992, a Tahitian-owned longline vessel was licensed for three months to conduct some longline trials, with 13 mt of fish caught, 5.9 mt being albacore (Bertram 1993). Two locally-based foreign longliners fished from Rarotonga under a joint venture arrangement in 1994/1995, but left soon after. Another locally-based foreign longliner fished one season (1995/1996) before departing (Mitchell 1996, Anon. 1998). In 1996, a local company was established in Rarotonga and imported a second-hand longliner from New Zealand. A second businessman purchased the government vessel and refurbished it into a small-scale longliner in 1996. Neither venture was large enough to export catch, so all catch was sold on the local market. To encourage expansion of tuna longlining in Cook Islands, SPC was requested in 1996/1997 to provide assistance to both operations. Catch rates were low at less than 40 kg per 100 hooks (Beverly and Chapman 1998).

In the late 1990s, two distinct longline fisheries developed, one in the northern group and the other in the southern group (Mitchell 2000, Chapman 2001, Sokimi and Chapman 2003). Vessels fishing in the northern group targeted albacore tuna and landed their catch in either Samoa or American Samoa (Mitchell 2000, Sokimi and Chapman 2003). The albacore were primarily sold to the cannery in American Samoa. The vessels in the southern group, mainly fished out of Rarotonga and landed fresh fish, mainly for the domestic market, although two private sector packhouses were operating in 2002 exporting part of the landed catch. In 1998/1999 there were four vessels fishing the northern group and two small longliners based in Rarotonga supplying the local market (Mitchell 2000).

In 2002/2003 there were 16 longline vessels licensed to fish in the Cook Island EEZ (Sokimi and Chapman 2003). At this time the Ministry of Marine Resources (MMR) requested technical assistance from SPC to provide some training in tuna longlining to encourage Cook Islanders to become crew on the vessels. A workshop was held in September and October 2002 with 24 participants, many from the outer islands, and this included both theory lessons and practical experience on a commercial longliner (Tatuava *et al.* 2002, Sokimi and Chapman 2003). The number of longline vessels continued to increase and in 2004 there were 46, with most of the larger vessels (>20 m) fishing the northern group (23 vessels), nine fishing the high seas and the rest fishing out of Rarotonga (Mitchell 2005). By 2006 the number of longline vessels had reduced to 30, the main reduction being in vessel numbers working out of Rarotonga (Anon. 2007).

*Small-scale tuna fishery including fishing around FADs*

Fishers in Cook Islands have a long history of fishing outside the reef from paddling and/or sailing canoes for tuna and other coastal pelagic species to meet subsistence needs (Powell 1962). The main methods used were trolling or troll-poling using pearlshell lures and mid-water handlining. During the 1950s and early 1960s, much change took place, with locally-made fibre lines being replaced by cotton, nylon and wire, palm-leaf torches replaced by lanterns, mat sails replaced by canvas and, most significantly, the introduction of outboard motors (Powell 1962). Wooden skiffs powered by outboards also started to replace the traditional outrigger canoes (Chapman 2004).

In support of developing fisheries outside the reef, the Government of Cook Islands purchased five 8.5 m boats in 1972 for the Fishermen's Cooperative Society. The Society ceased operation soon after, so the government sold the five boats to individual male fishers on hire-purchase (Marsters 1975). A 1979 census of the southern group showed 465 boats and canoes mostly fished part-time for personal consumption, selling surplus catch on the local market (Lawson and Kearney 1982).

Fish aggregating devices (FADs) were first introduced to Cook Islands in 1982, with four deployed around Rarotonga (Anon. 1984). The FADs proved to be very successful, with several lasting over 18 months, and funding was secured in 1983 for 25 devices to be deployed around all of the islands. These FADs were not as successful due to the design of the buoy system and the steep slope in some locations, with most FADs only lasting around three months (Anon. 1984). The SPC was asked to provide technical assistance to introduce new fishing methods to target the larger, deeper-swimming tuna that aggregate around the FADs. This assistance was provided in late 1985 for an eight-month period. Three fishing methods were introduced, the vertical longline, *palu-ahi* (Hawaiian mid-water handline method) and gillnets for catching suitable bait for the other two methods (Chapman and Cusack 1997). Fishing trials and training were very successful, with 4445 kg of tuna taken from around the FADs and 1264 kg of suitable bait caught in the gillnets (Chapman and Cusack 1997).

In support of continuing funding for a FAD programme, the Ministry of Marine Resources conducted a one-year creel-census of the artisanal offshore fishery to investigate the cost-benefit of FADs. The census started in August 1986, with an average coverage of 18.8% (Sims 1988a). The results were very convincing, with a 31.2% return on expenditure, especially when the FADs were only in operation for 46% of the time (Sims 1988a). In 1990, after the premature loss of several FADs off Rarotonga, SPC was asked for assistance. In late 1990, MMR staff were trained in the conducting of site surveys using a global positioning system (GPS) and deep-water echo sounder, with three suitable sites located and one FAD rigged and deployed (Desurmont 1992).

During the 1980s and 1990s an estimated 60 FADs were deployed, mainly around Rarotonga and Aitutaki, with the average price being USD 2250 per FAD. The MMR at the time claimed that FADs had been responsible for a large increase in the landings of pelagic fish species (Gillett 2002, Bertram *et al.* 1999). The FADs are also used by the local charter fishing vessels, of which there were five in Rarotonga and five in Aitutaki in 2000/2001, and over 50 recreational boats at both Rarotonga and Aitutaki (Whitelaw 2001).

In June 2001, a joint three-year project was commenced by the MMR in Cook Islands, the Department of Agriculture, Forestry and Fisheries in Niue, and SPC. The project was named 'Research into more cost effective mooring systems for fish aggregating devices (FADs) in the Pacific region as a means to limit fishing pressure on inshore marine resources'. The Cook Island component covered both Rarotonga and Aitutaki, with four and three experimental-design FADs deployed respectively in early 2002, followed by another one at each location in mid-2003, due to the failure of one mooring system (Anon. 2005). Overall, several mooring designs were proved to be effective at an average cost of NZD 3100 for shallow-water FADs (to 300 m) and NZD 4500 for deep-water FADs (to 1000 m). The cost-benefit analysis of catch and effort data collected during the project showed that at Rarotonga the recorded catch was 39 mt, worth an estimated NZD 230,300 (covering one-third of the fleet) compared to the NZD 91,000 spent on the FAD materials (Anon. 2005). The MMR continues an active FAD programme today in support of the small-scale tuna fishers around Rarotonga.

*Flying fish*

There are three species of flying fish (*maroro*) identified in Cook Islands: *Cheilopogon atrisignis*, *C. unicolor* (also called *C. antoncichi*) and *Cypselurus poecilopterus* (Gillett and Ianelli 1991). Flying fish are captured in Cook Islands for local consumption, being a highly regarded food fish and also a prime trolling bait for pelagic or reef-associated gamefish. In Rarotonga the season for flying fish is from the end of October to the end of March, while the season is shorter in Palmerston (Smith 1993). Flying fish are caught at night. In the past, coconut palm frond torches were held by male fishers on outrigger canoes to attract the fish that were then scooped up in dip nets. Since then, kerosene lamps, as well as electric torches attached to the fisher's helmet are used, and motorised boats have replaced canoes. The fishing technique is the same as is the use of scoop or dip nets. On a good night, male fishers can catch up to 400 flying fish (Preston *et al.* 1995, CIMMR 2001). It has been estimated that about 69 mt of flying fish is taken each year in Cook Islands (FAO 2008). Some gillnetting trials were undertaken in the late 1950s with good catches of flyingfish (Powell 1962); however, the method did not catch on and fishers continued with the use of outboard-powered skiffs, light attraction and scoop net.

According to Smith (1993) and Preston *et al.* (1995) there is no accurate data on flying fish distribution and abundance due to the taxonomic difficulties associated with the family Exocoetidae. Smith (1993) states that nothing is known about the status of flying fish stock in Cook Islands. Gillett and Ianelli (1991) note that flying fish have a short life span, are fast growing, and are highly fecund with a wide-ranging distribution. This indicates that overfishing to moderate catch levels observed in locally developed fisheries is unlikely.

There is no specific legislation relating to flying fish. The management of flying fish stock falls under the 1989 Marine Resources Act amended in 1990 and 1991. Under this Act, the

Island Councils are able to draft regulations to manage the marine resources of their reefs and lagoon (CIMMR 2001).

*Deep-water snapper*

Traditionally, Cook Island fishers have targeted castor oil fish and snake mackerel from outrigger canoes fishing outside the reef at night, using mid-water handlines, with Powell (1962) recording some good catches. However, bottom fishing for deep-water snappers was not encouraged in Cook Islands until 1975/1976, when the SPC's Outer Reef Fisheries Project conducted fishing trials and training at Aitutaki (Hume 1976). This was followed by further training and fishing trials by SPC at both Penrhyn and Rarotonga in 1981/1982, following a request for assistance in this area (Taumaia and Preston 1985). A third request and subsequent assistance in deep-water snapper fishing occurred off Rarotonga in 1983 (Mead 1997). Also, as part of a resource survey of Palmerston Islands, deep-water snapper trials were conducted in 1988 (Preston *et al.* 1995). Catch rates varied considerably between the different locations, with a high of 11.2 kg/line/hour at Penrhyn, to a low of 2.2 kg/line/hour at Rarotonga.

Dalzell and Preston (1992) undertook an assessment of the deep-water snapper stocks based on the fishing records of the earlier surveys. Overall the standing biomass was estimated to be around 413 mt for Cook Islands, with a maximum sustainable yield of between 41.3 and 123.8 mt/year. The deep-water snapper fishery has not become established in Cook Islands but rather it is an ad hoc fishery that fishers target when there are no tuna around. In 2003 there were two fishers in Rarotonga who fished for deep-water snappers from time to time (Chapman 2004).

***Aquaculture and mariculture***

The absence of substantial freshwater bodies means that there are no inland fisheries or freshwater aquaculture of significance in Cook Islands. However, mariculture (marine aquaculture) is now economically significant. Rapid developments in the mariculture of pearls using the blacklip pearl shell *Pinctada margaritifera* have led to the development of a black pearl industry in Cook Islands. Efforts are also being made to commercially develop milkfish (*Chanos chanos*) culture, and capture fisheries based on trochus shell (*Trochus niloticus*) (Smith 1993).

*Pearl oysters*

The pearl-shell fisheries of Manihiki and Penrhyn have been worked for over a century. It has only been since the late 1950s, however, that any serious efforts have been made to manage these fisheries. Culture trials of parau, the blacklip pearl oyster (*Pinctada margaritifera*) commenced in Manihiki around 1973. By 1988 more than 40 pearl farms had been established there, and were successfully producing both half and whole pearls. The number of farms increased rapidly thereafter and by 1990 there were 97 farms in operation. The first annual pearl auction was held in 1990 and approximately 6000 pearls were sold for USD 0.78 million. In 2000 there were about 100 pearl farms on Manihiki (about 1.5 million adult oysters being cultured) and on Penrhyn about 100 farms (200,000 oysters cultured). The MMR operates a pearl oyster hatchery on Penrhyn and is encouraging the spread of pearl farming to Palmerston, Aitutaki, and Pukapuka. MMR is mindful that pearl farming is susceptible to natural disasters and disease outbreaks. In late 1997, most of the pearl farming installations in Manihiki were destroyed or severely damaged by a cyclone which struck the island. In 2000, the black pearl industry in Manihiki was almost wiped out by a disease outbreak caused by poor farming practices. Recently the Penrhyn hatchery was upgraded and the production of spat from the facility was improved. A census and mapping of the pearl oyster farms in Manihiki was completed in early 2000 through the use of Geographic Information Systems (GIS) technology. Regular surveys of the pearl oyster stock are carried out to monitor spat collection, population density, pearl oyster growth, and water conditions. The GIS bathymetric mapping system and water-monitoring buoys are tools to help safeguard against another disease outbreak. (FAO 2008, Braley 1998, CIMMR 2001, Forstreuter 2002, Heffernan 2006).

A 'Pearl Culture and Pearl Shell Fisheries Management Plan' for Cook Islands was drafted in January/February 1990, to provide a coordinated management approach for the pearl industry. The drafting process centred on Manihiki, where the pearl culture industry is developing. The need for management was widely recognised on Manihiki, where there was a strong awareness of the limits of the pearl shell resource, and the inherent ceilings on pearl farm growth. Three areas of concern were particularly emphasised: controlling access by outsiders, minimising conflicts between farmers and between farmers and divers, and preventing the establishment of disease problems. Input was also obtained from MMR officials, pearl farmers, and other concerned parties on Rarotonga (Dashwood 1990). This plan has been updated several times over the years, with MMR in collaboration with the pearl farming community implementing a revised Pearl Management Plan in 2006 (Heffernan 2006).

Although the development and research focus has been on the blacklip pearl oyster, the lesser known *pipi*, or yellow pearl oyster (*Pinctada maculata*), is also harvested in both Manihiki and Penrhyn. This oyster is collected mainly by females, primarily for the natural pearls but also for the meat, which is consumed. The small pearls are stored in jars and used as a cash reserve. Although exact figures are difficult to obtain, jars are sold for several thousands of dollars (Passfield 1997).

*Giant clams*

There are two naturally occurring clam (*pa'ua*) species in Cook Islands: *Tridacna maxima*, which is relatively abundant, and *T. squamosa*, which is less so. Three other species were introduced to Aitutaki: *T. derasa* from Palau and, more recently in 1991, *T. gigas* and *Hippopus hippopus* from Australia (Lewis 1987).

A giant clam hatchery and quarantine facility (Araua Marine Research Station) was established on Aitutaki in 1990. The hatchery has worked with the three introduced species of giant clam as well as the two local species. According to Smith (1993), it is a positive development for the eventual re-stocking of depleted giant clam stocks and screening of introduced marine species. However, with respect to increasing the number of clams in the lagoons, the current thinking of the MMR is that the most effective way to manage existing stocks is to allow them to re-populate the lagoons naturally.

On Tongareva, falling *Tridacna* stocks due to large-scale commercial harvesting caused concern among the population. A study was conducted to suggest possible action to the Island Council. It recommended two measures: a capture size of 10 to 16 cm, and setting up reserves (*ra'ui*) for at least five years (Chambers 2007).

*Trochus*

Trochus (*Trochus niloticus*) is not indigenous to Cook Islands. Two hundred and eighty shells were introduced to Aitutaki from Fiji in 1957. Trochus densities became so great that the Island Council feared that indigenous species of Turbo (a traditional food) might be ecologically displaced, and commercial harvesting of trochus was instituted in 1981. A seeding programme was extended to the other islands in 1980/1981 using broodstock from Aitutaki. On Palmerston, trochus were initially introduced in 1973 and reseeded in 1985. From 1981 to after 2000 introduction attempts were made with varied success on Manaue, Mitiaro, Mangaia, Rarotonga, Rakahanga, Manihiki, Penrhyn, Suwarrow, Mauke, Atiu, and Takutea (Dashwood 1979, Anon. 1980, CIDDP 1984, Bertram 1995a, Tuara 1997, Ponia 2000).

Initially, the trochus population in Aitutaki was allowed to establish itself, being protected by the disinterest of local people rather than legislation. There is no written record of a monitoring programme linked to the introduction of the animals. However, following the first harvest season, surveys of the stock have been carried out on a regular basis (Tuara 1997). The Island Council, with the technical support of MMR, has introduced a system of management that includes a very limited harvesting season (generally less than one week per year), size limits (only shell between 80 and 110 mm), a quota on the overall catch (revised from year to year depending on the assessed population size, and based on a yearly take of 30% of the assessed population of shells within the size limits), a permanent reserve (at the site of original introduction) (Sims 1988b) and, latterly, a system of individual transferable quotas (allocated each year to every household on the island (Tuara 1992)). Many fishery specialists in the Pacific Islands consider the trochus fishery in Aitutaki to be the best managed fishery in the region. (Adams *et al.* 1992, Nash *et al.* 1994).

Smith (1993) noted that the 1989 Marine Resources Act and the 1990 Aitutaki Fisheries Protection By-Laws are the only two statutes which applied to the trochus fishery at the time.

*Green snail*

The introduction programme of green snail (*Turbo mamoratus*) to Cook Islands from French Polynesia began in 1981 with an initial seeding of twelve individuals on Aitutaki. In 1984 a further shipment of 22 individuals arrived, 14 were reseeded in the same location on Aitutaki, and eight were accidently seeded on Rarotonga during trans-shipment (Anon. 1984). In 1987, Lewis stated that smaller green snail shells found on Aitutaki and Rarotonga showed that they were producing successfully. However, he noted that it would be some time before commercial harvesting would be possible.

*Seaweed*

The *Kappaphyces alvarezii* variety of the *Eucheuma* commercial red seaweed was introduced to Cook Islands in 1987 from Fiji to test its potential for aquaculture production (Smith 1993). The status of *Eucheuma* stocks in Cook Islands is unknown. It is thought that none of the plants introduced into Aitutaki lagoon have survived. This species has no holdfast for anchorage and because it reproduces asexually, it does not produce spores (Tim Adams, pers. comm., cited in Smith (1993)). According to Smith (1993), there was no current legislation regarding seaweed stock.

*Freshwater prawns*

Apart from the introduced giant freshwater prawn *Macrobrachium rosenbergii*, there are six species of freshwater prawns recorded in Cook Islands: *Macrobrachium lar*, *M. latimus*, *M. australe*, *M. aemulum*, *Cardina weberi* and *Atyoida pilipes* (Kelvin Passfield, pers. comm., cited in Smith (1993)).

The giant freshwater prawn *M. rosenbergii* is not found naturally in Cook Islands. It was introduced in 1992 from French Polynesia by the MMR, for commercial farming trials on Rarotonga (Smith 1993). The first harvest was conducted in 1993. An economic analysis carried out showed an estimated annual revenue of a farm to be NZD 17,000. However the analysis showed an operating cost of feed and labour alone to be NZD 48,000 and NZD 10,400 respectively. The study showed that cheaper means of food and labour needed to be obtained to make farming of freshwater prawns in Cook Islands economically viable (Anon. 1994).

*Milkfish*

In 1990, milkfish (*ava*) (*Chanos chanos*) fry were purchased by the MMR from the northern group of Cook Islands for introduction to Lake Te Rotonui on Mitiaro. In 1991, a further introduction to the lake was made with fish purchased from the Oceanic Institute in Hawaii (Fujino and Patia 1993).

The status of milkfish stocks in Cook Islands is not known. Stocks in Lake Te Rotonui on Mitiaro are reported to be depleted and will need to be re-stocked (Cook Islands MMR cited by Smith (1993)). Rarotonga research on milkfish fry began in 1991. Sampling was carried out at two sites. The results of the survey showed that Rarotonga does not produce an adequate population of fry to support farming. Following the success of the milkfish project in Mitiaro, a number of other islands made requests for milkfish farming feasibility studies to be conducted (Anon. 1994).

*Tilapia*

Cook Islands received fingerlings of *Oreochromis mossambicus* from Fiji in 1955. The purpose of this introduction was most probably for aquaculture, with the aim of providing an additional source of food for local populations (Smith 1993). Populations of *O. mossambicus* are now well established in freshwater habitats and brackish water areas of Cook Islands (Nelson and Eldredge 1991). Tilapia are present in water bodies on Rarotonga, in Lake Te Rotonui on Mitiaro in abundance (Jellyman 1988), in Lake Tiriara on Mangaia and in brackish-water bodies on Atiu (Masatoshi Fujino, pers. comm., cited in Smith (1993)).

*Turtle farming*

In 1974, the South Pacific Commission (SPC), in collaboration with the University of the South Pacific (USP), initiated a turtle farming project in Cook Islands. This project was proposed to investigate the viability of raising hatchling turtles in captivity, from the egg to a size suitable for the market as an alternative source of protein for the Pacific Islands. Included within the scope of the Turtle Project was a small-scale population study of the marine turtles in Cook Islands, the establishment of a demonstration turtle hatchery and farm, and an attempt made to have a breeding stock in captivity. Infections, lack of suitable food, and cold weather led to an 87% mortality rate among hatchlings (Brandon 1977). The project was not feasible for Cook Islands and was terminated in 1977 (Anon. 1978).

***Reef and reef fisheries (finfish and invertebrates)***

The Cook Islands Natural Heritage Project estimates that there are 550–600 species of finfish in Cook Islands, of which 482 are reef fish. Only a fraction of the 482 species are fished for eating purposes. Clerk (1981) listed 128 reef fish species that were recognised and eaten by Mangaia islanders. Bullivant and McCann (1974) collected 103 species of fish from the reef and lagoon in a survey in Manihiki. The dominant families recorded by them were Holocentridae (squirrelfish) and Mullidae (goatfish), each with eight species. A total of 88 coral-reef fish species were recorded at Palmerston and Suwarrow by Grange and Singleton (1985). Their list shows Chaetodontidae (coral fish/butterflyfish/angelfish), Acanthuridae (surgeonfish/unicornfish) and Labridae (wrasse) to be numerically abundant.

As early as 1955, it was noted that the reef fish stocks at Rarotonga were over-fished (Van Pel 1955). The proliferation of spearguns has further aggravated this situation so that, near heavily populated areas on Rarotonga and Aitutaki, fish are less abundant in the lagoons than was formerly the case. Available data at MMR indicate that coastal fish species are under very heavy pressure in most of the group. Raumea (1992) states that 70% of fish landed on Mangaia were reef species, showing how important they were in the local diet. On Palmerston, fish is the main source of protein for local communities (Grange and Singleton 1985). This island also supplies most of Rarotonga's reef fish and invertebrates.

Fish poisoning is common in Cook Islands, the main species involved being striated surgeonfish (*maito*), unicorn fish (*ume*), brown eels (*a'a pata*), two-spot red snappers (*anga-mea*) and a few grouper (*patuki*) species (Laurent *et al.* 2005). On Rarotonga, almost all reef fish are considered toxic and the fish eaten comes mainly from Aitutaki or Palmerston. On Penrhyn, people avoid eating humphead wrasse (*maratea*), while on Atiu, parrotfish have been cited in ciguatera cases (Losacker 1992). On Palmerston, grouper sales were banned in 1988 for the same reasons (Bill Marsters, pers. comm..).

Since 1985, spearfishing has been banned in the Pukapuka lagoon by the traditional governing body, the Island Council, to protect the small, easily speared groupers and coral cod (*Epinephelus* and *Cephalopholis*), which are highly valued as food. Conservation practices are regularly reviewed by the Island Council, which includes two representatives from each village (Andrews 1987). The 1990 Aitutaki Fisheries Protection By-Laws ban the use of self contained underwater breathing apparatus (SCUBA) while spear fishing, gathering any species of fish and setting or gathering any set net or collecting of fish from any such net. There are also comprehensive laws regarding netfishing, namely: hauling of nets, restrictions on nets in channels, set nets and drag nets. In addition, there is a by-law banning the use of any explosive or poisonous substance to capture fish. The 1992 Rarotonga Fisheries Protection Regulations define a 'restricted area around Rarotonga including... the waters and seabed between mean high water mark and a line measured at right angles seaward from the outer limits of the reef to a distance of 500m'. There is a ban on the use of SCUBA in the restricted area to catch or take fish, set or gather a net, collect fish from any such net or capture fish with the intention of removing such fish from the restricted area. There are also restrictions on the use of nets in channels, set nets and drag nets (Smith 1993).

*Aquarium fishery*

The commercial exploitation of aquarium fish in Cook Islands was established in November 1988, with the main markets being USA, Europe and Japan. From 1988 to early in the millennium, annual capture rates remained fairly stable at 10,000–22,000 fish. In Cook Islands, a total of 35 different marine ornamental fish are collected by divers using SCUBA, with either small-meshed barrier or hand-held scoop nets (no chemicals used), at depths of mainly 8–35 m and occasionally to 70 m (Bertram 1996). While 35 species are caught, over 90% of the catches involve only five species (*Neocirrhites armatus* 30%, *Centropyge loriculus* 35%, *Pseudanthias ventralis* 15%, *Cirrhilabrus scottorum* 7% and *Centropyge flavissimus* 7%). Two rare endemic species, however, *Paracentropyge boylei* and *Centropyge narcosis*, significantly affect total export earnings, as they sell for USD 10,000 to 15,000 each (CIMMR 2002). However, Bertram (1993, cited by Smith (1993)) noted that the yield of flame angels was approaching maximum sustainable yield (MSY), indicating that monitoring of the catches of this species was urgently required (Smith 1993, Anon. 1994)

The fishery is largely self-managed as there is no licensing. The 1994 Marine Resources (licensing and regulations of fishing vessels) Regulations state that 'no person shall engage in fishing for any aquarium fish except with the written permission of the Minister and in accordance with such condition that s/he may specify'. The fishery is currently only carried out in Rarotonga and is restricted to the outer reef slope areas. Lagoon collection is banned. At present there is a legislative review of the designated fishery (CIMMR 2002).

*Bêche-de-mer*

There are eleven species of sea cucumber (*rori*) in Cook Islands. According to Zoutendyk (1989), these are the prickly redfish *ngata* (*Thelenota ananas*) and *rori ka'a/matu rori* (*Holothuria leucospilota*), the greenfish *rori mate* (*Stichopus chloronotus*) and *rori pua* (*Holothuria cinerascens*), the surf redfish *rori puakatoro* (*Actinopyga mauritiana*), the lollyfish *rori toto* (*Holothuria atra*), the black teatfish *rori-u* (*H. nobilis*), the leopardfish (*Bohadschia argus*), the *a'ei* (*Synapta maculata*), the *kanaenae* type (*Holothuria hilla*), and the *ngata* type (*Stichopus horrens*).

There are both subsistence and commercial fisheries for sea cucumbers in Cook Islands. In Rarotonga and some of the southern group islands such as Mangaia, several species are a traditional source of subsistence food, gathered mainly by females.

MMR has carried out bêche-de-mer surveys on several islands in the group, including Rarotonga and Aitutaki. Some beche-de-mer survey work was also done in connection with a general marine resource survey on Palmerston Atoll, in late 1988, carried out jointly by MMR, SPC and the Forum Fisheries Agency (Preston 1990). Zoutendyk (1989) noted that stocks of sea cucumber species used for subsistence purposes, though limited in size, appeared to be stable. Except on Rarotonga, where *A. mauritiana* has been gathered and sold on a small scale, sea cucumber stocks are not presently being exploited commercially.

*Sea turtles*

Two species of turtles (*onu*) are commonly found in Cook Islands: the *onu taratara* or hawksbill turtle (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*). Both species nest on Manihiki, Pukapuka, Penrhyn, Nassau, Suwarrow and Palmerston Atolls, while Rakahanga is a nesting site for green turtles only. Nesting occurs to a lesser degree in the southern islands of Takutea, Aitutaki and Manuae (CIMMR 2001).

There is no information on the stock status of sea turtles in the Cook Islands. Recent information suggests that sightings of turtles are becoming less frequent on most islands. Palmerston and Penrhyn may now be the atolls most frequently used by nesting turtles (Smith 1993 cites Bill Marsters, Fisheries Officer, pers.comm). Because they travel so far to feed and mate, it is difficult to know how much Cook Islands male fishers have contributed to their decline (CIMMR 2001).

In 1976, a ban on the use of spears was introduced to the Palmerston turtle fishery by the Island Council. This was in response to the number of turtles being found dead on the reef bearing spear scars (Preston *et al.* 1995).

*Lobsters*

Passfield (1988) reported that the most abundant and largest species of rock lobster in Cook Islands was the double-spined spiny lobster *koura tai* (*Panulirus penicillatus*), though the smaller and less commercial long-legged spiny lobster (*P. longipes femoristriga*) was reported to be present. The slipper lobster *koura papa*, probably *Parribacus caledonicus*, occurs in low numbers. Each of the islands in Cook Islands supports a fishery for spiny lobster to some degree, though usually only for subsistence. Commercial landings are only known from Rarotonga, Aitutaki, Palmerston and Rakahanga.

There is no information available on the status of the spiny lobster stocks in Cook Islands. Local bans, such as the 1988 six-month ban on lobster export from Palmerston, shows a realisation that the resource is under pressure. There is no specific reference to spiny lobster in the current Cook Islands legislation (Smith 1993).

### *1.3.3 Fisheries research activities*

The MMR undertakes fisheries and aquaculture research in Cook Islands. The research that has taken place is grouped in the following categories:

- Lagoon monitoring: baseline surveys and monitoring of fish, corals, and other invertebrates. Monitoring of the pearl culture industry, including the associated water quality, is an important feature of the lagoon monitoring work programme.

- Ciguatera programme: alerting the public to outbreaks of ciguatera poisoning around Rarotonga.

- Marine reserves: providing technical assistance to the managers of marine reserves in Rarotonga and Aitutaki.

- The MMR operates a pearl hatchery at Penrhyn, a giant clam hatchery at Aitutaki, a marine laboratory at Manihiki, and a water quality laboratory at Rarotonga (FAO 2008).

Research is carried out by MMR staff, or MMR staff in collaboration with local and/or external researchers, including regional organisations. In addition to the programmes above, MMR has carried out surveys of seafood retailers and restaurants in Rarotonga. Seafood consumption forms have been distributed to Mangaia, Aitutaki, Palmerston and Pukapuka (Anon. 1994). MMR works closely with the Cook Islands Conservation Service in carrying out coral reef monitoring, and fish taxonomy work. In collaboration with the Conservation Service and the Ministry of Health, MMR set up a ciguatera monitoring programme on Rarotonga in 1994. James Cook University (JCU) provided training in the collection and analysis of ciguatoxic algae. Examples of some of the documented research assistance provided by other agencies includes the work of SPC on the crown-of-thorns starfish population in Cook Islands (Hinds 1970), environmental surveys of Rarotonga lagoon (Dahl 1980), technical advice on MMR's research programmes (Lewis 1987), and the assessment of coastal resources in Palmerston using Satellite SPOT satellite imagery (Anon. 1990). The South Pacific Applied Geosience Commission (SOPAC) has provided assistance in water temperature monitoring of the Manihiki and Penrhyn lagoons to improve pearl oyster farming conditions. USP has provided technical assistance in turtle farming as noted elsewhere in this report. Volunteers from Japan's International Cooperation Agency (JICA), and the United Nations have provided assistance in aquaculture and mariculture in the areas of milkfish, and mullet farming (Smith 1993). The Australian Centre for International Agricultural Research (ACIAR) has provided assistance in the farming of giant clams, and in trochus stock assessment.

### *1.3.4 Fisheries management*

Responsibility for the fisheries and marine resources of Cook Islands is vested in the Ministry of Marine Resources (MMR), headed by a Secretary of Marine Resources. The Ministry was established under the Ministry of Marine Resources Act 1984. Previously it operated as the Fisheries Department, Ministry of Agriculture and Fisheries. It is administered through a headquarters office in Rarotonga. Outer islands with fisheries personnel are Pukapuka, Manihiki, Aitutaki, Penrhyn, Palmerston, Mitiaro, Rakahanga, Suwarrow and, occasionally, Mangaia (Smith 1993).

The Marine Resources Act (1989) is the cornerstone of the Cook Islands' control over the exploitation and management of the fisheries resources. The major features of the Act refer to designated fisheries, local fisheries committees, the power of Island Councils to produce bylaws, local fisheries licences, foreign fishing vessel licences, and access agreements. Other legislation relevant to fisheries includes: the Marine Resources (Licensing and Regulation of Fishing Vessels) Regulation 1995, the Continental Shelf Act (NZ) 1964, the Continental Shelf (Amendment) Act 1977, the Territorial Sea and Exclusive Economic Zone Act 1977, the Marine Farming Act 1971, the Fisheries Protection Act 1976, the Ministry of Agriculture and Fisheries Act 1978, the Outer Islands Local Government Act 1987, EEZ (Foreign Fishing Craft) Regulations 1979, the Aitutaki Fisheries Protection By-Laws 1990, the Manihiki Pearl and Pearl Shell By-Laws 1991, and the Rarotonga Fisheries Protection Regulations 1992 (FAO 2008). As described previously, CIMMR (2001) state that the tools used to manage the exploitation of stocks include limits or restrictions on fishing gear, the number of users, the size of animals caught, the number of animals caught, and closures (seasons, areas, permanent closure).

Apart from the above tools, the MMR, in cooperation with traditional leaders, has implemented a customary community-based managed system called *ra'ui*. The definition of the word *ra'ui* means 'a sign set in place by the owner of a piece of land or water reserving it or its produce for his/her own or some special use, the second meaning is simply a prohibition.'. The *ra'ui* system is unique in that it is not legislated for, rather it relies on community trust or peer pressure for enforcement (Raumea *et al.* 2001, Roi 2003). Rakahanga and Pukapuka have developed specific by-laws to establish and manage *ra'ui*. The people of Atiu, owners of the uninhabited island of Takutea, have started preparing draft bylaws to protect the biodiversity of the island. On Aitutaki there has been considerable discussion on giving legal status through bylaws to *ra'ui* (Tiraa 2006). The strength of this traditional system in today's context is the fact that it is initiated and managed by the community.

## 1.4 Selection of sites in the Cook Islands

Four CoFish sites were selected in Cook Islands following consultations with the Ministry of Marine Resources, the atolls of Aitutaki and Palmerston and the islands of Mangaia and Rarotonga (Figure 1.5). These sites were selected as they shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country, were relatively closed systems[7], were appropriate in size, possessed diverse habitats, presented no major logistical limitations that would make fieldwork unfeasible, had been investigated by previous studies (especially Palmerston), and presented particular interest for the Ministry of Marine Resources and the Island Councils.

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

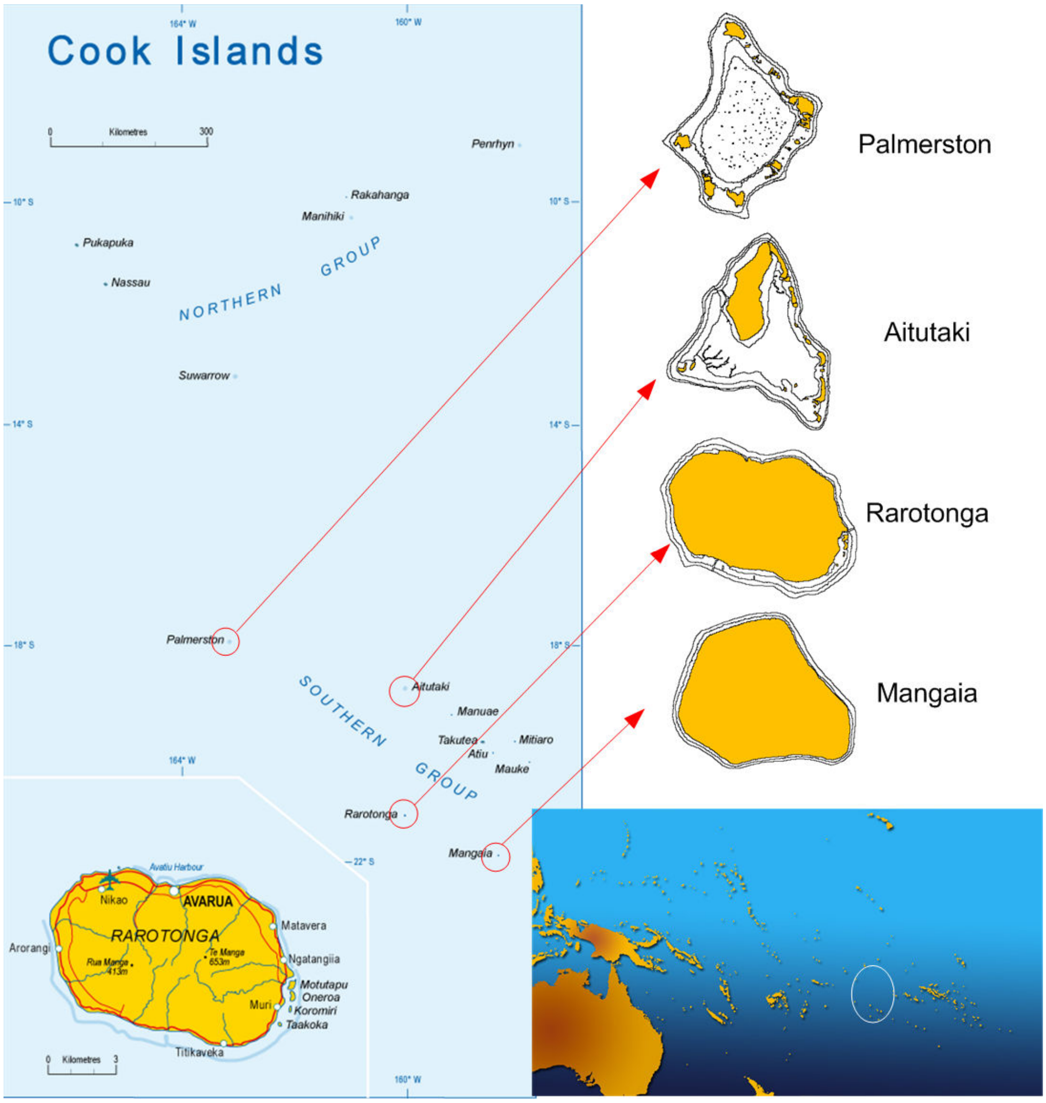



**Figure 1.5: Location of the four selected sites for CoFish in Cook Islands.**

# 2. PROFILE AND RESULTS FOR AITUTAKI

## 2.1 Site characteristics

The atoll of Aitutaki (Figure 2.1) is located at around 18°53'S latitude, and 159°47"W longitude, roughly 250 km to the north of Rarotonga, the capital of Cook Islands. It is a triangular-shaped atoll with 15 small islets mainly located on the eastern reef, and a main volcanic island with a height of 119 m in the north. The lagoon is shallow, attaining a maximum depth of 11 m, and almost completely enclosed by a substantial barrier reef. There is only one main passage through the reef in the west, making the lagoon cut off from ocean influence, with the lagoon substrate composed of very fine sand and little reef. The lagoon also differs slightly in temperature and salinity from the surrounding sea, depending on the state of the tide and rainfall. Live coral cover is much better outside the reef than in the lagoon. There were also several marine reserves, one at the northeast tip of the lagoon, one to the southeast, and two in the southwest where the Ministry also has a giant clam nursery area.

Aitutaki was the third choice of the Ministry of Marine Resources for surveying, as several surveys had been conducted there in the past. It is also a major tourist attraction with several flights per day from Rarotonga. The people of Aitutaki rely heavily on marine resources for subsistence needs, while there is also a market for fish to supply the restaurants and hotels on the island.

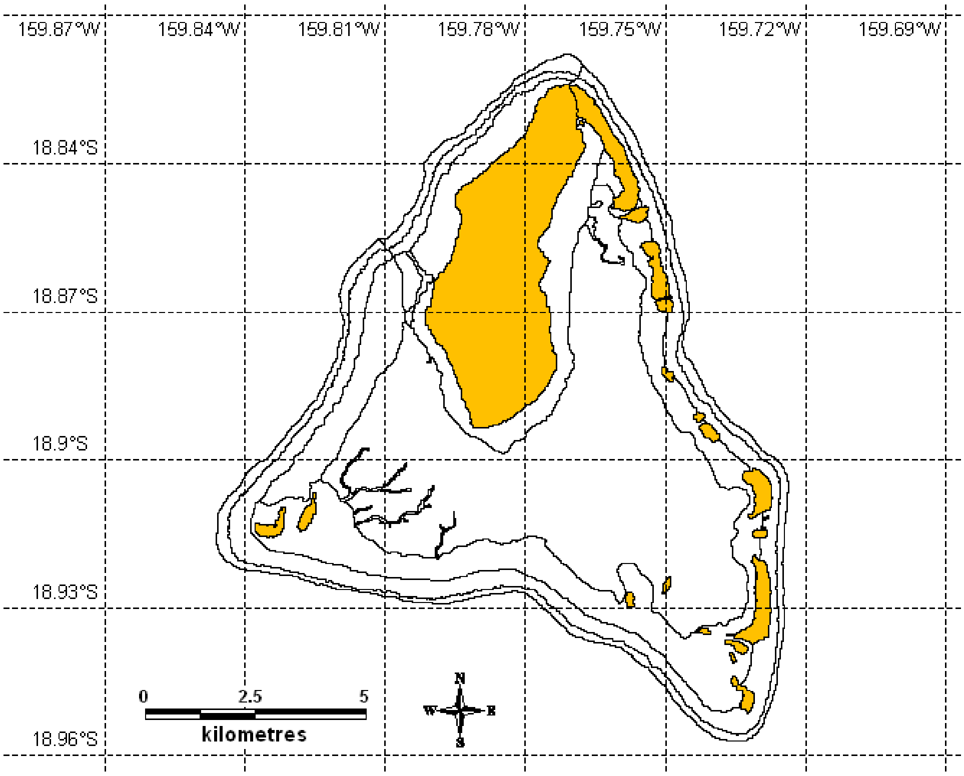



**Figure 2.1: Map of Aitutaki.**

## 2.2 Socioeconomic surveys: Aitutaki

Socioeconomic fieldwork was carried out on Aitutaki in February 2007. The survey covered 30 households, including 129 persons, a sample that represents ~7% of the total number of households (435) and the current population (1871) on the island. The sampling was distributed to proportionally represent each major village on the island (Table 2.1).

**Table 2.1: Demographic data for survey sample sizes of Aitutaki's villages**

| Village | Population | % of Aitutaki's total population | Number of household surveys |
|---|---|---|---|
| Amuri-ureia | 482 | 28 | 8 |
| Arutanga | 518 | 30 | 10 |
| Vaipae-avanui | 492 | 28 | 8 |
| Tautu | 251 | 14 | 4 |
| Total | 1743 | 100 | 30 |

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. In addition, a total of 26 individual interviews of finfish fishers (22 males, 4 females) and 22 invertebrate fishers (13 males, 9 females) were conducted. In some cases, the same person was interviewed for both finfish and invertebrate harvesting.

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

Survey results indicate that 80% of all households are engaged in fisheries with an average of two fishers per household. If we extrapolate our household data there are 841 fishers on Aitutaki: 290 females and 551 males. Two hundred and seventeen males fish exclusively for finfish, but only 43 females. Another 58 females but no males exclusively collect invertebrates. Overall, most males (333) and females (188) fish for both finfish and invertebrates, although not necessarily at the same time.

Data on income suggests that fisheries do not play a major role but have been significantly replaced by salaries (Figure 2.2). In fact, 70% of all households depend on salaries as first (~57%) or second source of income (~13%). 'Other' sources of income, mainly retirement fees and other social payments, are more important (33%) as first income than fisheries (~7%). However, almost a quarter (~23%) of all households depend on fisheries to provide them with a complementary income. Agriculture is of minor importance, i.e. ~17% and ~7% of households earn their first and second income from agriculture respectively. Remittances do not play a significant role in the livelihood of people on Aitutaki. The households that do receive remittances quoted an average annual amount of USD 1068, which corresponds to approximately 20% of the average annual household expenditure. Cost of living on Aitutaki is moderate, perhaps because the island produces a substantial amount of agricultural produce and perhaps also because 80% of all households are engaged in fishing, at least for subsistence purposes. According to the survey data, a household on Aitutaki spends on average about USD 5239 /year for basic food purchases, fuel, electricity and communication (Table 2.2).

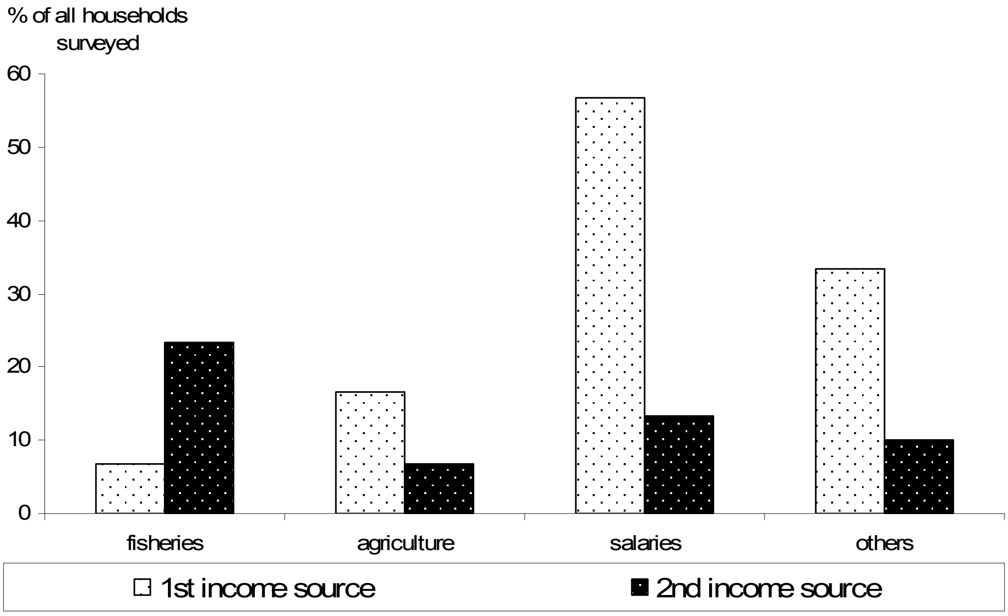



**Figure 2.2: Ranked sources of income (%) in Aitutaki.**
Total number of households = 30 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly retirement fees and other social payments.

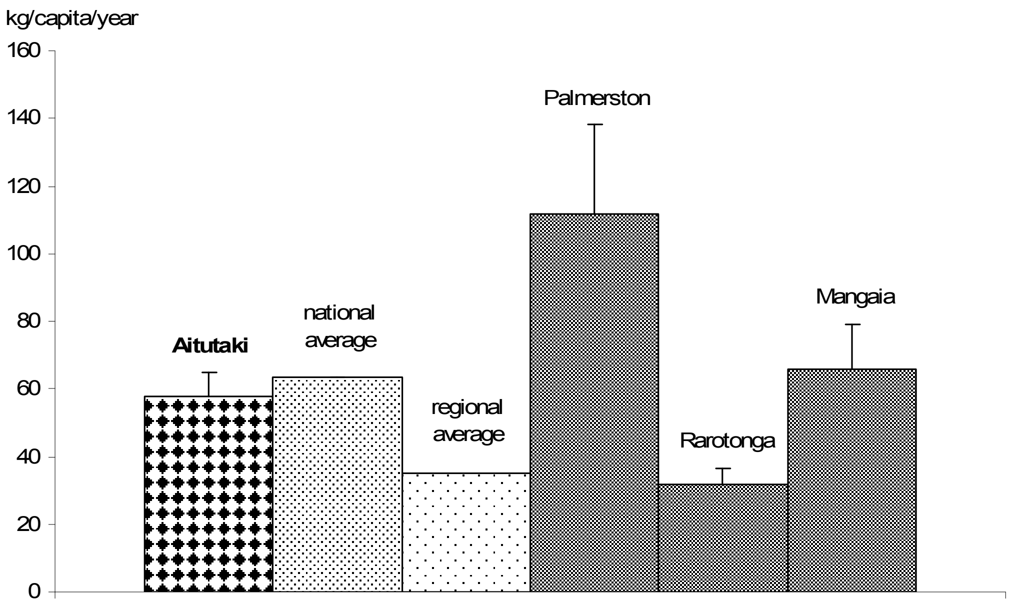



**Figure 2.3: Per capita consumption (kg/year) of fresh fish in Aitutaki (n = 30) compared to the national (Preston 2000) and regional (FAO 2008) averages and the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The average consumption of fresh fish (~58 kg/person/year) meets the figure estimated by Preston (2000) as the national average (~63 kg/person/year), but is higher than the regional average (FAO 2008) of 35 kg/person/year (Figure 2.3). However, if compared to the consumption of 100 kg as estimated by Adams *et al.* (1996), overall, fresh fish consumption has considerably dropped. Respondents, however, confirmed that canned fish is quite popular on the island and the average canned fish consumption of ~20 kg/person/year is high. In fact, canned fish is consumed 1–2 times per week; fresh fish 3 days per week. By comparison, invertebrates are only eaten once a month and the consumption is very low (2.5 kg/person/year).

**Table 2.2: Fishery demography, income and seafood consumption patterns in Aitutaki**

| Survey coverage | Site (n = 30 HH) | Average across sites (n = 138 HH) |
|---|---|---|
| **Demography** | | |
| HH involved in reef fisheries (%) | 80.0 | 68.8 |
| Number of fishers per HH | 1.93 (±0.53) | 1.33 (±0.14) |
| Male finfish fishers per HH (%) | 25.9 | 32.2 |
| Female finfish fishers per HH (%) | 5.2 | 2.7 |
| Male invertebrate fishers per HH (%) | 0.0 | 0.0 |
| Female invertebrate fishers per HH (%) | 6.9 | 18.6 |
| Male finfish and invertebrate fishers per HH (%) | 39.7 | 26.2 |
| Female finfish and invertebrate fishers per HH (%) | 22.4 | 20.2 |
| **Income** | | |
| HH with fisheries as 1st income (%) | 6.7 | 5.1 |
| HH with fisheries as 2nd income (%) | 23.3 | 7.2 |
| HH with agriculture as 1st income (%) | 16.7 | 7.2 |
| HH with agriculture as 2nd income (%) | 6.7 | 8.0 |
| HH with salary as 1st income (%) | 56.7 | 55.8 |
| HH with salary as 2nd income (%) | 13.3 | 8.7 |
| HH with other source as 1st income (%) | 33.3 | 39.1 |
| HH with other source as 2nd income (%) | 10.0 | 16.7 |
| Expenditure (USD/year/HH) | 5239.13 (±788.81) | 6909.08 (±352.39) |
| Remittance (USD/year/HH) (1) | 1068.09 (±584.44) | 1524.12 (±252.14) |
| **Consumption** | | |
| Quantity fresh fish consumed (kg/capita/year) | 57.71 (±7.31) | 51.88 (±4.90) |
| Frequency fresh fish consumed (times/week) | 3.35 (±0.33) | 2.79 (±0.15) |
| Quantity fresh invertebrate consumed (kg/capita/year) | 2.52 (±0.90) | 3.60 (±4.90) |
| Frequency fresh invertebrate consumed (times/week) | 0.25 (±0.10) | 0.42 (±0.06) |
| Quantity canned fish consumed (kg/capita/year) | 20.37 (±5.24) | 13.33 (±1.74) |
| Frequency canned fish consumed (times/week) | 1.64 (±0.37) | 1.17 (±0.13) |
| HH eat fresh fish (%) | 100.0 | 99.3 |
| HH eat invertebrates (%) | 63.3 | 71.0 |
| HH eat canned fish (%) | 73.3 | 73.2 |
| HH eat fresh fish they catch (%) | 73.3 | 73.3 |
| HH eat fresh fish they buy (%) | 36.7 | 36.7 |
| HH eat fresh fish they are given (%) | 66.7 | 66.7 |
| HH eat fresh invertebrates they catch (%) | 63.3 | 63.3 |
| HH eat fresh invertebrates they buy (%) | 6.7 | 6.7 |
| HH eat fresh invertebrates they are given (%) | 6.7 | 51.88 (±4.90) |

HH = household; (1) average sum for households that receive remittances; numbers in brackets are standard error.

### 2.2.2 Fishing strategies and gear: Aitutaki

*Degree of specialisation in fishing*

On Aitutaki, both males and females are fishers; however, more males than females actually fish (Figure 2.4). Often families enjoy a joint weekend fishing trip, all participating in the setting and cleaning of nets. However, males dominate the exclusive finfish fisheries (~25%). Only a small proportion of females (~5%) exclusively collect invertebrates. Overall, most males (~40%) and most females (~20%) do both finfish and invertebrate fishing, although not necessarily during the same fishing trip.

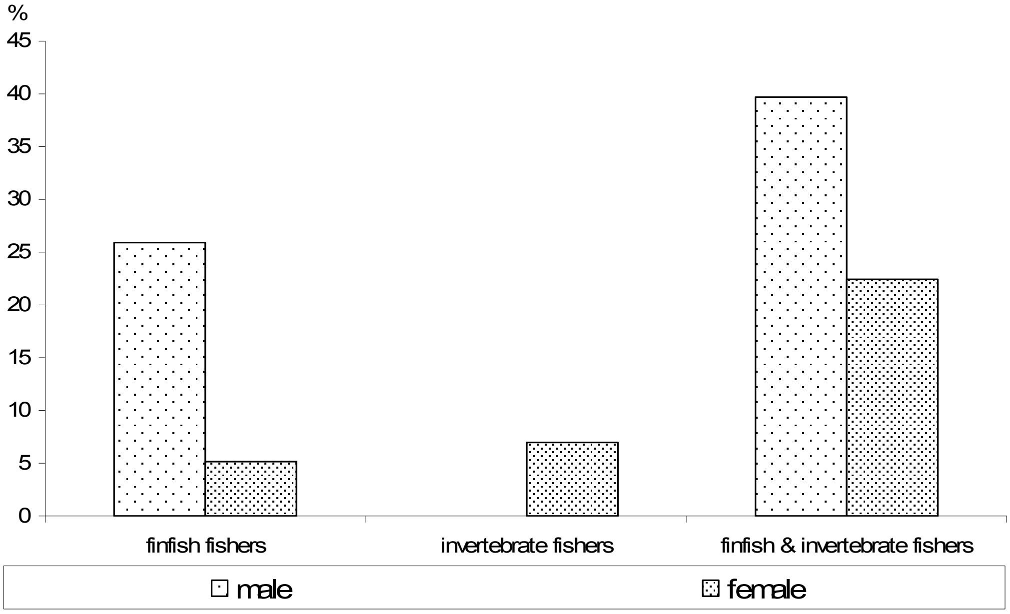



**Figure 2.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Aitutaki.**
All fishers = 100%.

Invertebrate fishers mostly target reeftops but a few other species are also collected from soft-bottom habitats, from sandy beach areas (intertidal) and from mangrove areas (Figure 2.5). Some respondents reported specifically targetting lobsters at times.

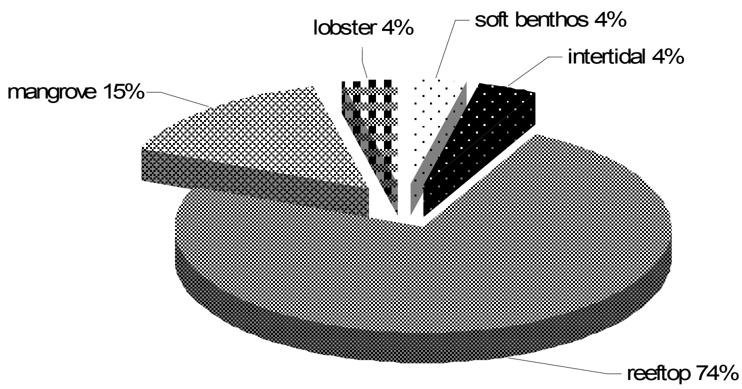



**Figure 2.5: Proportion (%) of fishers targeting the five primary invertebrate habitats found in Aitutaki.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

*Fishing patterns and strategies*

On Aitutaki, 70% of all households own a boat. Most of the boats (56%) are motorised and the remaining 44% are non-motorised hulls or canoes. However, family ties are close on Aitutaki, so boats are often shared, and fishers often join a fishing party. All male fishers and most female fishers (75%) use boat transport for finfish fishing. Sixty-eight per cent of male fishers and 25% of female fishers prefer motorised boats, while 32% of male fishers and 50% of female fishers use non-motorised canoes to reach their fishing grounds.

The investment level in fishing on Aitutaki seems to be low to moderate as far as finfish fishing is concerned. It seems that, due to the increasing importance of salaries, fishing is more and more becoming a weekend or leisure activity. Invertebrate collection does not require any gear other than knives, rods or sticks and, for free-diving, mask, snorkel and fins. No SCUBA gear is used for invertebrate harvesting on the island.

Fishing trips are mostly undertaken during the day (64–100%) but also at night in some cases when the lagoon area is targeted, depending on the tidal conditions (~32%), but hardly ever only at night (~4%). All fishers continue fishing throughout the whole year. Digging for shells in sandy beach areas, or collecting invertebrates from soft-bottom habitats are exclusively done during the day, while lobsters and mud crabs in mangroves are only harvested at night. Reeftop gleaning is mainly a daytime activity (75%) and only about 25% of fishers interviewed indicated that they may glean either at day or night, given the situation and tidal conditions. Invertebrate collection is not seasonal but done throughout the year with the exception of mud-crab harvesting, and seaweed and land crab collection from sandy beach areas, which seem to be seasonal.

*Targeted stocks/habitat*

Male and female fishers mostly fish the reeftop, and fewer females than males target reeftops for invertebrates (Figure 2.6). Lobster and soft-benthos harvesting is exclusively done by males; however, overall, very few male fishers on Aitutaki are engaged in either fisheries. Very few, females only, collect crabs in beach areas (intertidal); also the number of male and female fishers targeting mud crabs in mangroves is low (~10% of all male fishers, <5% of all female respondents). The major fishing grounds for invertebrates indicated by respondents are shown in Figure 2.7.

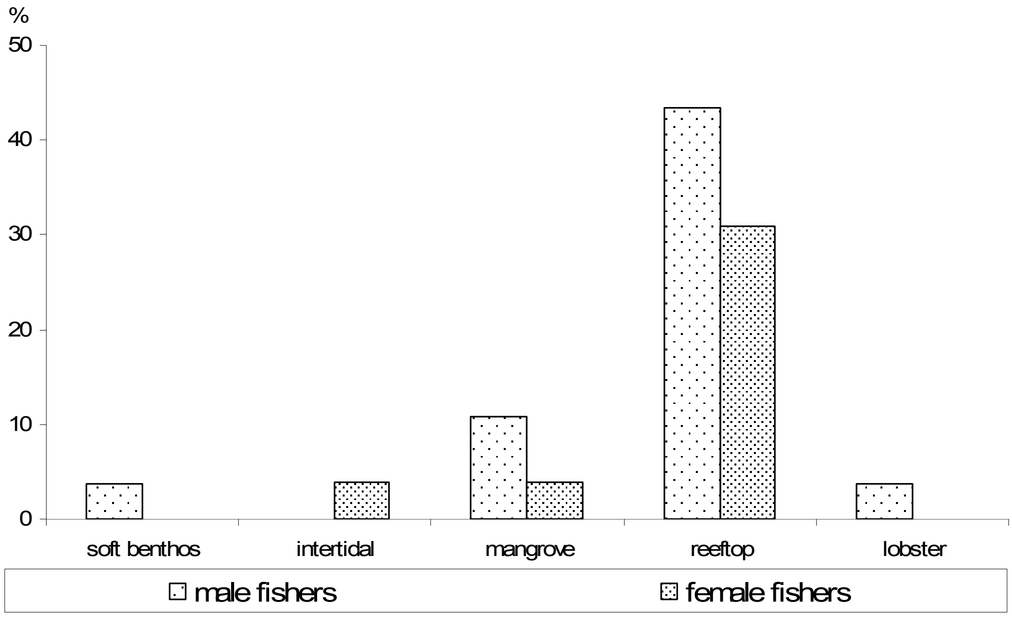



**Figure 2.6: Proportion (%) of male and female fishers targeting various invertebrate habitats in Aitutaki.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 17 for males, n = 10 for females.


**Figure 2.7: Major invertebrate fishing grounds and *ra'ui* areas on Aitutaki.**
Information obtained from survey respondents.

*Gear*

Fishing at Aitutaki involves a variety of techniques and two or more of these are often used during one fishing trip (Figure 2.8). Overall, gillnets are dominant, often used in combination with spear diving, handlines, cast rods or handheld spears. Passages were reported as a target area by one respondent only (4.5%) and this fisher used spear diving only; however, because of the small sample size, this information should be used with caution. In addition to reef and lagoon fishing there is an increasing focus on pelagic fishing, mainly trolling. However, pelagic fishing is not a subject of this survey, and is not considered here.

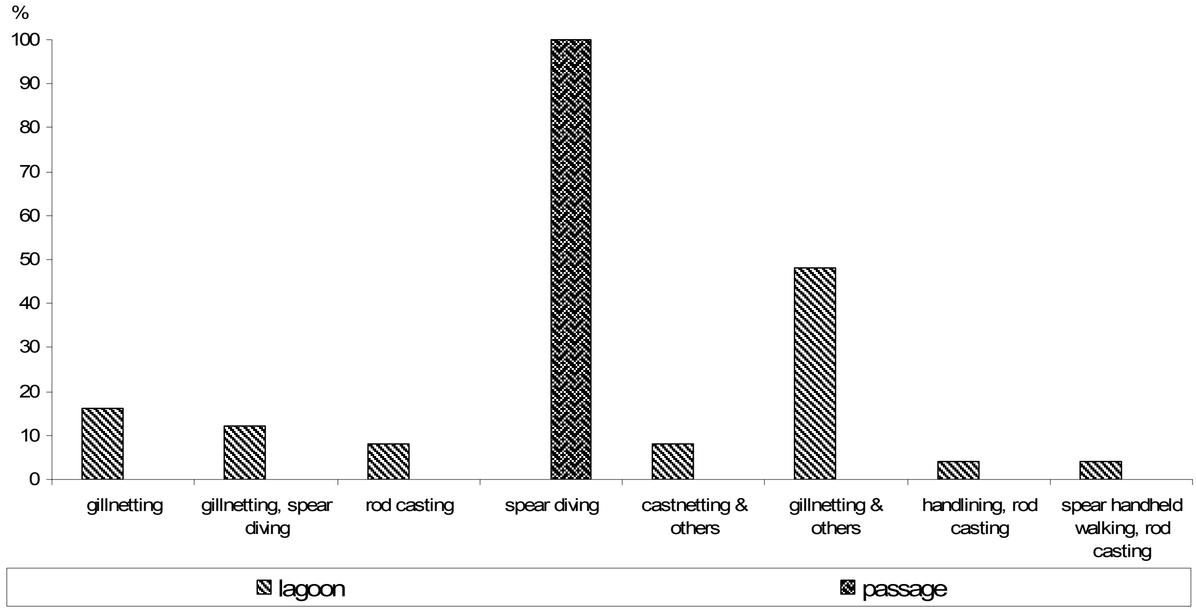



**Figure 2.8: Fishing methods commonly used in different habitat types in Aitutaki.**
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

*Frequency and duration of fishing trips*

Information on the number of fishers, frequency of fishing trips (Table 2.3) and average catch per fishing trip was used to estimate the fishing pressure imposed by the inhabitants of Aitutaki on their fishing ground (Table 2.4).

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

| Resource | Fishery / Habitat | Trip frequency (trips/week) | | Trip duration (hours/trip) | |
|---|---|---|---|---|---|
| | | Male fishers | Female fishers | Male fishers | Female fishers |
| Finfish | Lagoon | 1.00 (±0.10) | 0.84 (±0.16) | 4.26 (±0.37) | 4.00 (±1.41) |
| | Passage | 0.23 (n/a) | 0 | 2.00 (n/a) | 0 |
| Invertebrates | Lobster | 0.23 (n/a) | 0 | 5.50 (n/a) | 0 |
| | Mangrove | 0.38 (±0.15) | 0.23 (n/a) | 3.83 (±1.20) | 5.50 (n/a) |
| | Reeftop | 0.56 (±0.21) | 0.61 (±0.22) | 2.83 (±0.53) | 3.50 (±0.76) |
| | Intertidal | 0 | 0.23 (n/a) | 0 | 3.00 (n/a) |
| | Soft benthos | 0.08 (n/a) | 0 | 2.00 (n/a) | 0 |

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 22; females: n = 4. Invertebrate fisher interviews, males: n = 17; females: n = 10.

Reef finfish fishing on Aitutaki targets mainly the lagoon and its reefs that surround the numerous small *motu*. As shown in Table 2.3, on average fishers venture out once a week with no major difference between male and female fishers. Trips take on average four hours. Invertebrates are much less frequently collected. Collection of invertebrates from soft benthos is the least frequent activity reported and may be done a couple of times per year only. These figures also depend on the fact that some of the target species in this habitat are collected seasonally rather than continuously throughout the year. Lobster fishing and harvesting of shells from sandy beach areas (intertidal) are only done once a month at most. Reeftop gleaning is performed more regularly, about once a fortnight. This frequency was already reported in the 1995 survey (Adams *et al.* 1996). However, as mentioned earlier, reeftop gleaning is often combined with weekend family outings to a *motu*. Such trips may be used to collect some invertebrates, which are often consumed on the spot. On average, invertebrate collection trips take 2–6 hours depending on the species targeted. Lobsters and mud crabs are the most time-consuming fisheries, while intertidal, soft-benthos and reeftop gleaning take 2–3.5 hours.

### *2.2.4 Catch composition and volume – finfish: Aitutaki*

The annual catch reported by respondents from Aitutaki totalled 13.9 t/year (Figure 2.9). Considering the frequency and quantity of fresh-fish consumption reported by all households, Aitutaki's subsistence demand for fresh fish is estimated at 134.9 t/year. Because of our small sample size we refrain from extrapolating the catch data from respondents to include fishers in the households that have not been surveyed. According to the data provided by respondents only, about 37% of all catches are used for their own household consumption while 63% are either distributed on a non-commercial basis or sold mainly locally. Of the 27 fishers interviewed, seven (27%) sell their fish locally on a more or less regular basis. Fish is sold upon landing or at the home, rarely on the local market. All information collected indicates that the demand for fresh fish is much higher than the local supply. Due to ciguatera and the air-freight costs to Rarotonga, the annual volume of fish exported from Aitutaki elsewhere, and in particular to Rarotonga, is assumed to be very small.

The information provided by respondents shows that most of the fish is taken from the lagoon-reef system (99%) and an insignificant proportion (~1%) of reef fish is sourced from the passages. Overall, male fishers account for 96% of the total annual catch while female fishers contribute 4% only. Following the information provided by respondents, major impact is due to export rather than subsistence needs. However, as mentioned before, the proportion used for export is believed to be equal to or less than the share of catch that is locally consumed (Figure 2.9).

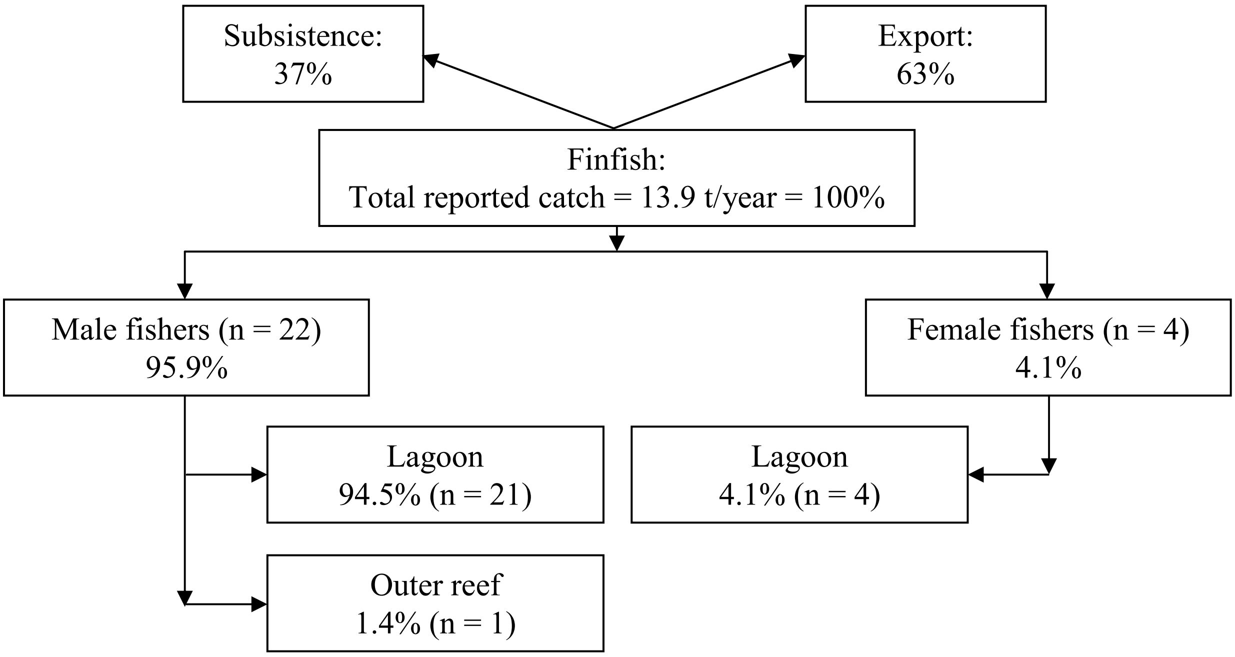



**Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Aitutaki.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The importance of catch for subsistence and social networking (gifts) in relation to the proportion used for sale (on the island and/or export to Rarotonga) is also shown in Figure 2.10. Targeting the lagoon is done equally for subsistence, gift (non-commercial exchange on the island but also export to relatives and families in Rarotonga and elsewhere) and income generation (export to Rarotonga). Passage fishing is not mentioned due to the small sample size (one fisher only). Passage fishing in general is not very common and, if performed, is done during the *arapo* (certain phases of the moon) or during times when old people and knowledgeable fishers are sure that certain fish are likely to run.

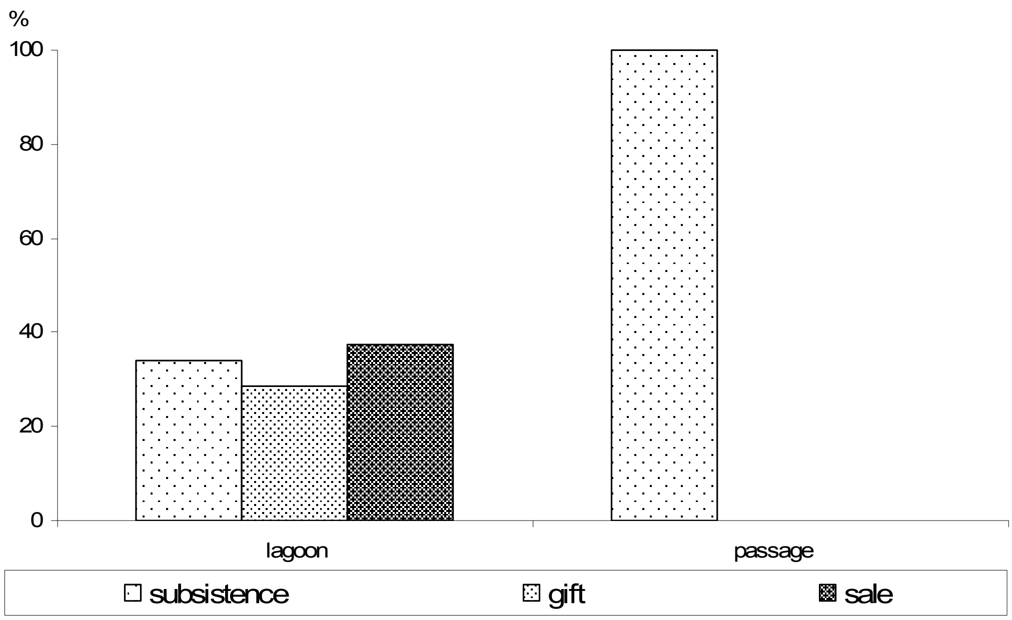



**Figure 2.10: The use of finfish catches for subsistence, gift and sale, by habitat in Aitutaki.**
Proportions are expressed in % of the total number of trips per habitat.

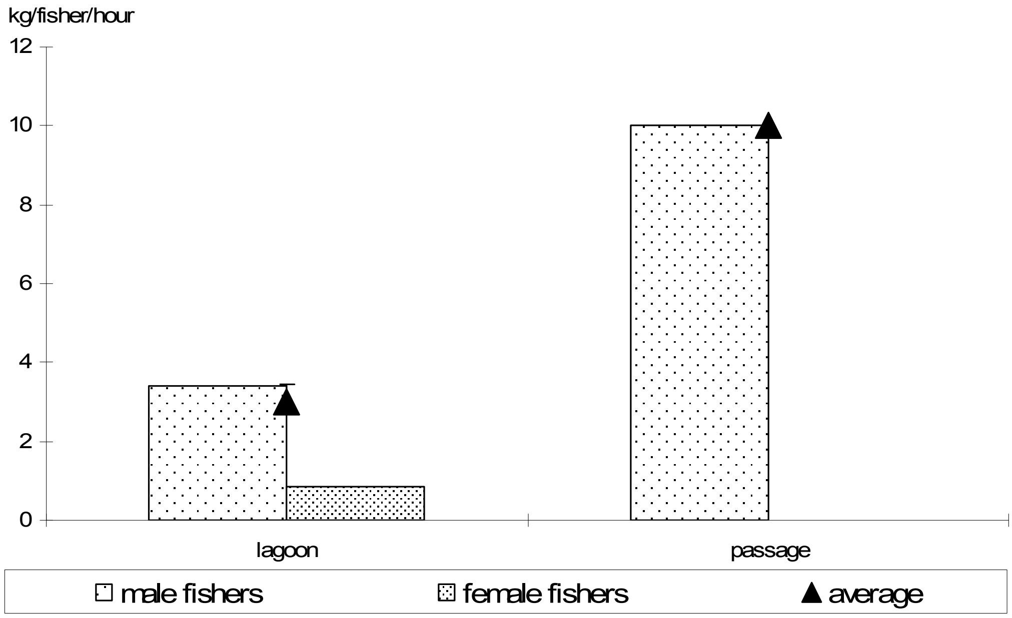



**Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Aitutaki.**
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The catch per unit effort on Aitutaki is relatively low, particularly considering the common use of gillnetting (Figure 2.11). The higher CPUE figure for male fishers on Aitutaki corresponds well with the earlier data that shows that far more males are active fishers than females. The low average CPUE also supports the argument that finfish fishing on Aitutaki is increasingly becoming a leisure activity. The CPUE figure provided for passage fishing is not considered here because it is sourced from one respondent only.

Catches from the Aitutaki lagoon and reef system are clearly determined by parrotfish: *Scaridae* were reported to determine over 45% of the reported catches. The remaining catch is mainly of Acanthuridae, Mullidae, Mugilidae and others. Details of the reported catch composition by habitat and fish species are provided in Appendices 2.1.1 and 2.1.4.

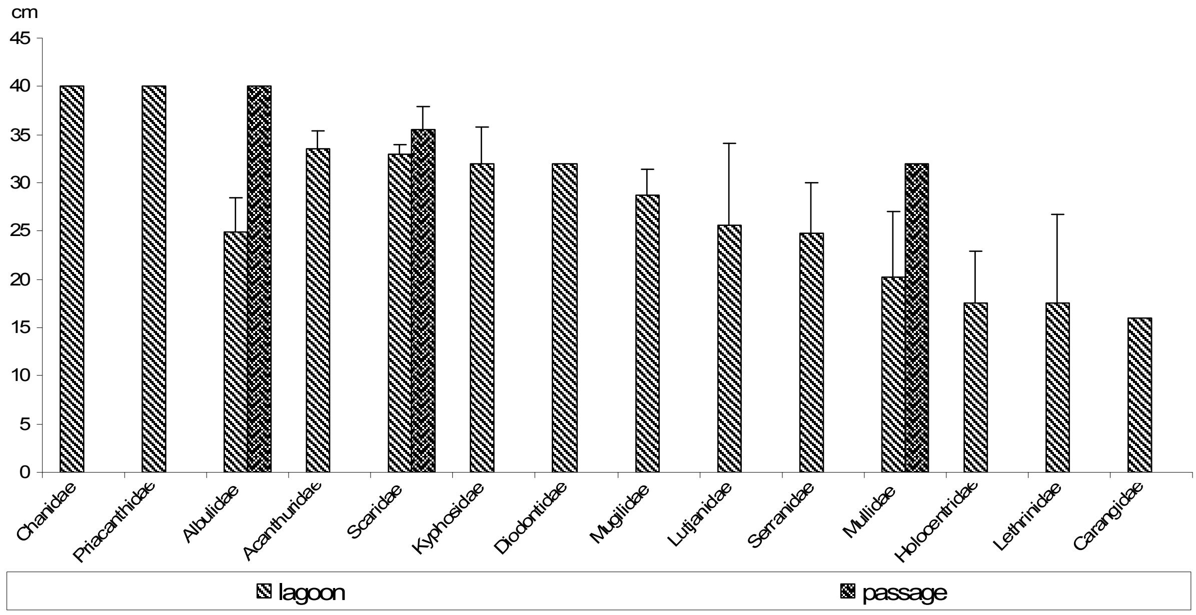



**Figure 2.12: Average sizes (cm fork length) of fish caught by family and habitat in Aitutaki.** Bars represent standard error (+SE).

Average fish sizes reported for catches on Aitutaki are moderate to large (Figure 2.12). Most fish species targeted and caught are reported to be >30 cm long, with Chanidae and Priacanthidae reaching 40 cm on average, and Acanthuridae, Scaridae, Kyphosidae and Diodontidae on average 30–35 cm. Holocentridae and Lethrinidae were the smallest reported fishes caught (17–18 cm on average), however, with a high variability in the reported fork length. The average length of Carangidae should be discounted because of the small sample size. The small sample size is also the reason for not comparing average length sizes reported for catches by families from the lagoon with those from the passages.

Estimates of fishing pressure, based on extrapolated survey responses, suggest that, while fisher density and fishing pressure are highest if only considering the available reef area, the total annual subsistence catch as expressed in t/km$^2$ of reef surface is moderate (Table 2.4). However, total fishing pressure may be higher if taking into account some fish exports (although these are mostly non-commercial) to Rarotonga or perhaps even elsewhere. Regarding the total available lagoon area and fishing ground, fisher density and fishing pressure are low due to its considerable size and the low number of fishers. However, care should be taken to relate the data only to the current situation and not previous development. For example, the data does not show necessarily whether a decrease in average catch may be due to ciguatera, which limits commercial fisheries, or resource status. It also does not show whether the number of commercial fishers has reduced due to alternative and more promising income sources or due to lower catch rates and marketing problems. However, the small number of fishers engaged in pelagic fisheries, which are not affected by ciguatera, and the high marketing potential for fresh fish in Rarotonga, point towards a change in lifestyle. The relatively low average annual catches and CPUE reported for lagoon fishing imply that the resource status may be decreasing. This interpretation is supported by the data reported by Adams *et al.* (1996). The 1995 survey results suggest generally higher CPUE, particularly for gillnetting, a higher demand due to a higher consumption, a higher population density and hence an annual finfish catch volume that is 2–2.5 times higher.

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

| Parameters | Habitat | | | | |
|---|---|---|---|---|---|
| | Sheltered coastal reef | Lagoon | Outer reef / Passages | Total reef | Total fishing ground |
| Fishing ground area ($km^2$) | 10.57 | 69.90 | 7.53 | 29.60 | 88.10 |
| Total number of fishers | 0 | 10.8 | 3.3 | 25.6 | 8.6 |
| Density of fishers (number of fishers/$km^2$ fishing ground) [(1)] | 0 | | | 63 | 21 |
| Population density (people/$km^2$) [(2)] | | 547.60 (±92.75) | 199.89 (n/a) | | |
| Average annual finfish catch (kg/fisher/year) [(3)] | | | | 3.5 | 1.2 |

Figures in brackets denote standard error; n/a = standard error not calculated; [(1)] total number of fishers is extrapolated from household surveys; [(2)] total population = 1871; total subsistence demand = 134.9 t/year; [(3)] catch figures are based on recorded data from survey respondents only.

## *2.2.5 Catch composition and volume – invertebrates: Aitutaki*

The number of species (as represented by the number of vernacular names) reported to be regularly caught from various habitats indicates the importance of these habitats and the fisheries they support. Figure 2.13 indicates that none of the invertebrate fisheries (except reeftop gleaning) is diverse, and that people on Aitutaki generally focus on a few species only.

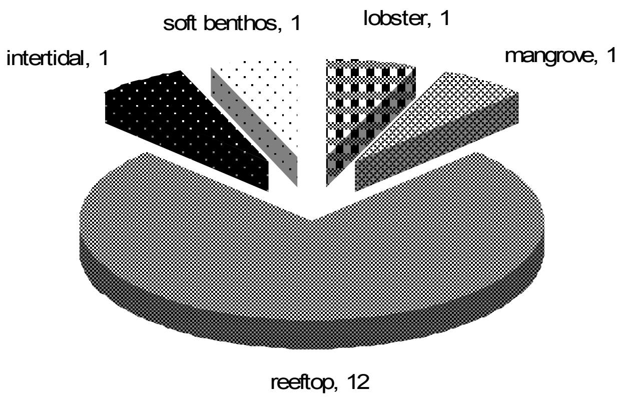



**Figure 2.13: Number of vernacular names recorded for each invertebrate fishery in Aitutaki.**

The data on the variety of species and habitats explored suggest that invertebrate fisheries in general are not important. This suggestion is also supported by the data presented earlier on the low invertebrate consumption by frequency and quantity as compared to finfish.

This trend is further reflected in the estimated total annual catch from interviewed fishers, which equals 4.14 t/year of wet weight only. Extrapolation of the average annual recorded catch per fisher to the total number of invertebrate fishers on Aitutaki brings the figure up to a total of 109.4 t/year (Figure 2.14). Almost all of the catch is sourced from reeftops (91%), and the remaining 9% is mainly accounted for by lobsters (5.4%) and mangrove species (2.9%). Females contribute >42% of the total annual catch while males are responsible for ~58%.

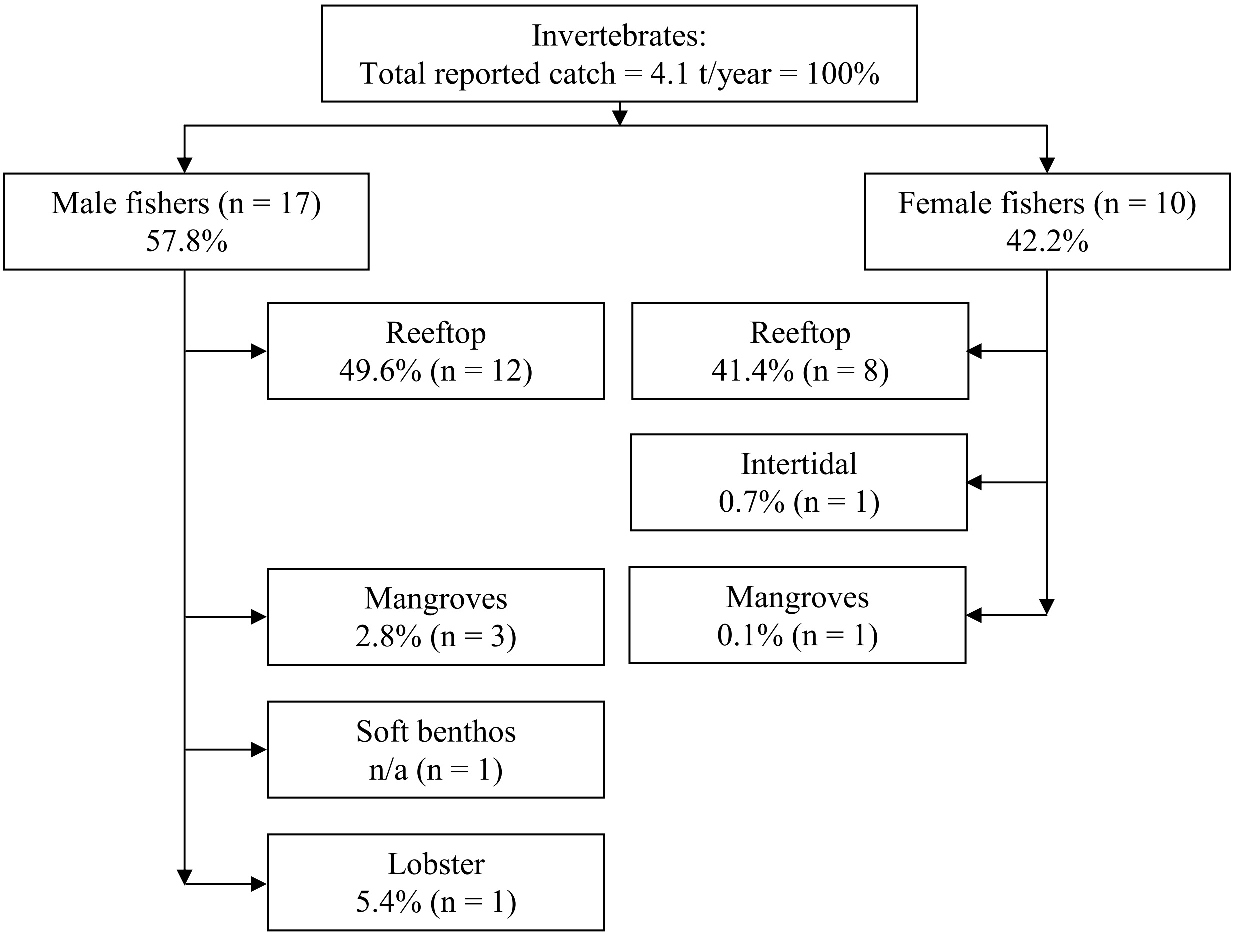



**Figure 2.14: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Aitutaki.**

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.

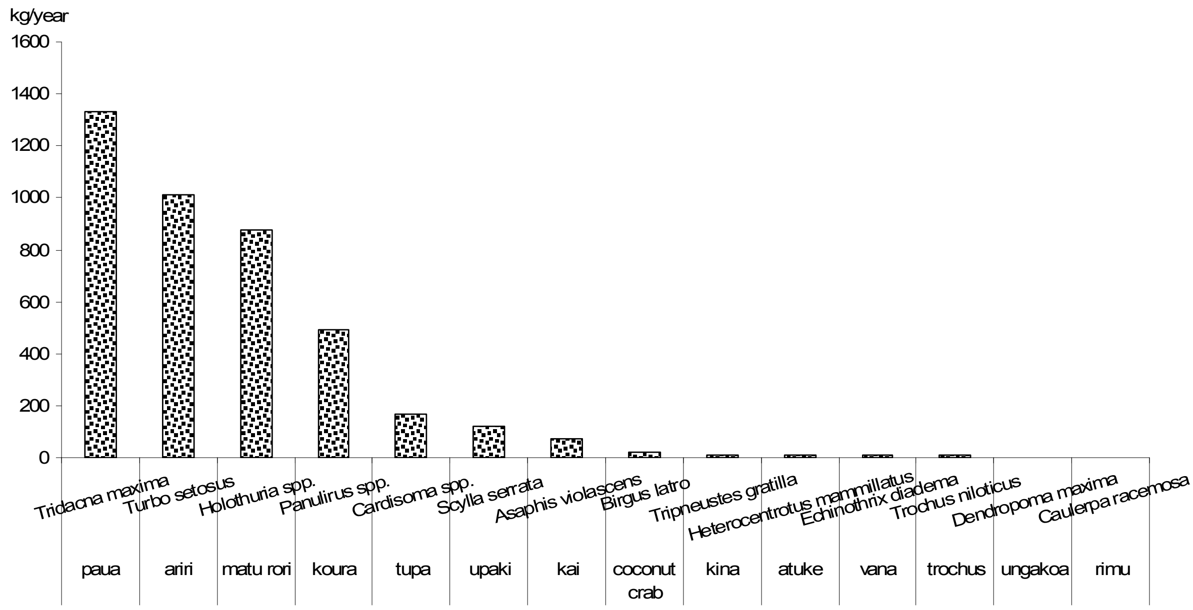



**Figure 2.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Aitutaki.**

Calculation of the total annual impact per species group (Figure 2.15) shows that about four species or species groups determine the reported and calculated annual catches (in terms of wet weight removed): giant clams (*Tridacna maxima*), *ariri* (*Turbo setosus*), *matu rori* (*Holothuria* spp.) and lobsters. Land crabs (*Cardisoma* spp.), *upaki* (*Scylla serrata*), *kai* (*Asaphis violascens*), and other species are of negligible impact.

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

All fishers interviewed reported that they collect invertebrates for the purpose of home consumption and as a gift for relatives and families on Rarotonga and only to a certain degree for commercial interests (Figure 2.16). Although the Aitutaki community lives very traditionally, and sharing on a non-commercial basis is an important social networking tool, invertebrates are less important than finfish when catches are shared. This may be due to the fact that invertebrates have never been as important as finfish for the nutrition of the island's population, and/or because some of the species are not commercial commodities and thus considered of lower value, and/or perhaps also because they are less targeted than finfish. In fact, very often invertebrates are collected as a by-product while fishers are out finfish fishing or while families spend time picnicking on a *motu*. Species that are more hazardously rather than purposefully found are consumed while on the reef or on the beach. Thus the invertebrate consumption estimated from the respondents' information may be underestimated as people reported only family meal consumption, but not what they may or may not consume while out fishing or boating.

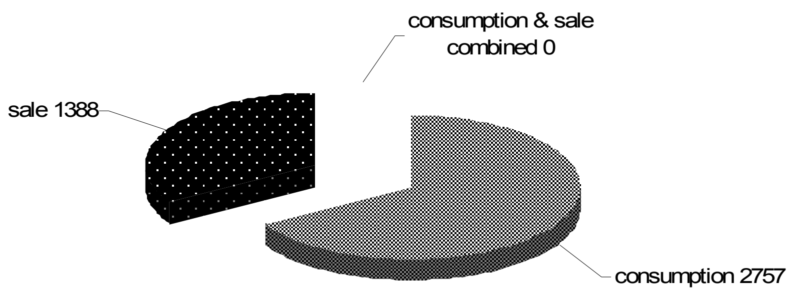



**Figure 2.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Aitutaki.**

As mentioned earlier, both genders participate in all fishing activities on Aitutaki. However, the few lobster fishers are males only. The same applies for most of the mangrove fisheries, which only target mud crabs and which are mostly done by male fishers at night. The collection of crabs (*Cardisoma* spp.) is a female activity. Although this activity is included under intertidal fisheries, fishers often glean on land rather than on the beach, for example, land areas close to Amuri, towards the airport and in Nikaupara, around the mudflats. Reeftop gleaning is done by both genders and productivity is comparatively high, at about 200 kg/fisher/year (Figure 2.17). The low general productivity figures also show that most invertebrate collection serves subsistence rather than commercial interests. Seaweed harvesting from soft benthos is insignificant if compared to the wet weight removed by other fisheries on Aitutaki.

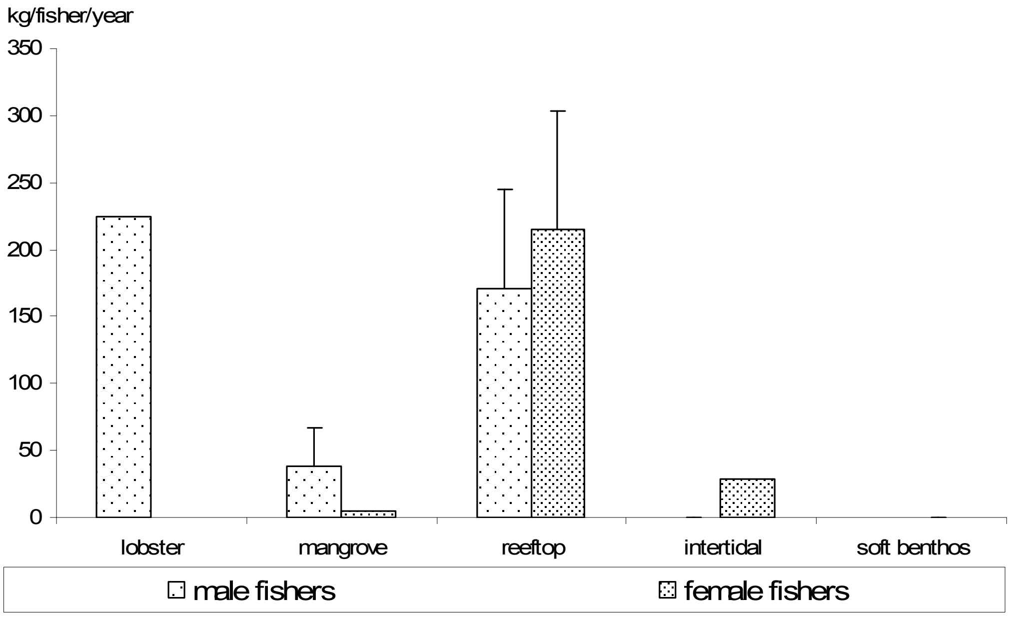



**Figure 2.17: Average annual invertebrate catch (kg wet weight/year) by fisher and gender in Aitutaki.**
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 13 for males, n = 9 for females).

Invertebrate fisheries are not very important on Aitutaki, which is reflected in the low fisher densities, the low average annual catches per fisher, and the low number of target species (Table 2.5). There are a few (~5–7) lobster fishers who sell lobsters more or less regularly to local restaurants. However, we have estimated that 25 fishers may be involved in this from time to time. The resulting fisher density and the average catch per fisher are insignificant or low. Mangrove fishing is exclusively for mud crabs and the ~5 identified active fishers who may at times sell to the local restaurants seem to make a very low impact on the resource, if any. The same observation applies for collecting *kai* (*Asaphis violescens*), *ugakoa* (*Dendropoma maxima*), seaweed (*rimu*, *Caulerpa racemosa*) and crab (*Cardisoma* spp.), which is done by a few people from Aitutaki, often targeting soft benthos and intertidal areas around *motu* that they visit for a weekend picnic or for fishing. The only possible impact may come from reeftop collection, which is done by most. It is important to note that *paua* (*Tridacna maxima*) is one of the most sought-after target species. The low average annual catch figures suggest that the island's *paua* resources are exhausted. As already reported by Adams *et al.* (1996), *T. maxima* was abundant and a first, marked decline is reported to have occurred between 1987 and 1993. This decline prompted a moratorium to be imposed in 1994 on the export of clams to other islands.

In this context, it may be noted that exploitation of commercial trochus was common on Aitutaki from 1981 to 2001, but has been stopped as the prices obtained from overseas clients are no longer competitive to local salaries. Trochus is not an important species for subsistence purposes.

**Table 2.5: Parameters used in assessing fishing pressure on invertebrate resources in Aitutaki**

| Parameters | Fishery / Habitat | | | | |
|---|---|---|---|---|---|
| | **Lobster (km)** | **Mangrove ($km^2$) (3)** | **Reeftop ($km^2$)** | **Intertidal (4)** | **Soft benthos (5)** |
| Fishing ground area ($km^2$) | 44.8 | 0.5 | 20.02 | n/a | n/a |
| Number of fishers (per fishery) (1) | 26 | 15 | 527 | 27 | 26 |
| Density of fishers (number of fishers/$km^2$ fishing ground) | 0.6 | 30 | 26 | n/a | n/a |
| Average annual invertebrate catch (kg/fisher/year) (2) | 224.88 (n/a) | 30.17 (±21.65) | 188.51 (±55.22) | 28.46 (n/a) | |

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers is extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only; (3) there were 3-5 active mud crab fishers identified during the survey; however, a total of 15 active and less active mud crab fishers is assumed;(4) the total intertidal potential fishing ground is difficult to determine as it applies mainly for *tupa* (*Cardisoma* spp.) collection only; *tupa* is usually chased on beaches of *motu*; (5) the total soft benthos potential fishing ground is difficult to determine as it applies mainly to *kai* (*Asaphis violascens*) and perhaps seasonally some seaweed (*Caulerpa* spp.) harvesting. *Kai* is mainly dug while people are on *motu* and also represents a seasonal fishery.

### *2.2.6 Tourist impact: Aitutaki*

Considering the fact that there are at least 10 times as many visitors per year than there are residents on Aitutaki, the survey also targeted major tourist operators, restaurants and hotels to quantify any possible impact by external consumers on the island's reef and lagoon resources. Table 2.6 shows major results obtained from individual interviews.

Considering that only a very few other hotels, resorts or restaurants were not included in the survey, the total impact on reef finfish resources due to the island's tourist sector may be estimated at 6–7 t/year (Table 2.6). Any other impact on reef and lagoon resources, such as lobsters, octopus, mud crabs or *ariri*, is negligible. In general, all respondents expressed major concern regarding the risk of ciguatera. In several cases, the increased risk of fish poisoning has resulted in a shift to providing only pelagic fish to tourists. Also, most if not all respondents confirmed that the demand for fresh fish on the island is much higher than the supply.

**Table 2.6: Estimation of finfish and other seafood demand for tourist sector on Aitutaki**

| Tourist industry | Pelagic finfish | Reef and lagoon finfish | Estimated quantity (kg/year) | Other reef and lagoon seafood | Estimated quantity (kg/year) |
|---|---|---|---|---|---|
| **Hotels / Resorts** | | | | | |
| Are Tamanu Beach Village [(1)] | Tuna | Parrotfish | 2000 | Mud crabs, lobsters | Mud crabs: 30–36; Lobsters: 30–40 |
| Pacific Resort Aitutaki | Locally bought or imported from Rarotonga | Parrotfish mostly imported from Rarotonga | | Rarely any local lobsters or mud crabs | |
| Samade on the Beach [(2)] | Mostly | Parrotfish on special occasions | 15 | Lobster; octopus; rarely mud crabs; *ariri* | Lobsters: 100–120; Octopus: 10–20 |
| **Restaurants** | | | | | |
| Blue Nunn Café [(3)] | Tuna, mahi-mahi, wahoo | Parrotfish bought locally | ~1800 | Rarely, *ariri*, octopus | Octopus: ~50 |
| Café Tupuna | Closed during survey | | | | |
| Boat Shed [(4)] Restaurant | Only | | | | |
| Spider Bar and Restaurant [(5)] | Only | | | | |
| Puffys Takeaways [(6)] | Tuna, *mahimahi* | Stopped in 2006 due to ciguatera | | Octopus | 9–10 |
| **Tours** | | | | | |
| Bishop Cruises [(7)] | Only | | | Seaweed for salads | |
| Island Tours | | | | | |
| Paradise Island Lagoon Tours | Only | Parrotfish used in 2006 (imported from Rarotonga) | | | |
| Teking Tours (Tautu) [(8)] | Tuna, wahoo, mahi-mahi | | | | |
| Lagoon Explorer | Yes | Mainly *mu* (*Monotaxis grandiculis*) | ~300 | | |
| Kia Orana Cruise | | Any species since 2007 | ~800–1000 | | |
| Black Pearl Charters | Only | | | | |
| **Fishing tours** | | | | | |
| Bexter Boys [(9)] | Only | | | | |
| Barry's Fishing Tour [(10)] | | Any species | 300–500 | | |
| Vaikiore Fishing Charter [(10)] | | Any species | 300–500 | | |

[(1)] Buys from 10 local fishers, sometimes too much tuna, buys mud crabs and lobsters for NZD 13 /kg, parrotfish for NZD 6 /kg, tuna for NZD 6 /kg; [(2)] buys regularly from 2 local fishers (Bexter Boys), NZD 7 /kg pelagic fish, NZD 5 /kg reef fish, NZD 12–15 /kg lobsters/mud crabs, NZD 6 /kg octopus, NZD 7–8 /kg squid, NZD 20 /10 kg *ariri* (= 1 bag); [(3)] buys from mainly 2 local fishers; consumption of pelagic and reef fish is about 50/50; crab sticks imported from New Zealand, local price is NZD 5 /kg parrotfish, NZD 6 /kg tuna, NZD 5 /kg octopus; [(4)] ~30–40 kg pelagic fish/week mostly imported from Rarotonga, all other seafood is pre-processed and imported; [(5)] buys pelagic fish from 4–5 local fishers for NZD 6 /kg; ~50 kg pelagic fish/month; seafood sold is imported; [(6)] buys from 4 local fishers; pays NZD 6.50 /kg for octopus, NZD 7 /kg for pelagic fish; [(7)] employs one full-time fisher and buys fish to feed tourists from other fishers (tuna, mahi-mahi, wahoo); has on average 15 tourists/day and uses about ~500 kg fish/year based on an average consumption of 9–10 kg fish/week (June – October);[(8)] buys ~30 kg/week from 1 fisher (his captain) and sometimes 2–3 others, pays NZD 7 /kg pelagic fish; [(9)] ~400 kg of game fish caught by clients/month that is sold to Pacific Resort, Puna Café, Te Vaka, Aitutaki Lagoon Resort, Samande On the Beach, cost NZD 7 /kg gutted; [(10)] fishing has dramatically deteriorated compared to 10 years ago; use casting rods for their tourist fishing on reefs.

### *2.2.7 Fisheries management issues: Aitutaki*

According to the laws and regulations in Cook Islands, Aitutaki resources are governed by the local government, represented by the Island Council. Although there were many concerns expressed during the survey that serious management interventions are needed to recover Aitutaki's lagoon and reef resources and to manage them sustainably in the future, knowledge of and compliance with the existing by-laws are limited and so are current initiatives and bans.

The Aitutaki Fisheries By-Laws (Manuae and Te-Au-O-Tonga 1990) (Cook Islands Government 1994) prohibit any export, whether private or commercial, or sale of any shellfish or sea mammal. They also prohibit any harvest of shellfish and sea mammals for feasts that are likely to be attended by many people.

The use of SCUBA gear is not allowed for spear fishing. Net fishing must be performed manually and its use is restricted to channels. For example, nets cannot be set between *motu*, nor within 100 m of any harbour or channel. Nets should not be longer than 1200 m and no wider than 4 m, having a mesh size of at least 2.5 inches; they are to be set not closer than 100 m to each other. A fisher should not set more than one net at a time and must continuously attend to the net that is set. The use of drag nets is prohibited and so are any destructive fishing methods, including explosives and poisonous substances.

The by-laws also require the appointment of enforcement officers and impose fines for any offences committed.

About seven years ago (~1999) four areas were designated as no-take marine reserves (*ra'ui*). These *ra'ui* were established using traditional methods, i.e. by seeking the consent and participation of the community rather than establishing by-laws. Nevertheless, the compliance level is not high and lack of policing was suggested as the major constraint. The areas are indicated in Figure 2.6 and include three marine parks and one area that is closed to support the establishment of introduced giant clams (*Tridacna gigas*, *T. derasa*, *Hippopus hippopus*). Following the introduction of trochus (*Trochus niloticus*) from Fiji in 1957, a breeding reserve was introduced in 1983, covering a 3 km stretch of the windward reef of Aitutaki (Adams *et al.* 1996).

During the previous 10 years, discussions have been ongoing regarding the banning of gillnetting for bonefish, the introduction of a quota system for residents to line-fish for bonefish, a catch-and-release system for tourists, and the general banning or restriction of gillnets.

Tour operators had a meeting about 15 years ago (~1992) with the Island Council. It was agreed that tourists should be fed with pelagic fish in order to spread the revenue from tourism among fishers and lessen the fishing pressure on lagoon resources. Survey results revealed that there are still a few operators who catch reef fish for feeding tourists.

The trochus fishery was last opened for harvest in 2001. The Island Council usually opens the trochus harvesting as a collective fishery for a certain time period. The total catch is reported as 18–45 t/year (except for the first harvest in 1981, which was 200 t, and in 2000, when there was no harvest at all) corresponding to a value of NZD 45,000–220,000 /year depending on the market price (increased from NZD 850 /t in 1981 to NZD 1500 /t in 2001 according to MMR records in Rarotonga). The collective system was improved in 1990/91 with Individual Transferable Quotas (ITQ), which allowed the quota to be shared equally among all Aitutaki residents (Bertram 1995a, b, c). Trochus is no longer harvested because the price for trochus shells is not considered economically attractive or competitive to the average local wage of NZD 7–8 /hour (Mayor of Aitutaki pers. comm.).

Fishing on Aitutaki follows an open-access system, whereby all community members are free to choose their fishing grounds. The tourist sector is increasingly important, and the number of tourists who visit Aitutaki (~18,000 tourists/year) is 10 times higher than the current resident population. It is felt that tourism has developed very much faster than the island's infrastructure, and is regarded as adding stress on the lagoon and reef resources.

Ciguatera has always been reported to occur; however, over the past years the occurrence of fish poisoning has been more frequent, more severe and affects more species. As a result, more and more pelagic species are targeted, particularly to supply the island's substantial tourist sector. For that reason, only smaller quantities of parrotfish and bonefish are exported by air[8] to Rarotonga, mainly as a gift to family members and relatives. However, seaweed is exported by air freight for both non-commercial and commercial purposes, mainly during the winter months (June to September).

In 1996 the community decided to undertake concerted efforts to decrease the number of crown-of-thorns starfish on Aitutaki reefs in response to the reported chronic outbreaks of *Acanthaster plancii* following widespread coral bleaching in 1991, 1992 and 1993 (Paulay 1994). Over 200 people organised per village and targeting different areas participated in collecting the starfish on the western and southern inner and outer reefs. All starfish collected (>2000 specimens) were burned. The same action took place in 1992 and is planned again for April 2007, depending on funding.

A new project for farming *ava* (milkfish) and mullets in ponds has been proposed by some people from Aitutaki. Approval from MMR has been advised. Furthermore, under the ongoing CIMRIS project, there are plans to replant coral.

Respondents indicated that mullet (*aua*, *Parupeneus* spp.) is a species that is now hardly fished in the lagoon. Mullet was traditionally caught using a village netting system and an average catch is reported to be 500–2000 fish >35 cm fork length.

### *2.2.8 Discussion and conclusions: socioeconomics in Aitutaki*

- Results from the survey suggest that the Aitutaki community is less dependent on fisheries than it may have traditionally been. The traditional dependency shows in a moderate-to-high fresh-fish consumption. However, people also consume canned fish at a significant rate, which suggests a change in lifestyle from fresh fish to processed fish, and also a higher availability of cash to substitute purchased meals for seafood caught for subsistence. Comparing our 2007 results with those from a 1995 survey reported by Adams *et al.* (1996), the total population on Aitutaki has decreased from 2300 to 1800, and so has the average household size, from 7 to 4 people, and the frequency and quantity of fresh fish has decreased from 4.7 to 3.3 meals/week and from 100 to 58 kg/person/year.

[8] NZD 2.00 /kg air freight.

- This argument is further supported by the fact that salaries are the most important source of income, while fisheries supply only 7% of households with first and another 23% with complementary income. One reason for the suggested lifestyle change may be tourism, which brings at least 10 times as many visitors to Aitutaki as there are residents.

- Information gathered also suggests a major drop in the importance of invertebrate fisheries. Records show that the island supported a commercial trochus fishery from 1981 to 2001 that was community-based, with equal shares of revenues for all fishers. However, trochus harvesting is no longer economically attractive. The island's lagoon system also provided the basis for an important giant clam fishery that served the Rarotonga market. Harvest bans that were already established in the mid to late 1980s were the first reaction to a perceived decline. Apparently these management measures were not effective because the island's giant clam resources are reported to have almost disappeared. Efforts are underway to establish imported giant clam species in a protected lagoon area, as well as a *ra'ui* (a no-take marine reserve) that aims to provide a recruitment area for *Tridacna maxima*. Today's consumption of invertebrates is very low, and fishing activities are done by a few active fishers and focus on a few species only.

- Finfish fishing is mostly done by gillnetting and this technique is held responsible for a decline in the lagoon's finfish resources. The dominance of gillnetting has not much changed since 1995. The low average frequency of fishing trips indicates a major shift from subsistence and commercially driven fisheries to leisure and lifestyle fisheries. Adams *et al.* (1996) reported that in 1995 fishers would go out more than twice per week, while in 2007 the average frequency dropped to once per week. Respondents often reported that fishing is done as a family outing at the weekend. Most catch is taken by males, and is sourced from the lagoon rather than the passages or outer reef. Both the fact that fishing is done more as a leisure activity rather than aiming to maximise productivity, and that resource status may also be limited may explain the low CPUE and low average annual catches per fishers recorded. Although the lagoon was also the major habitat targeted in 1995 (Adams *et al.* 1996) CPUEs may have dropped, in particular if comparing the average figure of 3.4 kg/hour in 2007 with a CPUE of 6.5 kg/hour for gillnetting in 1995.

- Overall, fishing pressure was not found to be alarmingly high, and is estimated to be 1.2–6.4 t/km$^2$ of total fishing ground or total reef area respectively. Assuming that today's total fishing impact on Aitutaki is mainly due to the population's own consumption needs, the total annual catch rate has substantially decreased from an estimated 790 t in 1978/79 to 250–300 t in 1995 (Adams *et al.* 1996) and 135 t in 2007.

- Tourist impact on the island's reef and lagoon resources is very limited if not insignificant. The tourist sector mainly demands pelagic finfish and relies on imported crustaceans and other seafood.

- Fisheries management interventions include *ra'ui*, restrictions concerning the use and character of gillnets, export of shellfish and any sea mammals and occasional community projects to reduce the number of crown-of-thorns starfish. There are efforts to establish imported giant clam species. Discussions have been held to direct fishing pressure away from reef and lagoon towards pelagic resources, in particular as regards the growing demand from the tourist sector. The increased occurrence of ciguatera may also help to reduce fishing pressure, in particular on fish for export to Rarotonga. However, compliance with fisheries management interventions is low, which also includes fishing in the designated no-take marine reserve (*ra'ui*) areas.

- According to the data collected and discussions held it seems as if the current status of Aitutaki's reef and lagoon resources has decreased from its earlier level. However, the previous population increase, the introduction of more effective fishing techniques (motorised boats, gillnets, etc.), and the market demand of Rarotonga may all have contributed to a decline in certain resources (giant clams, Scaridae). This trend may now be counterbalanced by a shift from income generation based on primary production to employment in the public and private sector, in particular in the tourism industry. The change in lifestyle is visible in the consumption pattern, with less fresh fish and more canned fish and other imported protein sources consumed. Fishing is no longer a necessity but often considered as a weekend and lifestyle activity that follows principles other than maximising productivity. Traditional values, however, are still acknowledged, resulting in a high proportion of catch being distributed among community members on a non-commercial basis. Ciguatera, freight cost, and income from other sectors than fisheries may also contribute to reduce fishing pressure on the island's resources, with less catch exported. The lack of economic incentive to further exploit trochus helps to maintain the island's trochus stocks.

- The Island Council undertakes efforts such as *ra'ui* areas, bans and restrictions on destructive fishing techniques, and harvesting control of shellfish and marine mammals, all aiming to re-establish the island's reef and lagoon resources for its future use, and to maintain its values for the tourism sector. However, the lack of local compliance gives reason for concern. The discussion and trial of a surveillance and monitoring system that is tailored to meet the expectations and acceptance of the local population is advised. The improvement and sustainable management of Aitutaki's reef and lagoon resources is believed to be an objective shared by the entire community due to the demand for fresh fish exceeding local supply, and its increasing dependency on tourism that is very much based on its lagoon attractions (fishing, SCUBA, snorkeling, excursions to *motu*, etc.).

## 2.3 Finfish resource surveys: Aitutaki

Finfish resources and associated habitats were assessed between 2 and 12 February 2007, from a total of 18 transects. No coastal reefs were present (very shallow water, little coral construction). Intermediate reefs are very rare in the lagoon, located in the southwest and east but in very shallow waters. The eastern reefs were not sampled due to the very low visibility. Regarding back-reefs, the eastern side did not present any; they were available only in the western and southern side of the atoll. They were mainly composed of a mix of dead coral rock and pockets of sand and rubble. Outer reefs were mainly sampled in the southern and eastern part of the atoll due to difficult access in the west because of strong winds.

Therefore three types of habitats were sampled, with six replicate transects conducted in each: 6 intermediate reefs, 6 back-reefs, and 6 outer reefs (See Figure 2.18 and Appendix 3.1.1 for transect locations and coordinates respectively.).

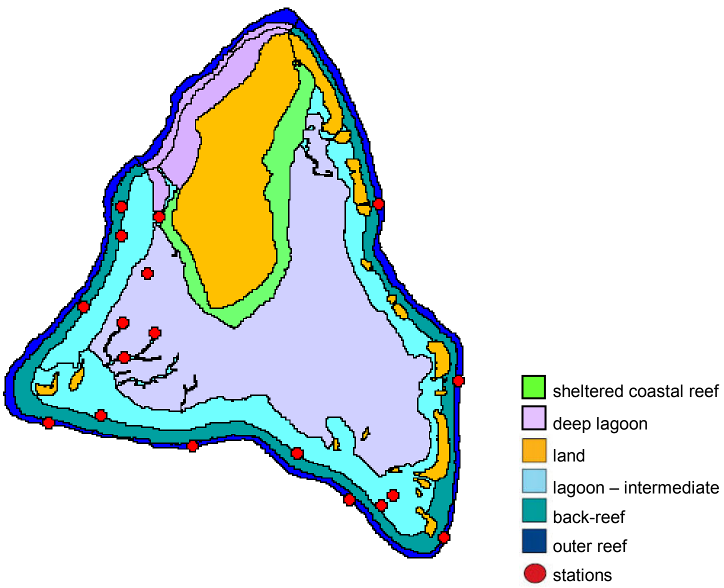



**Figure 2.18: Habitat types and transect locations for finfish assessment in Aitutaki.**

### *2.3.1 Finfish assessment results: Aitutaki*

A total of 22 families, 45 genera, 120 species and 9954 fish were recorded in the 18 transects (See Appendix 3.1.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 36 genera, 106 species and 9854 individuals.

Finfish resources varied greatly among the three reef environments found in Aitutaki (Table 2.6). The outer reef contained the greatest number of fish (1.0 fish/m$^2$), highest biomass (128 g/m$^2$), and highest biodiversity (45 species/transect) compared to the intermediate and back-reefs. Lowest biomass was recorded in the intermediate reefs (62 g/m$^2$), while size, density and biodiversity were the same in the intermediate and back-reefs. The back-reefs displayed also the smallest average fish size (17 cm FL).

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

| Parameters | Habitat | | | |
|---|---|---|---|---|
| | Intermediate reef [1] | Back-reef [1] | Outer reef [1] | All reefs [2] |
| Number of transects | 6 | 6 | 6 | 18 |
| Total habitat area (km$^2$) | 20.3 | 11.5 | 7.5 | 39.3 |
| Depth (m) | 3 (1-6) [3] | 1 (1-2) [3] | 7 (5-8) [3] | 3 (1-8) [3] |
| Soft bottom (% cover) | 39 ±2 | 21 ±9 | 2 ±1 | 14 |
| Rubble & boulders (% cover) | 6 ±2 | 34 ±9 | 1 ±1 | 22 |
| Hard bottom (% cover) | 34 ±4 | 34 ±5 | 53 ±4 | 41 |
| Live coral (% cover) | 18 ±4 | 11 ±2 | 37 ±2 | 21 |
| Soft coral (% cover) | 0 ±0 | 0 ±0 | 6 ±2 | 2 |
| Biodiversity (species/transect) | 29 ±4 | 29 ±1 | 45 ±4 | 34±3 |
| Density (fish/m$^2$) | 0.4 ±0.1 | 0.4 ±0.1 | 1.0 ±0.2 | 0.5 |
| Biomass (g/m$^2$) | 62.3 ±17.1 | 73.5 ±9.5 | 128.4 ±24.6 | 78.2 |
| Size (cm FL) [4] | 17 ±1 | 17 ±1 | 16 ±1 | 17 |
| Size ratio (%) | 51 ±2 | 56 ±3 | 56 ±2 | 53 |

[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.

## *Intermediate-reef environment: Aitutaki*

The intermediate-reef environment of Aitutaki was dominated by two major families of herbivores: Acanthuridae and Scaridae (Figure 2.19, Table 2.7). These two families were represented by 20 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Scarus altipinnis*, *Chlorurus sordidus*, *Naso lituratus*, *N. unicornis* and *Acanthurus triostegus* (Table 2.7). This reef environment was similarly composed of soft bottom (39%) and hard bottom (34%) with little live coral (18%, Table 2.6, Figure 2.19).

**Table 2.7: Finfish species contributing most to main families in terms of densities and biomass in the intermediate-reef environment of Aitutaki**

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.105 ±0.023 | 16.9 ±4.3 |
| | *Naso lituratus* | Orangespine unicornfish | 0.010 ±0.005 | 3.9 ±1.8 |
| | *Naso unicornis* | Bluespine unicornfish | 0.004 ±0.002 | 2.5 ±1.4 |
| | *Acanthurus triostegus* | Convict tang | 0.030 ±0.014 | 2.0 ±1.0 |
| Scaridae | *Scarus altipinnis* | Filament-finned parrotfish | 0.011 ±0.006 | 7.0 ±4.3 |
| | *Chlorurus sordidus* | Daisy parrotfish | 0.042 ±0.020 | 4.3 ±2.6 |

The density, size and biodiversity of finfish in the intermediate reefs of Aitutaki were smaller than the outer-reef values but similar to back-reef values. However, size ratio and biomass were the lowest recorded at the site (51% and 62 g/m$^2$). All the biological parameters were also smaller than the values from the intermediate reefs of Palmerston, the only other site with intermediate reefs. The trophic structure in Aitutaki intermediate reefs was highly dominated by herbivorous fish, here mainly represented by Acanthuridae and Scaridae. Carnivores were almost absent. Size ratios were below 50% for Holocentridae, Labridae, Lethrinidae and Lutjanidae, and especially Scaridae. This family is the most fished group from inside the lagoon (45% of total catches) and the smaller average size ratios suggest an impact from fishing. The intermediate reefs of Aitutaki displayed a substrate almost equally composed of soft and hard bottom, offering habitats for different families. The almost total lack of carnivores is therefore not fully explained by this substrate composition. Most of the fishing is done in the lagoon area, with gillnets and spears.

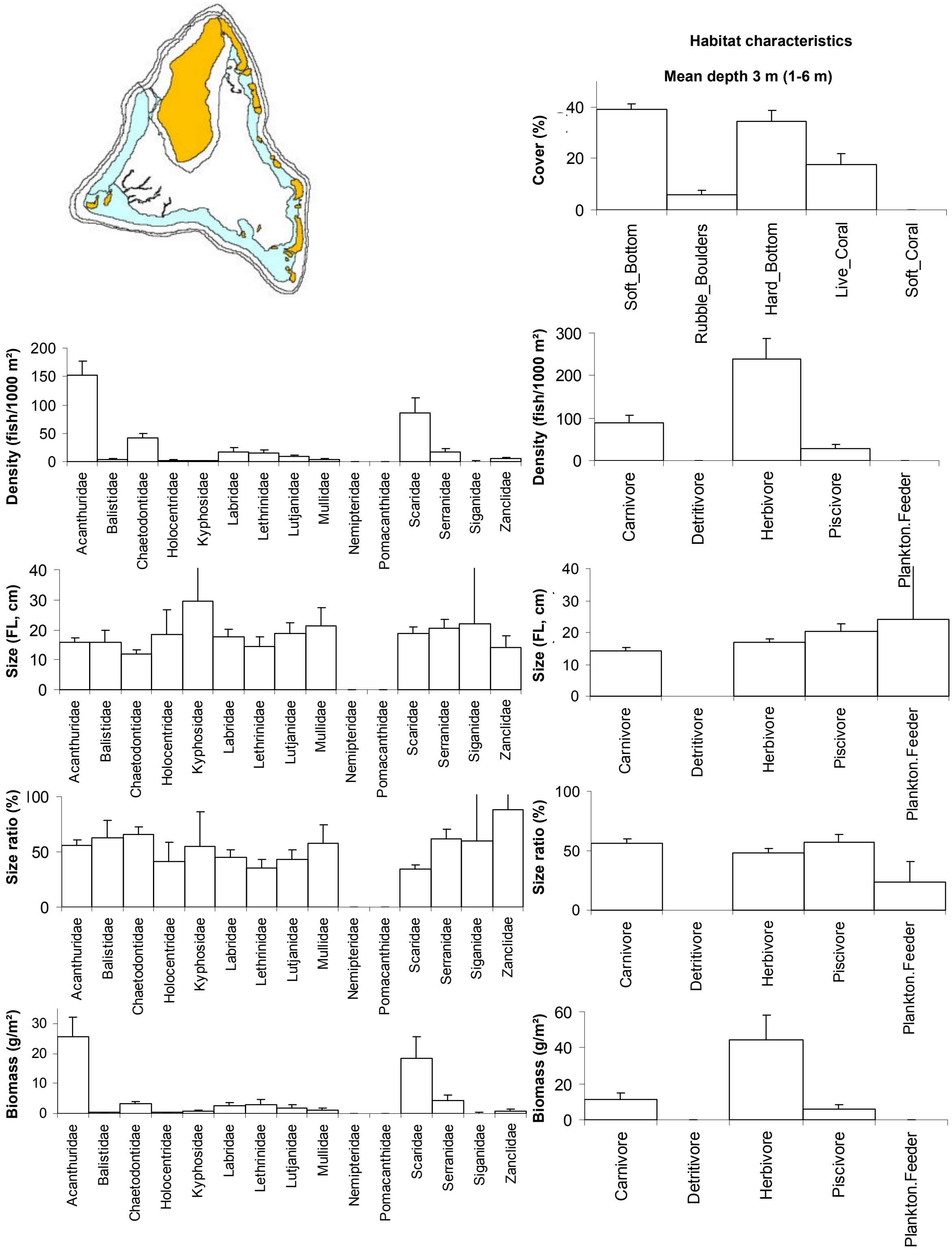



**Figure 2.19: Profile of finfish resources in the intermediate-reef environment of Aitutaki.**
Bars represent standard error (+SE); FL = fork length.

*Back-reef environment: Aitutaki*

The back-reef of Aitutaki was dominated, both in terms of density and biomass, by herbivorous Acanthuridae and Scaridae (Figure 2.20). These two families were present with 14 species; the most important in terms of biomass and abundance were: *Ctenochaetus striatus*, *Scarus psittacus*, *Acanthurus triostegus*, *Naso lituratus* and *Scarus ghobban* (Table 2.8). Hard-bottom cover (34%), rubble (34%) and soft bottom (21%) were almost equally important in defining substrate composition. Very little live coral was present (11%, Table 2.6, Figure 2.20).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.149 ±0.027 | 24.3 ±4.3 |
| | *Acanthurus triostegus* | Convict tang | 0.067 ±0.029 | 6.1 ±2.5 |
| | *Naso lituratus* | Orangespine unicornfish | 0.010 ±0.004 | 3.0 ±1.3 |
| Scaridae | *Scarus psittacus* | Common parrotfish | 0.060 ±0.023 | 10.4 ±4.6 |
| | *Scarus ghobban* | Bluebarred parrotfish | 0.007 ±0.003 | 2.1 ±1.1 |

The density, size and biodiversity at this reef were similar to in the intermediate reefs but lower than in the outer reefs. However, size ratio and biomass were higher than in intermediate reefs (74 versus 62 g/m$^2$). When compared to the back-reefs of Palmerston and Rarotonga, Aitutaki back-reef values of size, size ratio, biomass, biodiversity were the highest, while density was second to Rarotonga (Table 2.6). The trophic composition was highly dominated by herbivores; Acanthuridae and Scaridae represented the largest bulk of density and biomass, with several small to medium-sized species, such as *Ctenochaetus striatus* and *Scarus psittacus.* Size ratio was much lower than 50% for some families, but especially for Scaridae (36%), evidence of impact from fishing on this selected family. The substrate was composed of hard bottom, soft bottom and rubble (89% together), which naturally supports an abundance of different families. However, the low biodiversity and poverty of carnivores suggest a different cause for the poor fish composition, i.e. fishing pressure. The only relatively important carnivores from the point of view of biomass were Labridae, with *Cheilinus undulatus* of average size present in one survey transect location.

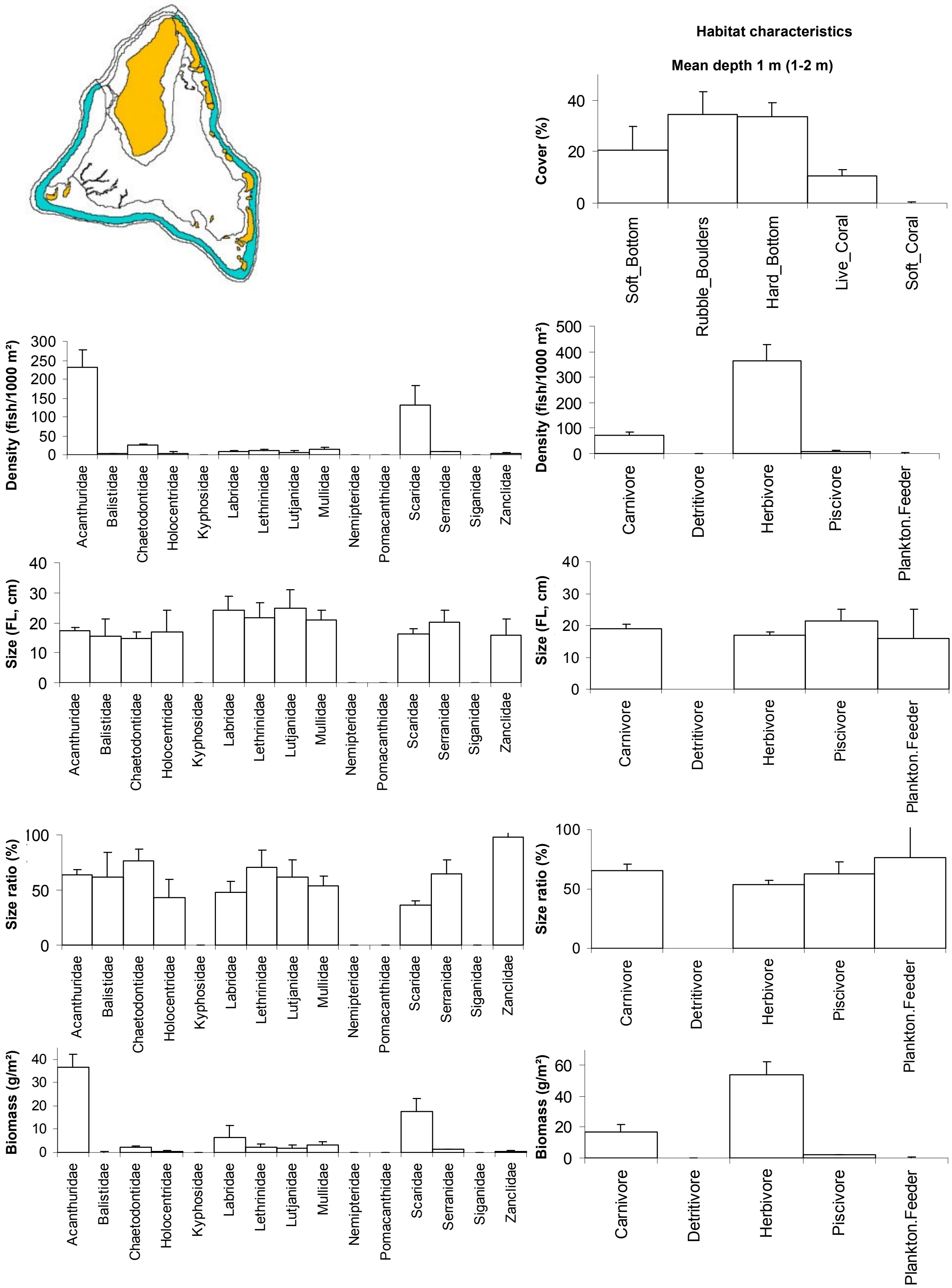



**Figure 2.20: Profile of finfish resources in the back-reef environment of Aitutaki.**
Bars represent standard error (+SE); FL = fork length.

*Outer-reef environment: Aitutaki*

The outer reef of Aitutaki was largely dominated, in terms of density and biomass, by herbivore Acanthuridae (Figure 2.21). This family was represented by a total of 12 species, the main ones being *Ctenochaetus striatus*, *Acanthurus triostegus* and *Naso lituratus* (Table 2.9). Hard bottom (53%) mainly covered the habitat and cover of live coral was also high (37%, Table 2.6 and Figure 2.21).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.510 ±0.084 | 60.1 ±13.1 |
| | *Acanthurus triostegus* | Convict tang | 0.133 ±0.133 | 8.1 ±8.1 |
| | *Naso lituratus* | Orangespine unicornfish | 0.026 ±0.004 | 7.0 ±1.3 |

The density, biomass, size ratio and biodiversity of this reef were the highest at the site. However, average fish size was lower than the back-reef values. When compared to the other outer reefs at Palmerston, Mangaia and Rarotonga, Aitutaki still displayed highest density, biomass and biodiversity, but values of size and size ratio were intermediate. Trophic structure was heavily dominated by herbivores in high abundance. Only Serranidae, mostly *Cephalopholis argus*, represented carnivores in relatively good numbers. This species was affected by ciguatera and therefore never targeted by male fishers. Other species affected were Carrangidae, here also quite abundant, with large-sized *Caranx melampygus* and *C. ignobilis* (not included in the coastal reef resource assessment), as well as Lethrinidae (*Lethrinus xanthochilus*) and Lutjanidae (*Lutjanus fulvus* and *L. monostigma*). Size ratio was much below 50% for Scaridae (38%), suggesting an impact from fishing on this targeted species group. Composition of habitat, dominated by hard bottom and live coral (90%), clearly favoured herbivores and disadvantaged soft-bottom associated carnivores, such as Lethrinidae and Mullidae. Fish were not particularly wary of divers, suggesting a low impact from spear diving. A total absence of sharks was noted and only one turtle was seen at the surface near the western passage.

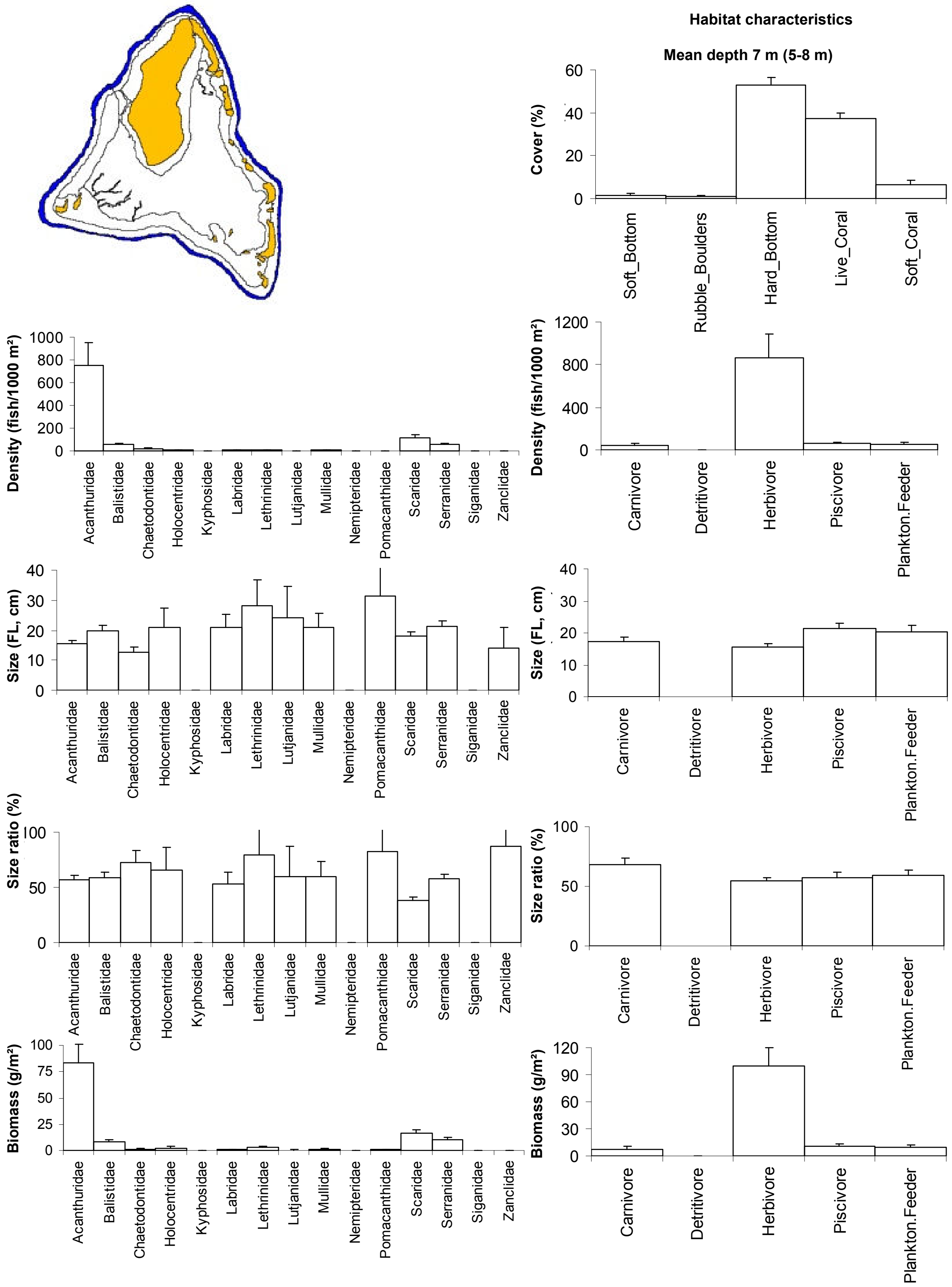



**Figure 2.21: Profile of finfish resources in the outer-reef environment of Aitutaki.**
Bars represent standard error (+SE); FL = fork length.

*Overall reef environment: Aitutaki*

Overall, the reefs of Aitutaki were heavily dominated by two main herbivore families, Acanthuridae and Scaridae (Figure 2.22). These two families were represented by a total of 32 species, dominated by *Ctenochaetus striatus*, *Acanthurus triostegus*, *Naso lituratus*, *Chlorurus sordidus*, *Scarus psittacus* and *S. altipinnis* (Table 2.10). Overall, hard bottom dominated the habitat (41%) and cover of live coral was relatively plentiful (21%, Table 2.6 and Figure 2.22). The overall fish assemblage in Aitutaki shared characteristics of primarily intermediate reefs (52% of total habitat), then back-reefs (29%) and outer reefs (19%).

**Table 2.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Aitutaki (weighted average)**

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.20 | 27.4 |
| | *Acanthurus triostegus* | Convict tang | 0.06 | 4.4 |
| | *Naso lituratus* | Orangespine unicornfish | 0.01 | 4.2 |
| Scaridae | *Chlorurus sordidus* | Daisy parrotfish | 0.04 | 4.0 |
| | *Scarus psittacus* | Common parrotfish | 0.02 | 3.8 |
| | *Scarus altipinnis* | Filamentfinned parrotfish | 0.01 | 3.6 |

Overall, Aitutaki appeared to support an average-to-low finfish resource, with intermediate biomass between the conditions at Palmerston and Rarotonga, highest average fish size among all sites, second-highest biodiversity for the country, although of small value compared to the regional average, but the lowest fish density. However, relationships among sites are valid only when values are compared with those of Aitutaki and Palmerston, which present the same type of reef habitats: intermediate, back- and outer reefs. These results suggest that the finfish resource in Aitutaki was in better condition than that in Palmerston, although values of density, biomass and diversity were rather low when compared to other countries. The detailed assessment of fish community composition revealed that carnivores were present at lower density and biomass than were herbivores, which strongly dominated the fish community. Few families dominated the community and a general lack or serious poverty of carnivores was the dominant profile: Labridae, Lutjanidae, Lethrinidae and Mullidae were present in extremely low numbers and only Serranidae displayed significant density (especially due to the relatively high concentration of the poisonous *Cephalopholis argus*). The dominance of herbivores can be partially explained by the composition of the habitat, which was mainly composed of hard rock and live coral, with little soft substrate, which normally favours most invertebrate-feeding carnivores. The study of size and size ratio trends disclosed the presence of smaller fish in the Scaridae family, indicating an impact on such a highly preferred group. The predominant fishing tools were nets, very effective, and spears, which are species- and size-selective.

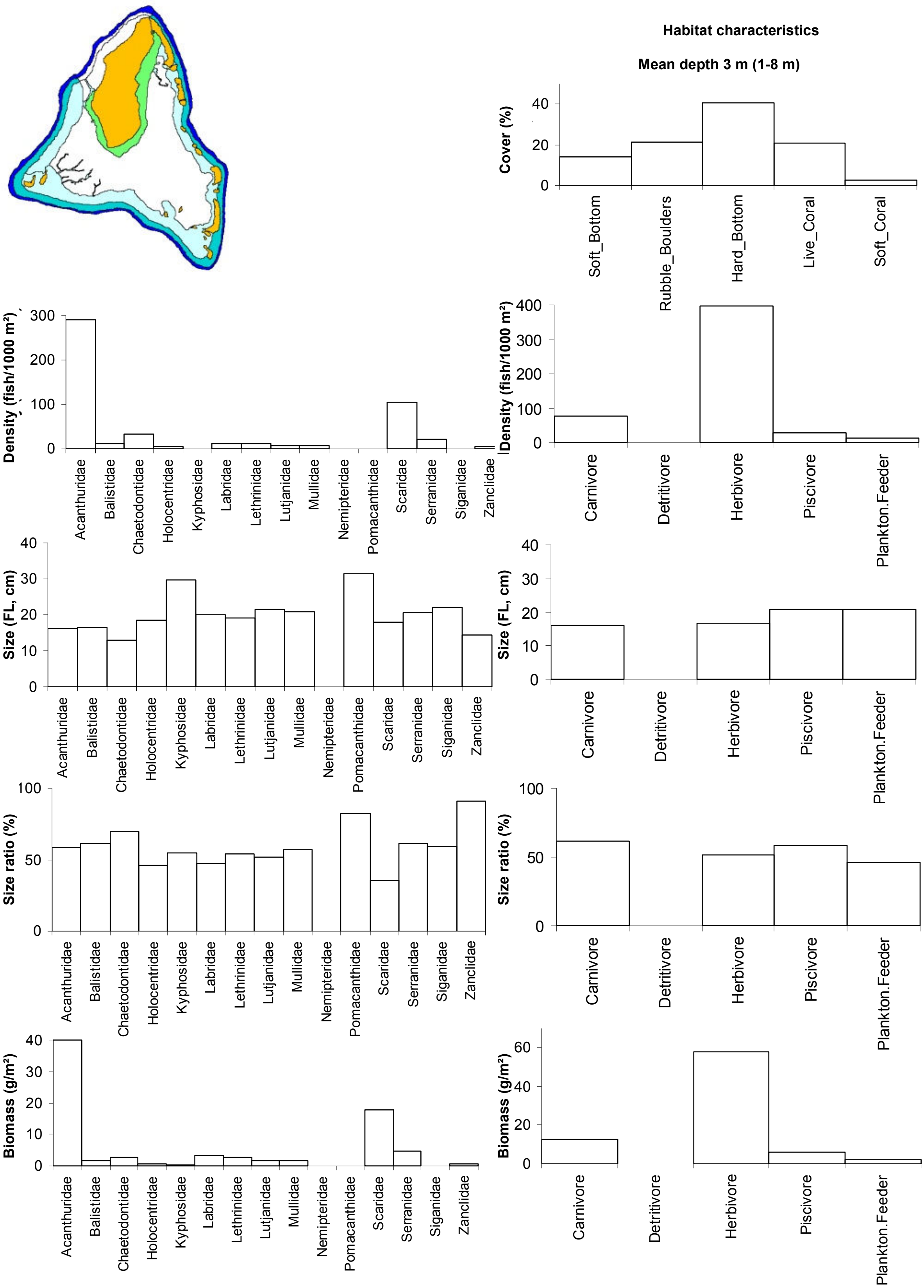



**Figure 2.22: Profile of finfish resources in the combined reef habitats of Aitutaki (weighted average).**
FL = fork length.

### *2.3.2 Discussion and conclusions: finfish resources in Aitutaki*

- Fishing in Aitutaki is open access and targets very specific species due to the high presence of ciguatera, recorded especially in *Cephalopholis argus*, *Lethrinus xanthochilus*, *C. melampygus*, *C. ignobilis*, *Lutjanus fulvus* and *L. monostigma.* Ciguatera has always occurred, however, over the past years its occurrence has been more frequent, severe and spread over many species. As a result, more and more pelagic species are targeted, in particular to supply the tourist sector. However, in general, people of Aitutaki are not very dependent on fishing for income generation and fishing is becoming more and more a leisure activity rather than an income-generating or subsistence practice. There are four protected areas or reserves (*ra'ui*), one in the northeast of the lagoon on sandy bottom, one to the southeast, near the island of Likopua, visited by tourists who practise fish-feeding and snorkeling, and two to the southwest around the island of Maina, where a giant clam nursery is placed. However, compliance with these restrictions is very limited.

- The assessment indicated that the status of finfish resources in this site at the time of surveys was average to poor. Density was low compared to the regional average; however, similar to density in Palmerston. Size, size ratio, biomass and biodiversity were higher than those recorded in Palmerston Atoll. Detailed analysis at family level showed that Scaridae were consistently small in all habitats (size ratio was only 34–38% of maximum recorded size per species). Catches from the Aitutaki lagoon and back-reef were mainly composed of Scaridae (>45% of catches). The remaining catches were composed of species of Acanthuridae, Mullidae, and Mugilidae families. The impact of this selective fishing was seen in the fish population as reduced sizes. The inner reefs (lagoon and back-reef) appeared to be the most frequently fished habitat and, in fact, biomass and density were lower there than at the outer reefs.

- Resources were, overall, in average-to-poor condition. The inner reefs were lacking in corals and finfish resources were neither diverse nor particularly abundant.

- The density, biomass and diversity of fish were higher in the outer reefs but the fish community composition was heavily dominated by Acanthuridae.

- Finfish abundance, size, biomass and biodiversity were lower in the internal reefs, where most fishing takes place.

- Sizes of Scaridae were much lower than the maximum size recorded for the relative species, indicating an impact from fishing on such favourite targets.

## 2.4 Invertebrate resource surveys: Aitutaki

The diversity and abundance of invertebrate species at Aitutaki were independently determined using a range of survey techniques (Table 2.11): broad-scale assessment (using the 'manta tow'; locations shown in Figure 2.23) and finer-scale assessment of specific reef and benthic habitats (Figures 2.24 and 2.25).

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 assessments were conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

**Table 2.11: Number of stations and replicate measures completed at Aitutaki**

| Survey method | Stations | Replicate measures |
|---|---|---|
| Broad-scale transects (B-S) | 12 | 72 transects |
| Reef-benthos transects (RBt) | 21 | 129 transects |
| Soft-benthos transects (SBt) | 0 | 0 transect |
| Soft-benthos infaunal quadrats (SBq) | 0 | 0 quadrat group |
| Mother-of-pearl transects (MOPt) | 4 | 24 transects |
| Mother-of-pearl searches (MOPs) | 1 | 6 search periods |
| Reef-front searches (RFs) | 8 | 48 search periods |
| Reef-front searches by walking (RFs_w) | 8 | 48 search periods |
| Sea cucumber day searches (Ds) | 3 | 18 search periods |
| Sea cucumber night searches (Ns) | 2 | 12 search periods |

**Figure 2.23: Broad-scale survey stations for invertebrates in Aitutaki.**
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

**Figure 2.24: Fine-scale reef-benthos transect survey stations for invertebrates in Aitutaki.**
Black circles: reef-benthos transect stations (RBt).

**Figure 2.25: Fine-scale survey stations for invertebrates in Aitutaki.**
Inverted black triangles: reef-front search stations (RFs);
black squares: mother-of-pearl transect stations (MOPt);
grey squares: mother-of-pearl search stations (MOPs);
grey circles: sea cucumber night search stations (Ns);
grey diamonds: sea cucumber day search stations (Ds).

Thirty-four species or species groupings (groups of species within a genus) were recorded in the Aitutaki invertebrate surveys: 4 bivalves, 11 gastropods, 7 sea cucumbers, 6 urchins, 2 sea stars, 1 cnidarian and 1 lobster (Appendix 4.1.1). Information on key families and species is detailed below.

### *2.4.1 Giant clams: Aitutaki*

Shallow-reef habitat that is suitable for giant clams was not very extensive at Aitutaki (19.1 $km^2$: ~11.6 $km^2$ within the lagoon and 7.5 $km^2$ on the reef front or slope of the barrier). The lagoon area was more extensive (74.9 $km^2$) and hard substrate was available at the barrier reef, intermediate and shoreline or coastal reef.

The high-island environment of Aitutaki had an influence on the distribution of clams as inputs from the land were notable close to the island and water movement was generally not very dynamic in large parts of the shallow system. Water that was greatly influenced by land was noted to flow to the southeast and east, with water of variable visibility flowing out over the barrier and through the small passages. Reefs close to the main island were difficult to survey because of the low visibility, and reefs affected by this water flow had notable levels of epiphytes and sediment cover.

Using all survey techniques, one species of giant clam was noted in survey: the elongate clam *Tridacna maxima*. The fluted clam *Tridacna squamosa* was also present at Aitutaki (only two local specimens held at the MMR clam nursery) but none were noted in our fieldwork. In a stocked section of the lagoon (MMR clam area), there was a number of hatchery-reared smooth clams (*T. derasa*) and true giant clams (*T. gigas*). Broad-scale sampling provided a good overview of giant clam distribution and density and revealed that *T. maxima* had a wide occurrence (found in 11/12 stations and 49/72 transects; see Figure 2.26).

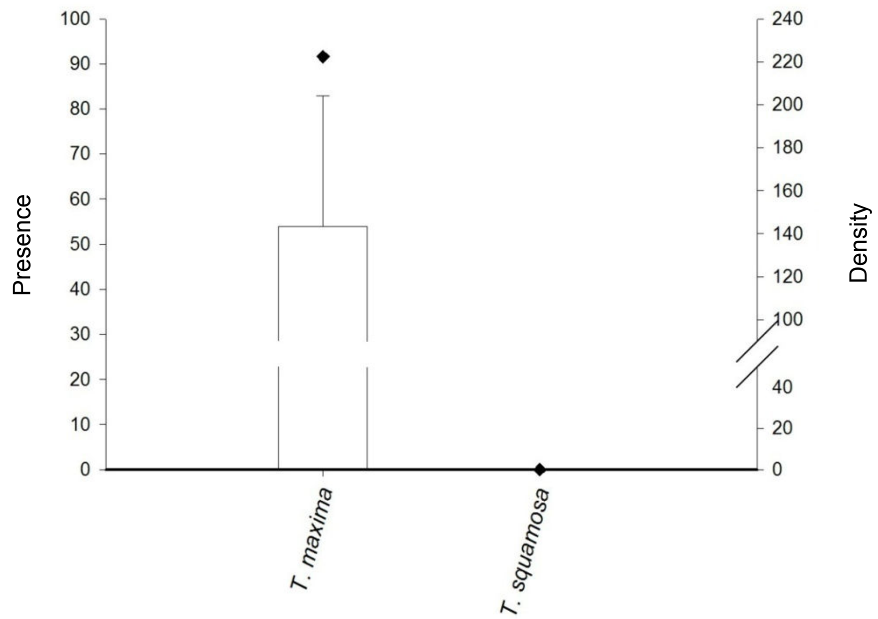



**Figure 2.26: Presence and mean density of giant clam species in Aitutaki based on broad-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 2.27). In these reef-benthos assessments (RBt) *T. maxima* was present in 95% of stations, the highest station density being 4625 clams/ha ±565. The stations with the highest average densities were positioned in the southeast and south of the atoll, on back-reefs.

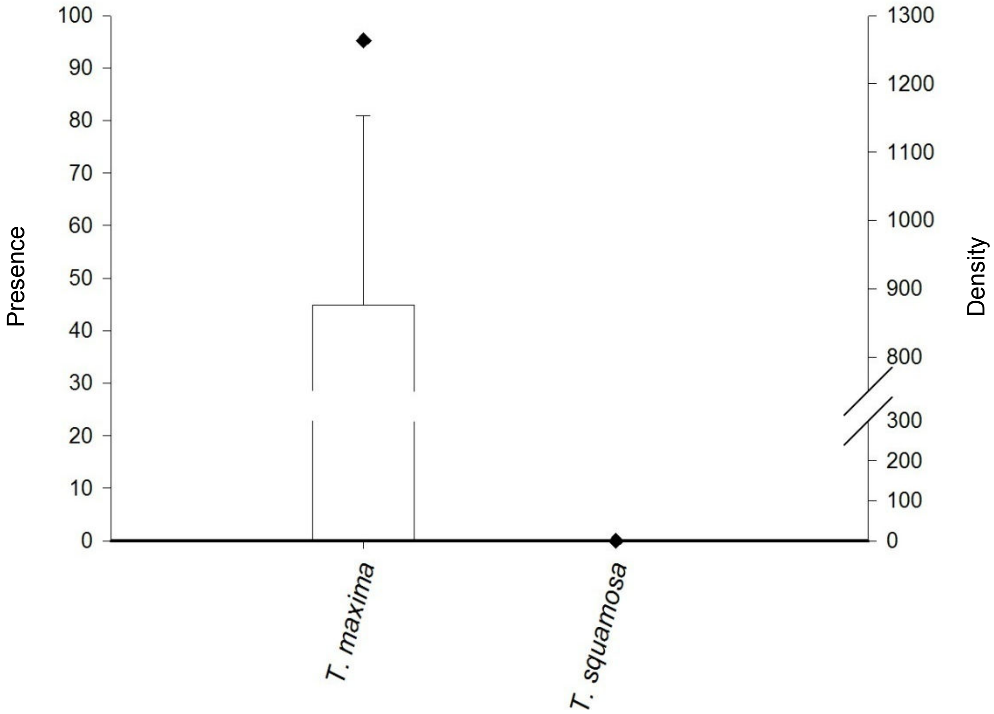



**Figure 2.27: Presence and mean density of giant clam species in Aitutaki based on fine-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

A full range of individual sizes of *T. maxima* (mean 8.0 cm ±0.2, n = 483) were recorded in survey. *T. maxima* from reef-benthos transects alone (shallow-water reefs) had a slightly smaller mean length (7.5 cm ±0.2, n = 309, which represents a clam of about four years old).

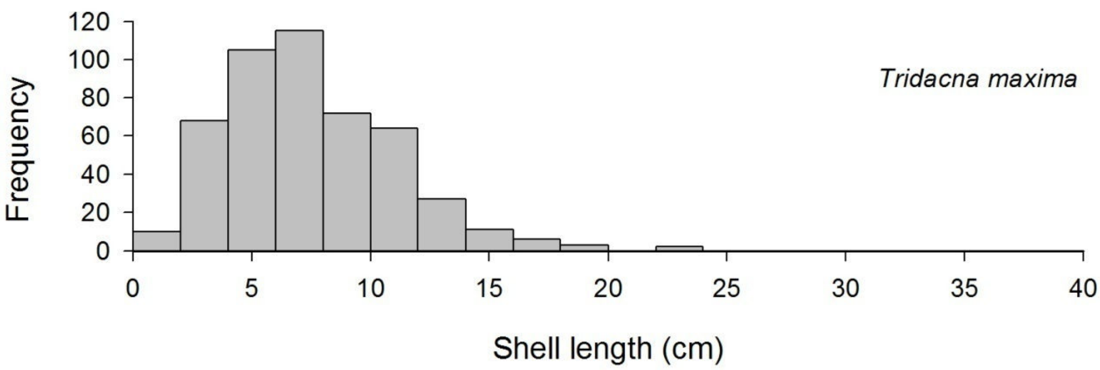



**Figure 2.28: Size frequency histogram of the giant clam *Tridacna maxima* shell length (cm) for Aitutaki.**

### *2.4.2 Mother-of-pearl species (MOP) – trochus and pearl oysters: Aitutaki*

(See seminal paper on Aitutaki MOP fishery by Nash *et al.* 1994, from which much of this background is sourced.)

Cook Islands is not within the natural distribution range of the commercial topshell, *Trochus niloticus* in the Pacific, and these commercial gastropods were introduced to Aitutaki in 1957 from Fiji. The initial introduction was made after two Cook Islands Department of Agriculture officers attended a SPC fisheries training course on the biology of *T. niloticus* (Gail 1957). Two separate air shipments of live shells of 5–6.3 cm basal diameter, collected by women in Vunibau, Fiji, were placed on the barrier reef at Akaiama *motu* in December 1957 and February 1958. Three hundred and twenty shells were reported to have survived out of a total of 600 transferred (Powell 1957).

Early surveys were carried out by Ron Powell, the officer in charge of the introduction (cited in Sims 1988a), who stated that trochus were 'plentiful' at Aitutaki by 1965. In 1970, the SPC Fisheries Officer reported that the stock of shells originally planted 'have become firmly established and have moved through subsequent channels around the entire reef area of Aitutaki Lagoon'. The bulk of the shells were about 4" in basal diameter, but 'fair numbers of shell up to 6" across the base were also found' (Hinds 1970). The 1974 survey measured the basal diameters of 14,382 shells and found their greatest abundance to be on the western face of the barrier reef (Marsters and Wichman 1974). The 1974 survey team spent at least 14 days at Aitutaki and possibly spent one day at each of the 30 study sites described in their report.

No harvesting of trochus took place until 1981, and this harvest was prompted by the continued wish of the Ministry of Agriculture to capitalise on a potential new export fishery and also, apparently, by a fear expressed during an Aitutaki Island Council meeting that the introduced trochus were out-competing the native *Turbo* species – an established food species (Sims 1984).

The Nash *et al.* 1994 study, states 'from a consensus of eyewitness accounts also, it appears that the 'virgin' stock densities in 1981 were certainly greater than before this 1992 harvest. The first harvest was comparatively unregulated, and took around 200 tonnes over a period of 15 months. The exact amount is not known. More regulated harvests took place on an annual or biennial basis throughout the 1980s'.

On Aitutaki, trochus are harvested only when there are sufficient numbers on reefs to ensure the quota can be reached sustainably and that harvests are valuable enough to warrant fishing. To ensure that harvesting is sustainable, the quota is set at 30% of the estimated number of trochus in the size range 8–11 cm. This ensures that trochus are able to reproduce before they reach harvestable sizes and that very large trochus (with lower-quality shells) remain as broodstock. Harvests typically have occurred once every one-to-two years until 1999 (or 2001, depending on whose statistics are used), which was the last commercial harvest before this survey. This means there has been ~5–6 years of moratorium on the commercial fishing of trochus.

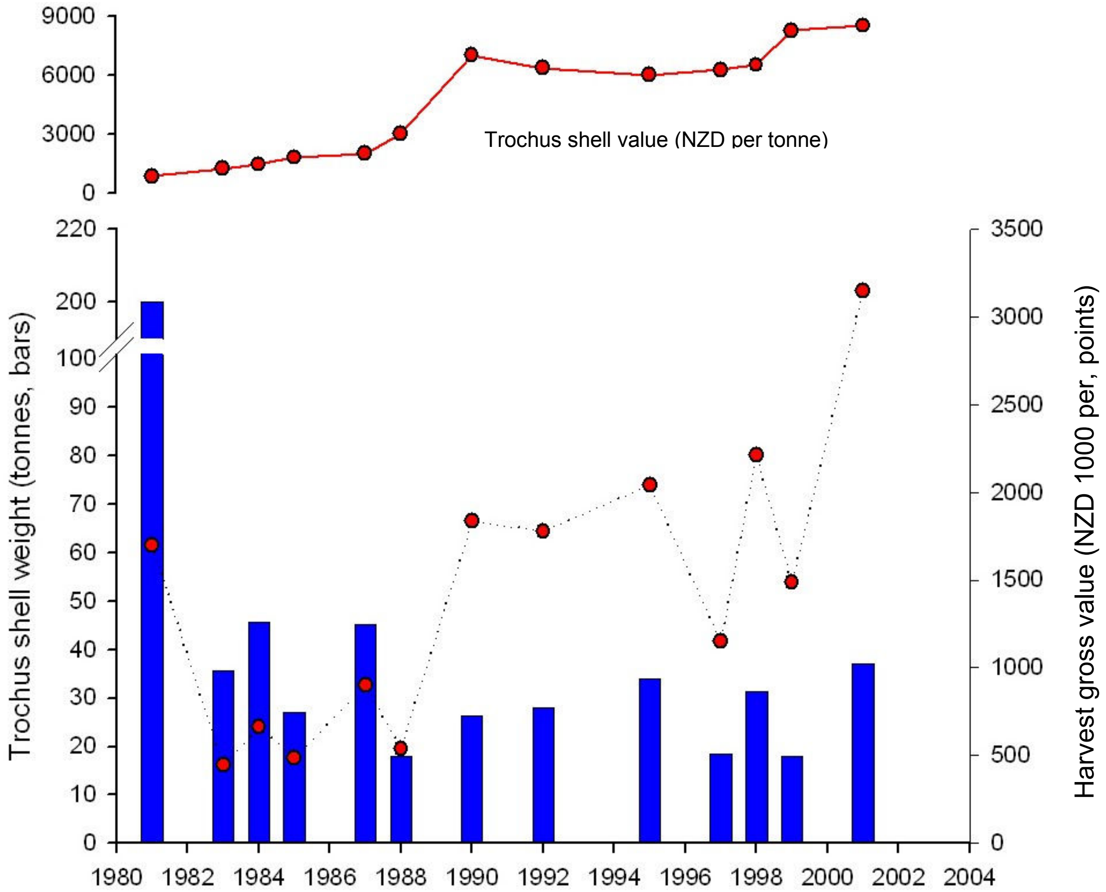



**Figure 2.29: Trochus weights and approximate harvest values: Aitutaki.**

From the CoFish survey work, we found the reef aspect and water movement regime very suitable for *T. niloticus* (Aitutaki had an outer reef of ~44.8 km lineal measure.). The barrier (outer and back-reef), intermediate and coastal reefs constitute an extensive benthos for *T. niloticus* survey and shells were present across most reefs in the lagoon. Greatest densities of trochus were recorded on back-reefs and reef platforms of the barrier, especially areas associated with water flows. About 60–70% of the shells were recorded from the back-reef to the reef-crest zones, which extended about 8.5 $km^2$ in area. Numbers at the outer reef (outside the barrier ~44.8 $km^2$ in area) were generally lower, although moderate-to-good shoaling habitat was available in some places, and aggregations were noted sporadically, especially in the southeast. In addition, trochus were also recorded at unusually deep locations, at one station down to 29 m (at the easterly site). The most significant trochus aggregations, or 'core' reefs, held significant numbers of trochus. The management of the trochus fishery in Cook Islands limits the commercial collection of trochus to specific harvest periods, with subsequent 'rest' periods for stock recovery.

CoFish survey work revealed that *T. niloticus* was present on both the barrier reef (outer-reef slope and back-reef) and on reefs within the lagoon and coastal areas (Table 2.12).

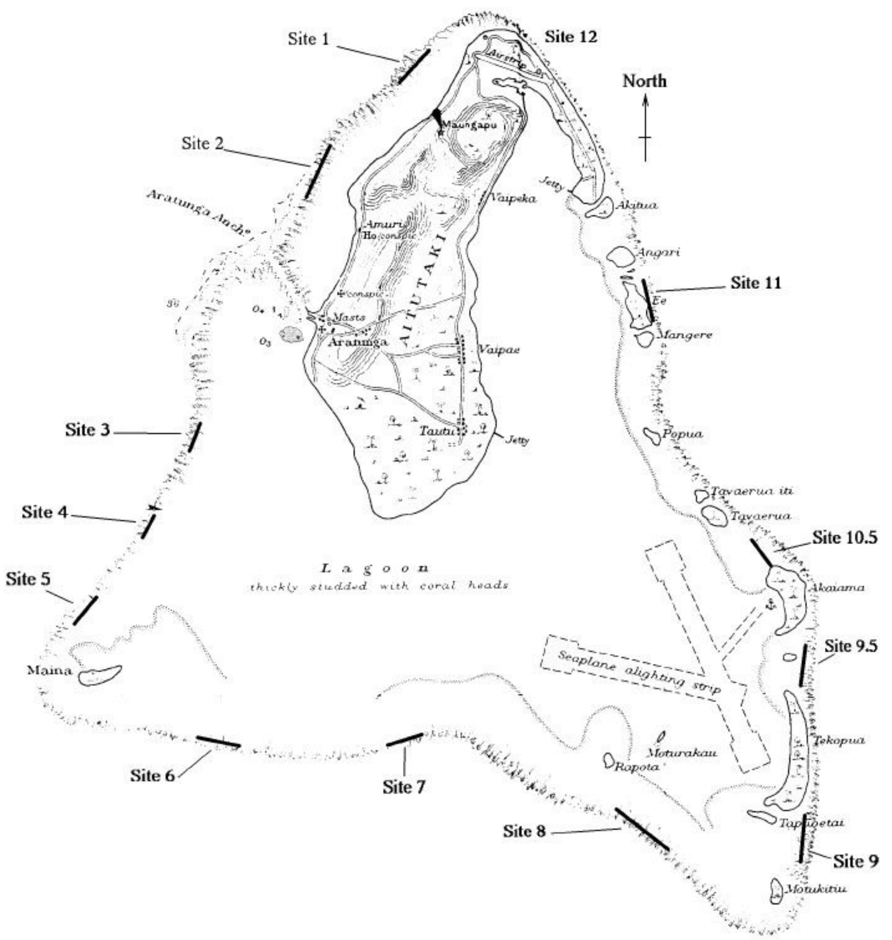
**Table 2.12: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Aitutaki**
Based on various assessment techniques; mean density measured in numbers per ha (±SE)

| | Density | SE | % of stations with species | % of transects or search periods with species |
|---|---|---|---|---|
| ***Trochus niloticus*** | | | | |
| B-S | 38.5 | 34.2 | 7/12 = 58 | 14/72 = 19 |
| RBt | 857.1 | 315.4 | 12/21 = 57 | 52/129 = 40 |
| RFs | 27.9 | 10.0 | 7/8 = 88 | 26/48 = 54 |
| RFs_w | 66.0 | 27.4 | 7/8 = 88 | 38/48 = 79 |
| MOPt | 599.0 | 265.6 | 4/4 = 100 | 20/24 = 83 |
| ***Tectus pyramis*** | | | | |
| | None recorded | | | |
| ***Pinctada margaritifera*** | | | | |
| B-S | 0.5 | 0.3 | 2/12 = 17 | 2/72 = 3 |
| RBt | 2.0 | 2.0 | 1/21 = 5 | 1/129 = 1 |
| RFs | | | 0/8 = 0 | 0/48 = 0 |
| RFs_w | | | 0/8 = 0 | 0/48 = 0 |
| MOPt | | | 0/4 = 0 | 0/24 = 0 |

B-S = broad-scale survey; RBt = reef-benthos transect; RFs = reef-front search; RFs_w = reef-front search by walking; MOPt = mother-of-pearl transect.

A total of 553 trochus were recorded during the survey (n = 464 were measured). The majority of the stock was on very shallow reef (depth ~1 m) that is easily accessible to fishers walking or collecting with a mask and snorkel.

Trochus density, as measured by average densities recorded through reef-benthos transect stations, ranged from 42 to 4833 trochus/ha in the 57% of stations holding trochus (Figure 2.30). In MOPt surveys all stations held trochus and the density ranged from 208 to 1333 trochus/ha. Earlier surveys (Nash *et al.* 1994) detected average densities of 221–7247 /sector.




| Sector | Sites | Average density (/ha) |
|---|---|---|
| Amuri | 1,2 | 221.2 |
| Wreck | 3,4,5 | 679.2 |
| Long Reef | 6,7,8 | 712.5 |
| Eastern | 9,10,11,12 | 7247.3 |

**Figure 2.30: Density of trochus calculated from Nash report (Nash *et al.* 1994).**

Bertram (1995a) explained that the trochus reserve introduced in 1983 was designed to promote the retention of settled larvae of trochus (Sims 1988b). This reserve covers a stretch of 3 km of windward reef, but has been 'poached' of trochus in the past (Sims 1988b).


**Figure 2.31: Density of trochus in RBt stations and 'other' stations.**

Although trochus were found all around Aitutaki, the northerly sections in both the east and the west held very little trochus. In both this survey and earlier work (Nash *et al.* 1994) the highest-density aggregations were recorded on the barrier platform in the southwest and southeast. In the earlier studies, the pattern was similar, but with greatest densities on the easterly reefs.

The data from the CoFish work reveal that a high proportion of RBt stations (33%) supported densities of trochus >500 shells/ha. In assessments of the main aggregations made on SCUBA (MOP transect stations), 50% of the stations held trochus at >500 shells/ha.

Shell size also gives important information on the status of stocks by highlighting new recruitment into the fishery, or the lack of recruitment, which could have implications for the numbers of trochus entering the capture size classes in the following few years. In Cook Islands, a 'gauntlet' fishery operates, which means that both small and large-sized trochus are protected from fishing. The legal size is currently >8 cm and <11 cm across the base.

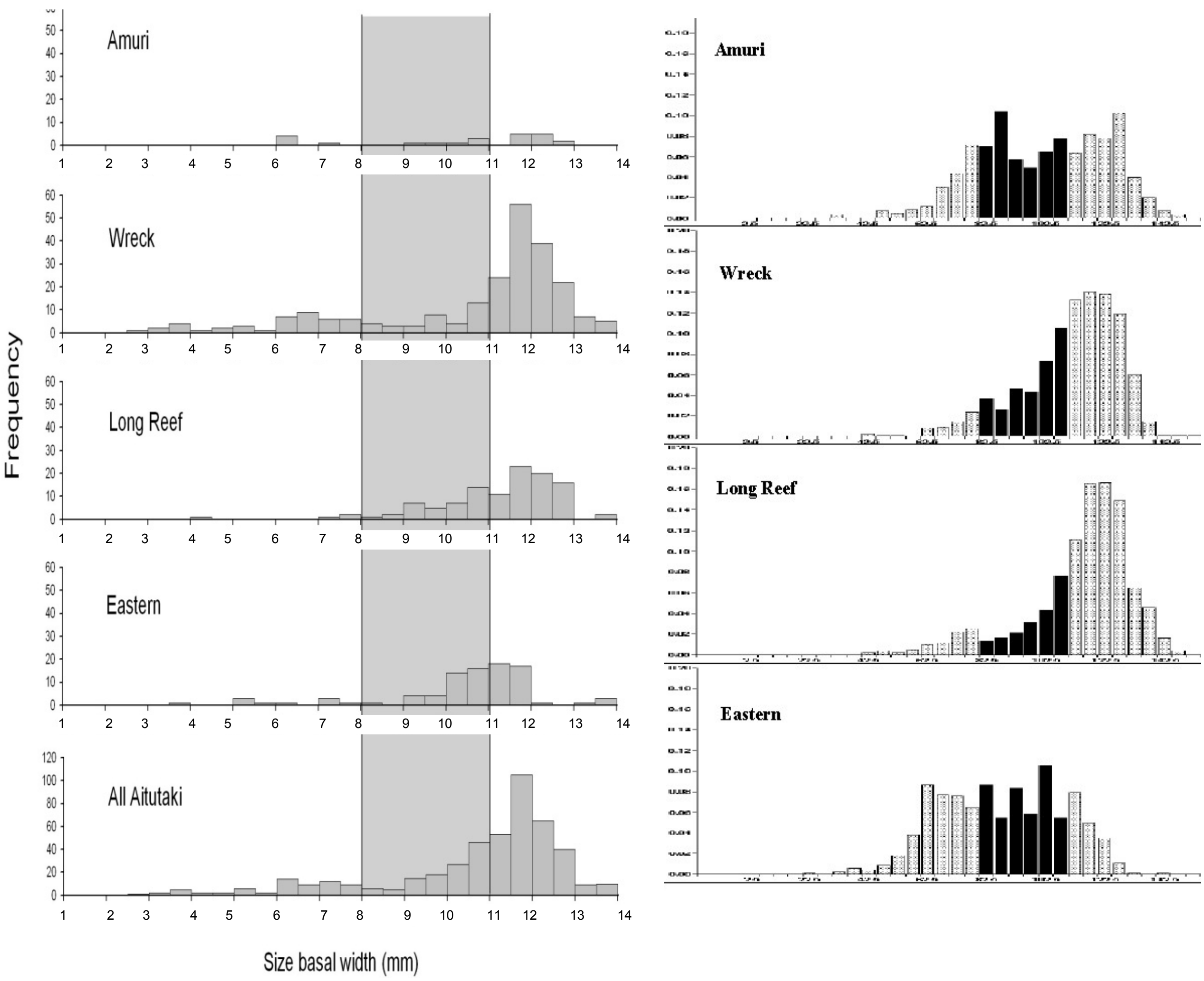



**Figure 2.32: Histograms of trochus (*Trochus niloticus*) shell base diameter from current study on left, with legal shell size classes banded in grey. On the right is a copy from Nash *et al.* (1994) with legal shell size classes in black.**

The mean basal width of trochus at Aitutaki was 10.8 cm ±0.1 (A shell of 10.8 cm basal width weighs ~310 g as a dry shell and ~411 g live; also see Figure 2.29.).

Although recruitment was ongoing, there was no large recruitment pulse of young trochus entering the legal size classes (The first maturity of trochus is at 7–8 cm, ~3 years old). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic phase of life and joining the main stock. This portion of the population was not abundant in current or past surveys.

In Aitutaki, 26% of the shell sizes recorded came from the legal size classes, and 61% of the stock was from 'over-size' size classes (>11 cm basal width). This size profile describes a stock dominated by older shells, which has important implications for the 'success' of the fishery. In fishery terms, it is important to maintain older, larger trochus as part of the population, as they provide by far the largest input of gametes for future generations (A 10 cm shell produces ~2 million eggs, whereas a 13 cm shell produces three times as many, ~6 million eggs.). However, some early researchers, e.g. Asano (1963), suggested that this proportion of the stock must not become 'too' dominant, and that it was better for the productivity of the fishery to fish the stock periodically, maintaining a number of large shells, but not letting them build up to become the dominant size class of the population. This is because larger, older shells can dominate some of the best trochus habitat, without using the available food source to produce new nacre (Much of the energy is taken up by maintenance and spawning.).

The marked spatial variation observed among the size-frequency distribution, with a higher proportion of small shells found to the east of the reserve and a high proportion of large shells found on Long Reef in the south was similar to the result that Nash *et al.* (1994) reported. The size frequency data from the current study indicate that small-sized recruits were not at high density at northern reefs and that the bulk of stock is presently of larger size classes. This distribution is likely to be due mainly to uneven recruitment or settlement of young shells on different faces of the reef, although differential harvesting rates in the past may have some influence. Interestingly, the latest recruitment peaks do not seem to be as large as those noted in past surveys. The population size profile suggests that, in recent seasons, young trochus are not coming through into the population; small trochus (trochus <8 cm basal width) made up an unusually low percentage of the population (13%) considering the present high densities of broodstock. This suggests incomplete spawning by adults or, more likely, high larval or post-settlement mortality rates from the summer of 1992/3–1996.

There are a number of views that explain the variability in recruitment of trochus, which is a common trait for both gastropods and bivalves (e.g. pearl oysters and clams). There is some anecdotal support for the theory that spawning has failed, as several (five) inductions of the local broodstock at the MMR hatchery have been unsuccessful in producing viable eggs (Richard Story pers. comm. 2007). Although this seems a convenient explanation, there are also other reasons that could equally explain the present scarcity of juveniles. Firstly, the period 2005 and 2006 saw unusually heavy weather patterns affecting Aitutaki, which would have noticeable impacts on shallow-water areas where juvenile trochus are found. In addition, El Niño periods (southern oscillation) have been suggested as a factor that could affect juvenile survival (SPC 1997), as El Niño–La Niña events can vary tides by up to 0.6 m, which also affects juvenile habitat (exposes shallow-water, juvenile habitat to unsuitable heating and drying). A look at the literature reveals that there has been highly variable recruitment in the fishery in Aitutaki in recent years – poorer recruitment was noted around 1989 (La Niña), followed by several year classes with very high recruitment (perhaps from spawning in 1992/3, El Niño). There is also a link with southern oscillation cycles and bivalve settlement in other mollusc fisheries (e.g. pearl oyster settlement in Western Australia).

Another mother-of-pearl species, the blacklip pearl oyster (*Pinctada margaritifera*) is cryptic and normally sparsely distributed in semi-open lagoon systems. The lagoon at Aitutaki was more suitable than most in that there are not many large passes; however, the shallow nature and sedimentary nature of the non-dynamic water was less suitable. In survey only three blacklip were recorded. The mean shell length (anterior–posterior measure) was 14.3 cm.

### *2.4.3 Infaunal species and groups: Aitutaki*

Soft benthos at the coastal margins of Aitutaki was suitable for areas of seagrass, but meadows were very sparsely populated (by infaunal invertebrate resources) and the survey team did not locate any concentrations of in-ground resources (shell 'beds'). No infaunal 'digging' stations (quadrat surveys) were completed at Aitutaki.

### *2.4.4 Other gastropods and bivalves: Aitutaki*

Seba's spider conch *Lambis truncata* (the larger of the two common spider conchs), was rare in survey; only five individuals were recorded and these were all in one transect on a deep-water search. No smaller Strombidae were noted (e.g. *Lambis lambis*, *Strombus luhuanus*) although *S. lentiginosus* was recorded in small numbers. The smaller strawberry conch, *S. luhuanus*, is noted as absent from Cook Islands (Bishop Museum 2008).

Two species of turban shell, the rough turban, *Turbo setosus*, and the silver-mouthed turban, *T. argyrostomus*, were noted in surveys (just a single record of silver-mouthed turban). The smaller reef-crest turban, *T. setosus*, was not particularly common considering the suitable nature of the environment present (recorded in 13% of RFs and 50% of RFs_w stations at low density). Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Conus*, *Cypraea* and *Thais*) were also recorded during independent surveys (Appendices 4.1.1 to 4.1.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus*, are also in Appendices 4.1.1 to 4.1.9. No creel survey was conducted at Aitutaki.

### *2.4.5 Lobsters: Aitutaki*

There was no dedicated night reef-front work for the assessment of lobsters (See Methods.). However, in addition to general day surveys, night-time assessments for nocturnal sea cucumber species (Ns) offered a further opportunity to record lobster species. Lobsters (*Panulirus versicolor* and spp.) were not noted, although a single slipper lobster, *Parribacus caledonicus*, was recorded. No prawn killer (*Lysiosquillina maculata*) burrows were noted in Aitutaki.

### *2.4.6 Sea cucumbers[9]: Aitutaki*

Around Aitutaki there are extensive areas of shallow- and deep-water lagoon (74.9 $km^2$) with intermediate and coastal reefs in a lagoon bordering the elevated land mass of Aitutaki (Total land area of Aitutaki and *motu* was ~19 $km^2$.). Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were extensive throughout the lagoon (Sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates.) and land inputs (allochthonous matter) were notable near the shoreline, especially

[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.

in the south and east of the main island. In fact, a full range of habitats was found in Aitutaki, with the rich, sedimentary inshore habitats becoming more oceanic in influence nearer the passages and with distance from the shore. More exposed reefs in the south of the system (especially the southwest) and on the barrier-reef fronts were more characteristic of an oceanic atoll system.

Sea cucumber species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.13, Appendices 4.1.2 to 4.1.9; also see Methods). Results from the full range of assessments yielded seven commercial species of sea cucumbers (plus one indicator species; see Table 2.13).

Sea cucumber species associated with shallow reef areas, such as the medium commercial value leopardfish (*Bohadschia argus*), were rare (only three specimens noted, found in 1% of broad-scale transects). High-value black teatfish (*Holothuria nobilis*), a species that is easily targeted by commercial fishing, was absent from the survey records and no incidental individuals were recorded.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was relatively common (recorded in 76% of broad-scale transects and 95% of reef-benthos stations) and at high density on shallow reef stations (447.8 /ha ±112.6, see Appendix 4.1.3). Another relatively common species was surf redfish (*Actinopyga mauritiana*), which was recorded in a range of assessments. As this species is mostly found, where its name suggests, on reef fronts, reef-front searches provide a valuable indication of its status. In Aitutaki, all reef-front by walking searches (RFs_w) held *A. mauritiana* and, in these surveys, the densities were recorded at an average of 197 specimens/ha (range 83–402 specimens/ha). In other locations in the Pacific, this species is recorded in densities >400–500 specimens/ha, but the density noted here is still relatively high as surf redfish are easy for fishers to target and in many other sites densities do not seem to be recovering from fishing as quickly as one might have hoped.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon returned disappointing results. Curryfish (*Stichopus hermanni*), blackfish (*Actinopyga miliaris*) and brown sandfish (*Bohadschia vitiensis*) were absent. In Cook Islands, *Holothuria leucospilota* is sometimes harvested for the gonad, which is eaten. This species was common around Aitutaki (recorded in 52% of RBt stations, density ≥1000 /ha).

In Aitutaki the lower-value species of sea cucumbers, e.g. lollyfish (*H. atra*), were also common (recorded in 81% of broad-scale survey transects) and present at high density (average density in broad-scale, 10,032 /ha). Unfortunately, no high-value sandfish (*H. scabra*) were found in Aitutaki, which is understandable considering the easterly location of Aitutaki in the Pacific (We have not recorded sandfish east of Wallis Island.). Even the low-value false sandfish (*B. similis*), which uses the same habitat as sandfish, was absent.

Deep-water assessments (18 five-minute search periods, average depth 26 m, maximum depth 33 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos with suitably dynamic water movement was not common around Aitutaki as most of the lagoon was shallow, and *H. fuscogilva* was not recorded in any of the searches. In general, the density of other deep-water species, such as *T. ananas*, was not high, and common species, such as amberfish and elephant trunkfish, were not noted.

### *2.4.7 Other echinoderms: Aitutaki*

At Aitutaki, the edible collector urchin (*Tripneustes gratilla*) and slate urchin (*Heterocentrotus mammillatus*) were recorded in survey. Collector urchins were quite common (recorded in 58% of broad-scale stations) and at reasonable density on shallow reef (average 216.3 /ha ±121.9 in RBt stations). Slate urchins were not common (recorded in 13–38% of RFs) and not recorded at high density (<20 /ha).

Urchins, such as *Diadema* spp. and *Echinothrix* spp., can be used within assessments as potential indicators of habitat condition. *Echinothrix* spp., the strong, black-spined urchin, was common (found in 81% of RBt stations) and at high density (average 1490.7 /ha ±669.4 in RBt stations). This species has a similar life habit to trochus (It grazes on algae and is also found in trochus habitat.) and may compete with the more valuable commercial gastropod for food and space. Other species of urchin, such as *Diadema* spp. (n = 66) and *Echinometra mathaei* (n = 7116) were also recorded at relatively high levels in surveys at Aitutaki (Appendices 4.1.2 to 4.1.9).

Starfish (e.g. *Linckia laevigata*, the blue starfish) were common (in 76% of broad-scale transects) and at moderately high density (mean RBt station density of 226.2 ±36.9). More destructive corallivore (coral eating) starfish were also recorded, with 20 crown-of-thorns starfish (*Acanthaster planci*, COTS) noted in survey. Unusually, no recordings of the pincushion star (*Culcita novaeguineae*) were made.

The crown-of-thorns starfish has the potential to be very destructive to coral cover if densities become high, as one starfish can devour as much as 2–6 m² of coral each year. These starfish begin to eat coral at about six months of age (1 cm in size) and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several COTS per m² and they can kill most of the living coral in an area of reef. In recorded cases, live coral cover of 25–40% can be reduced to less than 1%, and can take up to a decade to recover. In Aitutaki, the coral cover on RBt transects was low (average <10%). COTS are not thought to be responsible for this situation, but monitoring of this group is recommended, to know if the density becomes more critical. In CoFish surveys COTS were noted at <3 /ha during broad-scale and reef-benthos transect assessments. At this low density (compared to other reefs assessed in the Pacific), the numbers recorded are not indicative of an active outbreak. On the Great Barrier Reef of Australia, the following system is used for defining outbreaks of crown-of-thorns starfish (COTS):

- ***Incipient outbreak***: the density at which coral damage is likely. Occurs when there are 0.22 adults recorded per 2-minute manta tow; or >30 adults and subadults per ha. using SCUBA diving counts (Starfish may be mature at 2 years or at a size of 20 cm diameter but, for the definition of an outbreak, an indicator size of >26 cm is used.).
- ***Active outbreak***: COTS densities are >1.0 adults per 2-minute manta tow or, if SCUBA diving, at a density of >30 adults only starfish per ha.

**Table 2.13: Sea cucumber species records for Aitutaki**

| Species | Common name | Commercial value [5] | B-S transects n = 72 | | | Reef-benthos stations n = 21 | | | Other stations RFs = 8; RFs_w = 8; MOPs = 1; MOPt = 4 | | | Other stations Ds = 3; Ns = 2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | D [1] | DwP [2] | PP [3] | D | DwP | PP | D | DwP | PP | D | DwP | PP |
| *Actinopyga mauritiana* | Surf redfish | M/H | 10.5 | 68.4 | 15 | 26.5 | 138.9 | 19 | 74.5<br>197.5<br>114.6 | 85.2<br>197.5<br>152.8 | 13 RFs<br>100 RFs_w<br>75 MOPt | 1248.9 | 1248.9 | 100 Ns |
| *Bohadschia argus* | Leopardfish | M | 0.7 | 50.0 | 1 | | | | | | | | | |
| *Holothuria atra* | Lollyfish | L | 10,032.8 | 12,454.5 | 81 | 21,341.9 | 22,409.0 | 95 | 1.0<br>893.5<br>7.6 | 3.9<br>893.5<br>7.6 | 25 RFs<br>100 RFs_w<br>100 MOPs | 11,111.1 | 11,111.1 | 100 Ns |
| *Holothuria cinerascens* | | L | | | | | | | | | | | | |
| *Holothuria fuscogilva* [4] | White teatfish | H | | | | | | | | | | | | |
| *Holothuria hilla* | | L | | | | | | | | | | | | |
| *Holothuria impatiens* | | L | | | | | | | | | | | | |
| *Holothuria leucospilota* | | L | 82.2 | 295.8 | 28 | 1175.3 | 2243.7 | 52 | 0.2 | 1.9 | 13 RFs_w | 2733.3 | 2733.3 | 100 Ns |
| *Holothuria nobilis* [4] | Black teatfish | H | | | | | | | | | | | | |
| *Holothuria pervicax* | | L | | | | | | | | | | | | |
| *Stichopus chloronotus* | Greenfish | H/M | 93.1 | 121.8 | 76 | 447.8 | 470.1 | 95 | 8.1 | 16.2 | 50 RFs_w | 26.7 | 26.7 | 100 Ns |
| *Stichopus hermanni* | Curryfish | H/M | | | | | | | | | | | | |
| *Stichopus horrens* | Peanutfish | M/L | | | | | | | | | | 195.6 | 195.6 | 100 Ns |
| *Stichopus monotuberculatus* | | L/M | | | | | | | | | | | | |
| *Synapta* spp. | | | 0.7 | 25.0 | 3 | | | | | | | | | |
| *Thelenota ananas* | Prickly redfish | H | | | | | | | 0.5 | 3.7 | 13 RFs_w | 11.9 | 17.9 | 67 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; H/M is higher in value than M/H; B-S transects= broad-scale transects; RFs = reef-front search; RFs_w = reef-front search by walking; MOPs = mother-of-pearl search; MOPt = mother-of-pearl transect; Ds = sea cucumber day search; Ns = sea cucumber night search.

### *2.4.8 Discussion and conclusions: invertebrate resources in Aitutaki*

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

Data on giant clam distribution, density and shell size suggest the following:

- The range of shallow-water reef habitats and areas of dynamic water movement across the barrier reef in Aitutaki provides extensive suitable areas for giant clams.

- However, the lagoon was largely enclosed, shallow, with scattered coral bommies on a generally sandy benthos; inshore areas especially were sedimentary in nature and over-nutrified (with a limited area of hard benthos). Reefs remote from the high island of Aitutaki were in better condition (especially in the southwest) but even 'rubble' back-reef areas were exposed and did not support well developed coral stands. A large area of reef platform was present (tidal range was small at <90 cm), with moderately extensive shoals outside the barrier, especially in the south and southeast. A large proportion of reef area that was examined, both inside and outside the lagoon, was not in good condition. This was possibly due to the enclosed nature of the lagoon (restricted circulation and flushing), recent cyclones, and crown-of-thorns starfish (COTS, *Acanthaster planci*). Other reports stated that the reef condition was improving (Paulay 1994) after releases in the 1970s of chemicals used for banana treatments (PCRF 2004). Although corals looked to be suffering from high levels of disease, COTS occurred only at low abundance.

- Only a single species of giant clam was noted in general surveys, the elongate clam *Tridacna maxima*, although the fluted clam *T. squamosa* was also present at Aitutaki. This larger variety of clam, with more pronounced scutes on the shell, was very rare (only two local specimens held at the MMR clam nursery), and none were noted in outer-reef surveys. Some *T. squamosa* can undoubtedly still be found on the outer slopes of the barrier reef if greater effort was given to targeting this species for hatchery rearing and re-introductions.

- Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the abundance of clams close to the main settlement and larger clams was low, supporting the assumption that clam stocks are impacted by fishing.

- The current coverage, density and size records for *T. maxima* stocks reveal that overfishing is occurring (meat is a local delicacy), almost critically so in some areas. With dead-shell piles evident on most reefs open to fishing, the only 'complete' live populations were present on reefs that were protected. Within these areas there is promising recovery of stocks, most obviously inside the two *ra'ui*, where many juveniles were noted. Although the MPAs are playing an important role in the sustainability of this stock, there is still a lack of large *T. maxima* generally throughout the system. In addition open-access reefs seem to suffer from the continued removal of clams, being physically altered, and greater overgrowth by epiphytes than protected reefs.

- Introduced species, such as the true giant clam *T. gigas*, fluted clam *T. derasa*, and bear's paw clam *Hippopus hippopus*, are held in a suitable nursery area and in the reserve. These translocated clams were healthy and are an excellent resource for Cook Islands as large-sized *T. gigas* and *T. derasa* clams are becoming rare around the Pacific.

- According to the Manager, Mr Richard Story, the clam garden holds ~380 *T. derasa*, 160 *T. gigas* and 12 *Hippopus hippopus* adults from the group originally introduced from Australia and Palau in the early 1990s. In addition, the garden also holds 5000 juvenile *T. gigas* and 20,000 juvenile *T. derasa* produced from the hatchery in Aitutaki.

- A large percentage of the *T. gigas* stock should now be maturing into egg producers (similar to their cohort on the Great Barrier Reef in Australia), which has implications for potential future natural recruitment. Monitoring the settlement of this species will give an assessment of the potential 'spill-over' effect of MPAs, as the only mature *T. gigas* present on Aitutaki are found within the nursery MPA. *T. derasa* is a very fast growing species, offering some fishery potential, although *H. hippopus* might be the best option for Aitutaki. If *H. hippopus* recruits to the more sedimentary, inshore areas around Aitutaki, clams will play a role in clearing ambient water of particulates, and offer another fishable clam product.

- Staff from the MMR hatchery are continually seen at the clam nursery, and play a critical role in publicising and managing parts of these reserves.

- In general, the status of giant clams at Aitutaki was noted as impacted, with wholesale changes in the composition and even structure of reefs open to fishing. Clam coverage, even from reefs open to fishing, was still not critical, but density records and the 'missing' larger clam size classes, support the assumption that *T. maxima* stocks are greatly impacted by current levels of fishing.

In summary, the distribution, density and length recordings give a mixed picture of MOP stock health:

- The blacklip pearl oyster, *Pinctada margaritifera*, is relatively uncommon at Aitutaki.

- The commercial topshell, *Trochus niloticus*, is common at Aitutaki and local reef conditions constitute excellent habitat for adult and juvenile trochus. Commercial stocks are most common at easily accessible, shallow-water reefs inside the lagoon and on the barrier-reef platforms, generally those influenced by passage water flows.

- There has been a moratorium of ~5–6 years on commercial fishing of trochus, and the current survey suggests that, in 33–50% of stations, trochus stock density is greater than 500–600 /ha. This is the minimum density that main aggregations are recommended to reach before commercial fishing can be considered.

- Size-class information reveals that previous harvests have not comprehensively fished the stock, and larger size classes of trochus are beginning to dominate some areas within the fishery.

- Size-class information also reveals that commercial size classes are still relatively low in abundance, and no strong year class is currently visible below the commercial size class range. This is likely to be due both to environmental drivers affecting settlement and recruitment and possibly to the dominance of large-size shells.

Data on sea cucumbers revealed the following:

- Aitutaki had a diverse range of environments for sea cucumbers, including protected embayments near the main island and more exposed, oceanic-influenced areas at the southern edge of the lagoon. The combination of a lagoon influenced by a land mass with intermediate reef and rubble areas, including barrier reef, provides a suitable area for sea cucumbers.

- However, the position of Aitutaki in the eastern Pacific (biogeographical influence) limited the range of species that could be found at Aitutaki. In addition, the lagoon was relatively shallow, which limited its suitability for deeper-water species.

- Medium-value species, e.g. leopardfish (*Bohadschia argus*), were rare and high-value species that are easily targeted by fishers, e.g. black teatfish (*Holothuria nobilis*), were absent. Other species, such as the high-value white teatfish (*H. fuscogilva*), which is found in deeper water, was not present on searches near the passages.

- Only the low-value lollyfish (*H. atra*) was commonly recorded; *H. leucospilota*, which is targeted by Cook Islanders (for the gonad), was easily found.

- It is unknown if sea cucumber stocks at Aitutaki have been overfished in the past (although anecdotally there was a story of commercial fishing in the last decade through one operator). Whatever the scenario, stocks other than the medium/high-value greenfish (*Stichopus chloronotus*), have generally failed to recover or may just be naturally deficient due to some unidentified environmental factor or stress induced by humans.

- What can be deduced from this work is that there is no potential to develop a commercial sea cucumber fishery based on stocks at Aitutaki at this time, and there is little to warrant commercial interest in greenfish stocks at this time.

- Sea cucumbers play an important role in 'cleaning' benthic substrates of organic matter, and mixing ('bioturbating') sands and muds. When these species are removed, there is the potential for detritus to build up, and substrates to become more compacted, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) and anoxic (oxygen poor) conditions unsuitable for life.

## *2.5 Overall recommendations for Aitutaki*

- Spearfishing be controlled and night spearfishing banned.

- The use of gillnets in the lagoon be regulated, with all fishers to comply with the existing restrictions.

- A monitoring system be set in place to follow further changes in finfish resources.

- The establishment of community-managed marine reserves be supported and followed by compliance and patrolling if results such as finfish recovery are to be expected. The discussion and trial of a surveillance and monitoring system that is tailored to meet the expectations and acceptance of the local population is advised.

- For successful stock management, clams be maintained at higher density, and include larger-sized individuals to ensure there is sufficient spawning taking place to produce new generations.

- Any proposed fishing plans for trochus consider the option of raising the maximum size limit, to harvest or sell some of the large adult trochus to markets or other communities that are trying to revitalise their reef fisheries by augmenting or introducing broodstock.

- MMR consider shortening the 5–6 year resting period currently adopted, as it may be too long to optimise productivity in the trochus fishery. If smaller, interim harvests could be made, this might actually benefit productivity. Any such approach should still take recruitment signals into account (by monitoring length frequency) and large trochus should be moved only from areas with dense aggregations (where density is >500 shells/ha).

- MMR consider monitoring trochus stocks in a few small areas of reef in the north of Aitutaki, in order to detect any signs of settlement/recruitment. This could be conducted at any rubble area situated in shallow water, preferably one that is subject to regular water movement and has both ‘pink rock’ (crustose coralline algae) and epiphyte algae cover.

- If there was potential to stock the lagoon with teatfish sea cucumbers from nearby populations, this might be considered as an ‘experimental’ development.

# 3. PROFILE AND RESULTS FOR PALMERSTON

## 3.1. Site characteristics

Palmerston is a lozenge-shaped, enclosed atoll (Figure 3.1), located at 18°02'50"S latitude and 163°09'22"W longitude, roughly 500 km to the northwest of Rarotonga. It can only be reached by boat (no airstrip). The atoll is 12 km and 9.5 km wide, with over one-half of the lagoon deeper than 20 m, with a maximum depth of 35 m. There are seven *motu* around the rim of the logoon, with only one in the west-southwest being inhabited. Fishing at Palmerston was open-access and there were no protected areas or reserves, although on occasion, the Island Council may declare a partial *ra'ui* (traditional community-based management system) for parrotfish.

Palmerston was the first choice of the Ministry of Marine Resources for surveying, as it had been surveyed back in 1988, and there was an ongoing fishery for parrotfish that were shipped to Rarotonga for marketing. The islanders depended on fish and invertebrates for subsistence needs as well as income, and the Island Council had expressed concern about the future of the parrotfish fishery given the current fishing pressure.

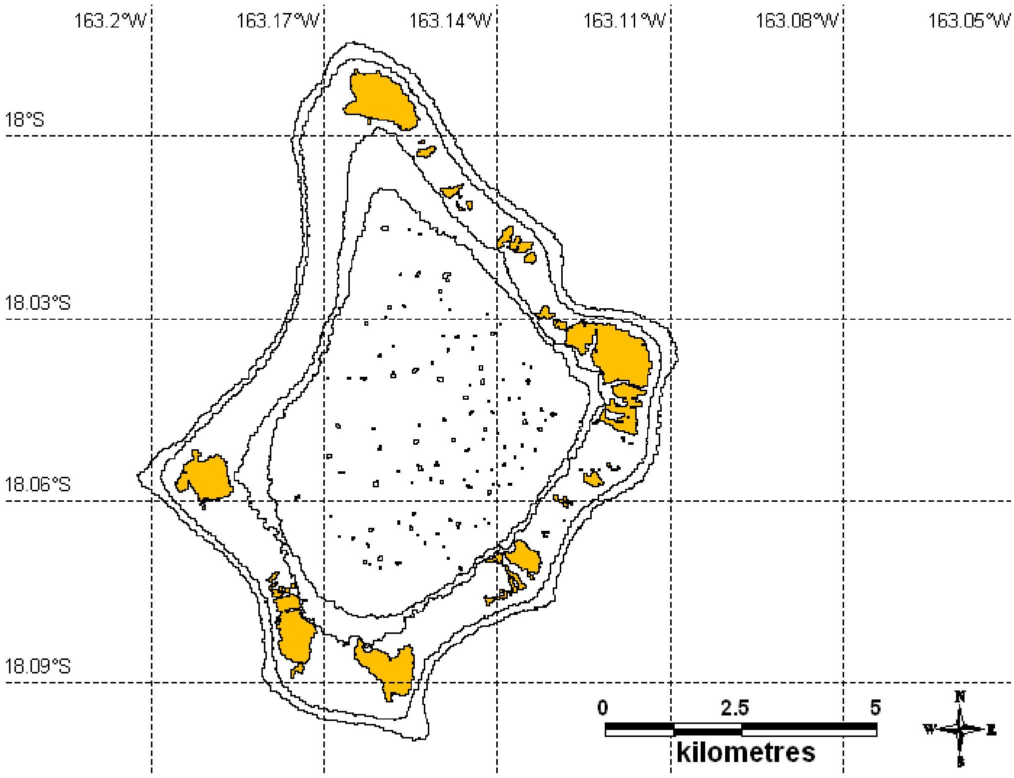



**Figure 3.1: Map of Palmerston.**

## 3.2. Socioeconomic survey: Palmerston

Socioeconomic fieldwork was carried out on Palmerston in February 2007. The survey covered all households (10) and the current total population of 56 people on the island.

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. In addition, a total of 12 individual interviews of finfish fishers (9 males, 3 females) and 13 invertebrate fishers (7 males, 6 females) were conducted. In some cases, the same person was interviewed for both finfish and invertebrate harvesting. Also, in the particular case of Palmerston, very often couples or family members fish together. Thus, some of the respondents provided information applicable to the family or a number of family members.

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

Survey results indicate that all but one household are engaged in fisheries with an average of more than two fishers per household. In total there are 24 fishers on Palmerston, including 12 female and 12 male fishers. All female fishers and eight male fishers are engaged in both finfish and invertebrate fishing, and only four male fishers exclusively target finfish.

Data on income suggests that fisheries plays a major role but has been significantly replaced by salaries (Figure 3.2). In fact, half of all Palmerston households now rely on salaries for first income and another two households for second income. Only four households depend on fisheries as first income source, and another two households live mainly on social fees and handicraft activities. Remittances are known but do not play a significant role for the livelihood of the Palmerston community. Those households that receive remittances quoted an average annual amount of USD 826, which corresponds to ~11% of the average annual household expenditure. Cost of living on Palmerston is expensive and a household spends on average about USD 7785 per year for importing basic food and fuel from Rarotonga by boat, and for electricity and communication (Table 3.1).

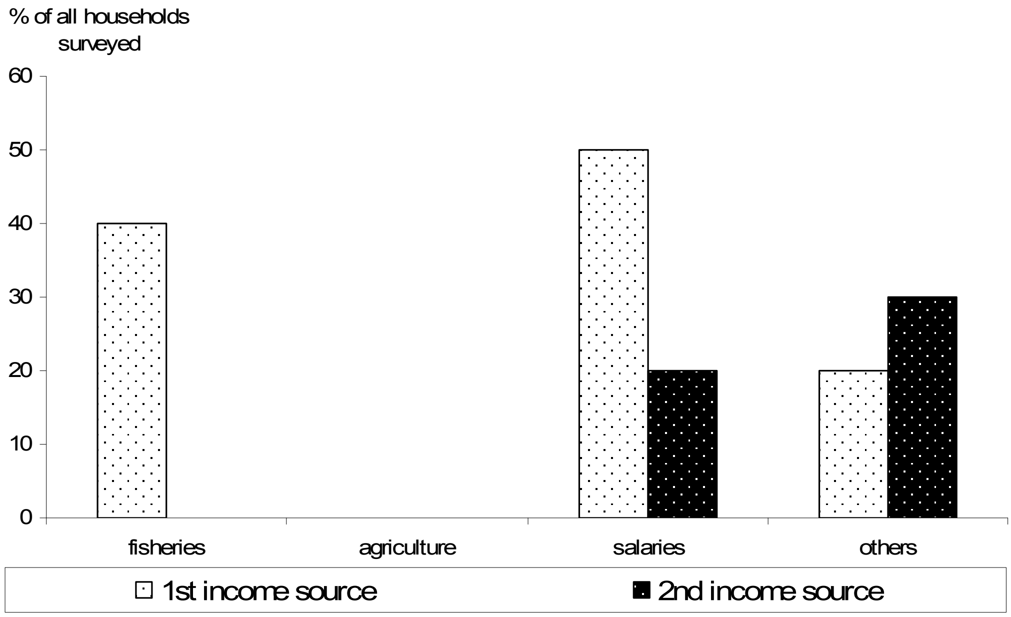



**Figure 3.2: Ranked sources of income (%) in Palmerston.**
Total number of households = 10 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

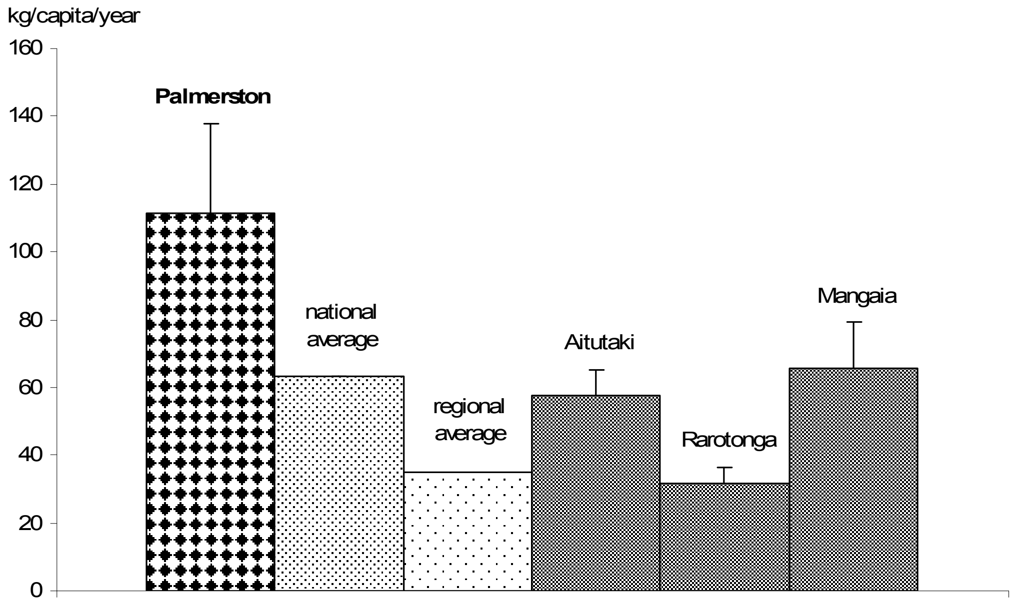



**Figure 3.3: Per capita consumption (kg/year) of fresh fish in Palmerston (n = 10) compared to national (Preston 2000) and regional averages (FAO 2008) and the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

The average consumption of fresh fish of about 112 kg/person/year is high compared to the national average estimated by Preston (2000) of ~63 kg/person/year and the regional average (FAO 2008) of 35 kg/person/year (Figure 3.3). However, it should be noted that Passfield (1997) estimated that the consumption of fish on Tongareva Island was 219 kg/person/year. People of Palmerston do not import canned fish and respondents confirmed that canned fish does not constitute their day-to-day diet. However, in rare cases, such as during visits to Rarotonga or when brought as a gift by visitors to the island, canned fish may be consumed. It is also interesting to note the relatively low consumption of invertebrates, i.e. about 4.3 kg/person/year of edible parts only. The difference between finfish and invertebrate consumption also shows if comparing the patterns of consumption frequencies. Fresh fish is consumed more than five days per week while invertebrates were reported to be eaten only about once per month.

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

| Survey coverage | Site (n = 10 HH) | Average across sites (n = 138 HH) |
|---|---|---|
| **Demography** | | |
| HH involved in reef fisheries (%) | 90.0 | 68.8 |
| Number of fishers per HH | 2.40 (±0.52) | 1.33 (±0.14) |
| Male finfish fishers per HH (%) | 16.7 | 32.2 |
| Female finfish fishers per HH (%) | 0.0 | 2.7 |
| Male invertebrate fishers per HH (%) | 0.0 | 0.0 |
| Female invertebrate fishers per HH (%) | 0.0 | 18.6 |
| Male finfish and invertebrate fishers per HH (%) | 33.3 | 26.2 |
| Female finfish and invertebrate fishers per HH (%) | 50.0 | 20.2 |
| **Income** | | |
| HH with fisheries as 1st income (%) | 40.0 | 5.1 |
| HH with fisheries as 2nd income (%) | 0.0 | 7.2 |
| HH with agriculture as 1st income (%) | 0.0 | 7.2 |
| HH with agriculture as 2nd income (%) | 0.0 | 8.0 |
| HH with salary as 1st income (%) | 50.0 | 55.8 |
| HH with salary as 2nd income (%) | 20.0 | 8.7 |
| HH with other source as 1st income (%) | 20.0 | 39.1 |
| HH with other source as 2nd income (%) | 30.0 | 16.7 |
| Expenditure (USD/year/HH) | 7784.32 (±1502.36) | 6909.08 (±352.39) |
| Remittance (USD/year/HH) (1) | 826.36 (n/a) | 1524.12 (±252.14) |
| **Consumption** | | |
| Quantity fresh fish consumed (kg/capita/year) | 111.52 (±26.48) | 51.88 (±4.90) |
| Frequency fresh fish consumed (times/week) | 5.30 (±0.42) | 2.79 (±0.15) |
| Quantity fresh invertebrate consumed (kg/capita/year) | 4.25 (±3.70) | 3.60 (±4.90) |
| Frequency fresh invertebrate consumed (times/week) | 0.30 (±0.25) | 0.42 (±0.06) |
| Quantity canned fish consumed (kg/capita/year) | 0.00 (±0.00) | 13.33 (±1.74) |
| Frequency canned fish consumed (times/week) | 0.00 (±0.00) | 1.17 (±0.13) |
| HH eat fresh fish (%) | 100.0 | 99.3 |
| HH eat invertebrates (%) | 70.0 | 71.0 |
| HH eat canned fish (%) | 0.0 | 73.2 |
| HH eat fresh fish they catch (%) | 90.0 | 73.3 |
| HH eat fresh fish they buy (%) | 0.0 | 36.7 |
| HH eat fresh fish they are given (%) | 100.0 | 66.7 |
| HH eat fresh invertebrates they catch (%) | 60.0 | 63.3 |
| HH eat fresh invertebrates they buy (%) | 0.0 | 6.7 |
| HH eat fresh invertebrates they are given (%) | 20.0 | 51.88 (±4.90) |

HH = household; (1) average sum for households that receive remittances; numbers in brackets are standard error.

### *3.2.2 Fishing strategies and gear: Palmerston*

At the time of the survey, there was no community-based fisheries management regime in place. However, a first attempt was made by the community to identify possible solutions to problems that they perceive are occurring and have increased over the past 15–20 years, as part of a community fisheries management plan. The results of the community planning activities facilitated during the implementation of the field survey on Palmerston are documented in Appendix 2.2.6.

*Degree of specialisation in fishing*

On Palmerston both males and females are fishers. Often, couples or family members join in the same fishing trip and share the setting and cleaning of nets. However, gender participation varies if regarding the proportion of male and female fishers who target finfish only, and those that fish for both invertebrates and finfish (Figure 3.4). Most males also collect giant clams and a few other invertebrates in addition to finfish, while most females only fish for finfish.

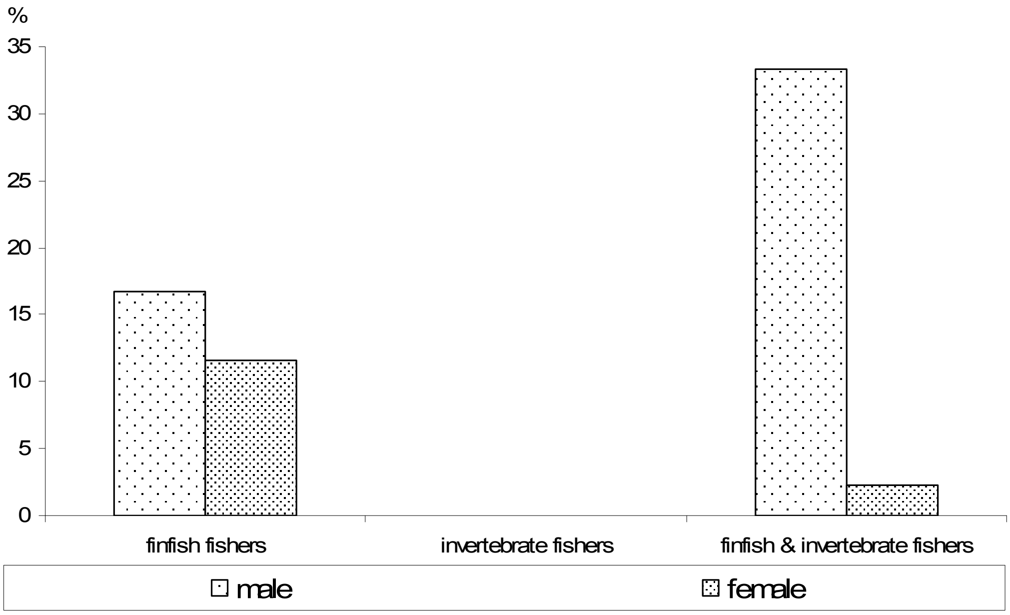



**Figure 3.4: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Palmerston.**
All fishers = 100%.

Invertebrate fishers collect on reeftops; a few other species are also collected from soft-bottom habitats (Figure 3.5). Some respondents selectively target lobsters at times.

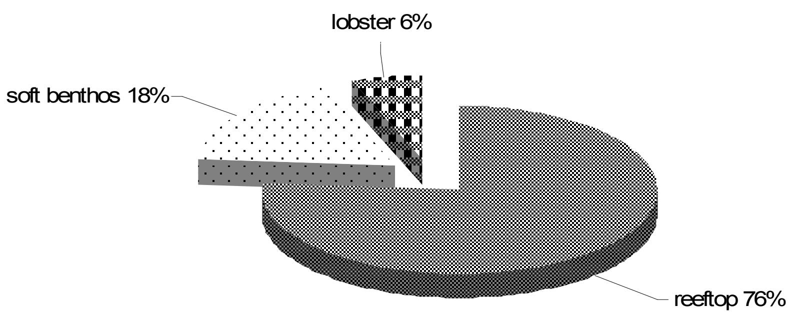



**Figure 3.5: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Palmerston.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated; 'other' refers to the giant clam and sea urchin fisheries.

*Fishing patterns and strategies*

On Palmerston, seven of the 10 households own a boat, but most have at least two boats. Most boats (60%) are motorised and the remaining 40% are non-motorised hulls, canoes and, in one or two rare cases, a canoe equipped with a sail. However, due to the small size of the population and the closeness of family ties and relationships, all families have access to a boat, and fishers are not shy to join in a motorised or non-motorised fishing party. The fact that most households own or have access to boat transport shows in data recorded on the transport used for fishing activities. Almost all fishers (89% of male fishers, 100% of female fishers) use boats for finfish fishing, usually motorised boats. Invertebrates are collected using motorised boats to reach the reef and soft-bottom habitats targeted.

Due to the frequent use of motorised boats and the costs and efforts involved to organise fuel, spare parts and any fishing equipment, reef fishing on Palmerston is not – as often observed elsewhere – a low, but rather a moderate investment activity. As far as equipment is concerned, higher investment costs accrue for finfish fishing (nets, rods, lines, spears) rather than for invertebrate collection. The latter does not require any input other than knives, rods or sticks and, in the case of free diving, mask, snorkel and fins. There is no SCUBA gear on the island.

Fishing trips are mostly undertaken during the day (82%) and rarely at night. Most fishers continue throughout the whole year; however, 10% of all respondents stop fishing at times. Reeftop gleaning is mainly a daytime activity (70%) and only about 1/3 of all persons interviewed indicated that they glean either during the day or night, according to the situation and tidal conditions. Seagrass collection is exclusively performed during the day and lobsters are caught only during the night. Invertebrate collection is done continuously throughout the year.

*Targeted stocks/habitat*

Male and female fishers are mostly engaged in reeftop fisheries, and the proportion of female fishers targeting reeftops for invertebrates is almost 20% higher than that of male fishers (Figure 3.6). Lobster harvesting is exclusively performed by male fishers; however, overall, very few male fishers on Palmerston fish for lobsters.

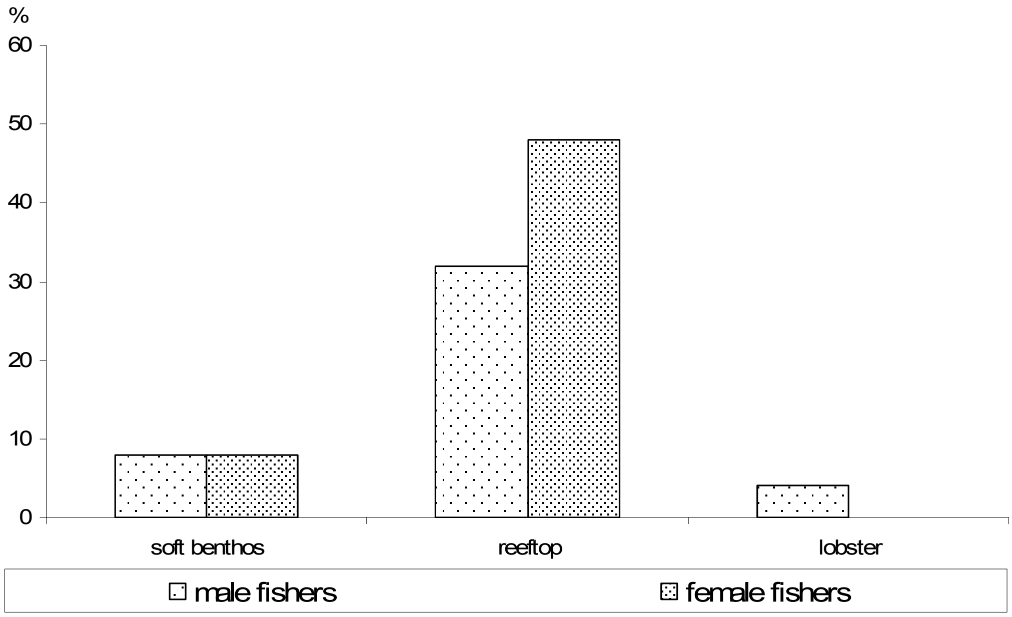



**Figure 3.6: Proportion (%) of male and female fishers targeting various invertebrate habitats in Palmerston.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 10 for males, n = 7 for females.

### *Gear*

Fishing on Palmerston involves a variety of techniques and two or more of these are often used during one fishing trip (Figure 3.7). Overall, gillnets are dominant; however, as mentioned before, gillnets are often used in combination with handlines, the traditional bamboo rod, spear diving or handheld spears. The use of handlines was reported by the only respondent for outer-reef fisheries, thus, caution is advised in using this information. Also, fishers targeting the outer reef mainly troll for pelagic fishes. Pelagic fishing is not considered here. About 20–30% of all fishing involves handlines, bamboo rod or spears (for diving or handheld by walking). Respondents indicated that nets are mainly used for commercial fishing, particularly if targeting parrotfish and mullets, while the traditional bamboo rod and handlines are used for subsistence fishing.

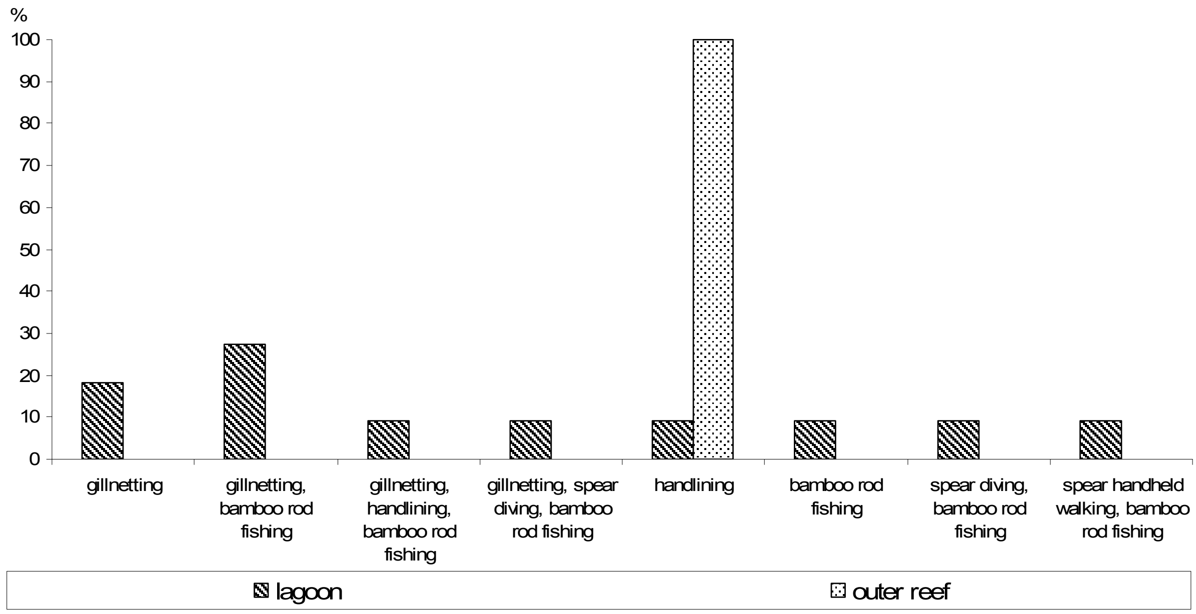



**Figure 3.7: Fishing methods commonly used in different habitat types in Palmerston.**
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

*Fishing pressure*

Information on the number of fishers, the frequency of fishing trips (Table 3.2) and the average catch per fishing trip was used to estimate the fishing pressure imposed by the inhabitants of Palmerston on their fishing ground (Table 3.3). Actual fishing grounds were shown in the framework of the first community planning meetings for fisheries management on Palmerston (Figure 3.8, Appendix 2.2.6).

**Table 3.2: Average frequency and duration of fishing trips reported by male and female fishers in Palmerston**

| Resource | Fishery / Habitat | Trip frequency (trips/week) | | Trip duration (hours/trip) | |
|---|---|---|---|---|---|
| | | Male fishers | Female fishers | Male fishers | Female fishers |
| Finfish | Lagoon | 1.78 (±0.29) | 1.50 (±0.29) | 3.56 (±0.45) | 3.33 (±0.44) |
| | Outer reef | 3.00 (n/a) | 0 | 4.00 (n/a) | 0 |
| Invertebrates | Lobster | 0.04 (n/a) | 0 | 1.00 (n/a) | 0 |
| | Reeftop | 0.55 (±0.41) | 0.60 (±0.48) | 2.64 (±0.51) | 2.67 (±0.46) |
| | Soft benthos | 1.50 (±0.50) | 2.00 (n/a) | 1.00 (±0.00) | 1.00 (n/a) |

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 9; females: n = 10. Invertebrate fisher interviews, males: n = 3; females: n = 7.

*Frequency and duration of fishing trips*

Reef finfish fishing on Palmerston targets mainly the lagoon with its coral reef heads and coral reefs that surround the numerous small *motu*, as well as the back-reef. As shown in Table 3.2, on average, fishers venture out once or twice a week with no major difference between male and female fishers. Trips take on average 3–4 hours. Invertebrates are much less frequently collected. Lobster harvesting is the most rarely performed, only once or twice per year. Reeftops may be gleaned once a fortnight. Soft-benthos harvesting is the most frequent activity, i.e. once to twice a week for both male and female fishers. Lobster fishing and soft-benthos gleaning are short activities that do not require more than one hour each on average. Reeftop gleaning trips take 2–3 hours.

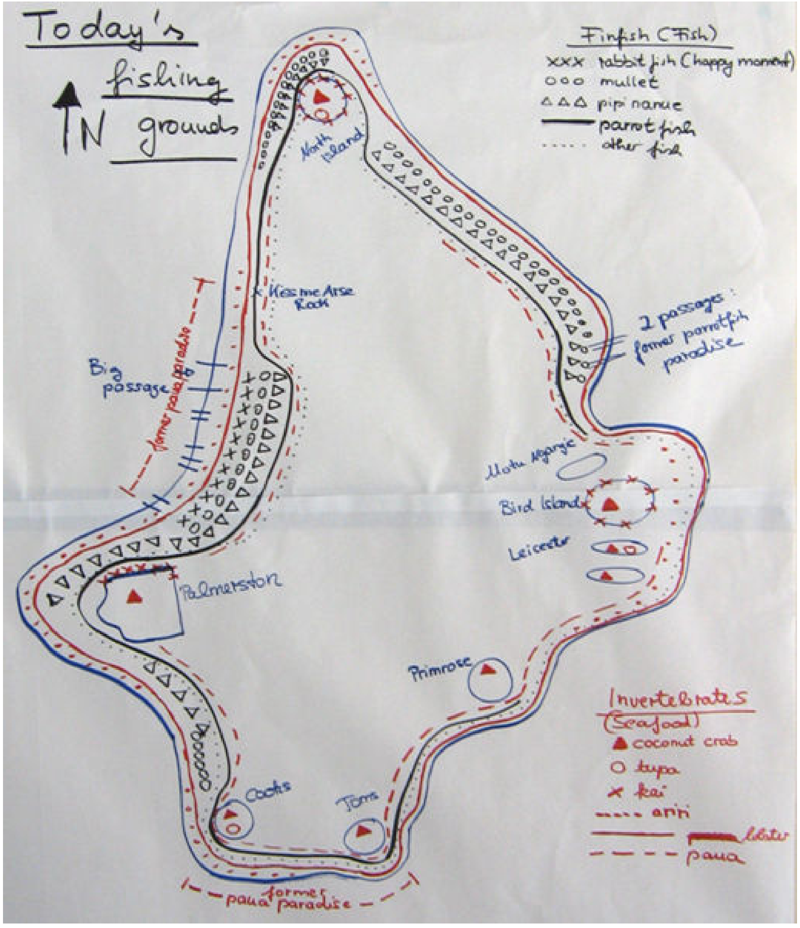



**Figure 3.8: Actual fishing grounds as indicated by community members for Palmerston.**

### *3.2.3 Catch composition and volume – finfish: Palmerston*

The annual catch reported by respondents from Palmerston totalled 15.3 t/year (Figure 3.9). Considering the frequency and quantity of fresh fish eaten reported by all households, Palmerston's subsistence demand for fresh fish is estimated at 7.8 t/year. Extrapolation of all catch data from respondents to include fishers in each of the 10 households who were not individually interviewed suggests that the total impact on Palmerston's reef and lagoon fisheries amounts to 31.2 t/year. Accordingly, about 25% of all catches are for subsistence needs while 75% or 23.4 t/year are either exported for commercial or non-commercial purposes. Considering the information provided by respondents, most of the fish is taken from the lagoon reefs (93%) and only a small proportion is sourced from the outer reef (7%). Overall, male fishers account for 74% of the total annual catch while female fishers contribute 26%.

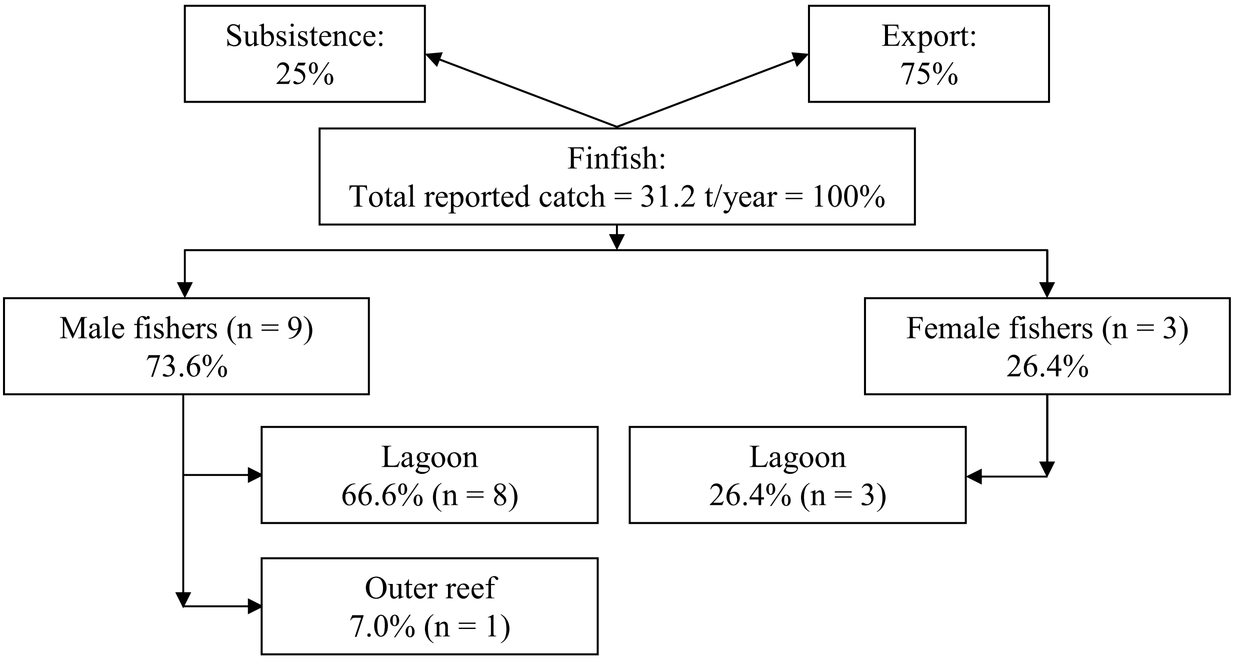



**Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Palmerston.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The triple objectives pursued by Palmerston's fishers when targeting the lagoon resources also show in Figure 3.10. Targeting the lagoon serves subsistence, gift (non-commercial exchange on the island but also export to relatives and families in Rarotonga and elsewhere) and income generation (export to Rarotonga). The shares shown in Figure 3.10, however, do not reflect the magnitude of export catches (monetary and non-monetary), i.e. about two-thirds of all finfish harvested.

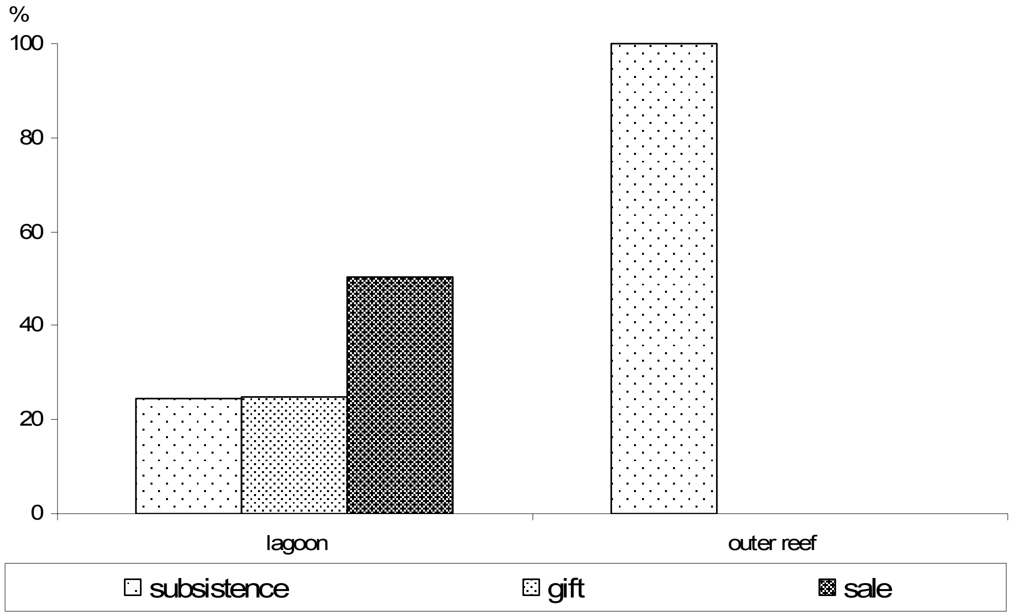



**Figure 3.10: The use of finfish catches for subsistence, gifts and sale, by habitat in Palmerston.**
Proportions are expressed in % of the total number of trips per habitat.

The data collected from respondents on Palmerston and their extrapolation to estimate the total annual impact seem to be realistic if they are compared with annual commercial export figures provided by respondents.

Apparently, fishing impact on Palmerston has been variable. It has ranged from as much as 90 t of parrotfish that was exported as whole, cleaned fish for sale on Rarotonga to 10–15 t/year of parrotfish filet export between the 1980s and early 2000s.

In 1990, a blast freezer was installed on the island with a capacity of 200 kg per load. Three chest freezers (1200 kg capacity) and another, privately-owned 2400 kg chest freezer determined the commercial stock volume of Palmerston's fisheries. In the year 2000, another two chest freezers and thus 1200 kg capacity were added. Today, the island's chest-freezer capacity amounts to ~6.8 t, held by four different households, and each household operates its own generating facilities to bridge the time period that is not covered by the public electricity supply, i.e. between 12:00 to 18:00, and from 24:00 to 6:00 hours.

Export figures provided by the island's main exporters suggest a volume of about 16 t parrotfish filets in 2006. Taking into consideration that filet weight corresponds to only about 60% of the total wet fish weight, the total catch in 2006 amounts to 24.3 t. The difference of about 0.9 t/year between this figure and the calculated total annual export figure based on interview data (23.4 t) is acceptable as it corresponds to an error range of 3–4% only. The fact that the communal and seasonal rabbitfish (*morava*) catch (See below.) is not included in our survey data and is estimated to account for 750–800 kg/year, may also explain why the estimated total catch based on interview data only is lower.

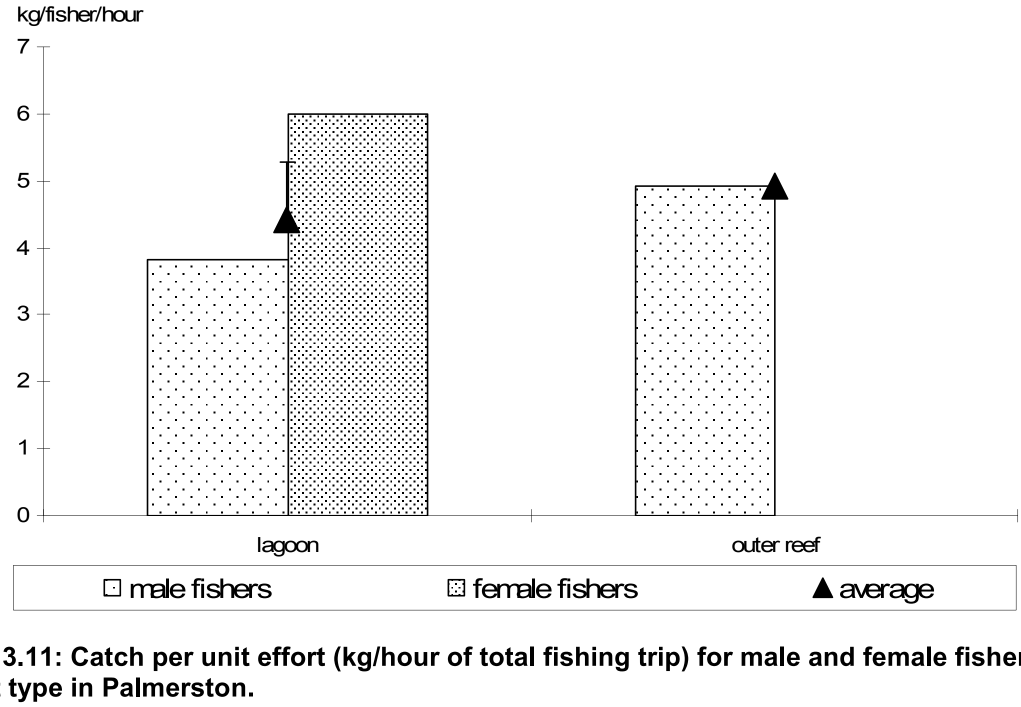



**Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat type in Palmerston.**
Effort includes time spent transporting, fishing and landing catch. Bars represent standard error (+SE).

The catch per unit effort (CPUE) on Palmerston is relatively high if considering the data shown in Figure 3.11 relate to average fishing trips aimed at commercial and subsistence catches respectively. The higher CPUE figure for female fishers on Palmerston is explained by the fact that most female respondents participate in netting, which is mainly for commercial purposes rather than subsistence fishing trips, which mainly target coral reef heads in the lagoon using handlines and/or the traditional bamboo rod. The CPUE data provided for outer-reef fishing is not considered here as it is sourced from one respondent only.

Catches from Palmerston lagoon are clearly determined by parrotfish: Scaridae were reported to determine over 70% of the reported catches. *Rei* (*Hipposcarus longiceps*) and greenfish (*poshow*, *Chlorurus microrhinus*) are the major species, contributing ~25% and ~21% to the total reported annual catch alone. The remaining catch falls mainly on species of Lutjanidae and Serranidae, as well as others. Details of the reported catch composition by habitat and fish species are provided in Appendices 2.2.1 to 2.2.4.

The seasonal rabbitfish catches are not reported here as this is a particular fishing activity jointly implemented by the community. During about three days per year, all Palmerston families drive by boat to a passage close to Palmerston (Rabbitfish used to school at Toms until 1996.), where rabbitfish seasonally school from November to February. Fishers use gillnets with a mesh size of 3 inches. During each fishing event, which takes about eight hours, about 400 rabbitfish (*morava*) are caught. The total annual catch is estimated to amount to 750–800 kg (average size 32 cm fork length) and is usually eaten on the island or shared with families and relatives elsewhere.

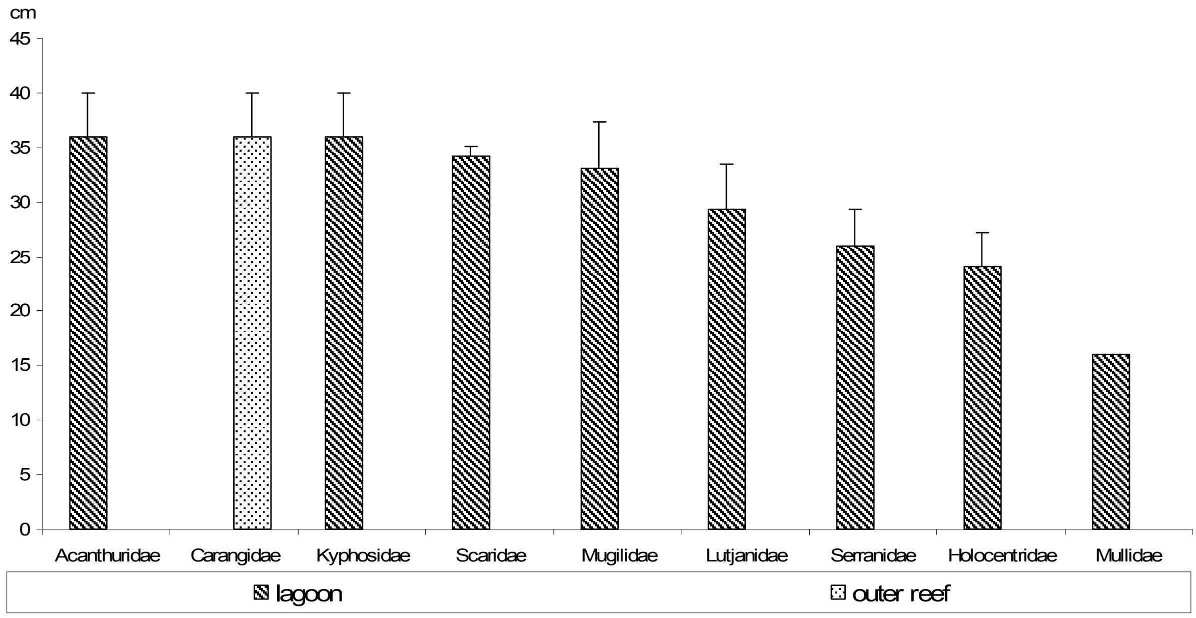



**Figure 3.12: Average sizes (cm fork length) of fish caught by family and habitat in Palmerston.** Bars represent standard error (+SE).

Average fish sizes reported for catches on Palmerston are large. Most fish species targeted and caught are reported to be around 35 cm long, with a range from 30 to 40 cm in general. Only Serranidae are reported to be smaller on average, i.e. about 25 cm long (Figure 3.12). As mentioned earlier, the small sample size of catches reported for the outer reef does not allow for any comparison.

Estimates of fishing pressure, based on survey responses and extrapolated to the entire population, suggest that fisher density and fishing pressure are low for all the areas fished (lagoon - including back-reef and coastal or intermediate reef areas, outer reef, total reef, total fishing ground). However, the total average annual catch per fisher is relatively high (Table 3.3). Also, it must be taken into account that most of the total catch is composed of Scaridae, in particular, *Hipposcarus longiceps*, *Chlorurus microrhinus*, *Scarus altipinnis* and *C. frontalis*.

**Table 3.3: Parameters used in assessing fishing pressure on finfish resources in Palmerston**

| Parameters | Habitat | | | |
|---|---|---|---|---|
| | Lagoon | Outer reef | Total reef area | Total fishing ground |
| Fishing ground area (km$^2$) | 53.50 | 5.88 | 24.99 | 59.37 |
| Density of fishers (number of fishers/km$^2$ fishing ground) (1) | 0.4 | 0.2 | 1.0 | 0.4 |
| Population density (people/km$^2$) (2) | | | 2 | 1 |
| Average annual finfish catch (kg/fisher/year) (3) | 1293.26 (±271.88) | 1067.26 (n/a) | | |
| Total fishing pressure of subsistence catches (t/km$^2$) | | | 0.19 | 0.08 |

Figures in brackets denote standard error; n/a = standard error not calculated; (1) total number of fishers is extrapolated from household surveys, lagoon n = 23, outer reef n = 1; (2) total population = 56; total subsistence demand = 4.7 t/year; (3) catch figures are based on recorded data from survey respondents only.

### 3.2.4 Catch composition and volume – invertebrates: Palmerston

The number of species (as represented by the number of vernacular names) reported to be regularly caught from various habitats indicates the importance of these habitats and the fisheries they support. Figure 3.13 indicates that none of the invertebrate fisheries is diverse and that people on Palmerston focus on a few species only. The highest number of species is recorded for reeftop gleaning.

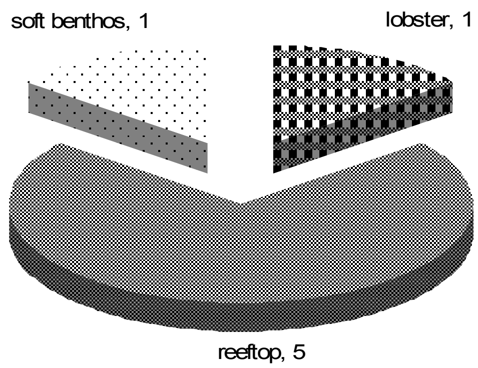



**Figure 3.13: Number of vernacular names recorded for each invertebrate fishery in Palmerston.**

The data on the variety of species and habitats explored suggests that invertebrate fisheries in general are not important. This suggestion is also supported by the data presented earlier on the low invertebrate consumption by frequency and quantity as compared to finfish.

This trend is further reflected in the estimated total annual catch by interviewed fishers that equals 1.66 t/year of wet weight only. Extrapolation of the average annual recorded catch per fisher to the total number of invertebrate fishers on Palmerston brings the figure up to a total of 2.3 t/year (Figure 3.14). Most of the catch is sourced from reeftops, and lobster catches yield the least. Females contribute less than 1/3 of the total annual catch, while male fishers catch most of the annual biomass in wet weight.

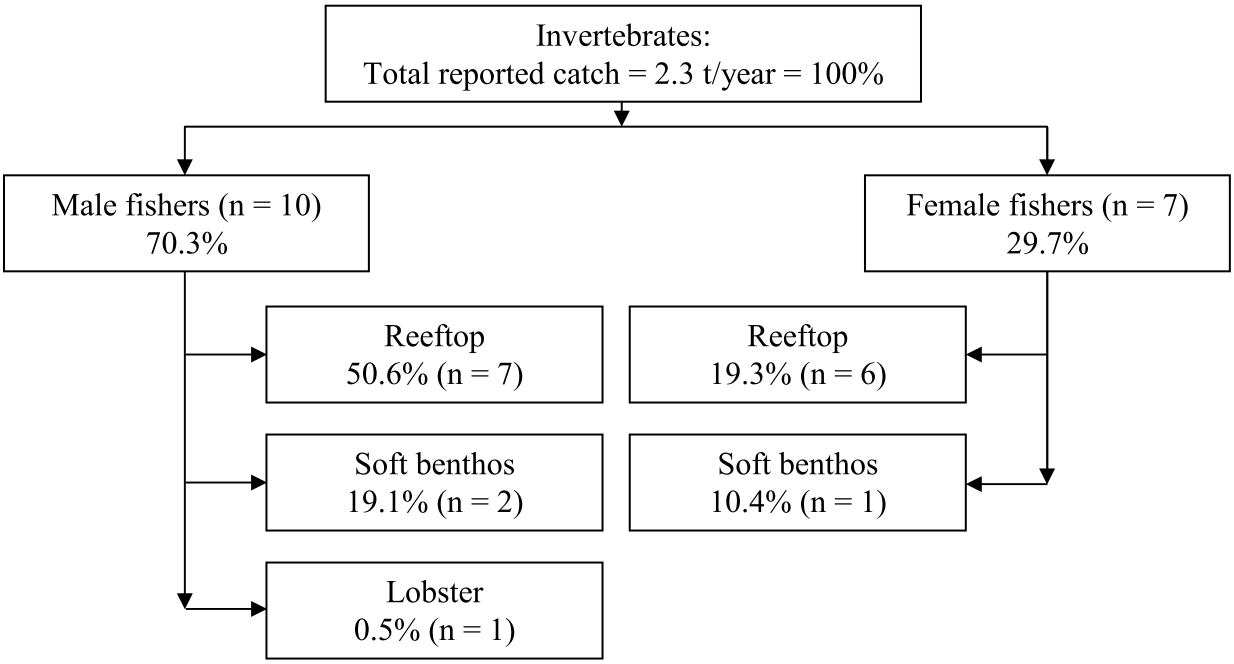



**Figure 3.14: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Palmerston.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Calculation of the total annual catch per species group (Figure 3.15) shows that the highest annual catches (in terms of wet weight removed) are almost equally accounted for by three species groups: *koura* (lobster), *paua* (giant clams; *Tridacna maxima*) and *kai* (*Asaphis violascens*). The other three species or species groups, including octopus, the land crab *Cardisoma* sp. and *ariri* (*Turbo setosus*), are of negligible impact.

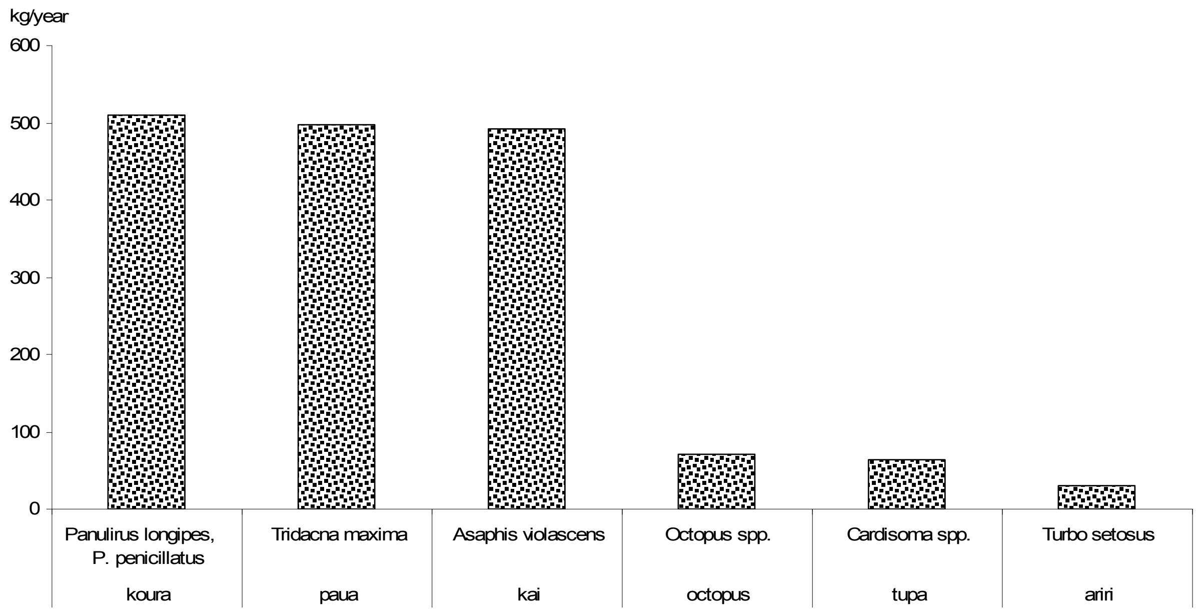



**Figure 3.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Palmerston.**

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.

All fishers interviewed confirmed that invertebrates are collected for the purpose of home consumption and to give to relatives and families on Rarotonga but not for commercial interests (Figure 3.16). Although the Palmerston community lives very traditionally and sharing on a non-commercial basis is an important social networking tool, invertebrates are less important than finfish when it comes to sharing catches. This may be due to the fact that invertebrates have never been as important as finfish for the nutrition of the island's population, and/or because they are not a commercial commodity and thus considered of lower value, and/or perhaps also because they are less targeted than finfish. In fact, very often invertebrates are collected as a by-product while fishers are out fishing for finfish or while families spend time picnicking on a *motu*. Often, invertebrates that are found by chance rather than targeted are consumed while on the reef or on the beach. Thus the invertebrate consumption estimated from respondents' information may be underestimated, as people reported invertebrates consumed at family meals only, not what they eat while out fishing or boating.

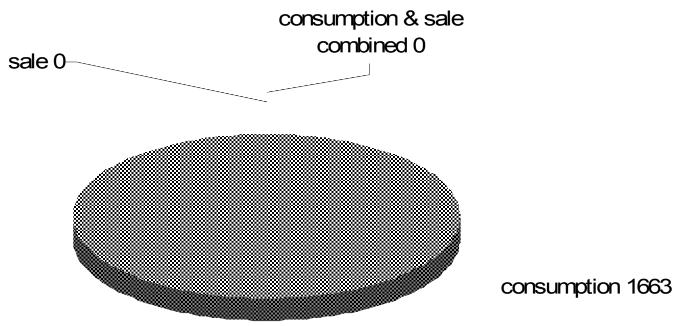



**Figure 3.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Palmerston.**

As mentioned earlier, both genders participate in all fishing activities on Palmerston. However, the few lobster fishers are only males and their productivity is low as already mentioned (Figure 3.17). As far as reeftop gleaning is concerned, females may contribute much less than male fishers to the total annual impact; however, they have a higher annual individual catch rate than males. There is no difference in total average annual catch between male and female fishers for soft-benthos fisheries.

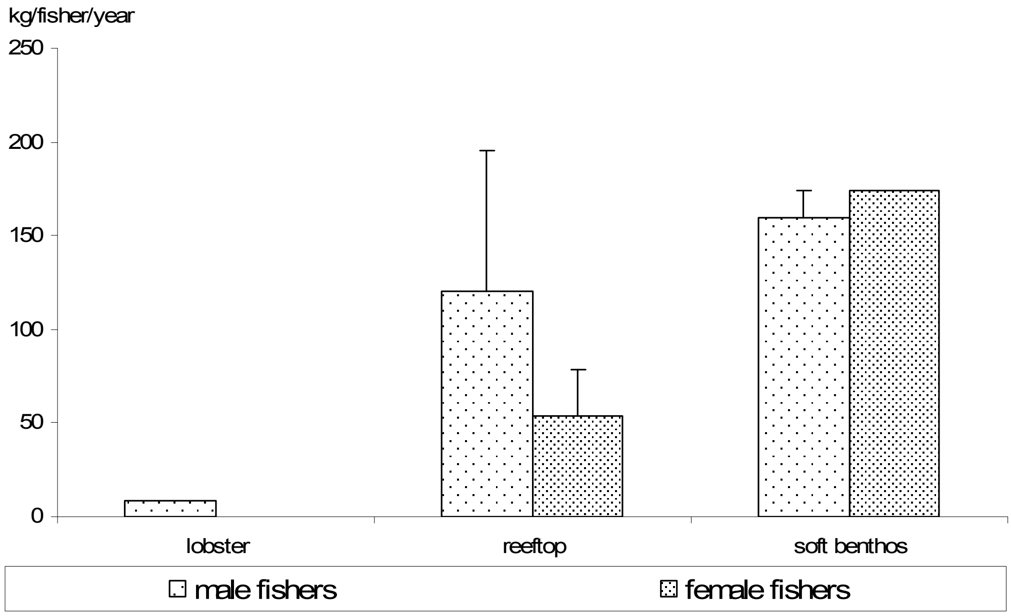



**Figure 3.17: Average annual invertebrate catch (kg wet weight/year) by fisher and gender in Palmerston.**
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 7 for males, n = 6 for females).

Parameters shown in Table 3.4 suggest that fisher density and average annual catch per fisher (in kg wet weight/fisher/year) are very low. In fact, the current data does not suggest any fishing pressure on any of the resources. However, given the fact that there are only very few invertebrate species targeted, and that these are all reported to be significantly reduced – if not exhausted – these figures may indicate a low current pressure as a reply to a severe status of depletion.

**Table 3.4: Parameters used in assessing fishing pressure on invertebrate resources in Palmerston**

| Parameters | Fishery / Habitat | | |
|---|---|---|---|
| | Lobster | Reeftop [3] | Soft benthos [4] |
| Fishing ground area ($km^2$) | 34.4 | 10.2 | n/a |
| Number of fishers (per fishery) [1] | 1 | 20 | 4 |
| Density of fishers (number of fishers/$km^2$ fishing ground) | 0.03 | 2 | n/a |
| Average annual invertebrate catch (kg/fisher/year) [2] | 8.33 (n/a) | 89.43 (±41.70) | 164.06 (±9.65) |

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; [1] total number of fishers is extrapolated from household surveys; [2] catch figures are based on recorded data from survey respondents only; [3] it should be noted that reeftop gleaning catches also include lobster catches; lobster catches are only exclusively dealt with under ‘lobster fishery’ if they are the only or the main target species of a fishing trip; [4] this fishery mainly targets *Asaphis violascens* (*kai*) and is estimated to total about 500 kg/year only; thus the impact is insignificant considering the available potential intertidal area around *motu*.

### *3.2.5 Perceptions of Palmerston fishers*

The joint mission of the CoFish, MMR and the CIMRIS project prompted an extension of the Palmerston survey to attempt to answer a few selected questions referring to the island’s parrotfish fishery, and to gain a better understanding of the local perception regarding the status of reef and lagoon resources. The additional questions are shown in Appendix 2.2.5.

The data collected from a total of ten finfish fishers, half fishing for income and the other half for subsistence only, suggests the following:

- Commercial parrotfish fishers target mainly *rei* (*Hipposcarus longiceps*), much less *poshow* (*Chlorurus microrhinus*) and *show* (*Scarus altipinnis*); *akau (C. frontalis*), *poshow* (*C. microrhinus*) and *show* (*S. altipinnis*) are often regarded as by-catch, especially *akau* (*C. frontalis*).

- There seems to be a consensus that the abundance and size of all reef and lagoon fish have declined over the past years; however, opinions varied as to when this decline began, but generally it was thought to have begun ≥10 years ago. Several respondents indicated that *kaka tavake* (*Cetoscarus bicolor*) has been disappearing over the last 10 years, and that particularly *patuki* (*Epinephelus hexagonatus*), *marau* (*Myripristis* sp.) and *rei* (*Hipposcarus longiceps*) are negatively affected. *Koperu* (*Decapterus marcarellus*) and *ature* (*Selar crumenophtalmus*) were reported to be previously fished right at the beach front, but to be no longer found anywhere close to the shore.

- A consensus exists about the decline of *paua* (*Tridacna maxima*); some fishers observed that there is no *paua* left at all, others that it has been progressively declining over the past ten or more years. Decline in abundance and size was also reported for octopus, lobsters, *ariri* (*Turbo setosus*) and *kai* (*Asaphis violascens*).

- A great variety of reasons are believed to be responsible for the perceived changes in reef finfish and invertebrate resources. These are listed in Table 3.5:

**Table 3.5: Possible reasons for the perceived decline in reef and lagoon finfish and invertebrate resources (reported by respondents in Palmerston)**

| Reasons for decline in finfish resources | | Reasons for decline in invertebrate resources | |
|---|---|---|---|
| **Rank** | **Reasons** | **Rank** | **Reasons** |
| 1 | Overfished | 1 | Overfished |
| 1 | Too much export to Rarotonga | 1 | Too much export to Rarotonga |
| 3 | Ciguatera for groupers | 2 | Cyclones, particularly in 2001 washed *kai* ashore |
| 3 | Damage of corals and food by cyclones | 3 | Introduction of trochus may have adversely affected on *paua*? |
| 3 | Perhaps no food on the reef, as corals are dying? | 3 | Corals are dying – loss of habitat for *paua* |
| 3 | Don’t understand | 3 | Water quality |
| | | 3 | Don’t understand |

Results of the community meetings held at Palmerston following the individual questionnaire survey (Appendix 2.2.6) confirmed the overall perception of a historical decline in reef and lagoon finfish and invertebrate resources. No major changes in the selection of fishing grounds were reported. The change of schooling rabbitfish from around Toms to a passage close to Palmerston since 1996, and the loss of two passages at Motu Ngangie (presumably due to shifts in sand deposits caused by cyclones and cultivation on the *motu*) that were formerly known for their richness in parrotfish are exceptions. However, changes in abundance and size of finfish and invertebrate species were highlighted; the results are shown in Table 3.6.

**Table 3.6: Changes in abundance and size of marine resources as perceived and agreed by the Palmerston community planning meeting**

| What has changed? | Size | Number | Since when? |
|---|---|---|---|
| Parrotfish | ↓↓↓ | ↓↓↓ | Early 1990s |
| *Pateke* | ↓↓↓ | ↓↓↓ | Early 1990s |
| *Taiva* | ↓↓↓ | ↓↓↓ | Early 1990s |
| *Ngatara* | ↓↓↓ | ↓↓↓ | Early 1990s |
| Mullet | ↓↓ | ↓↓ | Early 1990s |
| Lobster | ↓↓↓ | ↓↓↓ | Late 1990s |
| *Paua* | ↓↓↓ | ↓↓↓ | Early 1990s |
| *Ariri* | ↓↓ | ↓↓ | 2000 |
| *Kai* | ↓↓ | ↓↓ | 1991 (cyclone) |
| Coconut crab | ↓↓ | ↓↓ | Late 1990s |

↓ slight decrease; ↓↓ moderate decrease; ↓↓↓ severe decrease.

The community meeting also listed the major changes in fishing strategies that occurred in the 1980s and that may explain the progressive decreases that are reported to have started in the early 1990s. These changes were:

- The substitution of the traditional *rau* system by gillnetting. While the *rau* system involved most if not all fishers from the community as a joint effort, gillnetting can be practised in smaller groups and more frequently; it is also more effective.

- Also about 15 years ago, the traditional *tone*, a system to chase schools of fish, particularly *morava*[10] (*Siganus argenteus*) into stone traps from where they were then caught using scoop nets, was abandoned, as the schooling fish no longer occur close to the shore.

- The introduction of boats equipped with outboard engines to replace paddle and sailing canoes. As a result fishers had more choice of fishing ground and more fishing ground was covered by smaller but more frequent fishing groups.

- Freezers that replaced the traditional preservation options, i.e. keeping live fish in traps for sale, and salting *paua* meat. With the availability of more effective preservation methods, more catch could be stored; *paua*, *ariri* and lobsters could also be frozen; and more catch could be made available for commercial or non-commercial export.

- With the increased effectiveness and supply of fish and other seafood, there was also an increase in the frequency of boat trips to and from Rarotonga. In other words, more was caught and more was sold and exported to Rarotonga.

### *3.2.6 Fisheries management: Palmerston*

- The perception of the *paua* decline in the 1980s resulted in the community's decision to stop commercial export of giant clam meat to Rarotonga. However, although the commercial activity was effective since the 1980s, harvesting for non-commercial export to family members and relatives in Rarotonga continued, and these exports were reported to have been substantial.

[10] Referred to as *maemae* in Preston *et al*. 1995.

- Another *ra'ui* (no-take) was imposed and complied with by the Palmerston community in response to the observed decline in the lagoon's lobster resources. The lobster ban was effective for a 10-year period, from the early 1970s to early 1980s. However, no improvement in the lobster population was observed at the end of the ban.

- The Island Council also tried to react to early signs of decline in the island's parrotfish resources. A *ra'ui* for commercial fishing of parrotfish was pronounced in 1989; however, as many community members did not comply with the restriction, the ban was abandoned after 10 months.

- The occurrence of fish poison in previously unaffected species targeted by Palmerston fishers for subsistence purposes, such as *blaikot* (or *blaicot*) (*Cephalopholis argus*) and *maito* (*Acanthurus* sp.) following the blasting of a passage close to Palmerston in 2000, has resulted in a change of target species. Although ciguatera is – apart from the traditionally known occurrence in *tonu* (*Plectropomus laevis*) – not considered to persist any longer, families who were affected no longer catch any of the two species. However, the effect of less subsistence fishing on these two species is considered minor, if not insignificant.

- Following concerns that were raised in the mid 1980s by the Palmerston community of a perceived decline in the abundance and sizes of parrotfish and others, after a decade of commercial fishing, a baseline survey of Palmerston's fishery resources and identification of appropriate monitoring and management measures were recommended. A corresponding survey was undertaken in September 1988 (Preston *et al.* 1995) that also aimed at assessing possible ways of diversifying fishing effort and maximising economic returns on a sustainable basis.

- Results of this survey suggest that fishing pressure in the past may have exceeded sustainable yield estimates, and were at the time of the survey – in the mid to late 1980's – assumed to range between 23.1 and 30 t/year, in or beyond the upper end of an estimated annual yield estimated at 3.1 to 27.4 t/year. The estimated yield is based on:
  - a parrotfish secondary production on three Philippine coral reefs that ranged from 3.56 to 7.64 t/km²/year (Russ and St. John 1988),
  - an estimated coral reef area of 8.95 km² for Palmerston, and
  - a sustainable yield that corresponds to 10–40% of secondary production biomass.

- The survey also indicated that the exploitation of *paua* (*T. maxima*) is becoming increasingly important as an inshore fishing activity. However, survey results showed that, although densities of *T. maxima* were generally lower on Palmerston Island than on Aitutaki and some other islands in the country, they were still quite high in some areas (>20/m²) (Preston *et al.* 1995).

- The local crayfish resources were considered small by volume but representing a considerable commercial value. The report points out that a six-month export ban applied to crayfish, which were previously exported to Rarotonga in small quantities.

- Based on the survey results a number of management options were proposed, in particular for the island's parrotfish fishery. The desired long-term goal was a return of parrotfish stocks to levels observed in the early 1970s and that economic disruption be minimised. Management options included the collection of more accurate fishery statistics on the island, restrictions on fish size, gear (mesh size and type of gear), fishing effort (e.g. enforced rest periods, such as one month fishing, three months no fishing), areas fished (establishment of a permanent reserve covering at least 25% of the total reef area) in combination with an annual catch quota (maximum of 10 t/year for five years), and total closure of the fishery for various periods of time (a minimum of two years except for subsistence purposes).

- Management recommendations for giant clams included close monitoring of harvesting for export, triggered by the harvest ban on Aitutaki, rotational closures of commercial harvesting, and size restrictions. It was also recommended that no further export of crayfish be allowed and that the current ban on turtle spearing be maintained.

### *3.2.7 Discussion and conclusions: socioeconomics in Palmerston*

- The Palmerston community is highly dependent on its reef and lagoon resources due to the limited alternatives to gain income on this isolated atoll, as well as to its limited agricultural potential. This fact shows in a fresh-fish consumption of ~110 kg/person/year, which is much higher than that estimated by Preston *et al.* (1995) of ~70 kg/person/year.

- Living costs on Palmerston are high because all goods must be imported by boat from Rarotonga, and all perishable food items require freezing facilities.

- However, Palmerston is also subject to modernisation, which is seen in the changes that have occurred in nutrition, education, income and lifestyle. This conclusion is supported by comparison of the data from the current CoFish survey (2007) with results from a 1988 survey (Preston *et al.* 1995). This shows that the population decreased from 140 (in 1980–1990) to 66 (in 1986) and 56 (in 2007); also, the total number of motorised boats has decreased from 24 boats (reported in 1988) to 15 boats (9 motorised, 6 non-motorised) today.

- The status of reef and lagoon resources is reported to be depleted for almost all species that are of major interest for Palmerston's fishers. This trend of dwindling resources has been perceived since the early 1990s and may be a response to major changes in gear and fishing strategies that happened in the 1980s. However, catch ~1.3 t/fisher/year and CPUE (~4.5 kg/hour) are still high. Also, overall, fisher density and catch per habitat area are low and do not suggest any major problem.

- While the island's own subsistence demand is insignificant due to the small population, major impact is imposed by commercial and non-commercial export to Rarotonga and elsewhere. The export volume seems to be limited by the freezing capacity and frequency of boat cargo transport to and from Rarotonga. However, caution is advised because the exported finfish catch mainly comprises only 2–4 species.

- The community's perception that invertebrate resources are diminished, if not depleted, is supported by the data collected during the current survey. Invertebrates are hardly targeted, consumed, commercialised or exported on a non-commercial basis. Collection for commercial export, of *paua* (*Tridacna maxima*) in particular, is currently prohibited. Trials to introduce trochus and blacklip pearl oysters have been unsuccessful. There is only one recorded event of a 1.5 t shipment of trochus shells sent to Rarotonga in 1997

(MMR). However, *ariri* (*Turbo setosus*) and *kai* (*Asaphis violascens*) are collected for home consumption and at times also transported to Rarotonga as a gift for family members and relatives. Lobster resources apparently were never substantial and have hardly played a major role. In total, the current subsistence demand for invertebrates on Palmerston is low. However, the fact that *paua* (*T. maxima*) is in short supply (low in abundance and small in size) has been highlighted.

- There is no reason to assume that the Palmerston community will not continue with its rather isolated lifestyle. Due to the educational opportunities now re-established with the Luck School services, further emigration can be assumed. However, on the other hand, the governmental interventions aiming at improving the infrastructure on the island (public electricity, power and water supply, telecommunications, island administration, basic medical services) and providing jobs that allow almost all families to reduce their financial dependency on commercial fisheries, may not only enable some families to remain on the island, but also help to further decrease the current fishing pressure on the island's reef and lagoon resources. In addition, there are ongoing efforts to launch a pearl-farming project on Palmerston.

- However, as already suggested in the late 1980s, fisheries management interventions are needed to restore today's resources to the reported – even though perhaps not recorded – previous levels, and maintain them for sustainable use in the future. It may be more beneficial to focus on restoration and sustainable use, since opportunities to exploit alternative fishery options, such as aquaculture (e.g. pearl farming), seem to be rather limited. There are also no indications that the Palmerston community is interested in increasing its tourist industry.

- Given the particular social situation of the Palmerston community, the objective of developing and making operational an effective fisheries management plan can only be reached in joint cooperation between the island's community and the Cook Islands fisheries authorities, with a strong focus on ownership by the Palmerston community. The consensus of all community members to develop, implement and follow up a fisheries management plan in general and all steps and interventions in particular, as well as a continuous communication flow between the Palmerston community and the MMR, are believed to be the essential prerequisites for success.

## 3.3 Finfish resource surveys: Palmerston

Palmerston is a lozenge-shaped, enclosed atoll, located at 18º02'50"S, 163º09'22"W. Its length is 12 km and its width is 9.5 km. Out of the seven *motu* surrounding the rim, only one island, located at the west–southwest of the atoll, is inhabited. The fishing area is open-access. There are no reserves in the atoll.

Finfish resources and associated habitats were assessed in Palmerston (Figures 3.17 and 3.18) between 16 and 21 February 2007, from a total of 18 transects (6 intermediate-, 6 back- and 6 outer-reef transects, see Figure 3.19 and Appendix 3.2.1 for transect locations and coordinates respectively).

**Figure 3.18: The atoll of Palmerston.**

The inside of the atoll is dominated by a sandy floor dispersed with several small columnar-shaped pinnacles and small patches composing the intermediate reefs. The particularity of this habitat is its lack of both live and dead corals. In the south and southeast back-reef habitat, the small coral patches were composed of micro-atolls, which act as natural fish traps. This area is ~6.5 km long and is located very close to the inhabited island, therefore providing an easily accessible fishing area for fishers.

### *3.3.1 Finfish assessment results: Palmerston*

A total of 22 families, 48 genera, 112 species and 9358 fish were recorded in the 18 transects (See Appendix 3.2.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 37 genera, 98 species and 9161 individuals.

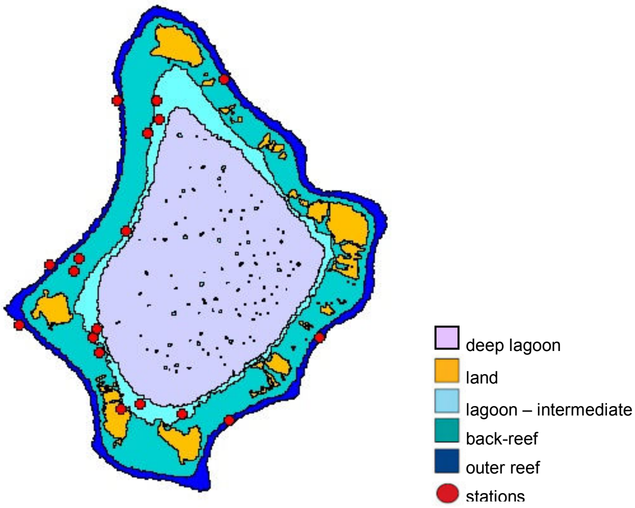



**Figure 3.19: Habitat types and transect locations for finfish assessment in Palmerston.**

Finfish resources varied slightly among the three reef environments found in Palmerston (Table 3.7). The intermediate reef contained the highest biomass (120 g/$m^2$), size (19 cm FL) and size ratio (57%), while outer reefs displayed the highest values of density (0.7 fish/$m^2$) and biodiversity (39 species/transect). Back-reefs displayed the lowest values of all such parameters.

**Table 3.7: Primary finfish habitat and resource parameters recorded in Palmerston (average values ±SE)**

| Parameters | Habitat | | | |
|---|---|---|---|---|
| | Intermediate reef [(1)] | Back-reef [(1)] | Outer reef [(1)] | All reefs [(2)] |
| Number of transects | 6 | 6 | 6 | 18 |
| Total habitat area ($km^2$) | 0.3 | 19.1 | 5.9 | 25.3 |
| Depth (m) | 4 (1-10) [(3)] | 2 (1-7) [(3)] | 8 (5-13) [(3)] | 4 (1-13) [(3)] |
| Soft bottom (% cover) | 19 ±4 | 28 ±11 | 2 ±1 | 22 |
| Rubble & boulders (% cover) | 18 ±3 | 30 ±11 | 2 ±1 | 23 |
| Hard bottom (% cover) | 43 ±7 | 30 ±5 | 59 ±3 | 37 |
| Live coral (% cover) | 20 ±5 | 11 ±2 | 33 ±3 | 16 |
| Soft coral (% cover) | 0 ±0 | 0 ±0 | 3 ±1 | 1 |
| Biodiversity (species/transect) | 31 ±2 | 18 ±2 | 39 ±2 | 29±2 |
| Density (fish/$m^2$) | 0.5 ±0.1 | 0.4 ±0.2 | 0.7 ±0.1 | 0.5 |
| Size (cm FL) [(4)] | 19 ±1 | 11 ±1 | 15 ±1 | 12 |
| Size ratio (%) | 57 ±2 | 34 ±2 | 52 ±2 | 38 |
| Biomass (g/$m^2$) | 120.9 ±32.0 | 43.6 ±19.3 | 79.8 ±15.4 | 52.8 |

[(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.

*Intermediate-reef environment: Palmerston*

The intermediate-reef environment of Palmerston was dominated by four major families: Acanthuridae and Scaridae, for both density and biomass, and Lethrinidae and Serranidae for biomass only (Figure 3.20). These four families were represented by 25 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Monotaxis grandoculis*, *Hipposcarus longiceps*, *Scarus altipinnis*, *Plectropomus laevis*, *Cephalopholis argus* and *Acanthurus triostegus* (Table 3.8). This reef environment presented a moderately diverse habitat with hard bottom covering 43% of the total surface, an average cover of live corals (20%), and 37% of substrate composed of mobile bottom (Table 3.7 and Figure 3.20).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.175 ±0.049 | 28.7 ±11.3 |
| | *Acanthurus triostegus* | Convict tang | 0.048 ±0.025 | 3.3 ±1.5 |
| Lethrinidae | *Monotaxis grandoculis* | Bigeye bream | 0.017 ±0.011 | 17.6 ±14.1 |
| Scaridae | *Hipposcarus longiceps* | Pacific longnose parrotfish | 0.035 ±0.015 | 16.6 ±9.4 |
| | *Scarus altipinnis* | Filament-finned parrotfish | 0.041 ±0.009 | 11.3 ±4.6 |
| Serranidae | *Plectropomus laevis* | Black-saddled coral grouper | 0.003 ±0.002 | 8.1 ±6.9 |
| | *Cephalopholis argus* | Peacock grouper | 0.019 ±0.007 | 7.4 ±3.2 |

The biomass, size and size ratio of finfish in the intermediate reefs of Palmerston were higher than in both back- and outer-reefs. However, density and biodiversity displayed intermediate values between the other two reef habitats. When compared to Aitutaki, the only other site with intermediate reefs, Palmerston displayed far higher values, with biomass twice as high as that in Aitutaki intermediate reefs. Mullidae and especially Scaridae presented very low size ratios, indicating heavy fishing pressure on such resources. The trophic structure in Palmerston intermediate reef was clearly dominated by herbivorous fish, represented primarily by small Acanthuridae and Scaridae. Substrate was composed of a good proportion of both soft and hard corals, but fish families associated with soft bottom were very limited.

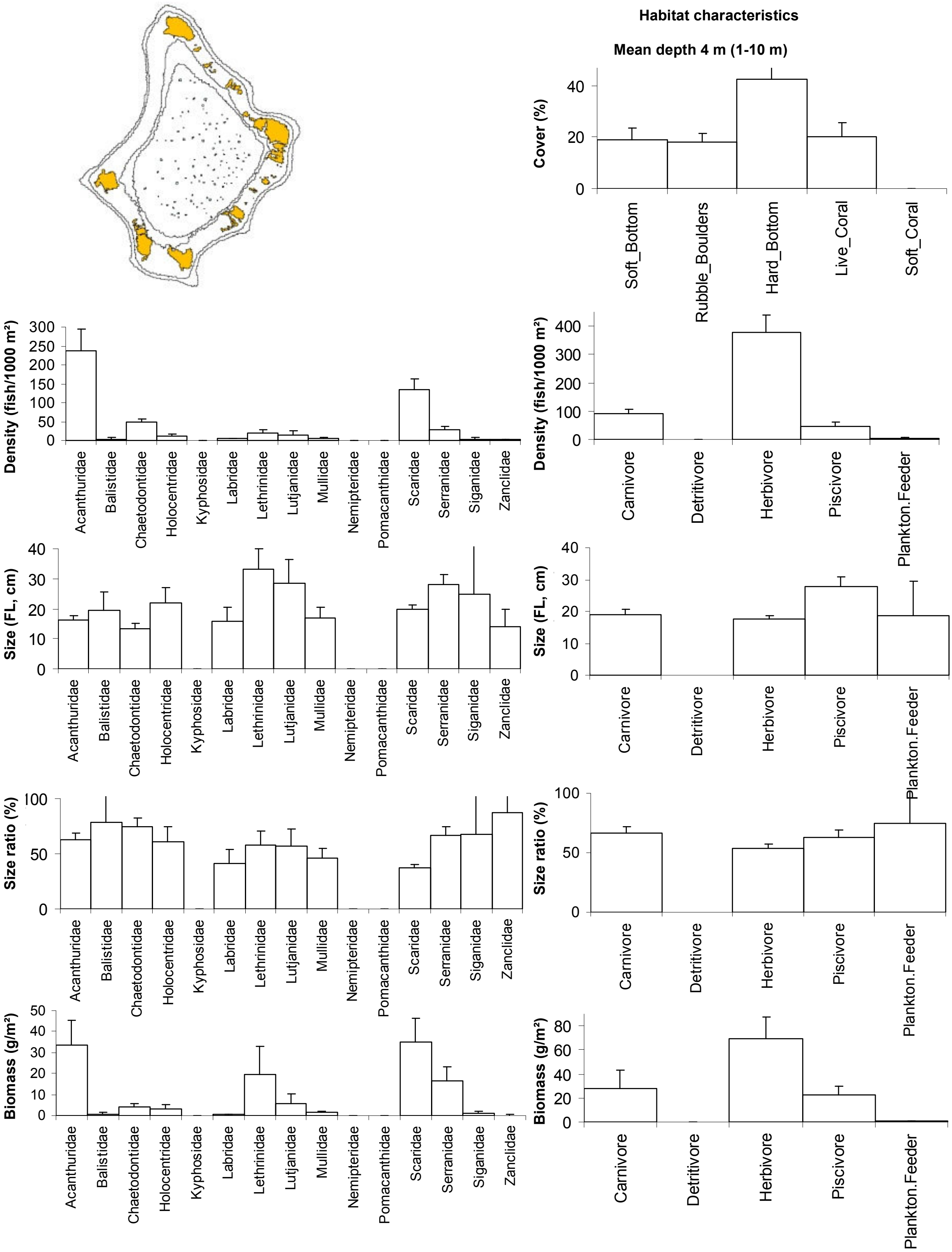



**Figure 3.20: Profile of finfish resources in the intermediate-reef environment of Palmerston.**
Bars represent standard error (+SE); FL = fork length.

*Back-reef environment: Palmerston*

The back-reef environment of Palmerston was dominated by two herbivorous families: Acanthuridae and Scaridae for both density and biomass and, in addition, by Serranidae for biomass (Figure 3.21). These families were represented by 18 species; particularly high biomass and abundance were recorded for *Chlorurus microrhinos*, *Plectropomus laevis*, *Hipposcarus longiceps*, *Ctenochaetus striatus*, *Acanthurus triostegus*, *Naso unicornis* and *A. olivaceus* (Table 3.9). This reef environment presented equal percentage cover of hard bottom (30%), rubble (30%) and soft bottom (28%), but very little live coral (11%), offering habitats suitable for several families (Table 3.9).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.208 ±0.180 | 4.2 ±2.3 |
| | *Acanthurus triostegus* | Convict tang | 0.073 ±0.033 | 3.9 ±2.1 |
| | *Naso unicornis* | Bluespine unicornfish | 0.001 ±0.001 | 3.0 ±3.0 |
| | *Acanthurus olivaceus* | Orangeband surgeonfish | 0.009 ±0.009 | 2.1 ±2.1 |
| Scaridae | *Chlorurus microrhinos* | Steephead parrotfish | 0.005 ±0.003 | 9.5 ±7.3 |
| | *Hipposcarus longiceps* | Pacific longnose parrotfish | 0.010 ±0.007 | 6.1 ±5.7 |
| Serranidae | *Plectropomus laevis* | Black-saddled coral grouper | 0.001 ±0.000 | 7.0 ±4.6 |

The density, biomass, size, size ratio and biodiversity of finfish in the intermediate reefs of Palmerston were the lowest of the site (Table 3.7). However, when compared to the same type of habitat in Rarotonga and Aitutaki, the intermediate reefs of Palmerston displayed by far the lowest values of all parameters. Herbivores dominated the trophic structure, with density 12 times higher and biomass 8 times higher than that of carnivores. Carnivores were mainly represented by Serranidae. The substrate of these back-reefs was equally composed of hard bottom, soft bottom and rubble, offering different niches for various species. However, the relative biodiversity was very low.

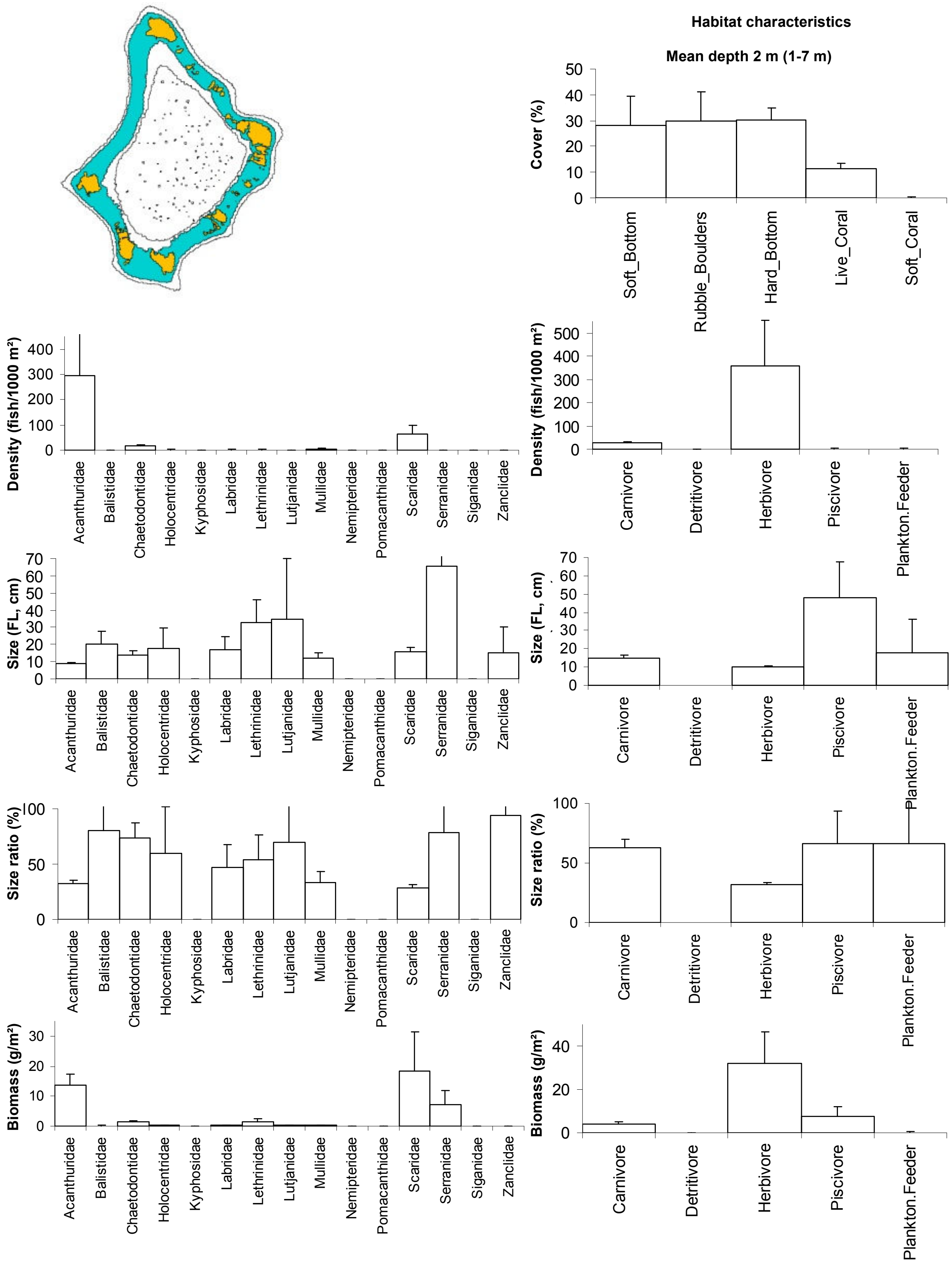



**Figure 3.21: Profile of finfish resources in the back-reef environment of Palmerston.**
Bars represent standard error (+SE); FL = fork length.

*Outer-reef environment: Palmerston*

The outer-reef environment of Palmerston was dominated by three major families: herbivorous Acanthuridae and Scaridae, and, to a much lower extent and only for biomass, carnivorous Serranidae (Figure 3.22). These were represented by 27 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Plectropomus laevis*, *Acanthurus achilles*, *Naso lituratus*, *A. nigrofuscus*, *Scarus altipinnis*, *A. nigricans* and *Chlorurus microrhinos* (Table 3.10). This reef environment presented a high dominance of hard bottom (59%), high coral cover (33%) and very little soft bottom and rubble cover (4%, Table 3.7).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.07 ±0.082 | 23.2 ±11.8 |
| | *Acanthurus achilles* | Achilles tang | 0.19 ±0.019 | 5.0 ±1.9 |
| | *Naso lituratus* | Orangespine unicornfish | 0.24 ±0.005 | 4.1 ±1.1 |
| | *Acanthurus nigrofuscus* | Brown surgeonfish | 0.07 ±0.061 | 3.4 ±2.6 |
| | *Acanthurus nigricans* | Whitecheek surgeonfish | 0.22 ±0.012 | 2.7 ±2.0 |
| Scaridae | *Chlorurus sordidus* | Daisy parrotfish | 0.01 ±0.068 | 12.6 ±4.2 |
| | *Scarus altipinnis* | Filament-finned parrotfish | 0.02 ±0.002 | 3.1 ±2.7 |
| | *Chlorurus microrhinos* | Steephead parrotfish | 0.04 ±0.001 | 2.6 ±2.6 |
| Serranidae | *Plectropomus laevis* | Black-saddled coral grouper | 0.002 ±0.001 | 6.3 ±6.1 |

The density and biodiversity of finfish in this outer reef were the highest of the site. However, size, size ratio and biomass were second to intermediate reefs. When comparing these outer reefs to the other three country sites, Palmerston displayed the poorest density and biomass of all. Only biodiversity was second in rank, after Aitutaki. Similarly to the condition in the back- and intermediate reefs, Scaridae had a very low size ratio (38%), suggesting an impact from fishing on this family. Herbivores heavily dominated the trophic structure and carnivores were almost absent, except for good numbers of average-sized *Plectropomus laevis*, found everywhere due to the fact that they were affected by ciguatera. In the northwest and northeast area of the atoll, high density and large sizes of *Hipposcarus longiceps* were recorded. *Chlorurus microrhinos*, *C. frontalis* and *Scarus altipinnis* also formed large schools and some of the sizes were quite exceptional. Since fish were not scared by the presence of divers, we deduced that spear fishing was not at all practised. The abundance of apex (top of the food chain) predators (especially *Carcharhinus amblyrhynchos* and *Triaenodon obesus*) was fairly high, although not exceptional.

The outer reefs of Palmerston displayed a good cover of live coral and a dominance of hard substrate, favouring herbivores over most carnivore families.

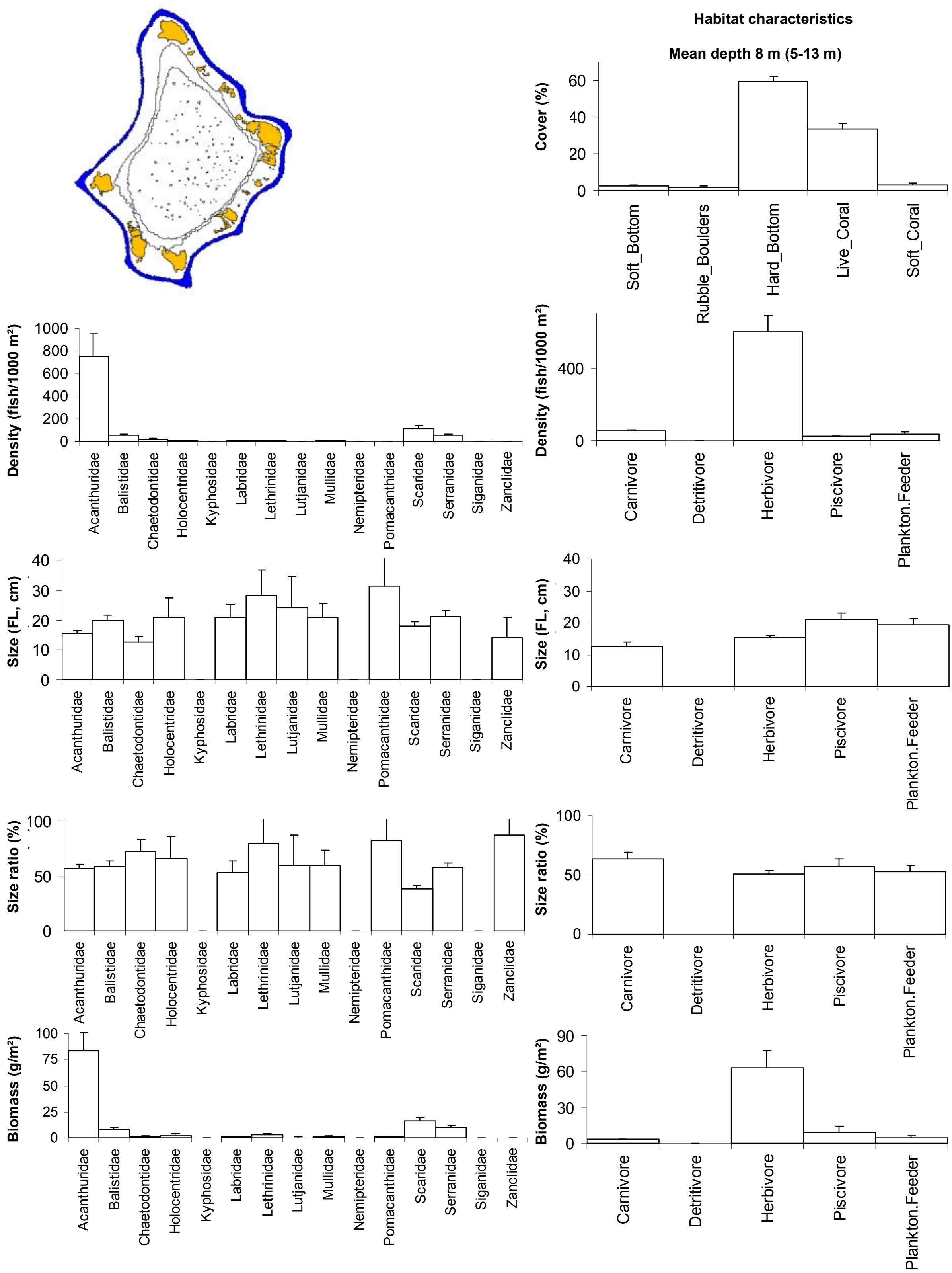



**Figure 3.22: Profile of finfish resources in the outer-reef environment of Palmerston.**
Bars represent standard error (+SE); FL = fork length.

*Overall reef environment: Palmerston*

Overall, the fish assemblage at Palmerston was dominated by herbivorous Acanthuridae and Scaridae and, only for biomass, by carnivorous Serranidae (Figure 3.23). These three families were represented by a total of 35 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Chlorurus microrhinos*, *Plectropomus laevis*, *Hipposcarus longiceps*, *Chl. sordidus*, *Acanthurus triostegus*, *Naso unicornis*, *A. olivaceus*, *Naso lituratus*, *Scarus altipinnis* and *A. achilles* (Table 3.11). The average substrate was almost equally composed of hard bottom (37%), rubble (23%) and soft bottom (22%), with relatively low live-coral cover (16%). The overall fish assemblage and substrate composition in Palmerston shared characteristics of primarily back-reefs (75% of total habitat), to a smaller extent outer reefs (23%) and, to a very limited extent, intermediate reefs (1% of habitat).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.203 | 8.9 |
| | *Acanthurus triostegus* | Convict tang | 0.056 | 3.0 |
| | *Naso unicornis* | Bluespine unicornfish | 0.001 | 2.3 |
| | *Acanthurus olivaceus* | Orangeband surgeonfish | 0.007 | 1.6 |
| | *Naso lituratus* | Orangespine unicornfish | 0.005 | 1.4 |
| | *Acanthurus achilles* | Achilles tang | 0.010 | 1.2 |
| Scaridae | *Chlorurus microrhinos* | Steephead parrotfish | 0.004 | 7.8 |
| | *Hipposcarus longiceps* | Pacific longnose parrotfish | 0.008 | 5.2 |
| | *Chlorurus sordidus* | Daisy parrotfish | 0.064 | 3.3 |
| | *Scarus altipinnis* | Filament-finned parrotfish | 0.004 | 1.4 |
| Serranidae | *Plectropomus laevis* | Black-saddled coral grouper | 0.001 | 6.9 |

Overall, Palmerston appeared to support an average-to-poor finfish resource, with lowest density, size and biomass, and only second-ranked biodiversity among the four country sites (Table 3.7). The more detailed assessment at the trophic and family level revealed a heavy dominance of herbivores over carnivores, mainly due to the high abundance of surgeonfish (many species but of small-to-average size) and, to a smaller extent, parrotfish. This trend could not be fully explained by the composition of the habitat, since this was complex and composed of both hard and soft bottom, offering niches to different families.

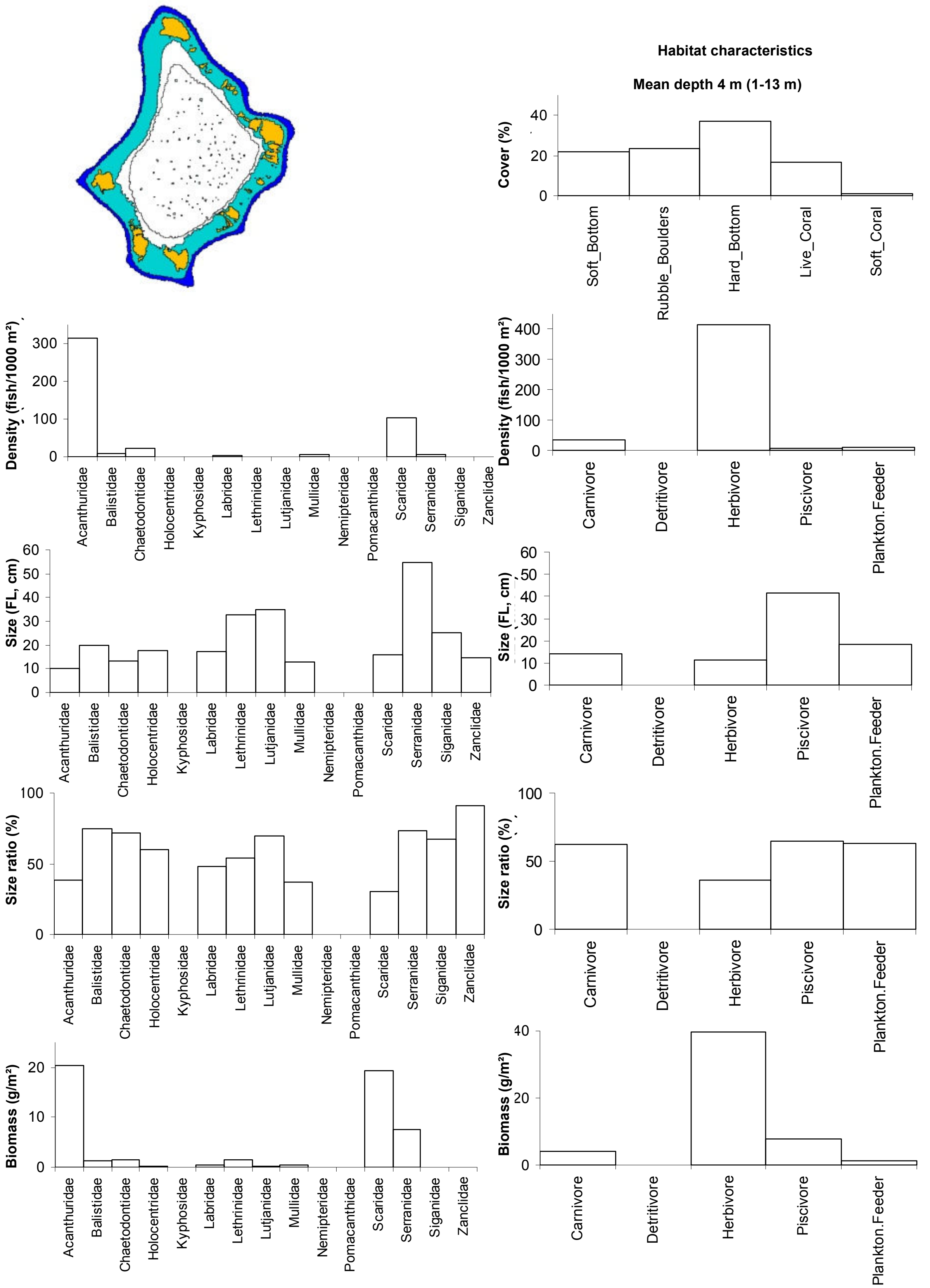



**Figure 3.23: Profile of finfish resources in the combined reef habitats of Palmerston (weighted average).**
FL = fork length.

## Scaridae; parrotfish

Finfish fishing in Palmerston principally targets Scaridae which are preferred by the local people as well as people of Rarotonga, to where the fish is mostly exported. Parrotfish are caught with nets and spears and this fishing technique imposes a serious threat on such a selected target group. The density and biomass of Scaridae were higher in the outer reefs than in the lagoon and finally in the back-reefs. The mean size for this family caught in ocean and lagoon reefs was much below 40% of the maximum values recorded in the literature, and below 28% in the back-reef. This data most probably indicates an impact from fishing. Among the twelve species of Scaridae assessed in the eighteen sites, *Chlorurus sordidus* (mainly juveniles, which explains the small average size), *Hipposcarus longiceps* and *Scarus psittacus* were the three most important species in terms of density. Biomass was dominated by *Chlorurus microrhinos*, *Cetoscarus bicolor*, *Hipposcarus longiceps* and *Scarus altipinnis* (Table 3.12). *Scarus globiceps*, *S. oviceps* and *Chl. microrhinos* displayed the highest values of size ratio in the family (>60%). *Chl. sordidus* dominated density in all habitats, while biomass was dominated by *Chl. sordidus* in the outer reef, *Hipposcarus longiceps* and *Scarus altipinnis* in the intermediate reef and *Chl. microrhinos* in the back-reef.

**Table 3.12: Species contributing to the Scaridae family across all reefs in Palmerston (weighted average), ordered by decreasing biomass**

| Species | Common name | Vernacular name [1] | Density (fish/m$^2$) | Biomass (g/m$^2$) | Size (cm FL) | Average size from 1988 records [2] | Size ratio |
|---|---|---|---|---|---|---|---|
| *Chlorurus microrhinos* | Steephead parrotfish | U'u | 0.004 | 7.83 | 44 | 48.5 | 0.6 |
| *Hipposcarus longiceps* | Pacific longnose parrotfish | Rai | 0.008 | 5.16 | 30 | 43.0 | 0.5 |
| *Chlorurus sordidus* | Daisy parrotfish | Pakati, koti | 0.064 | 3.26 | 10 | n/a | 0.2 |
| *Scarus altipinnis* | Filamentfinned parrotfish | Shaw | 0.004 | 1.37 | 24 | 40.3 | 0.4 |
| *Scarus psittacus* | Globehead parrotfish | Pakati, koti | 0.008 | 0.46 | 13 | n/a | 0.4 |
| *Cetoscarus bicolor* | Bicolor parrotfish | Kaka tavake | 0.0005 | 0.45 | 34 | n/a | 0.4 |
| *Scarus schlegeli* | Schlegel's parrotfish | Tomore | 0.003 | 0.33 | 17 | n/a | 0.5 |
| *Scarus frenatus* | Bluebarred parrotfish | Au'maori | 0.001 | 0.13 | 17 | n/a | 0.4 |
| *Scarus globiceps* | Common parrotfish | Pakati, koti | 0.001 | 0.09 | 20 | n/a | 0.7 |
| *Scarus ghobban* | Bridled parrotfish | Au'maori | 0.0002 | 0.02 | 19 | n/a | 0.3 |
| *Scarus oviceps* | Dark-capped parrotfish | | 0.0001 | 0.01 | 21 | n/a | 0.7 |

n/a = no information available; [1] Source for vernacular names in italics: Cook Islands Biodiversity Database; [2] Preston *et al.* 1995 (Report of a survey conducted in 1988).

From 1988 survey results, it appeared that *Chl. microrhinos* (named *Scarus gibbus* in the 1990 report), *Hipposcarus longiceps*, *Scarus altipinnis*, the only common species to these two studies with available size information, had much larger mean sizes than in the present study (Table 3.12). In the last survey (February 2007), the same species appeared to have mean sizes at 60%, 50% and 40% respectively of the maximum size ever recorded for the species (Table 3.12). These fish are heavily commercially exploited in Palmerston and our results indicated an obvious decrease over the 19-year period, which is a visible sign of impact.

### *3.3.2 Discussion and conclusions: finfish resources in Palmerston*

- The assessment indicated that, overall, the status of finfish resources in Palmerston was moderate to low. This was due to the natural condition of the site, which is very remote, with relatively poor live-coral cover. The density and biomass of food-fish were the lowest recorded among the four sites surveyed in the country. However, analysis at the reef habitat level was required to better understand the status and distribution of resources, due to their high spatial variability. The intermediate reefs, constituting only 1% of the total reef surface of this atoll, showed the highest value of average weighted fish biomass as well as the largest average fish size and size ratio compared to the other habitats. Back-reefs (composing 75% of the total reef area in Palmerston) displayed very low values of density, size, biomass and biodiversity, the lowest at this site as well as compared to the back-reefs at the other country sites. The outer reefs displayed intermediate values of size and biomass but highest density and biodiversity. This was the healthiest environment of the three, both in terms of habitat condition, with high cover of live coral, and in terms of species composition, although the outer reefs of Palmerston were poorer than all other country sites. The condition of Palmerston was, however, particular, due to the intense fishing of mainly parrotfish. This site is not affected by the serious problem of ciguatera recorded elsewhere in the country, except in the case of some species of Serranidae. Parrotfish are caught both to feed the local population (consumption of fresh fish being very high) and for export to Rarotonga (75% of catches) for sale and family gifts. Increased targeting of parrotfish has been noted in the past 20 years due to major changes in fishing and preservation strategies (use of gillnets, more motorboats, easy refrigeration access). As a result, impact has increased and was signalled during these surveys by the decreased size of some species, confirming the observation and feelings of the local people, who lamented the diminished resources and smaller sizes.

- Overall, Palmerston finfish resources appeared to be in average to poor condition. The healthy status of the intermediate reefs was not mirrored by the condition of the outer and back-reefs. In these two habitats, density, biomass, biodiversity and average size were fairly low compared to the country and regional average.

- The dominance of Acanthuridae and Scaridae could be explained by the type of environment, which was mostly hard bottom, especially in the outer reef.

- The relative lack of carnivores, mainly Serranidae, is most probably to be attributed to natural conditions.

- The current status of resources appeared sustainable for subsistence use only. The pressure imposed by increased amounts of fish exported is damaging local resources.

- Certain species of parrotfish showed signs of impact from heavy fishing, especially in average sizes. These results confirm the first *in situ* observations and impressions that these reefs were impacted as fish were very wary of divers and boats, especially in the back-reefs. Sizes and density were noted to be higher in the northwestern and northeastern outer reef areas.

## 3.4 Invertebrate resources: Palmerston

The diversity and abundance of invertebrate species at Palmerston were independently determined using a range of survey techniques (Table 3.13), broad-scale assessment (using the 'manta tow'; 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 assessments were conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

**Table 3.13: Number of stations and replicate measures completed at Palmerston**

| Survey method | Stations | Replicate measures |
|---|---|---|
| Broad-scale transects (B-S) | 9 | 54 transects |
| Reef-benthos transects (RBt) | 17 | 102 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) | 6 | 36 search periods |
| Reef-front searches (RFs) | 7 | 42 search periods |
| Reef-front search by walking (RFs_w) | 5 | 30 search periods |
| Sea cucumber day searches (Ds) | 4 | 24 search periods |
| Sea cucumber night searches (Ns) | 2 | 12 search periods |

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

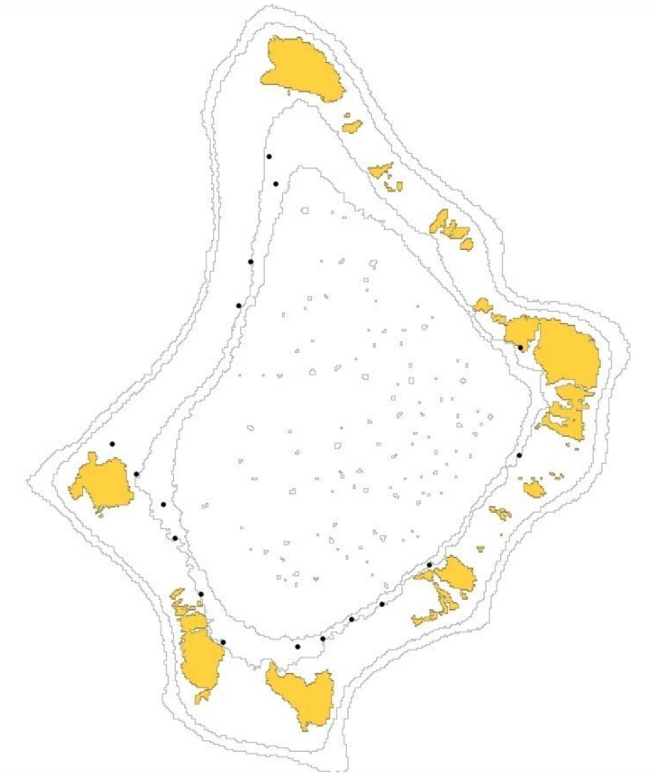


**Figure 3.25: Fine-scale reef-benthos transect survey stations for invertebrates in Palmerston.**
Black circles: reef-benthos transect stations (RBt).

**Figure 3.26: Fine-scale survey stations for invertebrates in Palmerston.**
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey circles: sea cucumber night search stations (Ns);
grey diamonds: sea cucumber day search stations (Ds).

Thirty-four species or species groupings (groups of species within a genus) were recorded in the Palmerston invertebrate surveys: 6 bivalves, 12 gastropods, 8 sea cucumbers, 3 urchins, 2 sea stars and 2 lobsters (Appendix 4.2.1). Information on key families and species is detailed below.

### *3.4.1 Giant clams: Palmerston*

Shallow-reef habitat that is suitable for giant clams was not very extensive at Palmerston Atoll (16.1 $km^2$: ~10.2 $km^2$ within the lagoon and 5.9 $km^2$ on the reef front or slope of the barrier). Hard substrate was available at the barrier reef, on intermediate pinnacles (over most of the lagoon) and small areas of ribbon patch reef (in the south). However, most of the lagoon shoreline was sand, rubble or flat platform, with little in the way of relief and complexity. The lagoon area was more extensive (50.8 $km^2$).

The low-island environment of Palmerston Atoll (main island <0.4 $km^2$ with all *motu* comprising <2 $km^2$) did not have a significant influence on the distribution of clams as 'land' inputs were minimal. Water movement was generally not dynamic in the large, relatively shallow system and, unexplainably, the system seemed in some way nutrified (from an unidentified source), with moderate visibility in many places and an abundance of coralline algal coating most surfaces. Only two areas had fast-flowing water, which passed over the barrier reef through small passages.

Two species of giant clam were noted in survey: the elongate clam *Tridacna maxima* and the fluted clam *T. squamosa*. The larger fluted clam was rare and only a single specimen was noted during mother-of-pearl surveys on the outer-reef slope. Broad-scale sampling provided a good overview of elongate clam distribution and density, and revealed a wide distribution (recorded in 9/9 stations and 51/54 transects; see Figure 3.27).

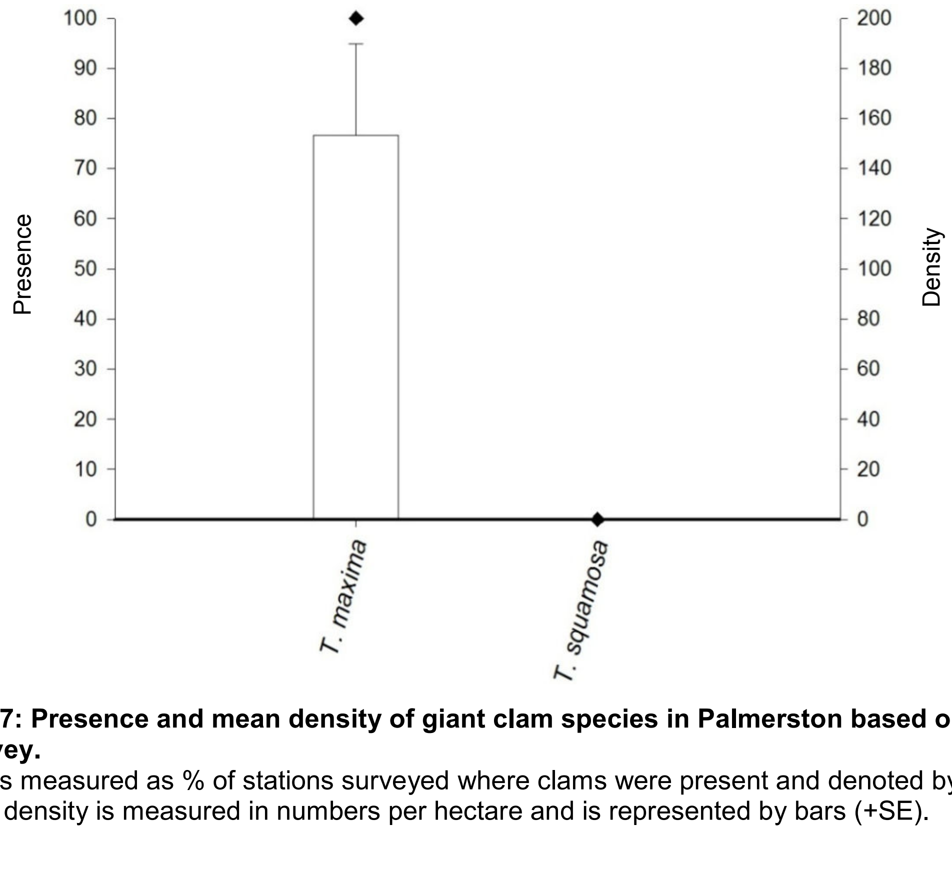



**Figure 3.27: Presence and mean density of giant clam species in Palmerston based on broad-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 3.28). In these reef-benthos assessments (RBt), *T. maxima* was present at all 17 stations, the highest station density being 1708.3 /ha ±384.1. The stations with the highest average densities were positioned in the south of the atoll, on reefs that ran into the lagoon.

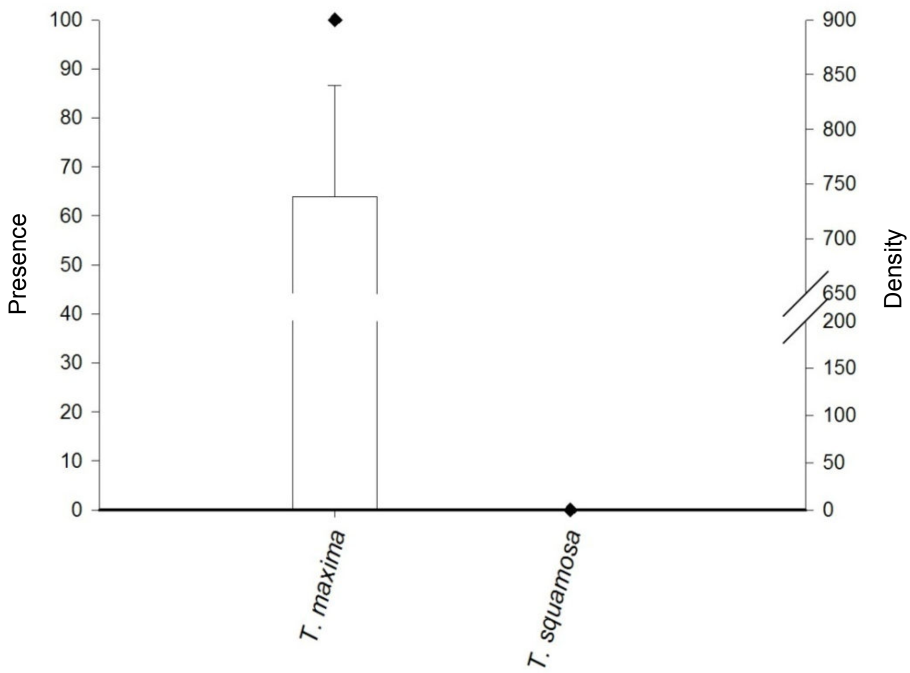



**Figure 3.28: Presence and mean density of giant clam species in Palmerston based on fine-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Earlier studies of Palmerston Atoll (Preston *et al.* 1995) showed that in 1988, there were very high-density patches of clams near to Home Islet. In studies based on smaller-scaled quadrats placed over especially rich areas of clam, they state, 'Densities of *T. maxima* are generally lower on Palmerston Island than on Aitutaki and some other Cook Islands, but are still quite high in some areas (>20 /m²). Up to 26 clams/m² were recorded from coral heads near Home Islet, with a mean of 6.5 /m² for 45 quadrats'.

A full range of sizes of *T. maxima* individuals (mean 11.3 cm ±0.3, n = 294) were recorded in shallow reef surveys (no broad-scale included). This represents a *T. maxima* of ~5–6 years old). Only a single *T. squamosa* was noted (26 cm in length). In the earlier study at Palmerston (Preston *et al.* 1995), they stated that larger clams (12–20 cm) were selectively culled from inner reef-flat areas to supply the market in Rarotonga (following the introduction of a ban of harvests in Aitutaki. Already at this time (1988) clams of larger size were only noted in small numbers, and very few clams over 20 cm were present (Figure 3.29).

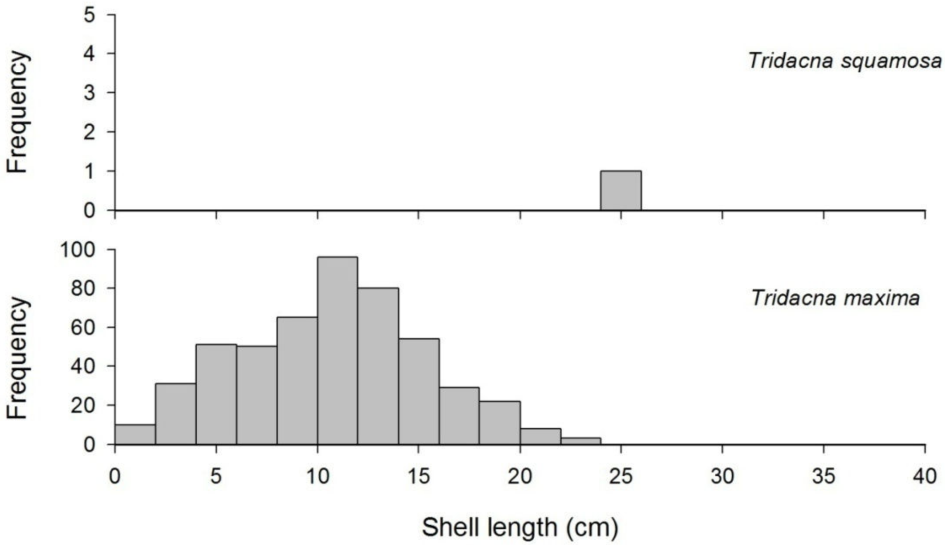



**Figure 3.29: Size frequency histograms of giant clams shell length (cm) for Palmerston.**

### *3.4.2 Mother of pearl species (MOP) – trochus and pearl oysters: Palmerston*

Cook Islands is not within the natural distribution range of the commercial topshell, *Trochus niloticus* in the Pacific, but these commercial gastropods have been introduced to Palmerston (Passfield 1997). The initial introduction was made in the late 1960s from Aitutaki, although the original shells were initially brought to Cook Islands from Fiji. Further introductions to Palmerston occurred in the early 1980s, when about 3000 trochus were transported to Palmerston, again from Aitutaki (Sims 1985). The blacklip pearl oyster, *Pinctada margaritifera*, has also been introduced to Palmerston (from Manihiki in the late 1950s) according to Preston *et al.* (1995), probably to augment the small number of natural stocks.

A survey in September 1988 found that only a small number of trochus persisted in limited areas of the northern reef and concluded that it was unlikely that trochus would constitute a major economic resource for the island (Preston *et al.* 1995). However, a commercial harvest in Palmerston in 1997 indicates that this initial pessimism may have been premature, as about 1.5 t of trochus shells were harvested and sold to a buyer on Rarotonga (Passfield 1997).

From the CoFish survey work, we found that the barrier (outer and back-reef), intermediate and coastal reefs constituted an extensive benthos for *T. niloticus* and that shells were present. The reef aspect and water movement regime was also suitable for *T. niloticus* (Palmerston had an outer reef of ~34.4 km lineal measure.), although the main aggregation was confined to the passage location near Home Islet, where the water flow was greatest.

The greatest density of trochus was recorded on the reef platform, back-reef and slope in an area covering ~0.4 km$^2$. Numbers on the outer reef (outside the barrier; 5.9 km$^2$ in area) were low, although moderate-to-good shoaling habitat was available in some places. The most significant trochus aggregations, or 'core' reefs, did not hold trochus at high density and there does not seem to have been a significant recovery from the harvest in 1997 (Table 3.14).

**Table 3.14: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Palmerston**
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 | 0.6 | 0.6 | 1/9 = 11 | 2/54 = 4 |
| RBt | 53.9 | 23.9 | 6/17 = 35 | 12/102 = 12 |
| RFs | 1.7 | 1.2 | 2/7 = 29 | 3/42 = 7 |
| RFs_w | | | 0/5 = 0 | 0/30 = 0 |
| MOPs | 10.1 | 6.7 | 2/6 = 33 | 4/36 =11 |
| ***Tectus pyramis*** | | | | |
| | None recorded | | | |
| ***Pinctada margaritifera*** | | | | |
| B-S | | | 0/9 = 0 | 0/54 = 0 |
| RBt | | | 0/17 = 0 | 0/102 = 0 |
| RFs | | | 0/7 = 0 | 0/42 = 0 |
| RFs_w | | | 0/5 = 0 | 0/30 = 0 |
| MOPs | | | 0/6 = 0 | 0/36 = 0 |

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

A total of forty-one trochus were recorded during the survey (n = 34 measured). The majority of the stock was located on very shallow reef (depth ~1 m) that is easily accessible to fishers walking or collecting with a mask and snorkel.

Average densities of trochus as measured through reef-benthos transect stations were 42–292 /ha (in the 35% of stations holding trochus; see Table 3.14). In MOP search surveys, the density was 23 and 38 /ha at the two stations with trochus. Although trochus were found near Home Islet in the southwest and the north, no aggregations supported trochus at the ‘commercial’ density of >500 shells/ha, and very few were found elsewhere.

Shell size also gives important information on the status of stocks by highlighting new recruitment into the fishery, or the lack of recruitment, which could have implications for the numbers of trochus entering the capture size classes in the following few years. In Cook Islands, a ‘gauntlet’ fishery operates (shells <8 cm and >11 cm across the base being illegal to harvest during the limited open period) and this means that both small and large-sized trochus are protected from fishing.

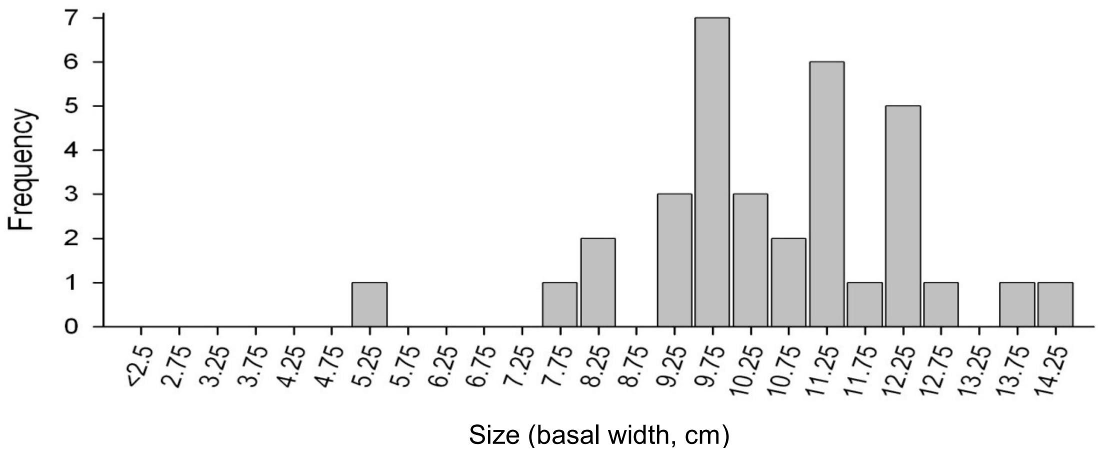



**Figure 3.30: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Palmerston.**

The mean basal width of trochus at Palmerston was 10.6 cm ±0.3 (Shells of 10.6 cm basal width weigh ~300 g as a dry shell and ~394 g live; also see Figure 3.30.). Although recruitment was ongoing, and noticeable by the presence of one smaller-sized shell, there was no large recruitment pulse of trochus entering the 'visible' size classes (First maturity of trochus is at 7–8 cm, ~3 years old). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic phase of life and joining the main stock. This portion of the population was not abundant in current surveys.

In Palmerston, 50% of the shell sizes recorded came from the legal size classes and 44% of the stock was from the 'over-size' classes (>11 cm basal width). This size profile describes a stock dominated by mature, older shells. As there is only a small amount of shells left on the reef (and no potential for commercial harvest), having a predominance of older shells within the system should be beneficial. Larger shells have the potential to boost reproduction, as they provide by far the largest input of gametes for future generations (A 10 cm shell produces ~2 million eggs, whereas a 13 cm shell produces three times as many, i.e. ~6 million eggs). In this case, the larger shells are in aggregations adjacent to reefs that are not holding trochus.

There are a number of views which explain the variability in recruitment of trochus, which is a common trait for both gastropods and bivalves (e.g. pearl oysters and clams). There is some anecdotal support for the theory that spawning of trochus may have failed in Aitutaki in recent years, and 2005 and 2006 have recorded some unusually heavy weather patterns affecting Cook Islands. El Niño periods (SO, southern oscillation) have been suggested as a factor that could affect juvenile survival, as El Niño–La Niña events can vary tides by up to 0.6 m (in an area that only has a 0.9 cm variation) which could also affect juvenile habitat by exposing shallow-water juvenile habitat to unsuitable heating and drying). There is also a link between SO cycles and bivalve settlement in other mollusc fisheries (e.g. pearl oyster settlement in Western Australia).

Another mother-of-pearl species, the blacklip pearl oyster (*Pinctada margaritifera*) is cryptic and normally sparsely distributed in most lagoon systems. In Palmerston, the lagoon is enclosed without large passes. Therefore the potential for any spawned larvae to be contained within the system and for numbers of pearl oysters to accumulate is good. However, only a few pearl oysters were recorded on this survey, or other surveys at Palmerston (Preston *et al.* 1995) The only blacklip pearl oyster noted was large, 19 cm in length (anterior–posterior measure).

### *3.4.3 Infaunal species and groups: Palmerston*

Soft benthos at the margins of islets at Palmerston were not suitable for seagrass meadows, and the survey team did not locate any concentrations of infaunal invertebrate resources (in-ground resources - shell 'beds'). The collection of the bivalve locally known as *ka'i* (*Asaphis violascens*) from rough benthos (stones, shell and gravel) was noted in the north of the lagoon, but no infaunal 'digging' stations (quadrat surveys) are completed for this species in the CoFish survey design, due to the difficulty of working this type of habitat.

### *3.4.4 Other gastropods and bivalves: Palmerston*

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was rare in survey with only three individuals recorded, and these were all in one broad-scale transect. No smaller Strombidae were noted (e.g. *Lambis lambis*, *Strombus luhuanus*) although a single *L. chiragra* was recorded. The smaller strawberry conch (*Strombus luhuanus*) is listed as absent from Cook Islands in the literature (Bishop Museum 2008).

Two species of turban shell, the rough turban (*Turbo setosus*) and the silver-mouthed turban (*Turbo argyrostomus*) were noted in surveys. The more protected-reef species *Turbo agyrostomus* was only recorded once, and the smaller, reef-crest turban *T. setosus* was not particularly common (n = 15) considering the suitable nature of the exposed reef-crest environments present (recorded in 0% of reef-front searches and in only 40% of RFs_w, at low density). Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Conus*, *Cymatium*, *Cypraea*, *Pleuroploca* and *Thais*) were also recorded during independent surveys (Appendices 4.2.1 to 4.2.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama*, *Modiolus* and *Spondylus*, are also in Appendices 4.2.1 to 4.2.9. No creel survey was conducted at Palmerston.

### *3.4.5 Lobsters: Palmerston*

There was no dedicated night reef-front assessment of lobsters (See Methods.). However, in addition to general day surveys, night-time assessments for nocturnal sea cucumber species (Ns) offered a further opportunity to record lobster species. Lobsters (*Panulirus penicillatus* and spp.) were noted once during shallow-water work, and the slipper lobster (*Parribacus caledonicus*) was recorded once during night searches. No prawn killer (*Lysiosquillina maculata*) burrows were noted in Palmerston.

### *3.4.6 Sea cucumbers[11]: Palmerston*

Around Palmerston there are extensive areas of shallow- and deep-water lagoon (50.8 $km^2$) with intermediate and coastal reef but no elevated land mass (The total land area of Palmerston is <2 $km^2$.). Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were extensive throughout the lagoon (Sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates.), but the lack of land inputs (allochthonous matter) meant that most habitats at Palmerston were oceanic in nature and, therefore, mostly nutrient-poor. The lagoon of Palmerston was unusual in a number of aspects. The growth of epiphytes on the coral pinnacles and the state of the benthos reflected a system that might have unusual bio-oceanographic cycles. Although just an observation, it might be that the deeper water becomes depleted in essential factors during times of the year (perhaps the overturning of the thermocline is only sporadic). The more exposed reefs in shallow water at the south of the system (especially the southwest) and the barrier reef fronts were more characteristic of an oceanic atoll system.

Sea cucumber species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.15, Appendices 4.2.2 to 4.2.9, also see Methods). Results from the full range of assessments yielded eight commercial species of sea cucumber (Table 3.15).

Sea cucumber species associated with shallow reef areas, such as the medium commercial value leopardfish (*Bohadschia argus*), were rare (only 19 specimens noted, recorded in 4% of broad-scale transects). Also rare was the high-value black teatfish (*Holothuria nobilis*), a species that is easily targeted by commercial fishing. Only three individuals of this species were recorded.

In a study conducted in 1988 (Preston *et al.* 1995), greenfish (*Stichopus chloronotus)* was described as ubiquitous and abundant. In the present study, this fast-growing and medium/high-value species was common (recorded in 100% of broad-scale transects, 85% of reef-benthos transects) and at very high density around the shallow reef transect stations (RBt average density 3399.5 /ha ±951.9, see Appendix 4.2.3). This species was noted throughout the lagoon and also at ~20% of stations on the reef slope outside the barrier. Interestingly, it was also common and recorded at high density on deeper water searches (100% of Ds, mean density 1555.4 /ha ±997.5).

Surf redfish (*Actinopyga mauritiana*) was also recorded in this and past surveys (Preston *et al.* 1995). Preston *et al.* also report that this species was processed for export to Tahiti for two years in the 1930s, but that no commercial exploitation had occurred since that time. As this species is mostly found, where its name suggests, on reef fronts, reef-front searches provide a valuable signal on its status. In Palmerston, all reef-front searches by walking (RFs_w) held *A. mauritiana* and the densities were recorded at an average of 154.8 /ha (range 20–315 /ha). The previous study noted surf redfish at an average of 8 /ha at similar locations. In other locations in the Pacific, this species is recorded in densities >400–500 /ha, but the distribution and density noted at Palmerston today is still relatively good for surf redfish, as this species is

[11] 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.

easily targeted by fishers. In many other survey sites across the Pacific, stocks have not recovered well from fishing, which has left many sites depleted.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon returned disappointing results. Curryfish (*Stichopus hermanni*), blackfish (*Actinopyga miliaris*) and brown sandfish (*Bohadschia vitiensis*) were absent. In Cook Islands, *Holothuria leucospilota* is sometimes harvested for the collection of gonad (as a subsistence fishery). This species was common around Palmerston (recorded in 29% of RBt stations, average density of 66 /ha).

In Palmerston the lower-value species of sea cucumbers, e.g. lollyfish (*Holothuria atra*), were also quite common (recorded in 57% of broad-scale survey stations) and present at high density (average broad-scale transect density, 3442.8 /ha ± 641.9). Unfortunately, no high-value sandfish (*Holothuria scabra*) were found in Palmerston, which is understandable considering the easterly location of Palmerston in the Pacific (We have not recorded sandfish east of Wallis Island.) and the oceanic influence of the environment. The low-value false sandfish (*Bohadschia similis*), which uses the same habitat as sandfish, was also absent.

Deep-water assessments (24 five-minute search periods, average depth 19 m, maximum depth 27 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos with suitably dynamic water movement was not common around Palmerston as the lagoon was enclosed; however, a single *H. fuscogilva* was recorded. The density of other deep-water species, e.g. *T. ananas*, was difficult to assess as lack of boat shelter prevented dives on the reef-slope when the swell increased, and no amberfish or elephant trunkfish were noted on the bottom of the lagoon.

### *3.4.7 Other echinoderms: Palmerston*

At Palmerston, no edible collector urchins (*Tripneustes gratilla*) or slate urchins (*Heterocentrotus mammillatus*) were recorded in survey. Preston *et al.* (1995) suggested that there were not many species of sea urchins and that none were harvested.

Other urchins, such as the thicker-spined *Echinothrix* spp. and thinner, long-spined *Diadema* spp., can be used within assessments as potential indicators of habitat condition. *Echinothrix diadema* was quite common (recorded in 53% of RBt stations) but was at moderate-to-low density (average 53.9 /ha ±22.8 in RBt stations). This species has a similar life habit to trochus (is a grazer and also is found in trochus habitat), and may compete with the more valuable commercial gastropod for food and space. Anecdotal evidence suggests locals might have cleared some of this species near Home Islet. Other species of urchin, such as *Diadema* spp. were not common (n = 4 individuals seen in survey), although *Echinometra mathaei* was more common (n = 539; see Appendix 4.2.2 to 4.2.9).

Starfish (e.g. *Linckia laevigata*, the blue starfish) were rare (found in 7% of broad-scale transects) and were at low density (mean RBt station density of 14.7 ±7.9). More destructive corallivore (coral eating) starfish, such as the crown-of-thorns (*Acanthaster planci*), were noted in survey, but only two individuals were recorded. Unusually, no recordings of the pincushion star (*Culcita novaeguineae*) were made.

**Table 3.15: Sea cucumber species records for Palmerston**

| Species | Common name | Commercial value [5] | B-S transects n = 54 | | | Reef-benthos stations n = 17 | | | Other stations RFs = 7; RFs_w = 5; MOPs = 6 | | | 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 | 0.6 | 16.7 | 4 | 7.4 | 62.5 | 12 | 20.2<br>154.8<br>3.8 | 47.1<br>154.8<br>11.4 | 43 RFs<br>100 RFs_w<br>33 MOPs | | | |
| *Bohadschia argus* | Leopardfish | M | 0.9 | 25.0 | 4 | 22.9 | 64.8 | 35 | | | | 31.1 | 62.2 | 50 Ns |
| *Holothuria atra* | Lollyfish | L | 1468.8 | 2558.6 | 57 | 3442.8 | 3658.0 | 94 | 0.6<br>808.1 | 3.9<br>808.1 | 14 RFs<br>100 RFs_w | | | |
| *Holothuria cinerascens* | | L | | | | | | | | | | | | |
| *Holothuria fuscogilva* [4] | White teatfish | H | 0.3 | 16.7 | 2 | | | | | | | | | |
| *Holothuria hilla* | | L | | | | | | | | | | | | |
| *Holothuria impatiens* | | L | | | | | | | | | | | | |
| *Holothuria leucospilota* | | L | 0.3 | 16.7 | 2 | 66.2 | 225.0 | 29 | | | | | | |
| *Holothuria nobilis* [4] | Black teatfish | H | | | | 8.2 | 69.4 | 12 | | | | | | |
| *Holothuria pervicax* | | L | | | | | | | | | | | | |
| *Stichopus chloronotus* | Greenfish | H/M | 856.8 | 856.8 | 100 | 3399.5 | 3612.0 | 94 | 2.2<br>401.1<br>35.4 | 7.8<br>501.4<br>212.1 | 29 RFs<br>80 RFs_w<br>17 MOPs | 1555.4 | 1555.4 | 100 Ds |
| *Stichopus hermanni* | Curryfish | H/M | | | | | | | | | | | | |
| *Stichopus horrens* | Peanutfish | M/L | | | | 2.5 | 41.7 | 6 | | | | 57.8<br>0.6 | 57.8<br>2.4 | 100 Ns<br>25 Ds |
| *Stichopus monotuberculatus* | | L/M | | | | | | | | | | | | |
| *Synapta* spp. | | | | | | | | | | | | | | |
| *Thelenota ananas* | Prickly redfish | H | | | | | | | | | | | | |

[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; H/M is higher in value than M/H; B-S transects= broad-scale transects; RFs = reef-front search; RFs_w = reef-front search by walking; MOPs = mother-of-pearl search; Ds = sea cucumber day search; Ns = sea cucumber night search.

### *3.4.8 Discussion and conclusions: invertebrate resources in Palmerston*

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

Data on clam distribution, density and shell size suggest the following:

- The range of shallow-water reef habitats and areas of dynamic water movement across the atoll's barrier reef provides extensive suitable areas for giant clams at Palmerston. The lagoon was largely enclosed, which would naturally entrain clam larvae; however, there were only scattered areas of coral, and a generally sandy benthos along the back-reef margin. A large area of reef platform was present (tidal range small at <90 cm) but only a moderately extensive shallow reef front outside the barrier reef.

- Both the elongate clam *Tridacna maxima* and the fluted clam *T. squamosa* were noted in general surveys. The larger *T. squamosa* clam was very rare at Palmerston Atoll (only one specimen noted on the outer-reef slope), although the smaller *T. maxima* clam was relatively plentiful (found at all RBt stations at a density of 41.7–1708.3 clams/ha). *T. squamosa* has not been common on Palmerston reefs for over a decade (only two noted by Preston *et al*. 1998).

- Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the abundance of large clams was low, supporting the assumption that stocks are impacted by fishing.

- The current coverage, density and size records for *T. maxima* stocks reveal that the effect of clam removal is noticeable within the current stocks. Although densities are not low, there is still a general lack of large *T. maxima* throughout the system, and the larger size classes do not make up the majority of the stock, as they would in a lightly impacted stock.

- In general, the status of the smaller elongate clam *T. maxima* at Palmerston was noted as only moderately impacted, with no wholesale change to stocks or structure of reefs open to fishing. Clam records from the larger *T. squamosa*, reveal the species to be at very low numbers, and this clam is now endangered at Palmerston Atoll.

In summary, the distribution, density and length recordings give a mixed picture of MOP stock health.

- The local reef environment, with large exposed reef platforms and extensive areas of lagoon and offshore reef, seemed to be suitable for both adult and juvenile trochus (*Trochus niloticus*). However, trochus were relatively uncommon at Palmerston, although an aggregation was noted near Home Islet, in the southwest of the atoll, near the main, shallow passage. This area was easily accessible to fishers and greatly influenced by passage water flows.

- There has been a moratorium on commercial fishing of trochus for ~10 years, after a harvest of ~1.5 t of shell (~3500–4200 individual trochus). This harvest may well have been the bulk of the stock that existed on Palmerston as there are reports of >3000 shells being moved from Aitutaki to Palmerston in the 1980s.

- Results from the current survey suggests that trochus are not well distributed around the atoll; most are recorded on the western side, within the lagoon. They occur at a density far lower than 500–600 /ha, which is the minimum threshold recommended for main aggregations to reach before commercial fishing becomes a viable option.

- Size class information reveals that commercial and ‘over-sized’ shells dominate the present trochus population. No strong year class is currently visible below the commercial size class range. This is likely to be due both to environmental drivers affecting settlement and recruitment of trochus and the small number of areas that support trochus at high enough density to stimulate a recovery.

- From the historical information available, and the present low estimate of stock (even after an extended period without harvest), it seems that the potential for developing a trochus fishery at Palmerston is marginal.

- The blacklip pearl oyster, *P. margaritifera*, is relatively uncommon at Palmerston, despite the enclosed nature of the atoll.

Data on sea cucumbers is summarised below:

- Palmerston had a diverse range of environments for sea cucumbers, but was mostly exposed to oceanic influences. There was no high-island land mass to provide nutrient input into the large, shallow lagoon, but intermediate reef, rubble areas, and a broad barrier reef provided many suitable locations for deposit-feeding sea cucumbers.

- Palmerston supported a limited range of sea cucumber species. This is mainly explained by its position in the eastern Pacific (biogeographical influence) and lack of significant nutrient inputs due to the oceanic nature of the enclosed lagoon.

- Medium-value species (e.g. leopardfish, *Bohadschia argus*) and high-value species that are easily targeted by fishers (e.g. black teatfish, *Holothuria nobilis*) were rare and at low density. The high-value white teatfish (*H. fuscogilva*) was found in deeper water, but again the stocks were poor.

- Greenfish (*Stichopus chloronotus*) was an exception, with very high densities and widespread distribution around the lagoon. Even on broad-scale surveys, which cover a range of suitable and non-suitable habitats, the average density recorded was high (857 /ha). Surf redfish (*Actinopyga mauritiana*) was not at commercial density, but some areas undoubtedly have potential to produce small harvests of this species. These two species present the only commercial possibility for the processing and sale of bêche-de-mer from Palmerston.

- Lollyfish (*H. atra*) was also common in the lagoon, but it may not be economically viable to harvest this lower-value species at this time. *H. leucospilota*, targeted by Cook Islanders for the gonad, which is eaten, was common and easy to find.

- It is unknown whether the sea cucumber stocks at Palmerston have been over-fished historically, although previous commercial fishing was anecdotally reported. Whatever the scenario, stocks other than the medium/high-value greenfish (*Stichopus chloronotus*) have generally failed to recover or may just be naturally deficient due to some unidentified environmental or human-induced factor.

- It must also be noted that sea cucumbers play an important role in 'cleaning' benthic substrates of organic matter and mixing ('bioturbating') sands and muds. When these species are removed, there is the potential for detritus to build up and for substrates to become more compacted, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) and anoxic (oxygen poor) conditions, unsuitable for life.

## 3.5 Overall recommendations for Palmerston

- Fisheries management interventions be implemented to restore today's resources, especially parrotfish, back to the reported previous levels and maintain them for sustainable use in the future. It may be more beneficial to focus on restoration and sustainable use, since opportunities to exploit alternative fishery options, such as aquaculture (e.g. pearl farming), seem to be rather limited.

- Given the particular social situation of the Palmerston community, the objective of developing and implementing an effective fisheries management plan can only be reached with full cooperation between the island's community and MMR at every step in the process, with a strong focus on ownership by the Palmerston community.

- For successful stock management, giant clams be maintained at higher density, and include larger-sized individuals to ensure there is sufficient spawning taking place to produce new generations.

- All fishing of *T. squamosa* be halted to allow numbers to recover, as the current numbers of this species are very low and this clam is now endangered at Palmerston Atoll.

- If possible, trochus broodstock be shipped to Palmerston and stocked in small patches of 20–30 shells in various areas on the north barrier and east reef slope. This may enable stocks to be increase to a level where harvesting is possible in the medium-term future.

# 4. PROFILE AND RESULTS FOR MANGAIA

## 4.1. Site characteristics

Mangaia is an upraised coral island surrounded by a narrow bench reef (Figure 4.1) located at 21°54'30"S latitude, and 157°59'40"W longitude. It is the southern-most island in the group, roughly 200 km southeast of Rarotonga. Surrounding Mangaia is an ancient raised coral reef, rising steeply from the shore, before dropping sharply to the interior of the island. These ancient reefs rise up to 60 m in a series of layers, separating the hilly interior from the coast. As a raised limestone island, Mangaia has only one reef type, which is the outer fringing reef surrounding the island. Mangaia has three main villages: Ivurua on the eastern side, Tamarua on the southern side and Oneroa covering the northwest side of the island. The island administration centre is based on Oneroa, where the main hospital and port are located. Marine resources are important to the communities for subsistence needs.

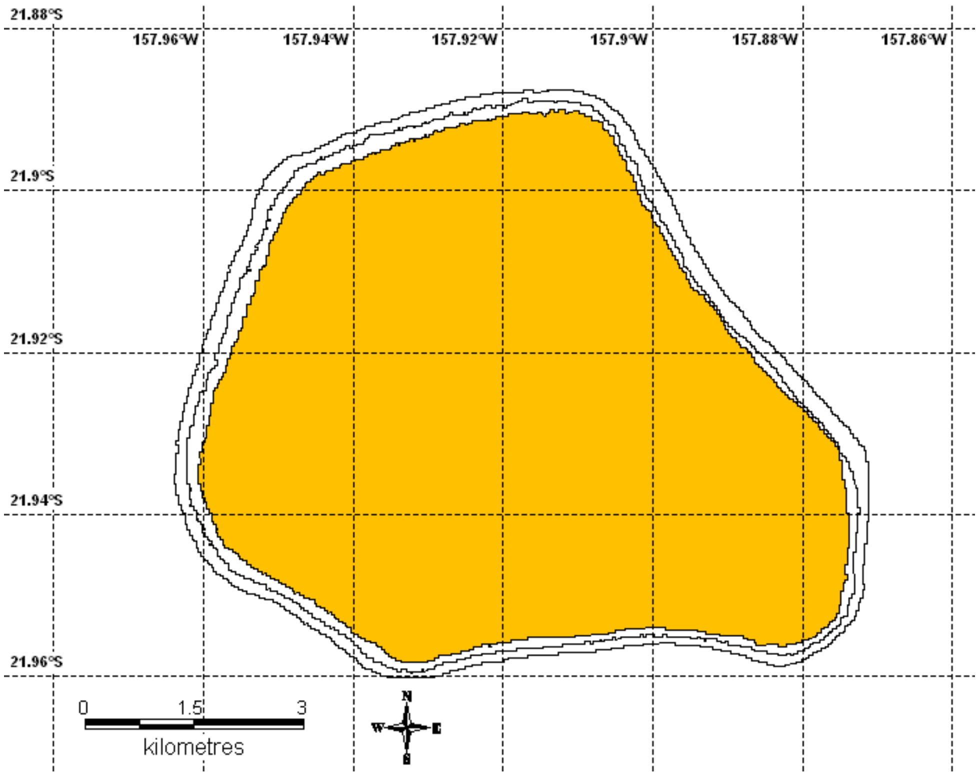



**Figure 4.1: Map of Mangaia.**

## 4.2. Socioeconomic survey: Mangaia

Socioeconomic fieldwork was carried out on Mangaia in October 2007. The survey covered 39 households and 143 people, representing 22% of all active households (180) and of permanent residents (660) on the island.

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. In addition, a total of 32 individual interviews of finfish fishers (24 males, 8 females) and 23 invertebrate fishers (4 males, 19 females) were conducted. In some cases the same person was interviewed for both finfish and invertebrate harvesting.

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

Survey results indicate that almost all households (92%) are engaged in fisheries, with an average of one to two fishers per household. In total there are 309 fishers on Mangaia, including 148 females and 161 males. One-third (111) of all fishers are males who exclusively fish for finfish and about another third (l0l) are females who exclusively fish for invertebrates. The remaining fishers (51 males and 46 females) catch both finfish and invertebrates.

Data on income suggest that fisheries do not play as important a role as salaries and other sources of income, which are mainly represented by pensions, retirement and other social payments (Figure 4.2). In fact, over 40% of all Mangaia households rely on salaries and over 56% on other sources as first income source. Only 3% of all households depend on fisheries as first income source, and another 8% of all households earn secondary income from fisheries. Agriculture is also not one of the main income sources; only 5% of all households earn first income and another 13% secondary income from agricultural produce. Remittances are known and may contribute about a quarter of the average annual household expenditures (on average USD 4840 /year). Cost of living on Mangaia is below the average across all sites surveyed in Cook Islands. Mangaians enjoy a rather traditional, self-contained lifestyle, and anything consumed that has not been produced on the island must be imported from Rarotonga by boat (Table 4.1).

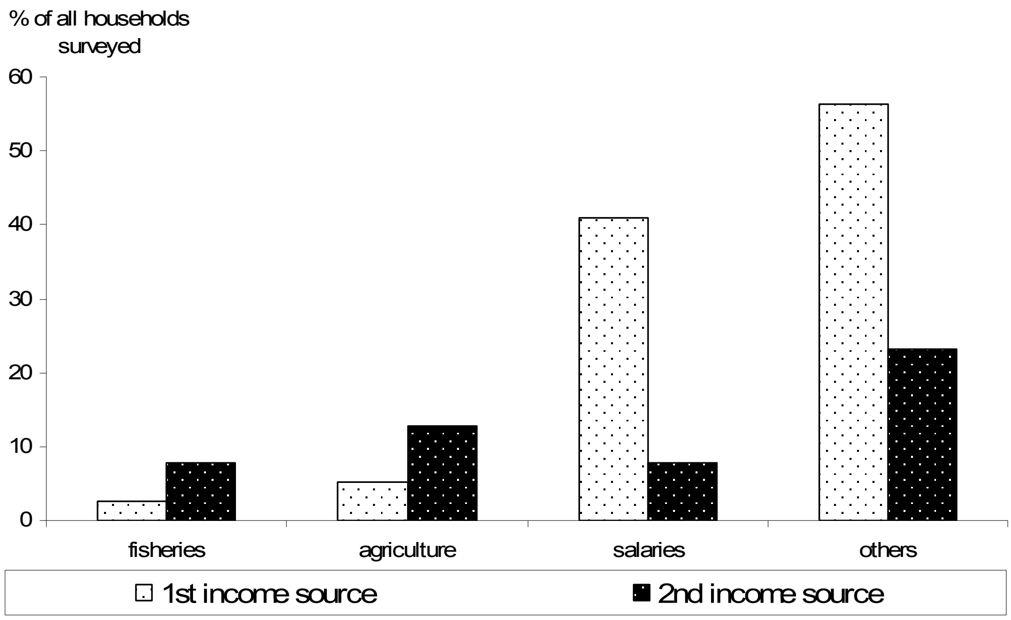



**Figure 4.2: Ranked sources of income (%) in Mangaia.**
Total number of households = 39 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly pensions, retirement and other social payments.

The average consumption of fresh fish (~66 kg/person/year) equals the national average estimated by Preston (2000) of ~63 kg/person/year but is almost twice as high as the regional average (FAO 2008) of 35 kg/person/year (Figure 4.3).

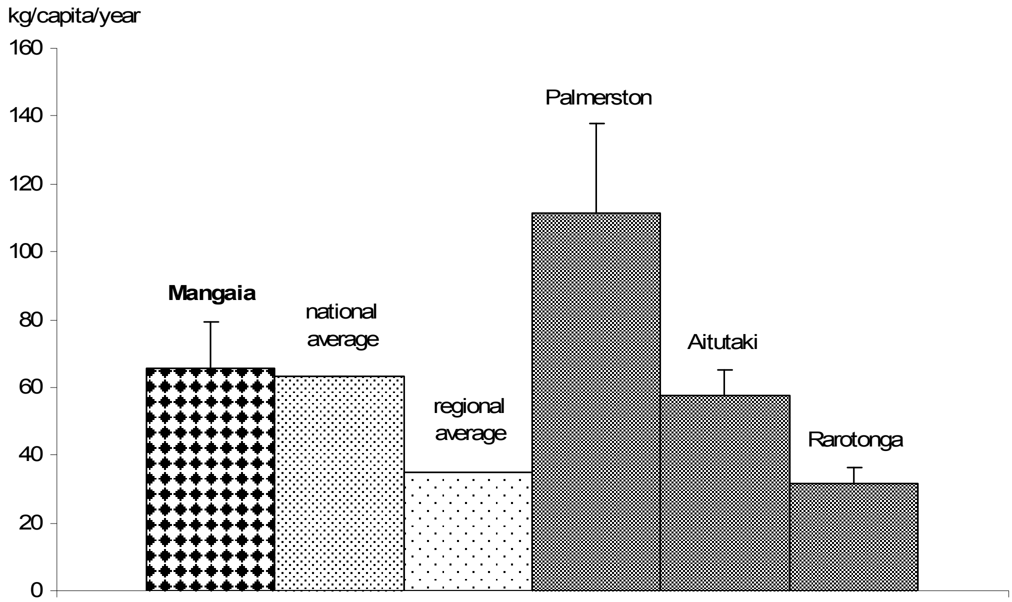



**Figure 4.3: Per capita consumption (kg/year) of fresh fish in Mangaia (n = 39) compared to the national (Preston 2000) and regional (FAO 2008) averages and the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

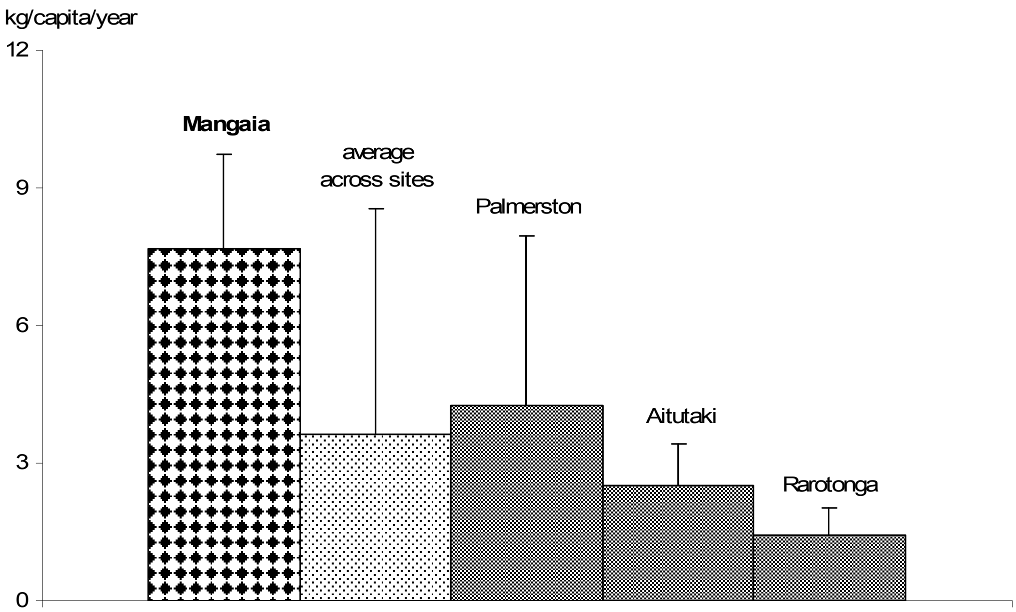



**Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Mangaia (n = 39) compared to the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

It is interesting to note that the rate of invertebrate consumption is pretty high as compared to the average across all sites surveyed in the country, i.e. 7.5 kg/person/year as compared to 3.6 kg/person/year (edible parts only) (Figure 4.4). The fact that finfish are much more important than invertebrates for consumption also shows in a higher consumption frequency. While fresh fish is consumed on average more often than three times per week, invertebrates are eaten less than once per week. Canned fish is consumed at least once a week by the average household, and the consumption is considerable, 15 kg/person/year.

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

| Survey coverage | Site (n = 39 HH) | Average across sites (n = 138 HH) |
|---|---|---|
| **Demography** | | |
| HH involved in reef fisheries (%) | 92.3 | 68.8 |
| Number of fishers per HH | 1.72 (±0.14) | 1.33 (±0.14) |
| Male finfish fishers per HH (%) | 35.8 | 32.2 |
| Female finfish fishers per HH (%) | 0.0 | 2.7 |
| Male invertebrate fishers per HH (%) | 0.0 | 0.0 |
| Female invertebrate fishers per HH (%) | 32.8 | 18.6 |
| Male finfish and invertebrate fishers per HH (%) | 16.4 | 26.2 |
| Female finfish and invertebrate fishers per HH (%) | 14.9 | 20.2 |
| **Income** | | |
| HH with fisheries as 1st income (%) | 2.6 | 5.1 |
| HH with fisheries as 2nd income (%) | 7.7 | 7.2 |
| HH with agriculture as 1st income (%) | 5.1 | 7.2 |
| HH with agriculture as 2nd income (%) | 12.8 | 8.0 |
| HH with salary as 1st income (%) | 41.0 | 55.8 |
| HH with salary as 2nd income (%) | 7.7 | 8.7 |
| HH with other source as 1st income (%) | 56.4 | 39.1 |
| HH with other source as 2nd income (%) | 23.1 | 16.7 |
| Expenditure (USD/year/HH) | 4835.33 (±250.90) | 6909.08 (±352.39) |
| Remittance (USD/year/HH) (1) | 1347.14 (±282.53) | 1524.12 (±252.14) |
| **Consumption** | | |
| Quantity fresh fish consumed (kg/capita/year) | 65.71 (±13.39) | 51.88 (±4.90) |
| Frequency fresh fish consumed (times/week) | 3.16 (±0.26) | 2.79 (±0.15) |
| Quantity fresh invertebrate consumed (kg/capita/year) | 7.54 (±2.05) | 3.60 (±4.90) |
| Frequency fresh invertebrate consumed (times/week) | 0.72 (±0.11) | 0.42 (±0.06) |
| Quantity canned fish consumed (kg/capita/year) | 15.05 (±3.22) | 13.33 (±1.74) |
| Frequency canned fish consumed (times/week) | 1.13 (±0.19) | 1.17 (±0.13) |
| HH eat fresh fish (%) | 100.0 | 99.3 |
| HH eat invertebrates (%) | 92.3 | 71.0 |
| HH eat canned fish (%) | 79.5 | 73.2 |
| HH eat fresh fish they catch (%) | 84.6 | 73.3 |
| HH eat fresh fish they buy (%) | 56.4 | 36.7 |
| HH eat fresh fish they are given (%) | 76.9 | 66.7 |
| HH eat fresh invertebrates they catch (%) | 84.6 | 63.3 |
| HH eat fresh invertebrates they buy (%) | 10.3 | 6.7 |
| HH eat fresh invertebrates they are given (%) | 28.2 | 6.7 |

HH = household; (1) average sum for households that receive remittances; numbers in brackets are standard error.

### *4.2.2 Fishing strategies and gear: Mangaia*

At the time of the survey, there was no community-based fisheries management regime in place. However, there is a fishers' club that tries to improve fishing conditions and fishing for income for Mangaian people. The club was more popular some years ago, and membership numbers have dropped from 30 in 2005 to only ten active fishers in 2007. Transport and marketing problems, as well as lack of external financial and technical assistance, are considered the main limiting factors to success, and may also explain the falling interest and engagement of the locals.

*Degree of specialisation in fishing*

On Mangaia both males and females are fishers. When weather and sea conditions are favourable, any family member may venture into the small lagoon area or to the outer reef, either for invertebrate collection or finfish fishing. There does not seem to be much of a gender distinction for fishing for both finfish and invertebrates, although both fisheries are not usually done at the same time. However, there is a pronounced gender distinction if regarding fishers who exclusively target finfish or invertebrates only. As shown in Figure 4.5, exclusive finfish fishers are always males, and exclusive invertebrate fishers are always females. Both these specialised fisher groups are significant, representing about one-third each of all fishers on the island.

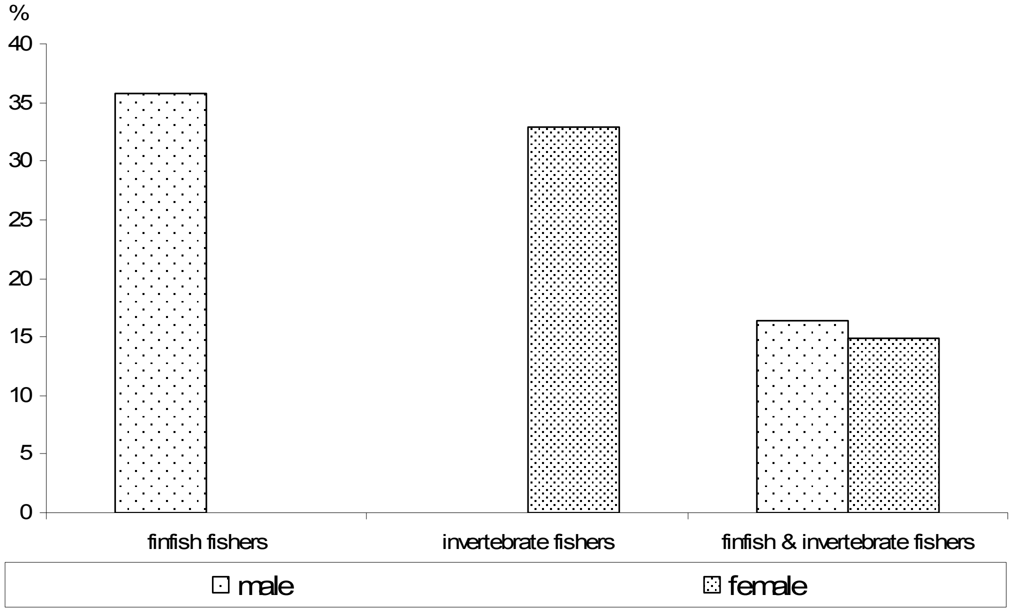



**Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Mangaia.**
All fishers = 100%.

Invertebrate fishers target reeftops, and a few male fishers specialise in lobster diving at the outer reef (Figure 4.6).

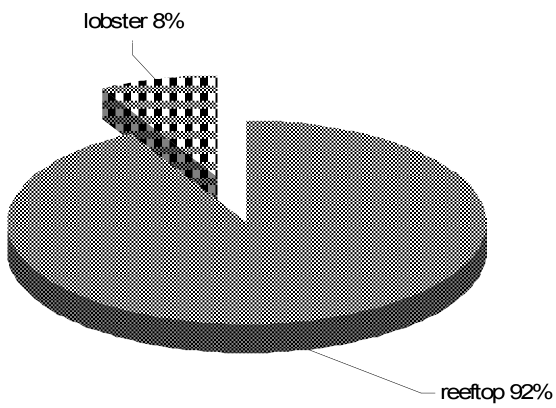



**Figure 4.6: Proportion (%) of fishers targeting the two primary invertebrate habitats found in Mangaia.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

*Fishing patterns and strategies*

On Mangaia, only 15% of all households own a boat, all of which are motorised. Apparently, there are about seven aluminum boats (≥5 m) on the island, usually equipped with a 25 HP outboard engine, but only five of these are used for fishing and only four were really operational at the time of survey. In addition there are five canoes, one equipped with a 4 HP outboard engine, and four with an 8 HP engine. While aluminum boats are large enough to take ice on their fishing trips along the outer reef and into the open ocean, canoes are too small. The local ice machine is not always operational and also not exclusively used for fishing but also for local food storage, particular during feasts and festive seasons. The last cyclone that hit the island in February 2005 destroyed the water tank, and water supply to the ice machine is now managed by using the community water tank. If the ice machine is operational, ice is sold at a price of NZD 5 per bag.

Twenty-five per cent of all male fishers and 12.5% of all female fishers use boat transport for their finfish fishing trips. All invertebrate fishers, regardless of whether they target reeftops or dive for lobsters, do so by walking on the reef or by walking to the edge of the outer reef, i.e. nobody reported using boat transport.

Fishing trips are mostly undertaken during the day (57% of trips to the lagoon and 62% of trips to the outer reef) and not often at night, in particular if targeting the outer reef (8% of trips to the outer reef and 29% of trips to the lagoon are at night.). However, some fishers fish according to tidal conditions and thus may fish at day or night. All fishers fish throughout the year, and no particular fishing season was reported. Reeftop gleaning is mainly a daytime activity (>90%) and only about 9% of all persons interviewed indicated that they may do so at night. Lobsters are exclusively harvested at night. Invertebrate collection is not seasonal but done throughout the year.

*Targeted stocks/habitat*

Although both male and female fishers are mostly engaged in reeftop fisheries, considerably more females do so than males (Figure 4.7). Lobster harvesting is an exclusive male activity; however, overall, very few male fishers on Mangaia are engaged in lobster fisheries.


**Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Mangaia.**
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 who target each habitat: n = 4 for males, n = 19 for females.

*Gear*

Fishing on Mangaia involves a variety of techniques and often two or more of these are used during one fishing trip (Figure 4.8). Overall, the exclusive use of gillnets or spear diving, or of gillnets in combination with spear diving and casting rods (bamboo or modern types) are the main fishing techniques used in the small and shallow lagoon. However, fishing at the outer reef, during favourable sea and weather conditions is done by walking on the reef flats to the edge of the outer reef using bamboo and casting rods and, if done from boats or canoes, using handlines. Spear diving, cast nets or gillnets are rarely used.

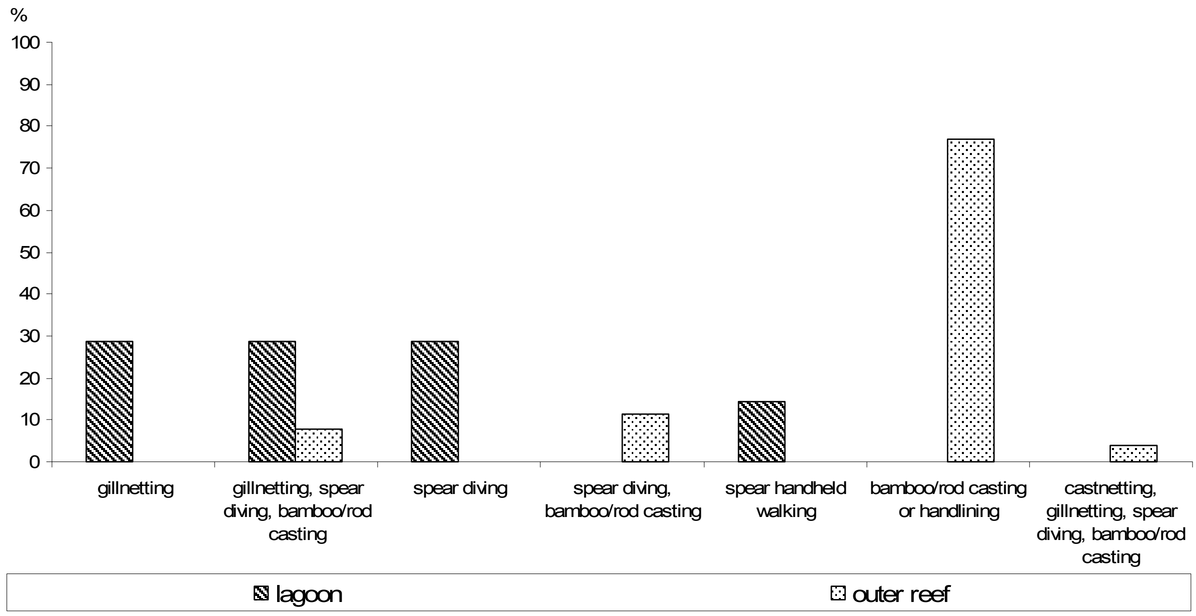



**Figure 4.8: Fishing methods commonly used in different habitat types in Mangaia.**
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

*Frequency and duration of fishing trips*

Information on the number of fishers, the frequency of fishing trips (Table 4.2) and the average catch per fishing trip was used to estimate the fishing pressure imposed by the inhabitants of Mangaia on their fishing ground (Table 4.3). All fishing pressure imposed on Mangaia's reef areas is determined by local demand and local fishers; there is no commercial export of fisheries produce, no fishers visiting from elsewhere, and very little export to family members living outside the island. However, the estimation of fishing pressure must also take into account that weather and sea conditions are often rough and limit access to reef areas. In fact, reef-flats and outer-reef fishing is impossible for most of the year on the southwest coast of the island.

**Table 4.2: Average frequency and duration of fishing trips reported by male and female fishers in Mangaia**

| Resource | Fishery / Habitat | Trip frequency (trips/week) | | Trip duration (hours/trip) | |
|---|---|---|---|---|---|
| | | Male fishers | Female fishers | Male fishers | Female fishers |
| Finfish | Lagoon | 1.20 (±0.32) | | 2.79 (±0.34) | |
| | Outer reef | 1.33 (±0.19) | 1.00 (±0.25) | 3.28 (±0.24) | 2.81 (±0.37) |
| Invertebrates | Lobster | 0.58 (±0.12) | 0 | 2.50 (±1.00) | 0 |
| | Reeftop | 0.76 (±0.43) | 0.82 (±0.17) | 2.50 (±0.29) | 2.71 (±0.28) |

Figures in brackets denote standard error.
Finfish fisher interviews, males: n = 25; females: n = 8. Invertebrate fisher interviews, males: n = 6; females: n = 19.

Fishing for reef fish on Mangaia targets the lagoon/reef flats that surround the island, as well as the outer reef. As shown in Table 4.2, on average fishers venture out about once a week and there is no significant difference among habitats targeted. Trips take 2.5–>3 hours and slightly longer if targeting the outer reef. Female finfish fishers go out a bit less often than males and their fishing trips are a bit shorter, too. Invertebrates are collected less frequently, i.e. twice a month in the case of lobster fishers and about three times a month for reeftop gleaners, regardless of gender. Invertebrate collection trips take on average 2.5 hours.

### *4.2.3 Catch composition and volume – finfish: Mangaia*

The annual catch reported by respondents from Mangaia totaled 7 t/year (Figure 4.9). Considering the frequency and quantity of fresh fish consumption reported by households, Mangaia's subsistence demand for fresh fish is estimated at 46.14 t/year. Extrapolation of all catch data from respondents suggests that the total impact on Mangaia's reef and lagoon fisheries amounts to 44.79 t/year. The balance of about 1.35 t/year of fish needed for local consumption is presumably met by local pelagic fisheries. Information provided by the Secretary of the Mangaia Fishermen's Club suggests pelagic-fish catch of 1.5 t/year by the club's five active fishers who regularly sell their catch locally. However, there are at least five other fishers who may pursue pelagic fishing on a less regular basis, and whose catch may explain the difference.

All catches are used for subsistence purposes, although some of the reef and pelagic catch is sold among members on the island. A small amount of the annual catch may be exported to Rarotonga or elsewhere as a gift for family members and friends. There is no commercial export due to the lack of air or sea transport facilities. Male fishers take most of the catch (~92%) and most of the catch is sourced from the outer reef (~75.6%).

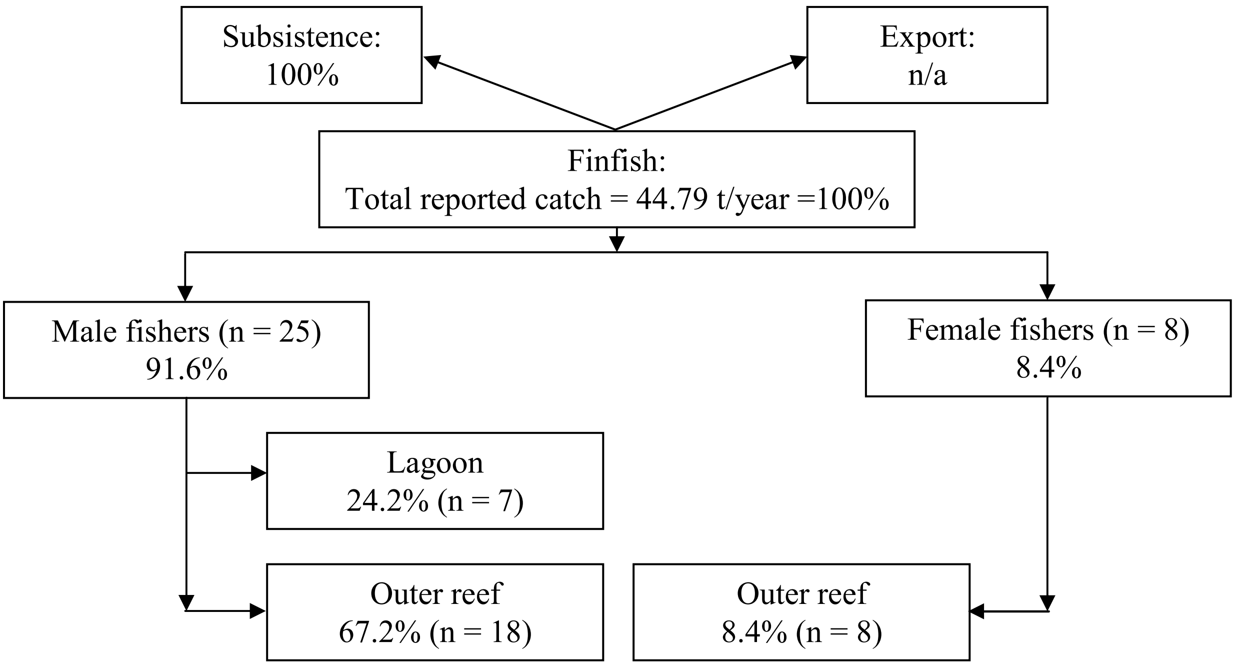



**Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mangaia.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The fact that fishing on Mangaia is basically for subsistence purposes also shows in Figure 4.10. Only a very low percentage of catches from the outer reef is intended for local sale, most of all catches are either consumed by the family of the fisher or distributed on a non-commercial basis among community and family members.

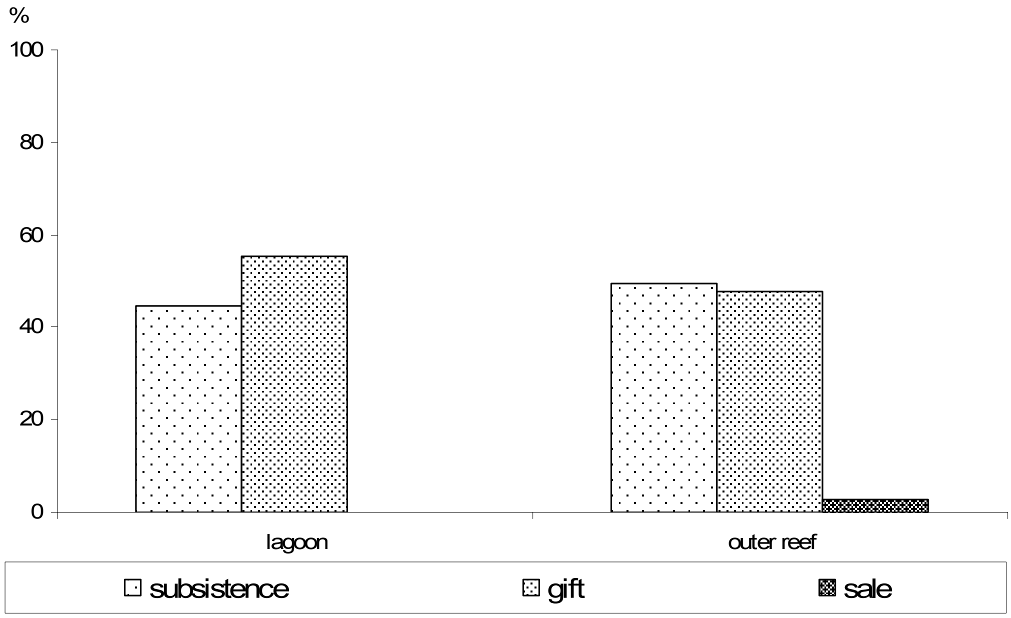



**Figure 4.10: The use of finfish catches for subsistence, gift and sale, by habitat in Mangaia.**
Proportions are expressed in % of the total number of trips per habitat.

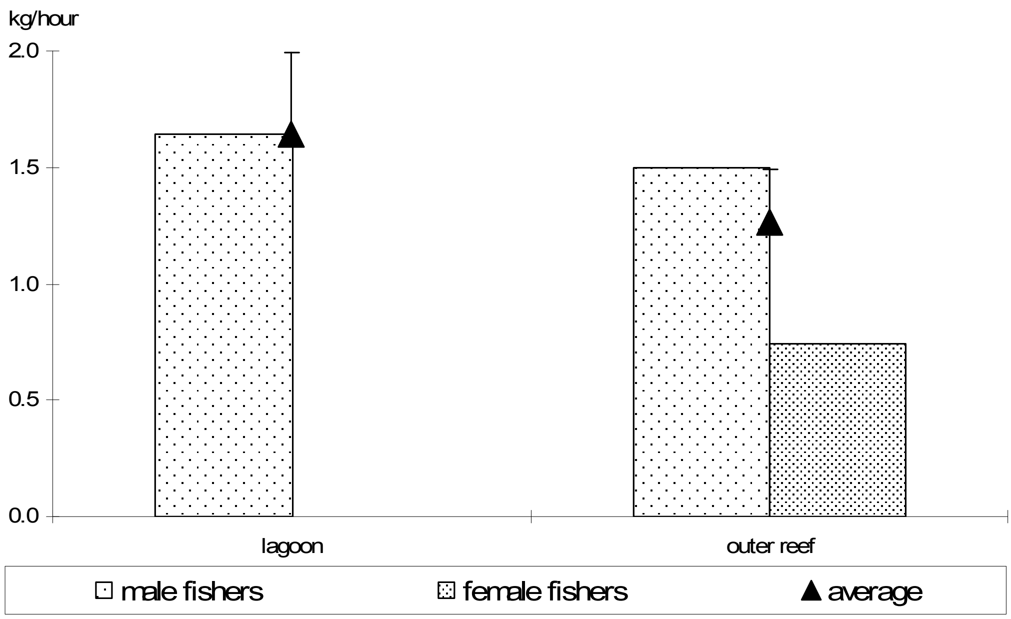



**Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Mangaia.**
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The catch per unit effort (CPUE) on Mangaia is relatively low and again may be explained by the fact that fishing is mainly for subsistence (Figure 4.10). CPUEs (Figure 4.11) reported for lagoon and outer reef catches do not differ significantly for males fishers' catches; however, females' productivity seems to be lower than that of males. Differences in the use of fishing techniques, e.g. bamboo rods as compared to spear diving, and in the overall engagement in finfish fishing (Females are less engaged, go less often and make shorter trips than males.), may all help to explain this difference.

Catches from Mangaia lagoon are determined by Kyphosidae (39.4%) (*tiotio*, *pipi*, *pipi nanue*), Acanthuridae (22.1%) (*api*, *ume*, *maito*, *manini*, *tiove*) and Scaridae (~12%) (*pakati*, *akau*); Mullidae and Serranidae determine another 25% of the total catches reported from the lagoon. Catches reported from the outer reef are mainly represented by Serranidae (~29%) and Kyphosidae (26%), while Holocentridae (12.5%) and Acanthuridae (11.8%) constitute another 24%. Scaridae (*akau*), to some surprise, only account for 3% of the reported catches at the outer reef. Details of the reported catch composition by habitat and fish species are provided in Appendices 2.3.1 and 2.3.4.

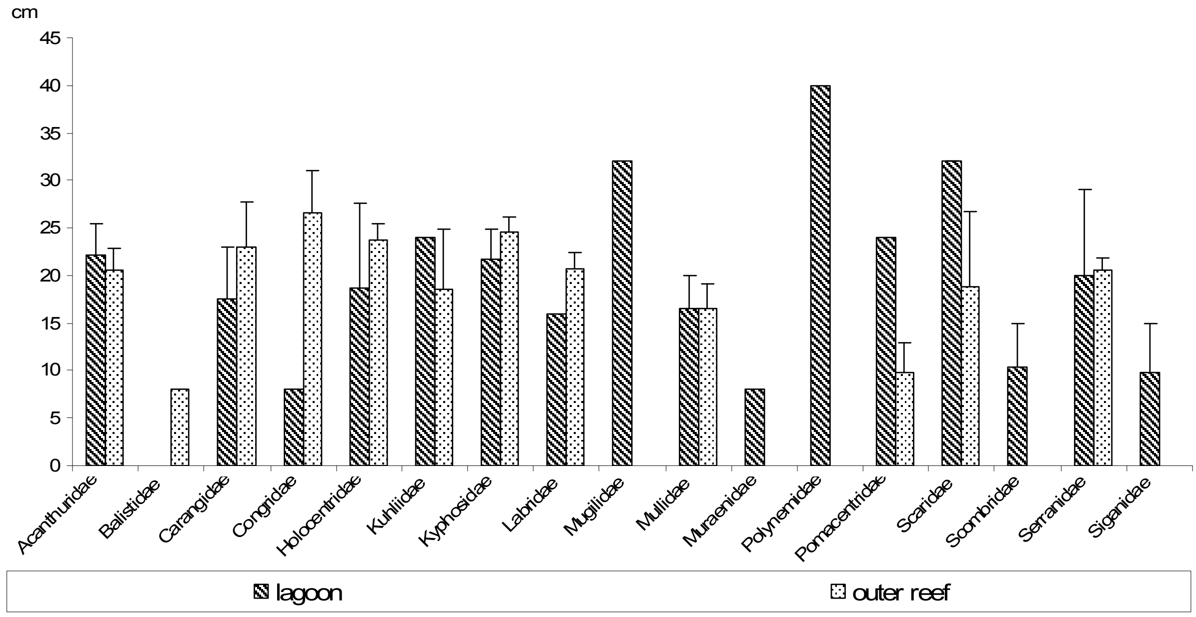



**Figure 4.12: Average sizes (cm fork length) of fish caught by family and habitat in Mangaia.**
Bars represent standard error (+SE).

Average fish sizes reported for catches on Mangaia are ~20 cm for the lagoon and ~25 cm for the outer reef. There are a number of average sizes that exceed these figures, e.g. sizes of Mugilidae, Polynemidae and Scaridae reported for lagoon catches (Figure 4.12). However, these should be viewed with caution as sample sizes are small. Average reported sizes for the most-caught fish families correspond to the normal trend, i.e. that fish caught closer to shore (here lagoon and reef flats) are smaller than those caught at the outer reef (Figure 4.12).

Estimates of fishing pressure, based on survey responses and extrapolated to the entire population, suggest that fisher densities and fishing pressure are moderate to high. Fisher density calculated for the lagoon area is less than half of the fisher density at the outer reef. Fishers targeting the lagoon, however, catch about 40 kg more per fisher and year as compared to fishers at the outer reef. Due to the higher number of fishers at the outer reef, most fish are caught here. However, current fishing pressure at the outer reef is not really worrying, given its direct interaction with the open ocean. Population density is relatively high and so is the total pressure of subsistence demand calculated for Mangaia's population. However, again it should be noted that much of the catch is taken from the outer reef.

**Table 4.3: Parameters used in assessing fishing pressure on finfish resources in Mangaia**

| Parameters | Habitat | | | |
|---|---|---|---|---|
| | Lagoon | Outer reef | Total reef area | Total fishing ground |
| Fishing ground area (km$^2$) | 3.59 | 4.77 | 8.36 | 8.36 |
| Density of fishers (number of fishers/km$^2$ fishing ground) (1) | 12.53 | 34.16 | 24.87 | 24.87 |
| Population density (people/km$^2$) (2) | | | 78.91 | 78.91 |
| Average annual finfish catch (kg/fisher/year) (3) | 243.99 (±69.94) | 203.34 (±38.67) | | |
| Total fishing pressure of subsistence catches (t/km$^2$) | | | 5.52 | 5.52 |

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 660; total subsistence demand = 46.14 t/year; (3) catch figures are based on recorded data from survey respondents only.

### *4.2.4 Catch composition and volume – invertebrates: Mangaia*

The number of species (as represented by the number of vernacular names) reported to be regularly caught from various habitats is indicative of the importance of these habitats and the fisheries they support. Figure 4.13 indicates that only reeftop gleaning yields a reasonable number of vernacular names (14) that describe a range of species targeted for mainly home consumption. The vernacular name used for lobster fishing covers possibly more than one scientifically named species.

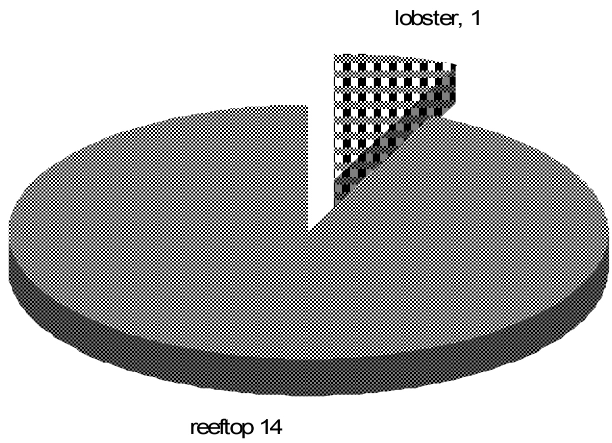



**Figure 4.13: Number of vernacular names recorded for each invertebrate fishery in Mangaia.**

The data on the variety of species and habitats explored suggests that invertebrate fisheries in general on Mangaia are not only a traditionally but also a currently important fishery for local use. This suggestion is further confirmed by the fact that the demand for meat of certain species, such as *ungakoa*, a vermetid gastropod, and giant clams, exceeds by far the supply by local fishers. There is a consensus among Mangaians that a few female fishers are particularly experienced in the collection of *ungakoa* and giant clams for local sale. The fact that demand for both specialties exceeds supply is not only reflected by the relatively high local sale price but also that local sale is mostly done on a one-to-one basis rather than at the weekly market.

This trend is further reflected in the estimated total annual catch from interviewed fishers, which is ~12 t/year of wet weight (Figure 4.14). Extrapolation of the average annual recorded catch per fisher to the total number of invertebrate fishers on Mangaia brings the figure up to a total of 108 t/year. Most of the catch is sourced from reeftops, and a small proportion only is contributed by lobster catches. Females are the main contributors, with almost 80% of all reported annual invertebrate catches (wet weight).

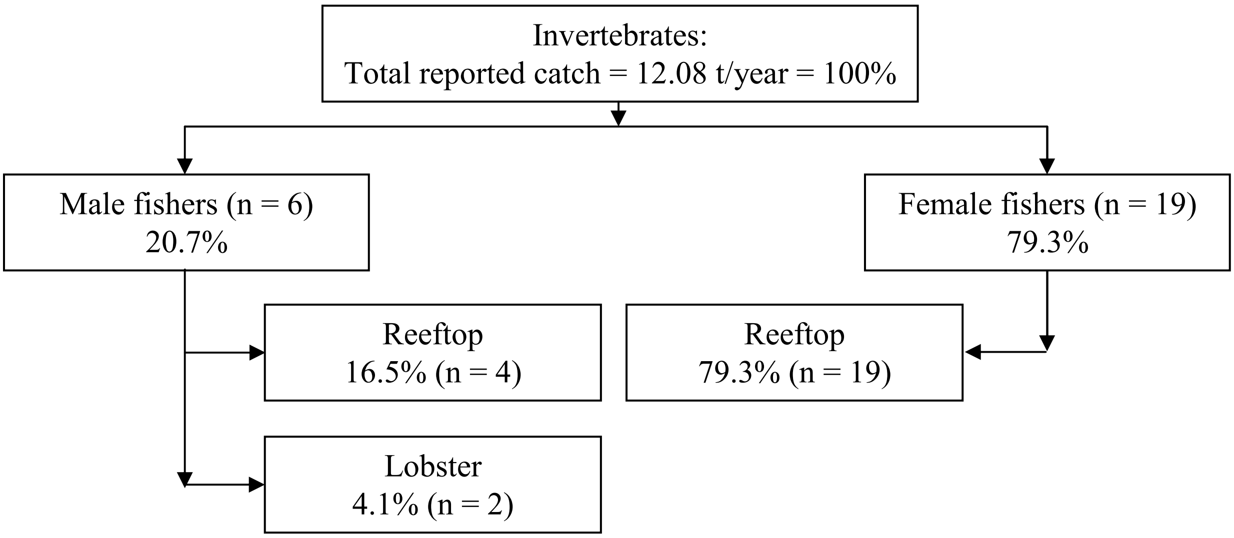



**Figure 4.14: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mangaia.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Calculation of the total annual impact per species group (Figure 4.15) shows that the highest annual catches (in terms of wet weight removed) are accounted for by *Holothuria* spp. Sea cucumbers collected are not entirely consumed; only a small amount of the inner parts are cut off and eaten. *Paua* (*Tridacna maxima*) and *ungakoa* (*Dendropoma* sp., *Serpulorbis* sp.) also contribute considerably to the total annual wet weight. Further proportions accounted for by lobster, *atuke* (*Heterocentrus mammillatus*), sea urchins (*vana*, *avake*, *kina*), *ariri* (*Turbo* sp.), octopus and others (mostly crabs) have little if any significant impact.

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.

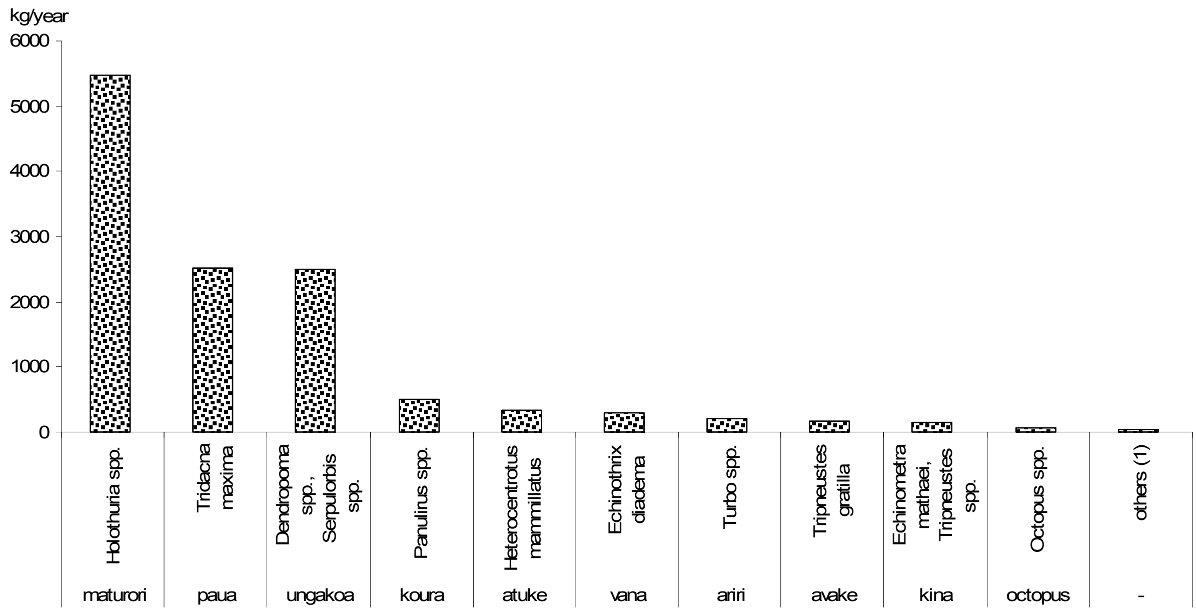



**Figure 4.15: Total catch (dry weight) by species for a bêche-de-mer harvesting season in Mangaia.**
'Others' include: *upaki* (*Carpilius maculates*, *Scylla serrata*); *mikia* (*Grapsus albolineatus*, *G. grapsus*); *papaka* (*Carpilius maculates*, *Grapsus albolineatus*, *G. grapsus*); *rimu* (*Vexillium* sp.) and *tioro* (*Scylla serrata*).

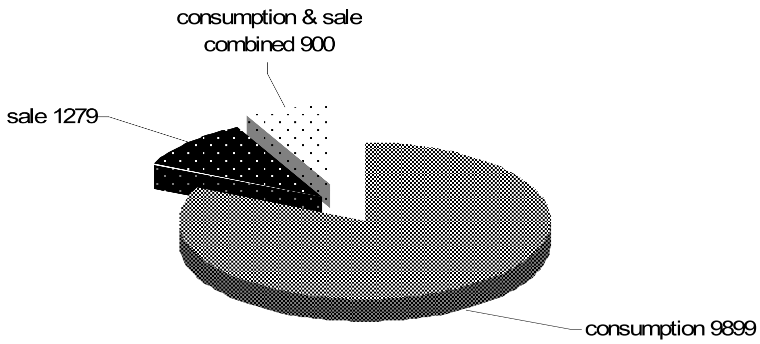



**Figure 4.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Mangaia.**

Most fishers interviewed confirmed that invertebrates are collected for home consumption and as a gift for relatives and families on Mangaia, but some also reported local sales (Figure 4.16). *Ungakoa*, giant clams and selected inner parts ('fats') of certain holothurians are considered local delicacies and sold at high prices. If assuming that about half of the catch of 900 kg per year is used for home consumption and half is sold, the total proportion of all annual reported invertebrate catches (wet weight) that is locally sold is 18%, i.e. 82% is collected for home consumption or gifts.

As mentioned earlier, both genders participate in all fishing activities on Mangaia. However, the few lobster fishers are males only and their productivity is low (Figure 4.17). As far as reeftop gleaning is concerned, females are responsible for most of the total annual impact, while males' contribution is low (16.5%). However, there is no difference between the total average annual catches of male and female fishers for reeftop fishing.

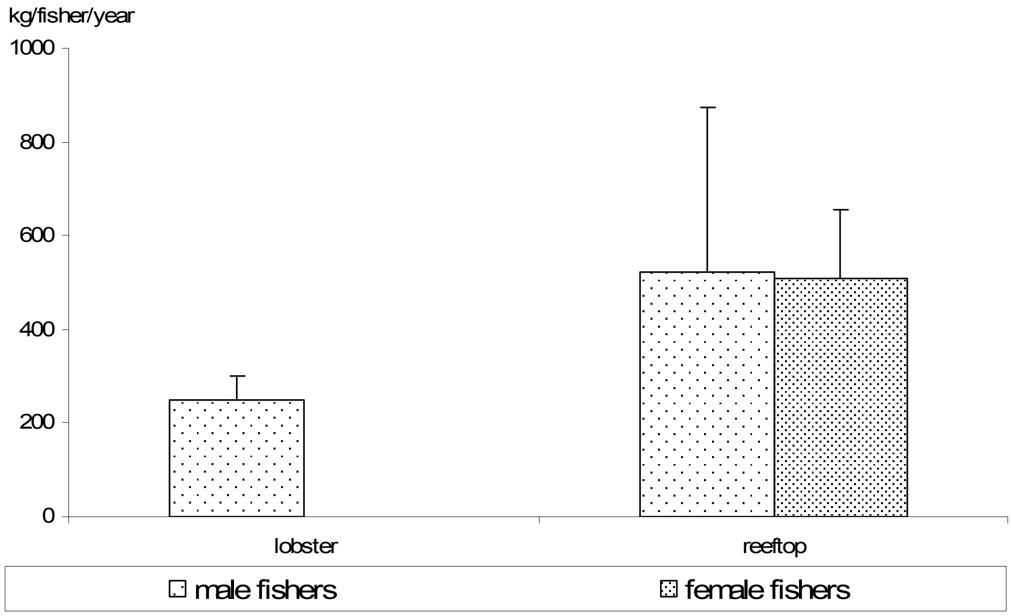



**Figure 4.17: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Mangaia.**
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 4 for males, n = 19 for females).

Figures shown in Table 4.4 suggest that fisher density and average annual catch per fisher (in kg wet weight/fisher/year) are very low for lobster diving. In the case of reeftop gleaning, fisher density is relatively high. However, if considering that the average annual catch per fisher is about 500 kg wet weight and that this weight is distributed over at least three major species (*ungakoa*, *paua* and *matu rori*) figures may best be interpreted according to the biological characteristics of major target species. For instance, the small-sizes of giant clams mainly harvested may indicate that fishing pressure on Managaia's *paua* resources are significant.

**Table 4.4: Parameters used in assessing fishing pressure on invertebrate resources in Mangaia**

| Parameters | Fishery / habitat | |
|---|---|---|
| | Lobster | Reeftop |
| Fishing ground area (km$^2$) | 27.4 [3] | 2.7 |
| Number of fishers (per fishery) [1] | 25 | 198 |
| Density of fishers (number of fishers/km$^2$ fishing ground) | 1 | 74 |
| Average annual invertebrate catch (kg/fisher/year) [2] | 249.86 (±49.97) | 503.42 (±131.37) |

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; [3] linear km outer-reef length.

### *4.2.5 Marketing and fisheries development: Mangaia*

- Mangaia has been subject to various development projects in the past, including reforestation for erosion protection and timber production, pineapple production to supply the Rarotonga market, and exotic projects such as ostrich farming. All of these projects have failed. The reforestation on Mangaia's steep slopes is unmanaged and has reached densities of trees too high. In places windbreak damage has created a chaotic accumulation of fallen and broken trees. From a labour and economics point of view, it seems impossible to ever use this resource. If the reforestation area was cleaned and the logs brought down to the coastline, transport costs to market the timber overseas would be very high.

- The pineapple cultivation was very labour intensive and finally collapsed due to failures in transport facilities, transport costs and the decrease of sale price at Rarotonga.

- The ostrich project apparently never materialised as the Mangaia council members became suspicious of its objectives and stopped the importation of the birds prior to the first arrival.

- Local people have tried and continue to try to build a tourist industry. However, Mangaia's air travel services are not as developed as, for instance, those between Rarotonga and Aitutaki. Also, accommodation facilities and the choice of organised leisure activities are limited. However, currently a new beach resort is being constructed. Also, discussions with local people revealed a lot of ideas that could be explored to attract international tourists.

- In the late 1990s and early 2000s, Mangaia had a special arrangement with Air Raro that allowed them to airfreight anything for NZD 1 /kg provided the client had an account with the airline. Thus, for five years Mangaia fishers supplied the Rarotonga-based Edgewater Resort with mainly wahoo and tuna filets. The weekly amount was about 20 kg, and the resort paid about NZD 40 /kg fish filet. However, after 3–4 years, longline boats started to supply Rarotonga with cheaper pelagic fish, which brought the Mangaia fish supply to a halt.

- The local male fishers' club, although suffering from loss of active members, has several projects. Firstly, the club would like to restore the water supply for the ice machine. The club has also called for financial support from Rarotonga to establish a shed at the local wharf for hosting the fishing club, an office, and the ice machine, and for storage and selling of ice to foreign visitors. While some funding may be available for this project, the small entrance to the wharf seems to limit landing by external boats. There are plans to have a survey done and to propose how to best change the seaward entrance to enable the landing of larger vessels.

- Currently, there is a weekly market each Friday, where any kind of local produce may be sold. People from Mangaia reported that, for fresh fish and invertebrate delicacies, you need to be first at the market, as most of the seafood is sold between 5:30 and 6:00 am. Some members of the fishing club sell flying fish and dogtooth tuna. Fish caught on purpose for the Friday market, or fish that had not sold earlier, may be offered frozen. Otherwise, fishers usually sell their surplus at the wharf upon landing, or they supply households door-to-door. Most fresh fish is sold for NZD 6–7 /kg but some fishers also sell whole fish for NZD ≤5 /kg.

- Regular lobster diving is only pursued by a few male fishers on the island as it must be done at the outer reef and during night time when shark attacks are feared. Lobsters are sold locally for NZD 10–15 each (1–2 kg wet weight each).

- Only certain invertebrates are locally sold. The most commonly marketed delicacy is *ungakoa* (vermetid gastropod) meat, which sells mostly for NZD 25 /kg. Some female fishers sell an ice cream container full (~2 kg) for as little as NZD 40. Also *ariri* (*Turbo* spp.) meat is sold in a small container weighing ~0.5–0.8 kg for NZD 6. Thus, the price for *ariri* meat is NZD ~9 /kg.

### 4.2.6 Discussion and conclusions: socioeconomics in Mangaia

- The Mangaia community is highly dependent on its reef and lagoon resources for protein, complemented by agricultural produce from subsistence activities. A high degree of self-sufficiency for food may be considered as a necessity due to the limited alternatives for gaining income and the high transport cost to bring food and any other items to this isolated atoll. Living costs on Mangaia are relatively high because all goods must be imported by boat from Rarotonga. The high dependency on marine resources for subsistence shows in the amount of seafood consumed, which is estimated at ~66 kg/person/year of fresh fish, and 7.5 kg/person/year of invertebrates.

- However, Mangaia is also subject to modernisation; changes in nutrition, education, income-earning and lifestyle are evident. Canned-fish consumption is relatively high (15 kg/person/year), and people have access to water supply (community tank system), electricity from a local power station, an ice-making plant (when operational), schools and medical facilities. On the other hand, many younger people migrate to Rarotonga and elsewhere for education and work.

- People on Mangaia do not believe that their reef and lagoon resources are threatened or have dwindled over the past years. Some concern was expressed on the invertebrate collection, particularly *ungakoa*, giant clams and *ariri* on the reef flats, and on sea cucumbers collected in the small lagoon.

- Survey results were extrapolated to estimate the current level of fishing pressure, fisher densities, population densities and the annual impact of finfish subsistence catch taken per $km^2$ of available reef surface on Mangaia. These were found to be moderate to relatively high. However, the reef geomorphology of the island suggests a high water exchange with the outer slope and the open ocean, which may act as buffer to current fishing levels. Parameters calculated to assess fishing pressure on invertebrate resources are not generally alarming. However, the biological characteristics of certain target species, such as giant clams, may need to be considered before judging whether current fishing levels are detrimental.

- As the island's own subsistence demand for seafood is relatively stable due to the emigration of young people and the low numbers of external visitors, current fishing pressure can hardly be considered to be detrimental or unsustainable. This conclusion is further supported by two major facts. Firstly, collection of invertebrates and finfish in the lagoon and on reef flats is limited by area and time, due to the mostly unfavourable sea and wind conditions. Secondly, new recruitment on the reef flats and lagoon may come from the slopes of the outer reef, where fishing pressure is even lower. The outer reef is directly exposed to the open ocean.

- There is no reason to assume that the Mangaian community will not continue with its rather isolated lifestyle. Educational and medical facilities provided may help to reduce the rate of emigration until students have reached the age for tertiary education. However, there are few income-earning opportunities on the island and government jobs for highly educated people are limited.

- There is no marketing infrastructure to link at least with the Rarotonga market. Transport costs and the size of Mangaia's market potential, be it for agricultural or for fisheries produce, may be major limiting factors. On the other hand, the local reef and lagoon resources may not be sufficient to allow any significant increase in fishing if they are to be sustained for the future. Thus, the lack of transport and marketing access may help to maintain Managaia's fishery resources for subsistence. However, the local demand for seafood exceeds supply, and thus it would be desirable to support the current plans of the local male fishers' club to establish good and healthy conditions. With an operational cold store and storage facilities, a few local fishers could make a living from selling their catch and satisfying local demand. From a nutritional and also an economic viewpoint, consumption of local seafood is preferable to that of imported, processed food items. The collection of local invertebrate delicacies will continue to generate complementary income for households with experienced female fishers.

- Given all the unfavourable economic factors, ecotourism may be the best option for future economic development on Mangaia. A joint development plan that engages all families on the island, that attempts to solve any property and land ownership disputes, and that includes the various options may be useful. Such a development plan should include community-based fisheries resource management actions where needed.

## 4.3 Finfish resource surveys: Mangaia

Mangaia is located 194 km southeast of Rarotonga and is the southernmost island in the country. After Rarotonga, Mangaia is the second-largest island at nearly 52 km² in area. Surrounding Mangaia is an ancient, raised coral reef, which rises steeply from the shore before dropping sharply to the interior of the island. These ancient reefs rise up to 60 m in a series of layers, separating the hilly interior from the coast. As a raised limestone island Mangaia has only one reef type, which is the outer fringing reef, surrounding the island (Figure 4.18).

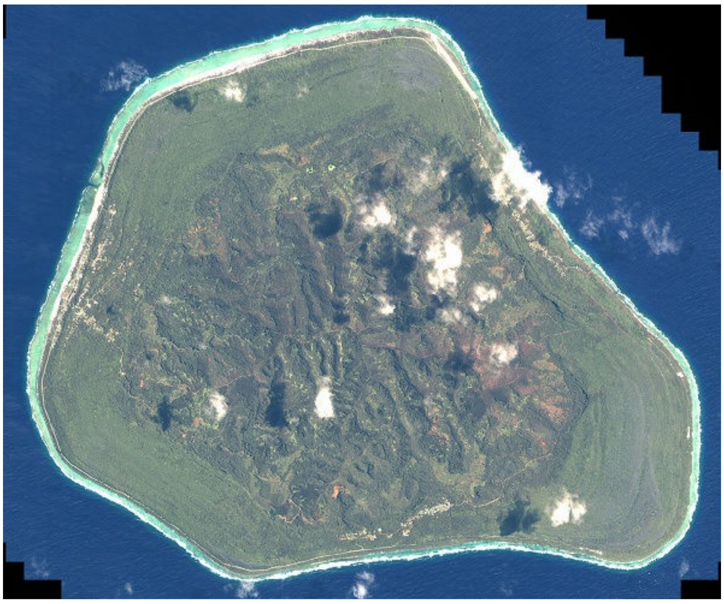


**Figure 4.18: The island of Mangaia.**

Finfish resources and associated habitats were assessed between 8 and 12 October 2007, from a total of 13 outer-reef transects off the north, west and south of the island (Figure 4.19).

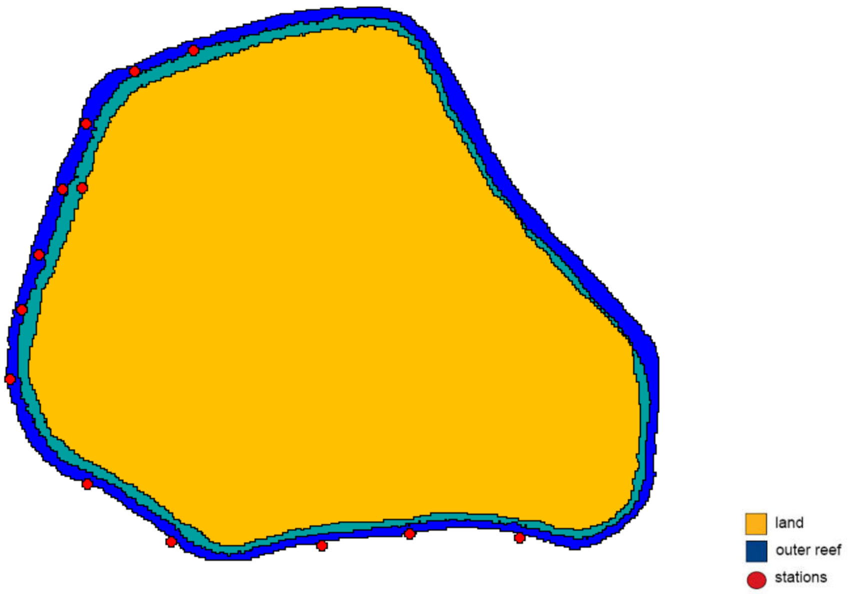



**Figure 4.19: Habitat types and transect locations for finfish assessment in Mangaia.**

### *4.3.1 Finfish assessment results: Mangaia*

A total of 19 families, 44 genera, 102 species and 11,182 fish were recorded in the 13 transects (See Appendix 3.3.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 37 genera, 94 species and 10,888 individuals.

Finfish resources were assessed only from outer reefs (Table 4.5).

**Table 4.5: Primary finfish habitat and resource parameters recorded in Mangaia (average values ±SE)**

| Parameters | Habitat |
|---|---|
| | **Outer reef** (1) |
| Number of transects | 13 |
| Total habitat area ($km^2$) | 4.78 |
| Depth (m) | 8 (5-12) (2) |
| Soft bottom (% cover) | 0 ±0 |
| Rubble & boulders (% cover) | 4 ±3 |
| Hard bottom (% cover) | 81 ±3 |
| Live coral (% cover) | 8 ±1 |
| Soft coral (% cover) | 6 ±2 |
| Biodiversity (species/transect) | 36 ±2 |
| Density ($fish/m^2$) | 0.8 ±0.1 |
| Size (cm FL) (3) | 17 ±1 |
| Size ratio (%) | 48 ±2 |
| Biomass ($g/m^2$) | 112.4 ±11.1 |

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

*Outer-reef environment: Mangaia*

The outer-reef environment of Mangaia was highly dominated by one family, the herbivorous Acanthuridae (Figure 4.20), represented by 18 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus leucopareius*, *A. nigricans*, *A. auranticavus*, *Naso unicornis*, *N. lituratus* and *A. guttatus* (Table 4.6). This reef environment was mostly covered by hard bottom (81%), with very little live coral (8%) (Table 4.5).

**Table 4.6: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Mangaia**

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.32 ±0.03 | 36.1 ±4.1 |
| | *Acanthurus leucopareius* | Whitebar surgeonfish | 0.19 ±0.05 | 27.3 ±6.9 |
| | *Naso lituratus* | Orangespine unicornfish | 0.03 ±0.01 | 5.6 ±1.9 |
| | *Acanthurus nigricans* | Whitecheek surgeonfish | 0.04 ±0.02 | 4.6 ±2.0 |
| | *Naso unicornis* | Bluespine unicornfish | 0.03 ±0.02 | 3.6 ±2.5 |
| | *Acanthurus guttatus* | Whitespotted surgeonfish | 0.03 ±0.01 | 3.5 ±1.2 |
| | *Acanthurus auranticavus* | Orange-socket surgeonfish | 0.03 ±0.02 | 2.6 ±1.4 |

The density (0.8 fish/m$^2$) and biomass of finfish in Mangaia outer reefs were lower than in Rarotonga (0.9 fish/m$^2$) and Aitutaki (1.0 fish/m$^2$) outer reefs, and higher than in Palmerston (0.7 fish/m$^2$). Average fish size was the highest (17 cm FL) among all outer reefs, but size ratio the lowest (48%). Biodiversity (36 species/transect) was lower than values in Aitutaki (45 species/transect) and Palmerston (39 species/transect) and higher than in Rarotonga (31 species/transect). Herbivores highly dominated the trophic structure, with one single family, Acanthuridae, represented by several species at high density and biomass. Carnivores were almost absent, disadvantaged by the substrate, mainly hard bottom. Average size ratios were low for Acanthuridae, Scaridae, Siganidae and Labridae, suggesting impacts from fishing.

Coral coverage was very poor and the number of sea urchins on the western side of the island was very high, exposing the coral slabs to heavy grazing. The benthic profile of all of the dive stations on the western side of the island showed that the level of encrusting algae and turfs was very low and the rock slabs were just bare rocks. Coral coverage was particularly low in this part of the reef, ranging from 2 to 5% coverage, with encrusting corals dominating in most stations on the western side and slowly increasing to 10–20% from the south to the southeastern part of the island. The same trend was experienced with fish density, which was very low on the western side and gradually improving around the southern point towards the southeastern side of the island. This might be caused by the fact that the western side of the island is usually more exposed to fishing than the eastern part of the island due to dominant southeasterly winds rendering fishing difficult on the eastern side.

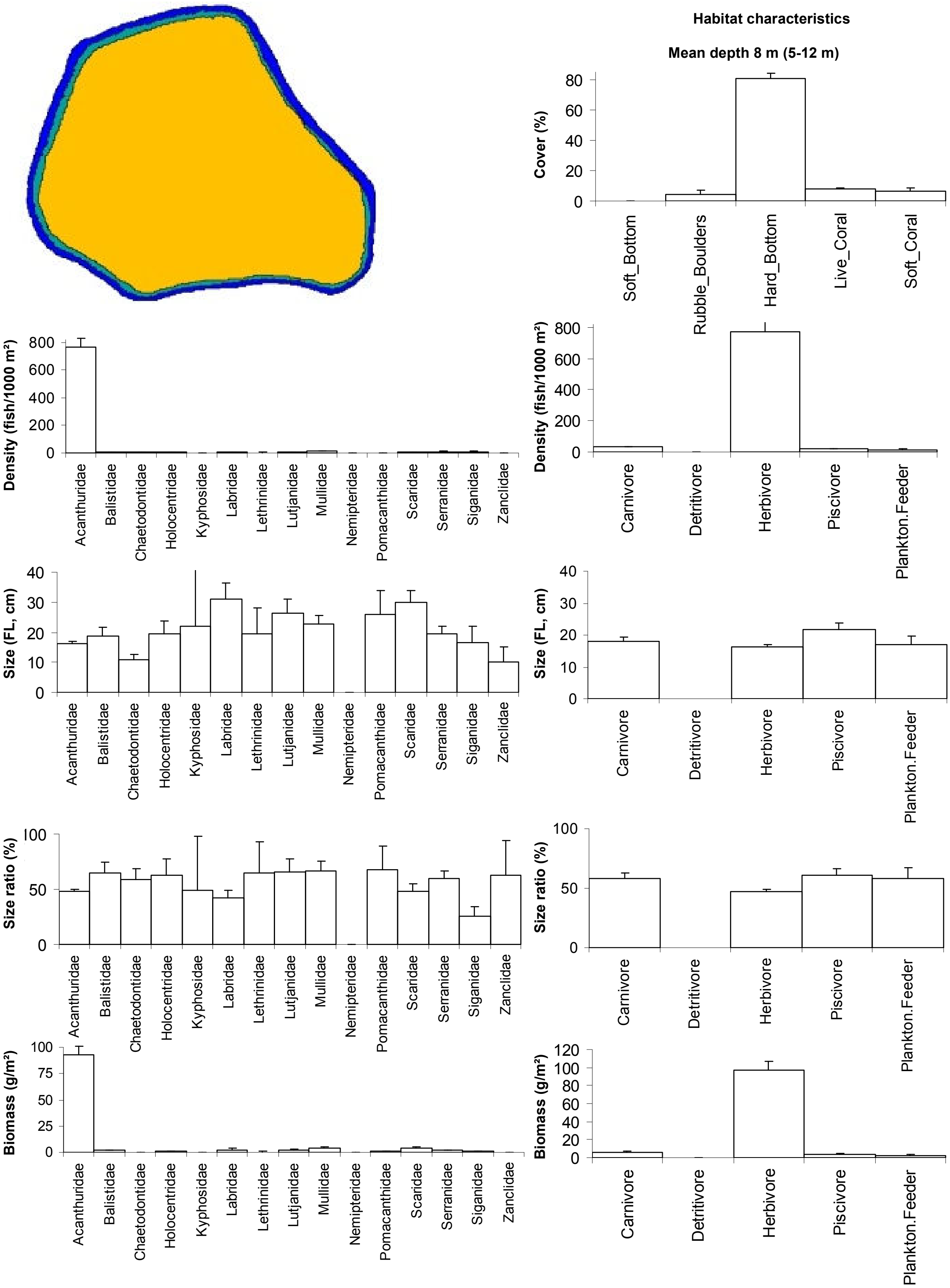



**Figure 4.20: Profile of finfish resources in the outer-reef environment of Mangaia.**
Bars represent standard error (+SE); FL = fork length.

### *4.3.2 Discussion and conclusions: finfish resources in Mangaia*

- The assessment indicated that the status of finfish resources in this site was rather poor. Only one type of habitat is present, an outer reef, where habitat is naturally poor, and exposed to wind and erosion from sea urchins. The substrate was mainly composed of bare, hard bottom with very little live coral. The finfish community was almost homogeneous and composed almost uniquely of Acanthuridae. These observations, along with the analysis of the collected data, suggest that Mangaia is a relatively poor site. Fishing was mostly done by handline (mostly over grounds 60–100 m deep); however, some spear diving and gillnetting were also practised, even at night.

- The finfish resources of the outer reef of Mangaia appeared to be in rather poor condition. The reef habitat is limited to outer habitat and it is naturally poor in corals and mostly composed by bare rock, especially on the western side of the island.

- Overall fish density and diversity were poor, especially in areas more accessible to spear fishing on the western side of the island.

- The dominance of herbivores, especially Acanthuridae, could be partially explained by the type of environment, mainly composed of hard bottom and offering very limited niches for different fish.

- Natural fish resources were not sufficient to allow any increase in fishing level for commercial purposes in a sustainable way. Local consumption is already imposing an impact on the natural resources.

## 4.4 Invertebrate resources: Mangaia

The diversity and abundance of invertebrate species at Mangaia were independently determined using a range of survey techniques (Table 4.7): broad-scale assessment (using the ‘manta tow’; locations shown in Figure 4.21) and finer-scale assessment of specific reef and benthic habitats (Figures 4.22 and 4.23).

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 assessments were conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

**Table 4.7: Number of stations and replicate measures completed at Mangaia**

| Survey method | Stations | Replicate measures |
|---|---:|---:|
| Broad-scale transects (B-S) | 7 | 42 transects |
| Reef-benthos transects (RBt) | 15 | 90 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) | 4 | 24 search periods |
| Reef-front searches (RFs) | 0 | 0 search period |
| Reef-front search by walking (RFs_w) | 10 | 60 search periods |
| Sea cucumber day searches (Ds) | 4 | 24 search periods |
| Sea cucumber night searches (Ns) | 2 | 12 search periods |

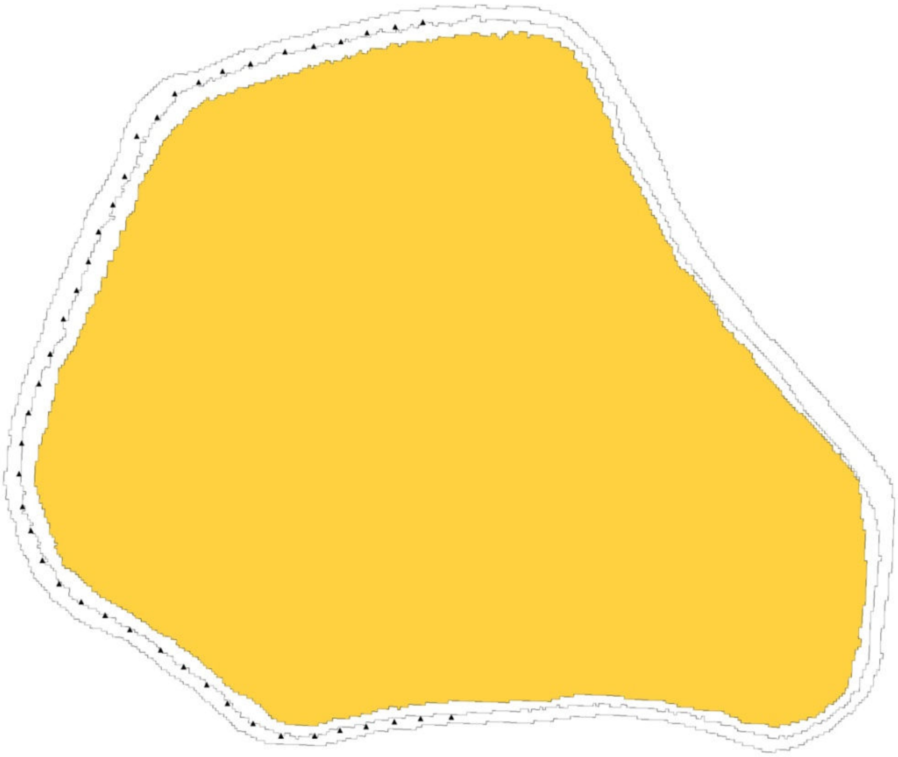


**Figure 4.21: Broad-scale survey stations for invertebrates in Mangaia.**
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

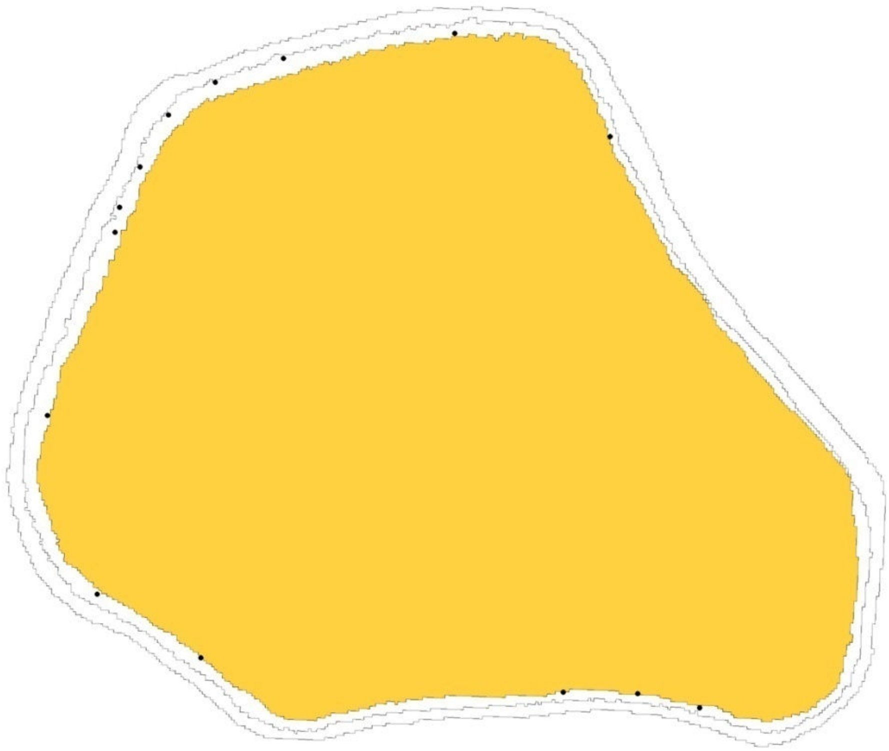


**Figure 4.22: Fine-scale reef-benthos transect survey stations for invertebrates in Mangaia.**
Black circles: reef-benthos transect stations (RBt).

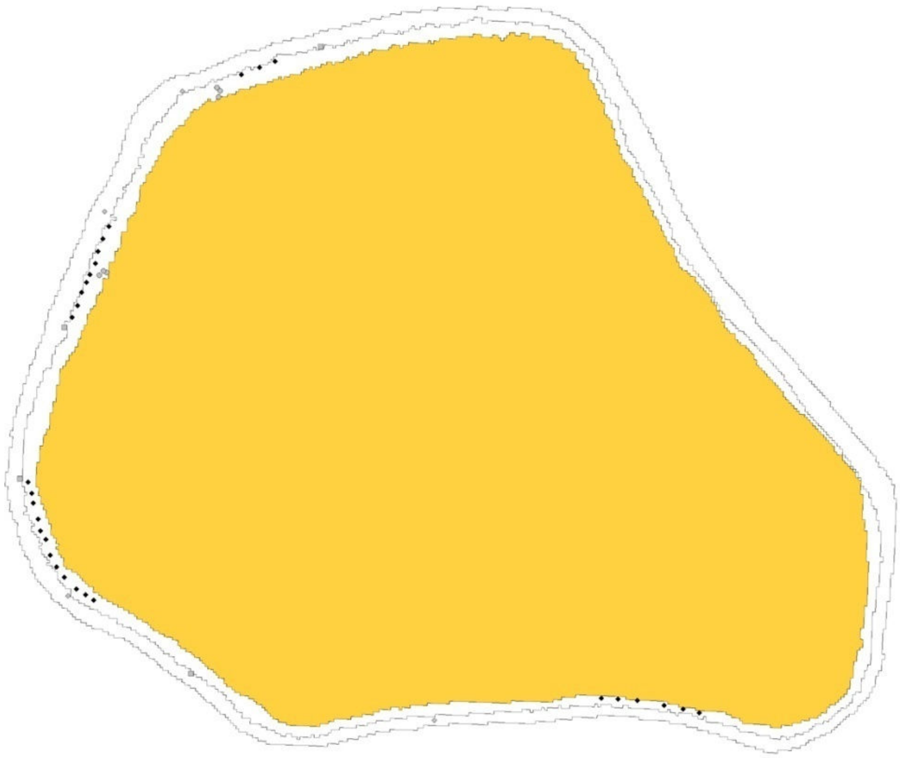


**Figure 4.23: Fine-scale survey stations for invertebrates in Mangaia.**
Inverted black triangles: reef-front search stations (RFs);
black diamonds: reef-front search by walking stations (RFs_w);
grey squares: mother-of-pearl search stations (MOPs);
grey circles: sea cucumber night search stations (Ns);
grey diamonds: sea cucumber day search stations (Ds).

Thirty-five species or species groupings (groups of species within a genus) were recorded in the Mangaia invertebrate surveys. Among these were 4 bivalves, 14 gastropods, 6 sea cucumbers, 6 urchins, 2 sea stars, 1 cnidarian and 1 crab (Appendix 4.3.1). Information on key families and species is detailed below.

### *4.4.1 Giant clams: Mangaia*

Shallow-reef habitat that is suitable for giant clams was small at Mangaia (7.5 $km^2$: ~2.7 $km^2$ of oceanic fringing reef and 4.8 $km^2$ on the reef front or slope). There is no lagoon *per se*, and the fringing reef is narrow and emerged during most low tides, with only the pools and cuts remaining underwater. Most of the reef platform is hard substrate (pavement) with some sand on the inner section. However, despite these factors, the habitat was quite suitable for giant clams.

Despite the high-island environment present, the influence of 'land' (riverine inputs) was limited and the coastline was very exposed, with dynamic water movement affecting shallow-water reef.

Two species of giant clam were noted on Mangaia: the elongate clam *Tridacna maxima* on the reef slope and the larger, fluted clam *T. squamosa.* Broad-scale sampling provided a good overview of the distribution and density of *T. maxima* on the reef slope (recorded in 4/7 stations and 12/42 transects; see Figure 4.24).

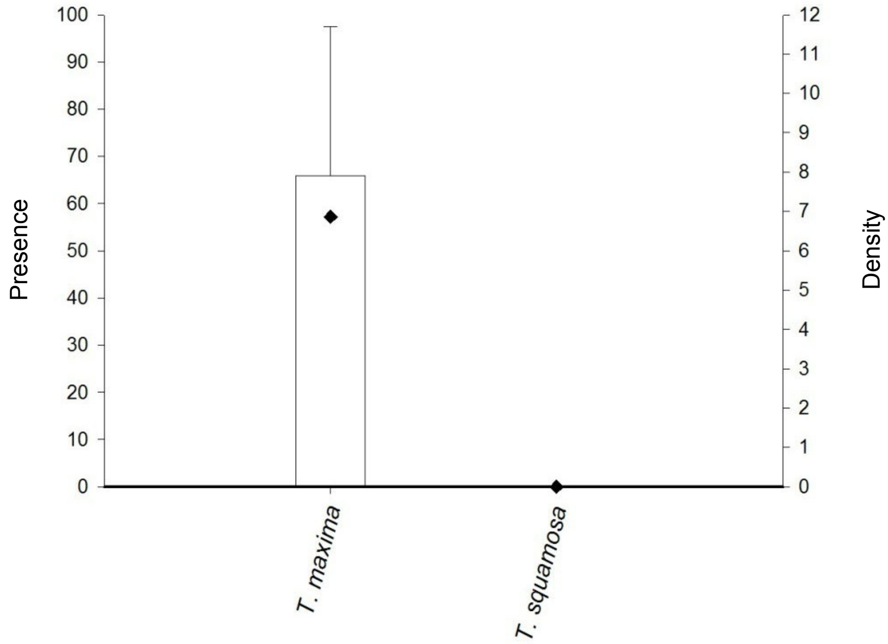



**Figure 4.24: Presence and mean density of giant clam species in Mangaia based on broad-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

As can be seen, *T. maxima* was relatively rare, sparsely distributed, and at low density in broad-scale surveys that targeted the reef slope. Finer-scale surveys (RBt) targeted specific areas of clam habitat. Unusually, these reef-benthos transect surveys (RBt) were conducted on the reef flat at low tide; normally they are conducted over reef that is fully immersed. *T. maxima* was present in 93% of these stations, with a high average station density of 550 /ha ±188.3. The greatest station density was 2458 /ha ±277.0. No *T. squamosa* were recorded across RBt stations (Figure 4.25).

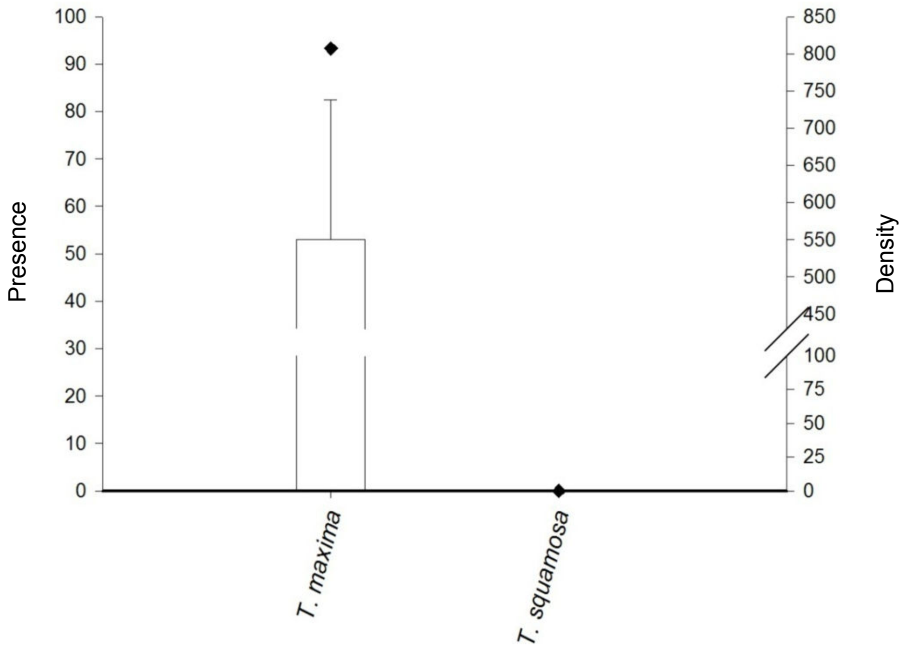



**Figure 4.25: Presence and mean density of giant clam species in Mangaia based on fine-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

The larger *T. squamosa* was only recorded during deeper-water work on the reef slope, either when looking for the commercial gastropods (MOPs) or during searches for sea cucumbers (Ds). In both cases, *T. squamosa* was not common (recorded in 1 of 4 stations in shallower water MOPs survey and 3 of 4 Ds stations, generally at low average density 1.9 /ha ±1.9 in MOPs, and 3.6 /ha ±2.1 in Ds stations). This density may be indicative of a naturally low density on this oceanic island, where generally no SCUBA and little snorkel fishing occurs.

A full range of sizes of *T. maxima* individuals (mean 6.1 cm ±0.3) was recorded in survey. *T. maxima* from reef-benthos transects alone (on shallow-water reefs) were smaller at a mean of 5.0 cm ±0.2, compared to those from the reef slope, which had an average of 15.7 cm ±2.2 and reached a maximum length of 22.5 cm. This is a smaller average size than is generally recorded across the CoFish sites. On the reef flat, the recruitment was good, but the intensive gleaning at low tide does not allow clams to reach mature size classes. Clams are harvested without concern for minimum sizes and generally eaten straightaway. Nevertheless, the outer slope held a small number of larger 'broodstock' clams, which efficiently seed the reef flat. This stock is out of easy reach for the few divers and snorkelers who fish the reef.

Only seven of the faster-growing *T. squamosa* clams were recorded. This species averaged 30.8 cm shell length ±1.2, which equates to a clam over 7 years of age (asymptotic length $L_\infty$ is 40 cm) (Figure 4.26).

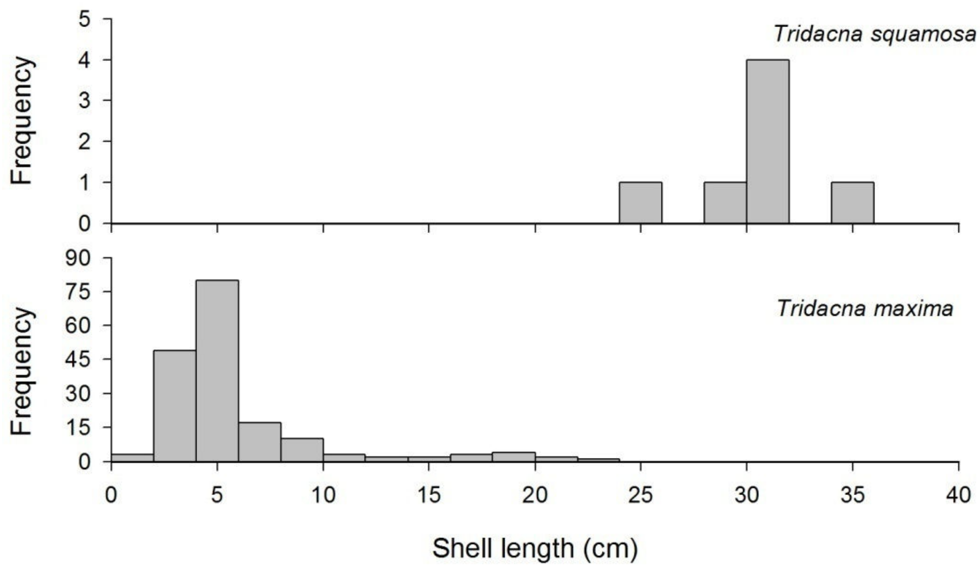



**Figure 4.26: Size frequency histograms of giant clam shell length (cm) for Mangaia.**

### *4.4.2 Mother of pearl species (MOP) – trochus and pearl oysters: Mangaia*

Mangaia is not within the natural distribution range of the commercial topshell, *Trochus niloticus*, in the Pacific. This species was introduced by the Cook Islands Ministry of Marine Resources (MMR) to Mangaia between 1981 and 1983 (300 shells (Gillett 1988)), and an increase in stocks occurred in early 2000.

The habitat available for trochus is quite limited on Mangaia, with a narrow fringing reef platform and relatively steep reef slope. This means that juvenile habitat in the form of rubble bottom in shallow water is not abundant and adult habitat is very exposed. A secondary obstacle might be a recruitment limitation due to the strong currents that are found around the exposed reef systems of this oceanic island.

CoFish work revealed that *T. niloticus* was quite rare at Mangaia, with only eleven individuals recorded in survey. Most were in deeper water, with only a single individual located on the reef flat in a remote and exposed area away from villages (All other trochus were found on SCUBA.).

**Table 4.8: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Mangaia**
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 | 0 | 0/7 = 0 | 0/42 =0 |
| RBt | 2.8 | 2.8 | 1/15 = 7 | 1/90 = 1 |
| RFs_w | 0 | 0 | 0/10 = 0 | 0/60 = 0 |
| MOPs | 18.9 | 10.0 | 3/4 = 75 | 8/24 = 33 |
| ***Tectus pyramis*** | | | | |
| | None recorded | | | |
| ***Pinctada margaritifera*** | | | | |
| | None recorded | | | |

B-S = broad-scale survey; RBt = reef-benthos transect; RFs_w = reef-front search by walking; MOPs = mother-of-pearl station.

It is interesting to note that, as in Rarotonga, we recorded trochus deeper than usual, and none were noted in the typical surf zone. Also, the reeftop, which usually provides a useful habitat in high-impact areas that receive spray from ocean swells, was virtually empty of stock.

The density recorded on MOPs stations (18.9 ±10.0 individuals/ha) showed the trochus stock to be small, with no potential for commercial exploitation in Mangaia. Stocks in the main aggregations need to reach at least a minimum threshold of 500–600 /ha in the main aggregations before commercial fishing can be considered.

Shell size also gives important information on the status of stocks by highlighting new recruitment into the fishery, or the lack of recruitment, which could have implications for the numbers of trochus entering the capture size classes in the following two years (Figure 4.27).

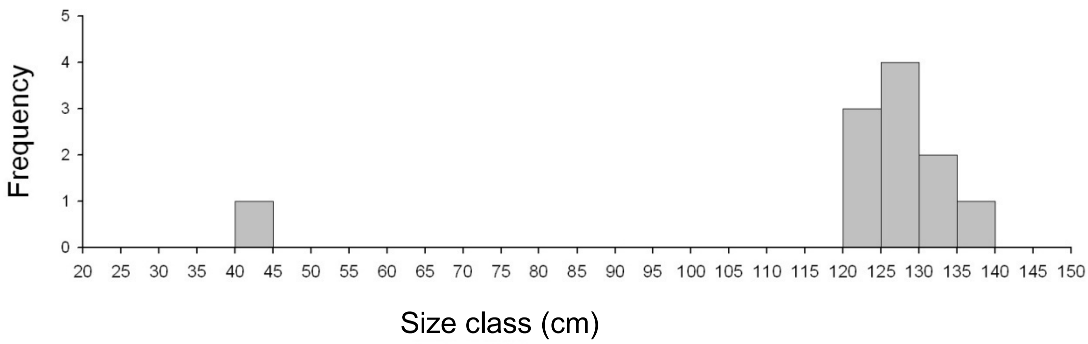



**Figure 4.27: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Mangaia.**

The single trochus found on the reef flat was 4.1 cm, while the average size of the 10 recorded on SCUBA was 12.9 cm ±0.5. The continual gleaning activity on the reef platform is the likely cause of the low number of recruited trochus detected, although the current regime and low number of trochus recorded at depth are also likely to limit the number of available settlers. On the reef slope, no trochus smaller than 12.0 cm were found during the survey, and these larger, older shells might be from the translocated shells that were brought in to augment trochus stock. The absence of smaller class sizes suggests that either recruitment is harvested before it can reach the slope at a mature size, or recruitment events are not very successful at Mangaia. Undoubtedly, the high level of gleaning activity explains some of the depletion on the reef platform.

Neither of the other common mother-of-pearl shells, the lower-value green topshell (*Tectus pyramis*) nor the blacklip pearl oyster (*Pinctada margaritifera*) was noted in survey.

### *4.4.3 Infaunal species and groups: Mangaia*

Soft benthos habitat at the coastal margins of Mangaia was very limited and unsuitable for supporting shell beds. Most of the oceanic fringing reef is made of pavement and only a few pools hold sand. As no habitat existed, no infaunal 'digging' stations (quadrat surveys) were completed.

### *4.4.4 Other gastropods and bivalves: Mangaia*

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded in surveys of the outer slope (n = 11 individuals, average size 23.3 cm ±2.2), and four *L. chiragra* were recorded (Appendices 4.3.1 to 4.3.7). Not surprisingly, due to the lack of proper habitat, the strawberry or red-lipped conch (*Strombus luhuanus*) was not recorded. This species may well not extend this far east in the Pacific and was noted as absent from Cook Islands (Bishop Museum 2008).

Two species of turban shell (*Turbo agyrostomus* and *T. setosus*) were recorded during surveys. The larger, silver-mouthed turban (*T. agyrostomus*) was rare (recorded once in the reef-front search by walking stations, mean 0.2 /ha ±0.2). None were found in reef-benthos transect surveys. The rough turban (*Turbo setosus*), usually abundant close to the reef crest, was only recorded at low density during the RFs_w (mean density 3.5 /ha ±0.9).

One gastropod species typically targeted in Cook Islands for subsistence is the operculate worm shell (*Dendropoma maxima*). As these often occur at very high density and within folds and crevices on the tops and sides of coral structures (with often only the operculum visible), it is not generally realistic to attempt to count them in multi-species assessments. One rough density estimate made during broad-scale surveys was 2275 /ha ±511. On the reef flat (RBt), the average density was especially high (28,094 ±12,587 individuals/ha). The worm shells on the reef platforms were smaller in size than those on the reef slope. Other resource species targeted by fishers (e.g. *Cerithium*, *Charonia*, *Conus*, *Cypraea* and *Thais*) were also recorded during independent surveys (Appendices 4.3.1 to 4.3.7).

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

### *4.4.5 Lobsters: Mangaia*

There was no dedicated night reef-front assessment of lobsters (See Methods.). However, two Fisheries Department staff members went night fishing and caught 20 *Panulirus penicillatus* within two hours, which indicates that there is still a good level of this resource available.

### *4.4.6 Sea cucumbers[12]: Mangaia*

Around Mangaia, the homogeneity of the fringing reef platform and steep reef slope did not provide a wide range of sheltered habitats for the sea cucumber species found in this region. The strongly ocean-influenced habitats are mainly composed of hard limestone and coral with little sediment in the depressed parts of the reef. As sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates, the exposed nature of the environment and hard structure of the substrates was not ideal for many sea cucumbers.

Sea cucumber species distribution and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 4.9, Appendices 4.3.2 to 4.3.7; also see Methods). Results from the full range of assessments yielded six commercial sea cucumber species (Table 4.9).

Sea cucumber species associated with more sheltered areas of shallow reef areas, such as the medium commercial value leopardfish (*Bohadschia argus*), were absent at this more dynamic site. The high-value black teatfish (*Holothuria nobilis*), a species that is easily targeted by commercial fishers, was noted in few surveys (recorded in 2% of broad-scale transects, n = 3 individuals).

Sea cucumber species especially associated with reef crests, such as the medium commercial value surf redfish *Actinopyga mauritiana*, were well distributed all around the island. *A. mauritiana* was found in 66% of reef-benthos transects and 100% of RFs_w stations at a mean density of 386.1 /ha ±113.5 and 283.5 /ha ±25.1 at RBt and RFs_w stations respectively. In some other locations in the Pacific, this species is recorded at densities above 400–500 specimens/ha, but the density noted here is still relatively high, as surf redfish is easy to target. In many other sites, this species does not seem to be recovering well from fishing.

The high-value species *Thelenota ananas* was also well distributed at Mangaia (recorded in 100% of Ds stations, 75% of MOPs stations, and 17% of broad-scale transects) and found at high density. The highest densities noted in deep dive (Ds) and MOPs stations on the reef slope were 64.3 and 151.5 /ha respectively. Interestingly, *T. ananas* had a relatively small average and maximum size, even in the absence of fishing pressure. The average size for *T. ananas* was 33.3 cm compared to 41.3 cm for the rest of the Pacific and the maximum size was 48 cm compared to ≥55 cm. There is no obvious explanation for this 'dwarfism', but Mangaia is remote from other islands, lacks noticeable terrestrial input, and is relatively southerly in position. The remoteness, lack of primary productivity and relatively cold waters might have an effect on the development of this species.

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[12] 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.

No white teatfish (*Holothuria fuscogilva*) were recorded in surveys, and this high-value commercial species, normally found on sand at the base of reef slopes influenced by current, is likely to be absent from Mangaia. At Mangaia, the Ds dives reached a maximum depth of 32 m (average depth was 27 m), but still failed to locate any shelves of soft benthos.

Four other species (*H. atra*, *H. cinerescens*, *H. leucospilota and H. pervicax*) were recorded on the platform. According to anecdotal reports, these species were actively fished for local consumption in the past, and were quite depleted until a few years ago, when people stopped targeting them so regularly. Today, few of the younger generation still eat these species, and the sea cucumber populations have markedly recovered. *H. cinerascens*, locally called *rori pua*, is mostly found in reef with strong water flow and the abundance in some places makes it impossible to count, especially on the algal crest, where tentacles mimic the algae, while the rest of the body hides in cracks in the reef. The densities observed during RFS_w and RBt were 804.4 and 597.2 /ha respectively, but this is likely to be an underestimation, especially in the RFs_w stations where strong algae cover masked some of the abundance.

### *4.4.7 Other echinoderms: Mangaia*

At Mangaia, edible slate urchins (*Heterocentrotus* spp.) were noted at many locations and recorded at moderate density (RFs_w mean density 231 /ha). Very high-density patches were seen on the exposed reef crest. Edible collector urchins (*Tripneustes gratilla*) were also quite common (n = 204 individuals), reaching a density of 58.7 /ha on MOPs survey stations. Surprisingly, *Tripneustes gratilla*, a heavily harvested species in Mangaia, was also recorded during deep surveys (present in 50% of Ds stations at an overall mean density of 94 /ha).

The strong black-spined *Echinothrix diadema* and *E. calamaris* were commonly noted on the reef platform and slope (n = 13,810 recorded in survey). Urchins such as *Echinothrix* spp. and *Echinometra mathaei* can be used within assessments as potential indicators of habitat condition. *Echinothrix* spp. were recorded at high densities on the reef platform (mean of 883.3 /ha ±366.5 at RBt stations) and outer slope (mean of 12,225 /ha ±4679 at MOPs stations). *Echinometra mathaei* was also recorded at very high density on the reef platform (mean of 20,481 /ha ±7319 at RBt stations; see Appendices 4.3.2 to 4.3.9).

Starfish (e.g. *Linckia laevigata*, the blue starfish and *L. guildingi*) were relatively rare (respectively 8 and 3 specimens noted). Corallivore (coral eating) starfish were also rare, with no recordings of the pincushion star *Culcita novaeguineae* and only one crown-of-thorns starfish (*Acanthaster planci*) noted in survey.

**Table 4.9: Sea cucumber species records for Mangaia**

| Species | Common name | Commercial value [5] | B-S transects n = 42 | | | Reef-benthos stations n = 15 | | | Other stations RFs_w = 10; MOPs = 4 | | | 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 | 3.2 | 16.7 | 19 | 386.1 | 579.2 | 67 | 283.5 | 283.5 | 100 RFs_w | 53.3 | 53.3 | 100 Ns |
| *Bohadschia argus* | Leopardfish | M | | | | | | | | | | | | |
| *Holothuria atra* | Lollyfish | L | 6.3 | 29.6 | 21 | 3769.4 | 3769.4 | 100 | 522.6<br>13.3 | 522.6<br>17.7 | 100 RFs_w<br>75 MOPs | 777.8<br>28.0 | 777.8<br>28.0 | 100 Ns<br>100 Ds |
| *Holothuria cinerascens* | | L | | | | 597.2 | 814.4 | 73 | 804.4 | 804.4 | 100 RFs_w | 4.4 | 8.9 | 50 Ns |
| *Holothuria fuscogilva* [4] | White teatfish | H | | | | | | | | | | | | |
| *Holothuria hilla* | | L | | | | 11.1 | 166.7 | 7 | | | | 8.9 | 8.9 | 100 Ns |
| *Holothuria impatiens* | | L | | | | 2.8 | 41.7 | 7 | | | | 53.3 | 106.7 | 50 Ns |
| *Holothuria leucospilota* | | L | | | | 269.4 | 310.9 | 87 | 30.4 | 50.6 | 60 RFs_w | 1831.1 | 1831.1 | 100 Ns |
| *Holothuria nobilis* [4] | Black teatfish | H | 0.4 | 15.4 | 2 | | | | 3.8 | 7.6 | 50 MOPs | | | |
| *Holothuria pervicax* | | L | | | | 2.8 | 41.7 | 7 | | | | 115.6 | 231.1 | 50 Ns |
| *Stichopus chloronotus* | Greenfish | H/M | | | | | | | | | | | | |
| *Stichopus hermanni* | Curryfish | H/M | | | | | | | | | | | | |
| *Stichopus horrens* | Peanutfish | M/L | | | | | | | | | | | | |
| *Stichopus monotuberculatus* | | L/M | | | | 5.6 | 41.7 | 13 | | | | 431.1 | 431.1 | 100 Ns |
| *Synapta* spp. | | L | | | | | | | | | | | | |
| *Thelenota ananas* | Prickly redfish | H | 7.9 | 47.6 | 17 | | | | 45.5 | 60.6 | 75 MOPs | 51.8 | 51.8 | 100 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; H/M is higher in value than M/H; B-S transects= broad-scale transects; RFs_w = reef-front search by walking; MOPs = mother-of-pearl search; Ds = sea cucumber day search; Ns = sea cucumber night search.

### *4.4.8 Discussion and conclusions: invertebrate resources in Mangaia*

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

Data on giant clam distribution, density and shell size suggest the following:

- The scale and range of habitats in Mangaia suitable for giant clams were limited by the shallow-water reef-platform habitats and the dynamic water movement on the reef-front, induced by swells.

- Only two giant clam species were present: the smaller elongate clam *Tridacna maxima* and the larger fluted clam *T. squamosa*. *T. maxima* were common on the reef platform and sparsely distributed on the reef slope. The larger clams were on the reef slopes. Giant clams are broadcast spawners that only mature as females at larger size classes (protandric hermaphrodites). Therefore these large, older specimens are essential for successful fertilisation of gametes and production of new clams.

- *T. squamosa* are only found at low density on the reef slope. In many other locations in the Pacific, e.g. Niue, stocks in such a position have declined to a point where spawning and the production of future generations becomes unsustainable, with a subsequent decline in the number of this species.

- In general, the status of giant clams at Mangaia was impacted by fishing, due to the high fishing pressure on the reef platform frequented by gleaners. *T. maxima* density remained quite high on the reef platform, possibly due to the larger 'broodstock' clams on the reef slope. The bulk of the stock is not mature, as shown by the distribution of size classes, due to size overfishing on the fringing reef, and care must be taken to ensure that the broodstock remaining on the reef slope is protected from fishing in order to maintain a source of gametes for future generations of clams.

In summary, the distribution, density and lengths recorded give the following picture of the environment and MOP stock health:

- Reef conditions constitute an adequate but small habitat for adult and juvenile trochus (*Trochus niloticus*). There is no commercial trochus stock at the moment, but a small broodstock of large, old individuals remains on the outer slope. Trochus are scarce, due to excessive gleaning; most of the recruitment is taken before reaching mature size.

In summary, the environment, distribution, density and length recordings of sea cucumber species gives the following picture of stock health:

- The small area of fringing reef platform and steep reef slope that is exposed to swell at Mangaia Island is only suited to a small number of sea cucumber species. The small range of environments and depths did not suit many of these deposit feeders, and limited potential.

- Only six commercial sea cucumber species were noted at Mangaia, which is is low, but reflects the limited environment available. In addition, two subsistence species (*Holothuria cinerescens* and *H. pervicax*) were also noted in survey.

- Presence and density data collected suggested that sea cucumbers are not under significant fishing pressure, and even those species fished for subsistence purposes are not noticeably impacted (This resource is no longer harvested by younger generations.).

- Surf redfish (*Actinopyga mauritiana*) and, at a lower level, prickly redfish (*Thelenota ananas*) are relatively abundant and may be sufficient to allow periodic commercial harvesting at a low level, e.g. using a pulse-fishing strategy.

## 4.5 Overall recommendations for Mangaia

- Ecotourism be investigated as possibly the best option for future economic development on Mangaia.

- MMR work with the people of Mangaia to develop a joint management plan that engages all families on the island, that attempts to solve any property and land ownership disputes, and includes community-based fisheries resource management actions where needed.

- Strong management measures to protect the recruitment of clams and trochus be taken, with the larger clams in the deeper water protected from fishing.

- Small, no-take areas be established on the reef platform and protected from fishing to allow clam and trochus recruitment to occur.

- Stocks of surf redfish (*Actinopyga mauritiana*) and prickly redfish (*Thelenota ananas*) may be sufficient to allow periodic commercial harvesting at a low level. MMR may consider using a pulse-fishing strategy to control such a harvest, whereby a few days of fishing to reach a predetermined quota would be followed by an adequate period of rest.

# 5. PROFILE AND RESULTS FOR RAROTONGA

## 5.1. Site characteristics

Rarotonga is a high island and the capital of Cook Islands (Figure 5.1) located at 21°14'30"S latitude and 159°46'33"W longitude. At 67 km², Rarotonga is the largest island in the group, near the centre of the Cook-Austral chain of seamounts, with the highest point being 653 m above sea level. The oval-shaped island measures 11 km in length (east to west) and has a maximum width of 8 km (north to south). The fringing reef defines the lagoon, which is broad and sandy to the south and narrow and rocky to the north and east. The lagoon surrounding Rarotonga is quite small at 8 km² and in most areas is relatively shallow. Marine resources have been heavily impacted in the past both through fishing activity and other human activities including pollution, soil erosion and agriculture runoff (from farming and animals). Many reef fish species are now considered ciguatoxic, which has caused a change in subsistence activities. A system of *ra'ui* (traditional community-based management) has been implemented in the 2000s to safeguard the marine resources around Rarotonga.

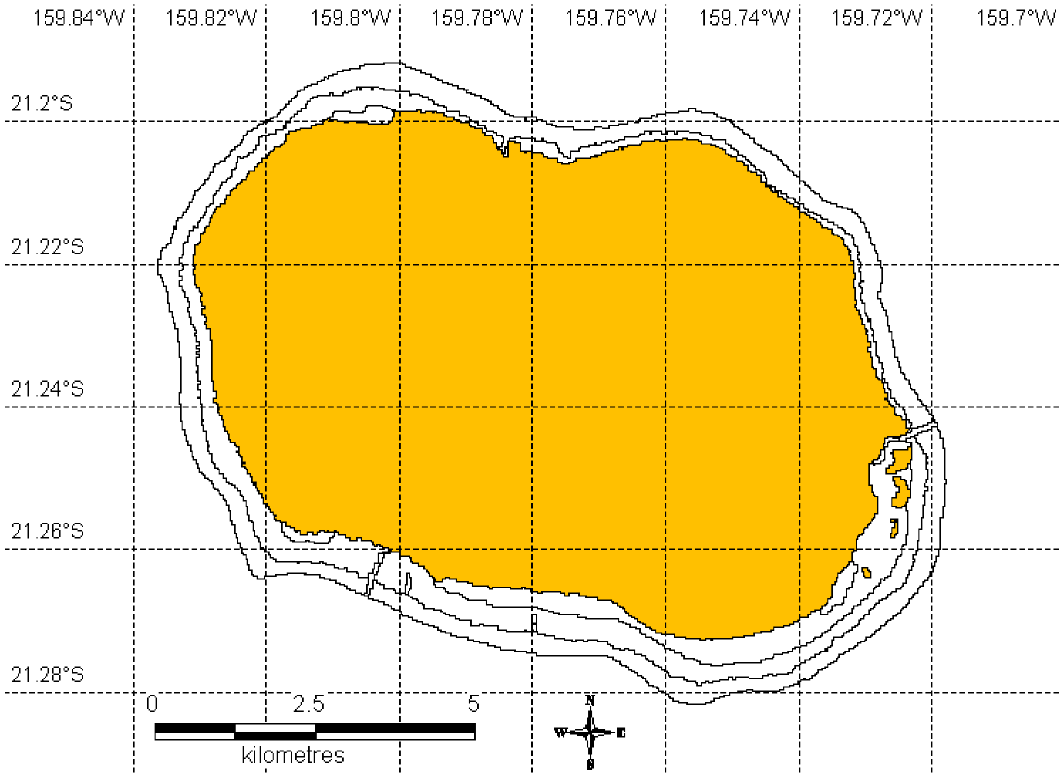


**Figure 5.1: Map of Rarotonga.**

## 5.2. Socioeconomic surveys: Rarotonga

Socioeconomic fieldwork was carried out on Rarotonga in October 2007. The survey covered 59 households and 229 people, representing ~12% of all active households (508) and of permanent residents (1972). This population refers to the communities of Titikaveka and Ngatangiia located on the southeastern part of the island. Both communities were selected for surveying due to their ongoing coastal community management planning and the fact that the total population of Rarotonga (18,027 people according to the 2001 census) exceeded by far the possible scale of work by any of the CoFish surveys. However, the combined survey of Titikaveka and Ngatangiia is referred to as 'Rarotonga' (Takitumu district) in the following.

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. In addition, a total of 19 individual interviews of finfish fishers (16 males, 3 females) and 15 invertebrate fishers (6 males, 9 females) were conducted. In some cases the same person was interviewed for both finfish and invertebrate harvesting.

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

Survey results indicate that less than half of all households (44%) are engaged in fisheries, with an average of one fisher per every second household only. These figures also include sport fishers and households owning a motorised boat used for weekend trolling outside the outer reef. In total there are 293 fishers in the community surveyed (103 females and 190 males). About half (155) of all fishers are males who target finfish; only a very few females specialise in finfish fishing only. About a quarter (69) are females who exclusively fish for invertebrates. The remaining fishers (69 fishers of both gender groups in both communities) catch both finfish and invertebrates.

Data on income suggests that there is not a single household earning any income from fisheries. Rarotonga is a very urbanised island and, not surprisingly, salaries and other sources are the most important sources of income for all households surveyed. (Figure 5.2). In fact, over 66% of all Rarotongan households rely on salaries as first and another 5% as second source of income. 'Others', including small business, contractor works and, above all, old-age pensions and retirement payments, provide first income for 34% and secondary income for 14% of all households surveyed. Agriculture does not play an important role, providing 5% of households with first, and 7% with secondary income.

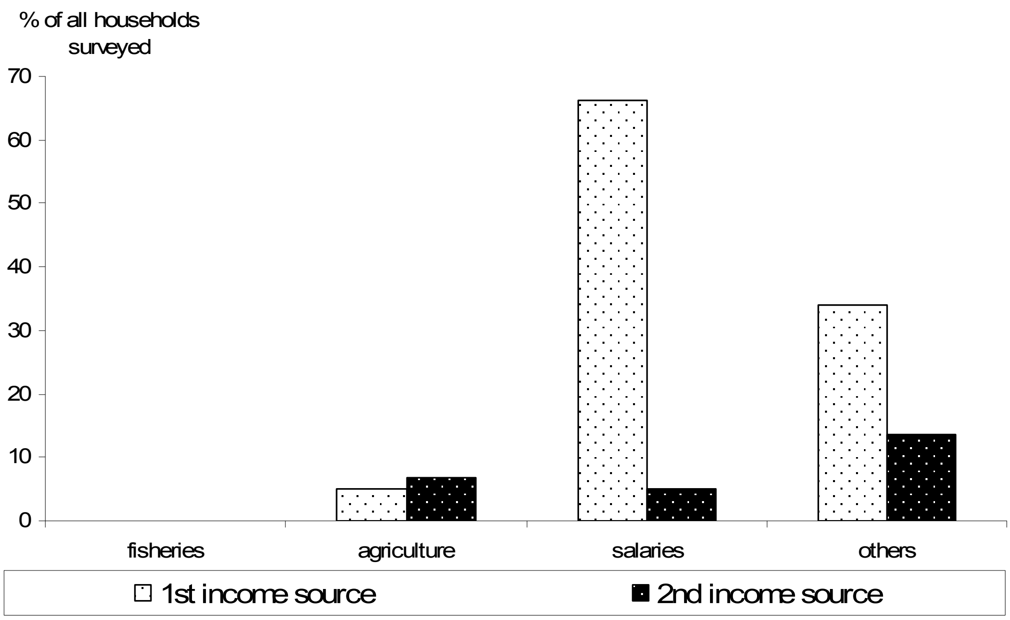


**Figure 5.2: Ranked sources of income (%) in Rarotonga.**
Total number of households = 59 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small businesses.

Remittances are known and may contribute about a quarter of the average annual household expenditure (USD 8945 /year). Costs of living on Rarotonga are high and well above the average across all sites surveyed in Cook Islands. The fact that Rarotongan people have very limited access to healthy reef and lagoon resources may have limited access to land or limited time to allow for subsistence agriculture. The urban and mostly salary-based lifestyle may also contribute to the high cost of living as most, if not all, goods consumed must be bought (Table 5.1).

The consumption of fresh fish of about 32 kg/person/year meets only about half of the national average estimated by Preston (2000) of ~63 kg/person/year, and slightly below the regional average (FAO 2008) of 35 kg/person/year (Figure 5.3). Rarotonga's fresh-fish consumption is also the lowest among all sites surveyed in Cook Islands and much below the average across all sites. Not surprisingly, the invertebrate consumption is also pretty low at 1.4 kg/person/year (edible weight only), i.e. not even half of the average across all sites surveyed (Figure 5.4). The much higher importance of finfish than invertebrates for consumption also shows if comparing the frequencies of consumption. Fresh fish is consumed once to twice a week, while invertebrates only about once per month. Canned fish is consumed at least once a week by the average household, and on an annual basis the average Rarotongan person eats ~11 kg, an amount that is 2 kg/person/year below the average across all sites surveyed.

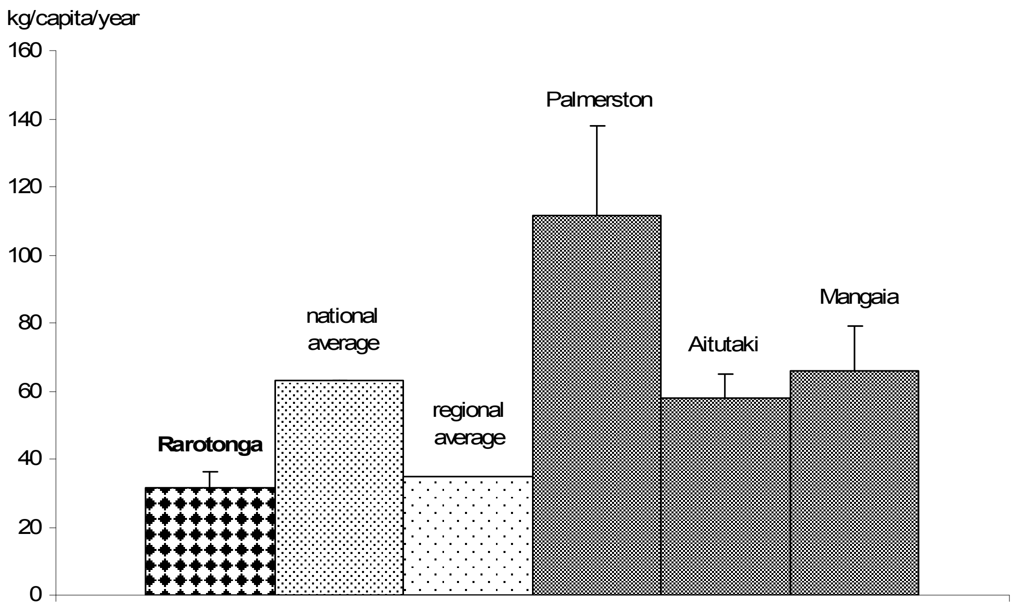


**Figure 5.3: Per capita consumption (kg/year) of fresh fish in Rarotonga (n = 59) compared to the national (Preston 2000) and regional (FAO 2008) averages and the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

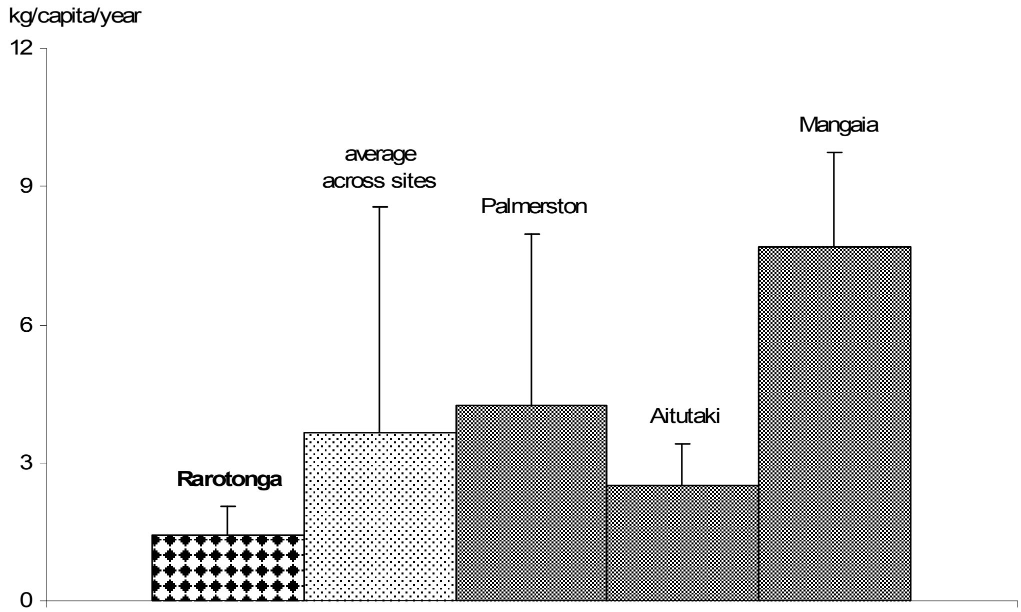


**Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Rarotonga (n = 59) compared to the other three CoFish sites in Cook Islands.**
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

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

| Survey coverage | Rarotonga (n = 59 HH) | Average across sites (n = 138 HH) |
|---|---|---|
| **Demography** | | |
| HH involved in reef fisheries (%) | 44.1 | 68.8 |
| Number of fishers per HH | 0.58 (±0.10) | 1.33 (±0.14) |
| Male finfish fishers per HH (%) | 47.1 | 32.2 |
| Female finfish fishers per HH (%) | 5.9 | 2.7 |
| Male invertebrate fishers per HH (%) | 0.0 | 0.0 |
| Female invertebrate fishers per HH (%) | 23.5 | 18.6 |
| Male finfish and invertebrate fishers per HH (%) | 17.6 | 26.2 |
| Female finfish and invertebrate fishers per HH (%) | 5.9 | 20.2 |
| **Income** | | |
| HH with fisheries as 1st income (%) | 0.0 | 5.1 |
| HH with fisheries as 2nd income (%) | 0.0 | 7.2 |
| HH with agriculture as 1st income (%) | 5.1 | 7.2 |
| HH with agriculture as 2nd income (%) | 6.8 | 8.0 |
| HH with salary as 1st income (%) | 66.1 | 55.8 |
| HH with salary as 2nd income (%) | 5.1 | 8.7 |
| HH with other source as 1st income (%) | 33.9 | 39.1 |
| HH with other source as 2nd income (%) | 13.6 | 16.7 |
| Expenditure (USD/year/HH) | 8944.86 (±537.77) | 6909.08 (±352.39) |
| Remittance (USD/year/HH) (1) | 2270.96 (±602.84) | 1524.12 (±252.14) |
| **Consumption** | | |
| Quantity fresh fish consumed (kg/capita/year) | 31.66 (±4.62) | 51.88 (±4.90) |
| Frequency fresh fish consumed (times/week) | 1.85 (±0.17) | 2.79 (±0.15) |
| Quantity fresh invertebrate consumed (kg/capita/year) | 1.43 (±0.61) | 3.60 (±4.90) |
| Frequency fresh invertebrate consumed (times/week) | 0.33 (±0.08) | 0.42 (±0.06) |
| Quantity canned fish consumed (kg/capita/year) | 10.88 (±2.02) | 13.33 (±1.74) |
| Frequency canned fish consumed (times/week) | 1.16 (±0.19) | 1.17 (±0.13) |
| HH eat fresh fish (%) | 98.3 | 99.3 |
| HH eat invertebrates (%) | 61.0 | 71.0 |
| HH eat canned fish (%) | 81.4 | 73.2 |
| HH eat fresh fish they catch (%) | 27.1 | 73.3 |
| HH eat fresh fish they buy (%) | 83.1 | 36.7 |
| HH eat fresh fish they are given (%) | 52.5 | 66.7 |
| HH eat fresh invertebrates they catch (%) | 20.3 | 63.3 |
| HH eat fresh invertebrates they buy (%) | 27.1 | 6.7 |
| HH eat fresh invertebrates they are given (%) | 33.9 | 6.7 |

HH = household; (1) average sum for households that receive remittances; numbers in brackets are standard error.

### *5.2.2 Fishing strategies and gear: Rarotonga*

At the time of the survey, a community-based coastal management project was underway in cooperation between MMR and the communities concerned. This project is part of the ongoing Cook Islands Marine Resource Institutional Strengthening (CIMRIS) project, funded by the New Zealand Agency for International Development (NZAID). The goal of the CIMRIS project is to enhance the management and sustainable use of marine resources for the benefit of all Cook Islanders. The purpose of the project is to build the capacity of MMR and related agencies to ensure that Cook Islands marine resources are sustainably managed (Cahn and Tuara 2007). The pilot project includes the three communities of Matavera, Ngatangiia and Titikaveka. Ngatangiia and Titikaveka were selected for the CoFish socioeconomic survey.

Major findings of the community input, monitoring and evaluation analysis which was done in May – June 2007 include:

- The health of the lagoon had deteriorated over the previous 10 years; pig effluent was perceived to be the most serious cause of the problems;
- The most important uses of the lagoon for households were: recreation (picnics, family outings, etc.), source of food (fishing, food and seafood), swimming and exercise, identity and pride, as well as others, such as health, well-being, tourism and livelihoods;
- Ngatangiia and Titikaveka respondents thought that proper monitoring (32%) was the best approach to fix the problems in the lagoon, and government funding was the preferred option for this;
- Resort, motel, hotel and guesthouse owners thought that the government could help by setting and enforcing regulations; and the Takitumu Vaka Council was perceived to have a supportive role and to provide information and education.

*Degree of specialisation in fishing*

On Rarotonga both males and females are fishers. However, any fishing activity in the lagoon system that surrounds the island is limited due to severe ciguatera risks. Many respondents confirmed that they no longer fish as the risk of fish poisoning is too high. Others stated that they only go leisure fishing for pelagic species outside the outer reef during weekends or leisure hours. The deterioration of resources in the lagoon was also reported for invertebrates. Some respondents feared poisoning, others reported that most of their former target species are no longer easily available. Among these are *ungakoa*, *ariri*, *matu rori* and giant clams. Limited access due to marine reserves in areas where tourist hotels are operated were also mentioned to have reduced fishing.

While most respondents, regardless of gender, confirmed their interest in fishing, trolling at the outer reef seems to be more of a male activity. Some females, on the other hand, reported that they still collect invertebrates on the reef or soft benthos. A small group of male and female fishers still do both finfish fishing and invertebrate collection (Figure 5.5).

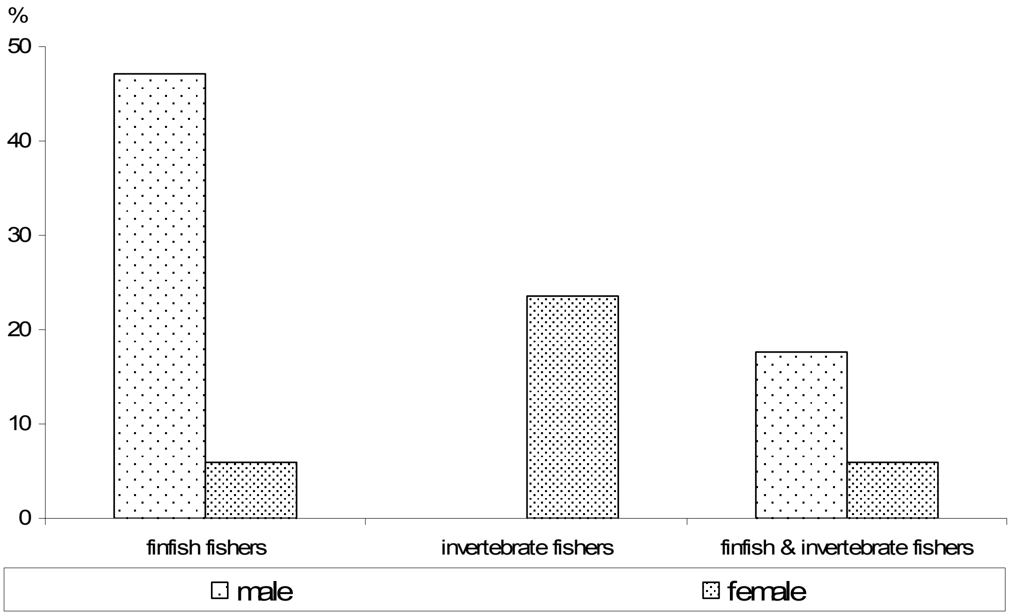


**Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Rarotonga.**
All fishers = 100%.

Invertebrate fishers target mostly soft benthos and reeftops, but a few male fishers specialise in lobster diving at the outer reef (Figure 5.6).

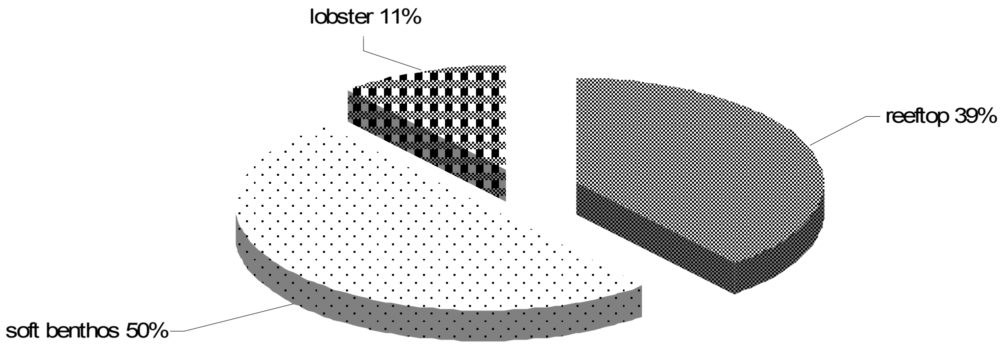


**Figure 5.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Rarotonga.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

*Fishing patterns and strategies*

Among Rarotongan respondents, only 10% of households own a boat. While 38% of boats are motorised, 62% are paddle canoes.

None of the finfish or invertebrate fishers surveyed used any boat transport for fishing in the shallow and narrow lagoon system. Because this survey does not include pelagic species, no use of motorised boats for trolling was recorded.

Fishing trips are mostly undertaken during the day (61% of trips to the outer reef, 100% to the sheltered coastal reef) and few fishers prefer fishing at night (22% targeting the lagoon, 15% targeting the outer reef). Very few fishers go fishing according to the tidal conditions (11% of lagoon and 23% of outer-reef fishers). Most fishers continue throughout the year; only 20% of fishers targeting the outer reef seem to stop fishing for about two months per year. Reeftop and soft benthos gleaning is mainly performed during the day (66–89%) and only about 11–14% of fishers interviewed indicated that they may fish at night or according to tidal conditions (night or day). Lobsters are exclusively harvested at night. Invertebrates are collected 8–10 months per year.

*Targeted stocks/habitat*

Male fishers are less involved in collecting invertebrates, but their interest in any of the three main activities, i.e. soft benthos and reeftop gleaning and free diving for lobsters, seems about equal. Most females seem to target the soft benthos and much less the reeftop. No females are engaged in free-diving or for collecting lobsters (Figure 5.7).

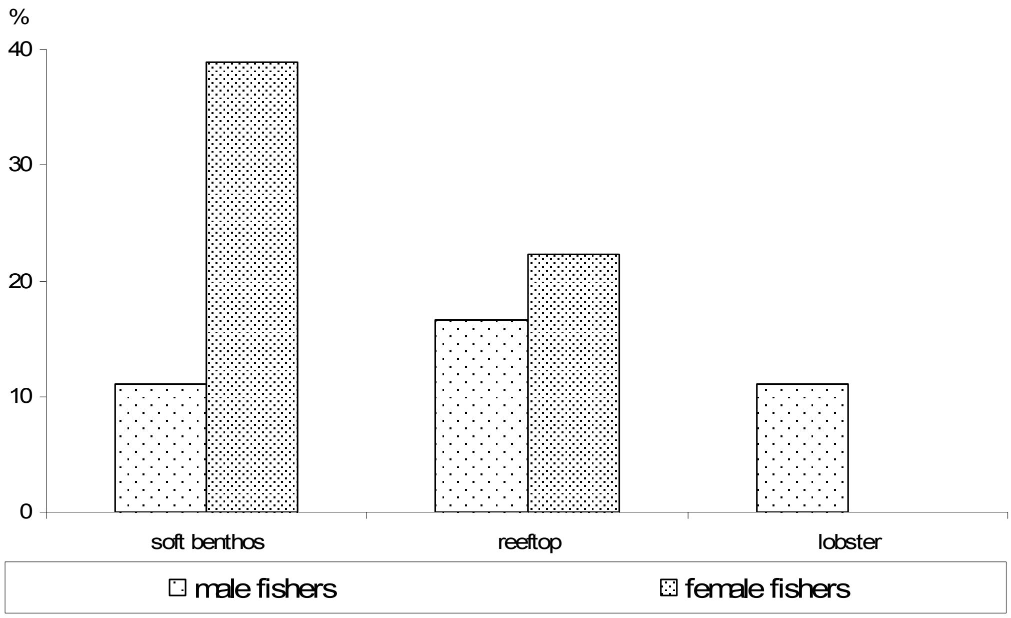


**Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Rarotonga.**
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 6 for males, n = 9 for females.

*Gear*

Fishing on Rarotonga involves a variety of techniques; however, gillnets are mainly used (Figure 5.8). Male fishers also spear fish at the outer reef. Nowadays, fishing with handlines, rod casting, and handheld spearing are practised relatively rarely.

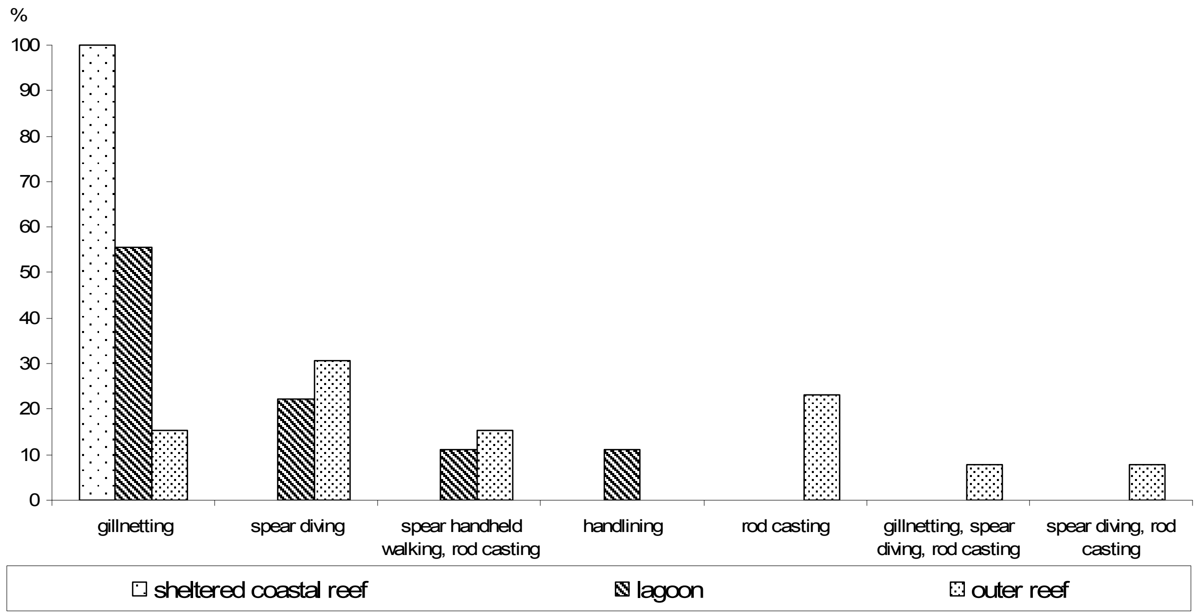


**Figure 5.8: Fishing methods commonly used in different habitat types in Rarotonga.**
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

*Fishing pressure*

Information on the number of fishers, the frequency of fishing trips (Table 5.2) and the average catch per fishing trip was used to estimate the fishing pressure imposed by the inhabitants of Rarotonga on their fishing ground (Table 5.3). Any fishing pressure imposed on Rarotonga's reef areas may be also determined by residents on Rarotonga who live outside the communities surveyed. The fishing grounds that are under no protective or conservation measure are open to all.

**Table 5.2: Average frequency and duration of fishing trips reported by male and female fishers in Rarotonga**

| Resource | Fishery / Habitat | Trip frequency (trips/week) | | Trip duration (hours/trip) | |
|---|---|---|---|---|---|
| | | Male fishers | Female fishers | Male fishers | Female fishers |
| Finfish | Sheltered coastal reef | | 1.00 (n/a) | | 1.50 (n/a) |
| | Lagoon | 0.65 (±0.21) | 1.00 (±0.00) | 2.36 (±0.26) | 1.75 (±0.25) |
| | Outer reef | 0.65 (±0.12) | 1.00 (n/a) | 2.67 (±0.26) | 1.50 (n/a) |
| Invertebrates | Lobster | 0.29 (±0.06) | 0 | 2.50 (±0.50) | 0 |
| | Reeftop | 0.26 (±0.22) | 0.62 (±0.22) | 1.67 (±0.67) | 3.38 (±0.24) |
| | Soft benthos | 0.23 (±0.00) | 0.60 (±0.27) | 1.50 (±0.50) | 2.50 (±0.38) |

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 16; females: n = 3. Invertebrate fisher interviews, males: n = 6; females: n = 9.

*Frequency and duration of fishing trips*

Fishing for reef fish in Rarotonga targets some of the small areas of sheltered coastal reef, the lagoon and the outer reef. As shown in Table 5.2, on average, fishers go out once per week or once per fortnight, and there is no significant difference among habitats targeted. Trips may take 1.5–2.5 hours, with not much difference between lagoon and outer-reef trips. Female finfish fishers may go out slightly more frequently than males, but their trips are slightly shorter. Invertebrates are less frequently collected, i.e. once or twice per month and, again, regardless of which habitat is targeted. Invertebrate collection trips often take 1.5–3 hours. Again, females collect slightly more often than males. However, in the case of invertebrate fishing, females' trips are usually longer than males' trips.

### *5.2.3 Catch composition and volume – finfish: Rarotonga*

The annual catch reported by respondents from Rarotonga totalled ~2 t/year and the extrapolated total annual catch for the communities surveyed was estimated at 19.3 t/year (Figure 5.9). Considering the frequency and quantity of fresh-fish consumption reported by all households, Rarotonga's subsistence demand for fresh fish for the communities surveyed is estimated at 52 t/year. Extrapolation of all catch data from respondents suggests that the total annual catch of Rarotonga's reef and lagoon resources is only a small proportion of the total annual subsistence demand. The balance of about 31.6 t/year of fish needed for local consumption is supplied commercially and mostly provided by pelagic species, caught by longline.

All catches are used for subsistence purposes. As already mentioned, the high risk of ciguatera poisoning is well known and, therefore, there is little if any commercial demand for reef and lagoon fish. As shown in Figure 5.9, male fishers take most of the catch (~84%) and most of the impact is accounted for by catches sourced from the outer reef (~61%).

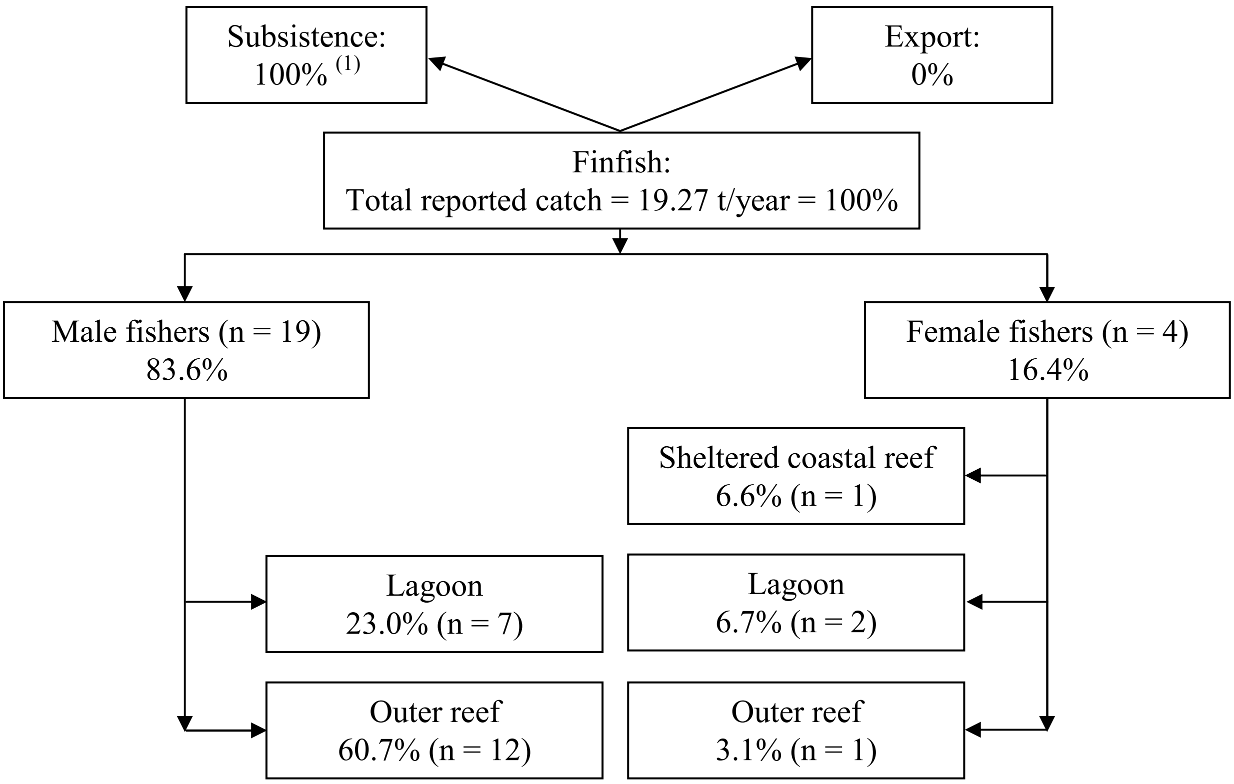


**Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Rarotonga.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. (1) The subsistence demand in the communities surveyed exceeds by far the total annual reported and extrapolated catch, i.e. by 164%. Most of the fish consumed are pelagic species, which are bought.

Figure 5.10 confirms earlier findings that fishing on Rarotonga is exclusively for subsistence purposes. No respondent reported selling any catch at any time. However, sharing fish with family members and friends on a non-monetary basis is still very common among those who continue to fish.

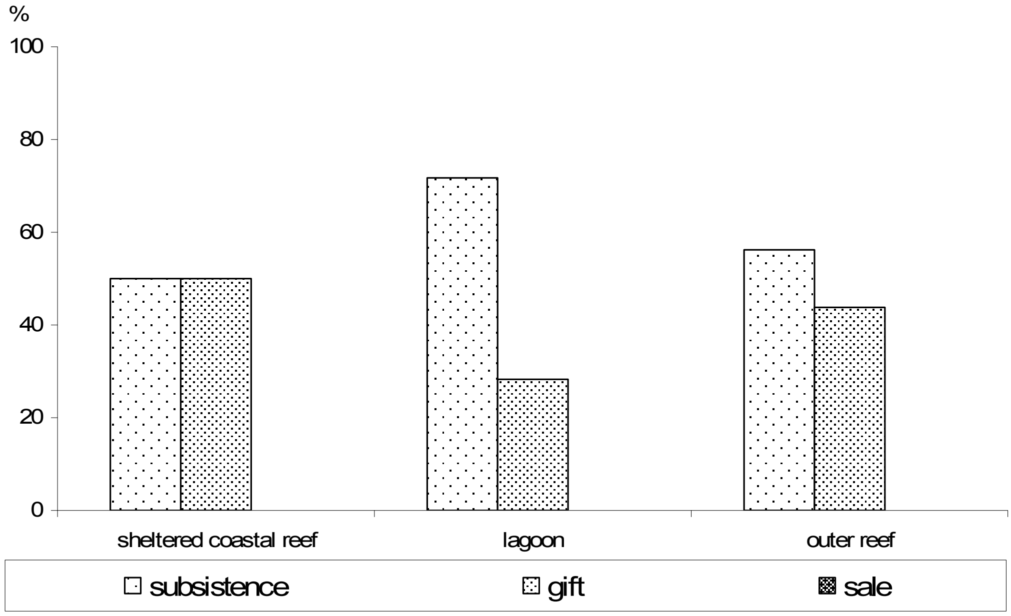


**Figure 5.10: The use of finfish catches for subsistence, gifts and sale, by habitat in Rarotonga.**
Proportions are expressed in % of the total number of trips per habitat.

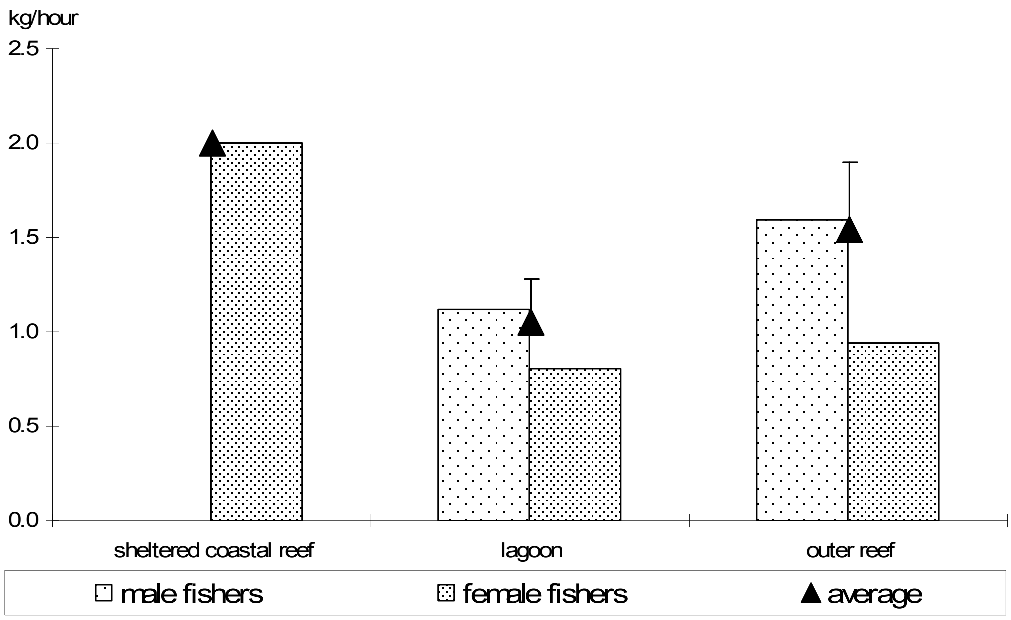


**Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat type in Rarotonga.**
Effort includes time spent transporting, fishing and landing catch. Bars represent standard error (+SE).

The catch per unit effort (CPUE) on Rarotonga is low. This may be explained by the fact that fishing is mainly for subsistence needs, as well as by the high risk of ciguatera, i.e. fishers may target particular species only and throw back catch they do not want to bring home (Figure 5.10). The CPUEs (Figure 5.11) reported for the three major habitats targeted show highest figures for sheltered coastal reef catches (~2 kg/hour fished) and much lower average catch rates for lagoon and outer-reef catches (~1–1.5 kg/hour fished). Female fishers have lower catch rates if fishing in the lagoon and at the outer reef. Nevertheless females are the only ones targeting the sheltered coastal reef, where CPUEs were reported to be highest.

Catches from the sheltered coastal reef are determined by very few target species. Among these are *Mulloidichthys flavolineatus*, *Selar crumenopthalmus* and *kokokino* and *tumaro* (which have not been scientifically identified). Lagoon catches are reported to be more varied, mainly determined by *Siganus argenteus* (34%), *Kyphosus cinerascens* (26%), *Myripristis* sp. and *Kyphosus bigibbus* (each 18–19%). Again, the few species reported are explained by the known high ciguatera risk and the belief of fishers that certain species are of low or no risk. Because fishers may target species at the outer reef that are less prone to ciguatera poisoning, reported catches may include more species as compared to the lagoon area. Catches are determined by *Chlorurus frontalis* (26%), *Siganus argenteus*, *Naso unicornis*, *Kyphosus cinerascens*, *Epinephelus hexagonatus* (each representing 12–13%), and nine other species that may represent 0.6–8.2% of the total reported catch. Details of the reported catch composition by habitat and fish species are provided in Appendices 2.4.1 and 2.4.4.

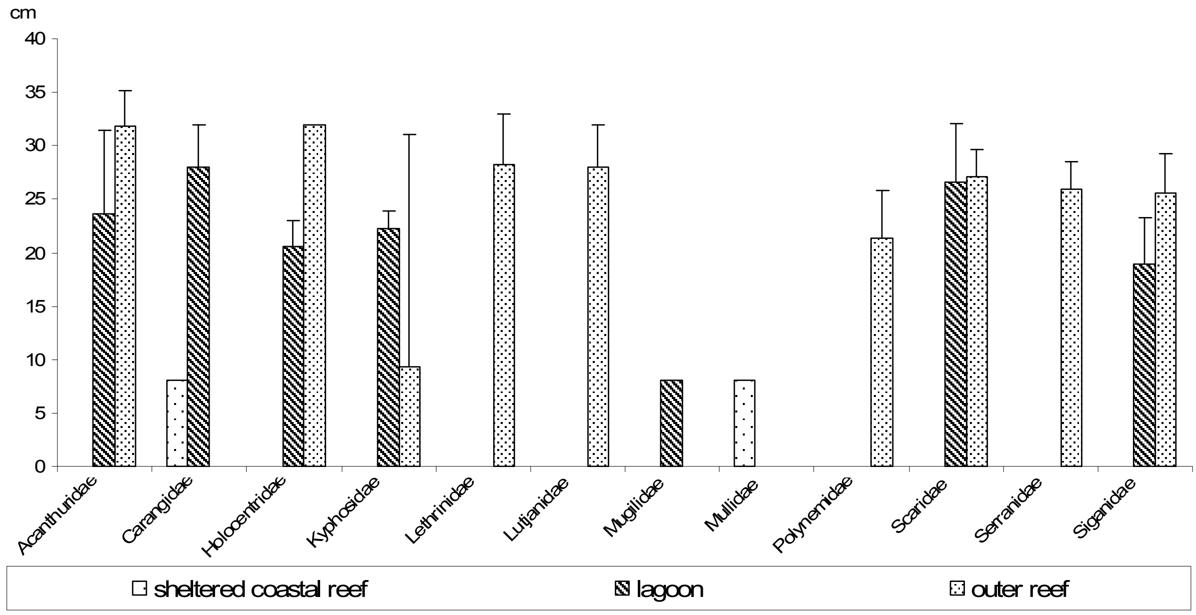


**Figure 5.12: Average sizes (cm fork length) of fish caught by family and habitat in Rarotonga.** Bars represent standard error (+SE).

Average fish sizes reported for catches on Rarotonga are 25–30 cm for outer-reef catches, 20–>25 cm for lagoon catches and 5–8 cm for catches from the sheltered coastal reef (Figure 5.12). In general, the picture shown in Figure 5.12 looks evenly distributed among fish families and habitats. Exceptions are usually of families with very small sample sizes, for example, Mugilidae (lagoon), Mullidae (sheltered coastal reef) or Carangidae (sheltered coastal reef) and therefore these are not included in the discussion.

Extrapolation of our survey data is somewhat restricted due to the small survey sample as compared to the total population of both communities included in the survey, i.e. 12%. This bias is much larger if taking into account Rarotonga's total population, i.e. the socioeconomic survey sample represents only 2.3% of all households surveyed only (Census 2001 reports 2531 households on Rarotonga.). Resource surveys included the entire reef system of the island and, hence, the habitat areas presented in Table 5.3 refer to the island's total available fishing ground. Geographical distribution of the island's main reef and lagoon resources suggests, on the other hand, that both communities surveyed by the socioeconomic team have best access to most of the reef and lagoon resources. Nevertheless, it must be taken into account that Rarotonga enjoys an open-access fishing ground system and, hence, all resources not under any kind of protection are theoretically accessible by all.

Overall, the results presented so far suggest that reef and lagoon fishing for finfish and invertebrates is very low-level among Rarotongan people due to a number of reasons, including ciguatera poisoning and the urbanised lifestyle. Thus, calculations were done for both scenarios. Firstly survey results are extrapolated to the total population of the communities surveyed only. The resulting impact assessment was done by taking into account all available reef and lagoon areas. Secondly, survey results are extrapolated to the total population on Rarotonga, again using the total available reef and lagoon surface areas. These figures are shown in Table 5.3.

**Table 5.3: Parameters used in assessing fishing pressure on finfish resources in Rarotonga**

| Parameters | Habitat | | | | |
|---|---|---|---|---|---|
| | Sheltered coastal reef (4) | Sheltered coastal reef & lagoon | Outer reef | Total reef area | Total fishing ground |
| Fishing ground area (km$^2$) | 4.61 | 6.64 | 10.06 | 21.13 | 21.31 |
| Density of fishers (number of fishers/km$^2$ fishing ground) (1) | | 21 [103] | 8 [38] | 14 [67] | 11 [53] |
| Population density (people/km$^2$) (2) | | | | 93 [572] | 93 [572] |
| Average annual finfish catch (kg/fisher/year) (3) | 130.29 (n/a) | 65.12 (±19.51) | 96.97 (±20.06) | | |
| Total fishing pressure of subsistence catches (t/km$^2$) | | | | 0.9 [4.51] | 0.9 [4.51] |

Figures in brackets denote standard error; n/a = standard error not calculated; numbers within square brackets denote figures extrapolated for the whole population of Rarotonga; (1) total number of fishers is extrapolated from household surveys; sheltered coastal reef & lagoon: n = 96 [477], outer reef: n = 129 [639]; (2) total population = 1972 [12,188]; total subsistence demand = 19.3 t/year [96 t/year]; (3) catch figures are based on recorded data from survey respondents only; (4) the sheltered coastal reef is insignificant and rather part of the lagoon habitat, thus both are combined here.

As to be expected, fisher densities, as well as the total annual finfish catch harvested per km² of available reef and lagoon areas are moderate if considering the communities surveyed only. The fact that little is fished on average by each of the fishers further suggests that the total current pressure is relatively low. Of course, if Rarotonga's total population is included in the calculation, all these figures increase significantly and suggest a moderate fishing pressure at least. In both scenarios, population density figures are high; however, the proportion of fishers is low. This situation is explained by the fact that most of the subsistence demand for finfish on Rarotonga is supplied by pelagic fish or, in the case of reef fish, imported from other islands. It should also be noted that probably most of the population on Rarotonga that was not included in the survey lives a much more urbanised lifestyle than do the communities surveyed. Hence, their engagement in reef and lagoon fisheries may be overestimated and thus suggest much higher fisher densities and fishing pressure than are actually the case. Before finally deciding whether or not the current fishing level may be detrimental the resource survey results need to be considered, particularly focusing on the few target species that are believed not to be at risk for ciguatera.

### *5.2.4 Catch composition and volume – invertebrates: Rarotonga*

The number of species (as represented by the number of vernacular names) reported to be regularly caught from various habitats is indicative of the importance of these habitats and the fisheries they support. Figure 5.13 indicates that only reeftop and soft-benthos gleaning target a reasonable number of species each, i.e. 12 and 10 vernacular names respectively. These vernacular names usually represent a range of species that people target only for home consumption. The two vernacular names used for the lobster fishery include possibly more than two scientifically named species.

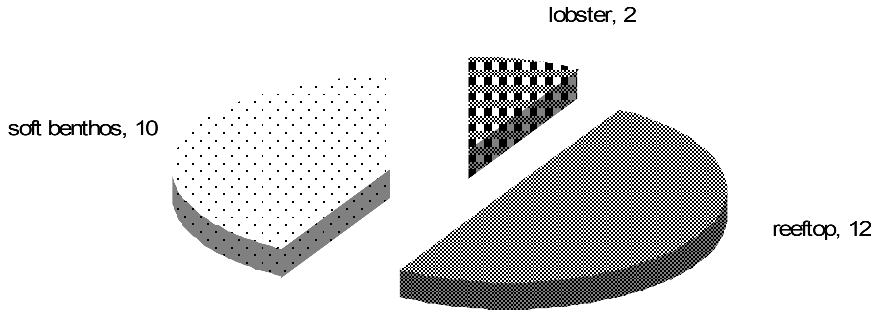


**Figure 5.13: Number of vernacular names recorded for each invertebrate fishery in Rarotonga.**

The data on the variety of species and habitats explored suggest that the invertebrate fisheries in general on Rarotonga are no longer of much importance, although traditionally they have been in the past. Often, respondents pointed out their favourite invertebrate dishes, mostly containing *ariri* (*Turbo* spp.), *matu rori* (*Holothuria* spp.), *ungakoa* (vermetid gastropod) and *paua* (*Tridacna maxima*), and their regret that these dishes are no longer easily available.

This trend is further reflected in the estimated total annual catch from interviewed fishers that equals only ~2 t/year of wet weight (Figure 5.14). Extrapolation of the average annual recorded catch per fisher to the total number of invertebrate fishers in the surveyed communities on Rarotonga brings the figure up to a total of ~17 t/year. Most of the catch is sourced from reeftops followed by soft benthos, and only a very small proportion is accounted for by lobster catches. Females contribute the most, over 80% of all reported annual invertebrate catches (wet weight).

Calculation of the total annual impact per species group (Figure 5.15) shows that the highest annual catches (in terms of wet weight removed) are accounted for by *Holothuria* spp. The sea cucumbers collected are not entirely consumed; only a small amount of the inner parts is cut out and eaten. *Paua* (*Tridacna maxima*), *vana* (*Echinothrix diadema*), *atuke* (*Heterocentrotus mammilatus*), *kai* (*Asaphis violascens*), *koura* (*Panulirus spp.*), *kina* (*Echinometra mathaei*, *Tripneustes gratilla*), trochus (*Trochus niloticus*) and octopus (*Octopus* spp.*)* determine most of the remaining 34% of the total annual reported catch. There are a couple of other species that were reported to be harvested in insignificant quantities harvested (~10–30 kg/year each).

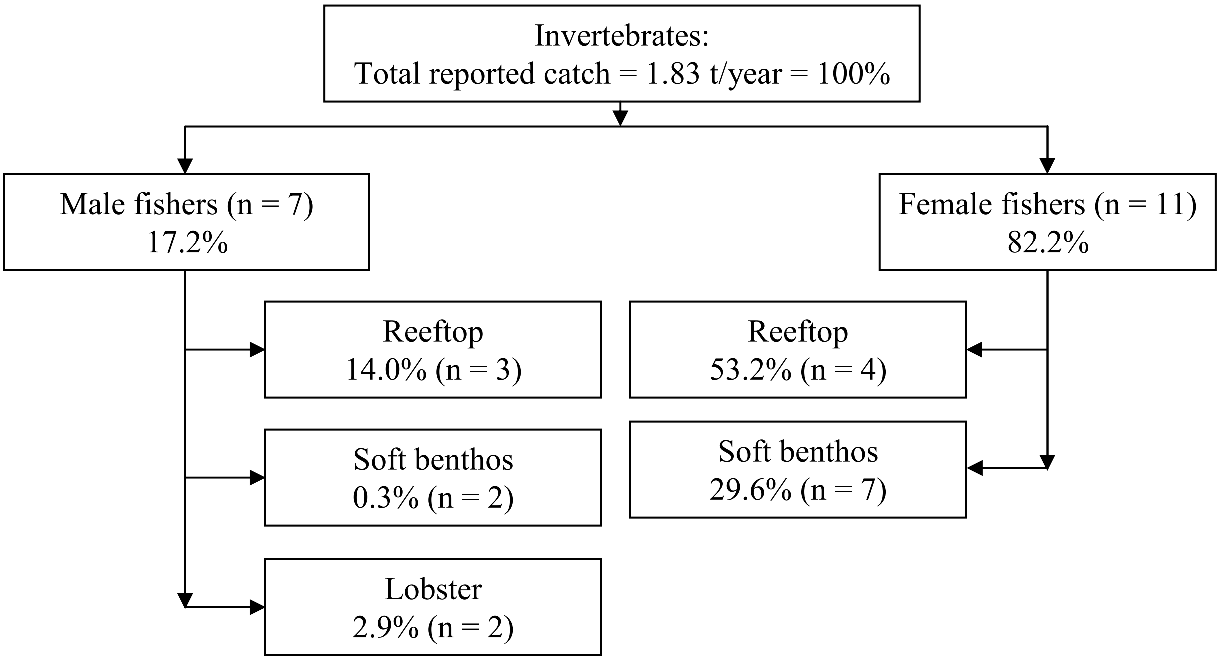


**Figure 5.14: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Rarotonga.**
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

Details on the species distribution per habitat, and on size distribution by species, are provided in Appendices 2.4.2 and 2.4.3 respectively.

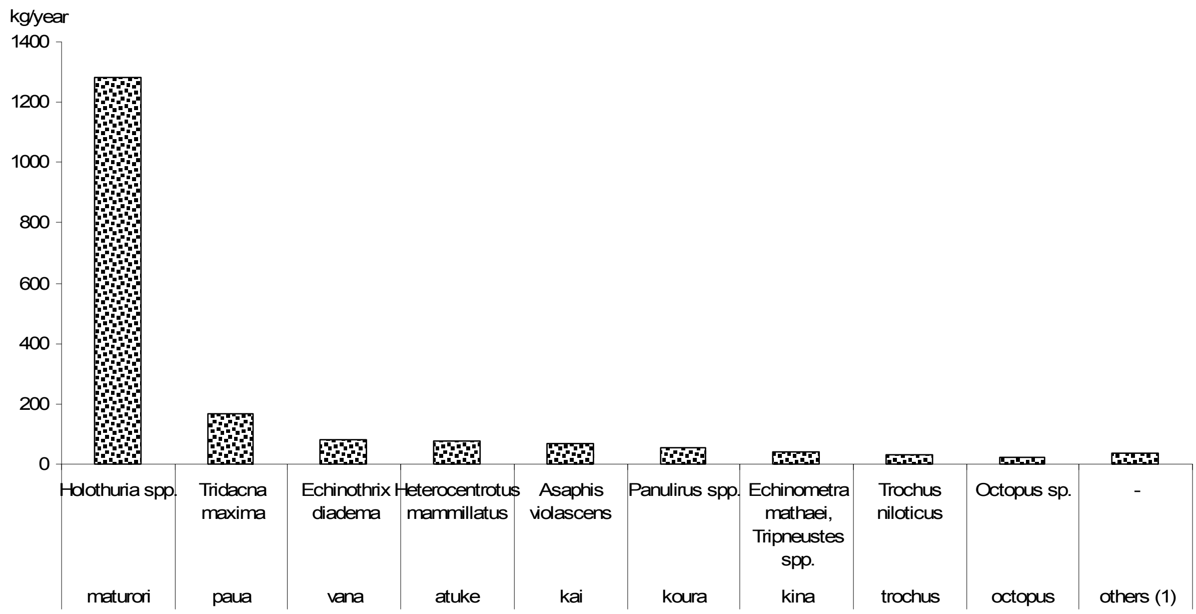


**Figure 5.15: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Rarotonga.**
(1) Others include *Turbo marmoratus*, *T. setosus* (~11 kg/year); *Dendropoma* sp. (~11 kg/year); *Dendropoma maximum*, *D.* spp., *Serpulorbis* spp. (~8 kg/year); *Tripneustes gratilla* (~5 kg/year); *Parribacus antarcticus*, *P. caledonicus* (n/a); *Vexillum* spp. (n/a) and *Scylla serrata* (n/a); n/a = no information available.

As is the case for finfish catches and confirming the fact that none of the households reported earning any income from fishing, invertebrates are exclusively collected for home consumption (Figure 5.16). This figure may include some proportion that is shared among family and community members on a non-commercial basis.

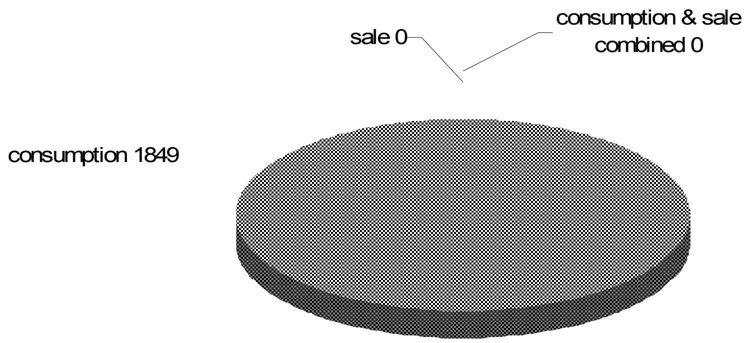


**Figure 5.16: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Rarotonga.**

As mentioned earlier, both genders participate in most fishing activities on Rarotonga. However, the few lobster fishers are all males and their productivity is low (Figure 5.17). As far as reeftop gleaning is concerned, females fishers determine the total annual impact, while males contribute only a little (~14%). Figure 5.17 suggests that female fishers' annual average catches from reeftops are much higher than those of male fishers. However, considerating the large variation (SE), the comparison only indicates that the annual catch of female reeftop gleaners may vary substantially. The seasonality of certain species, such as *matu rori*, *patito* (sea hare) and urchins may also cause certain variations in harvesting for reeftop gleaning.

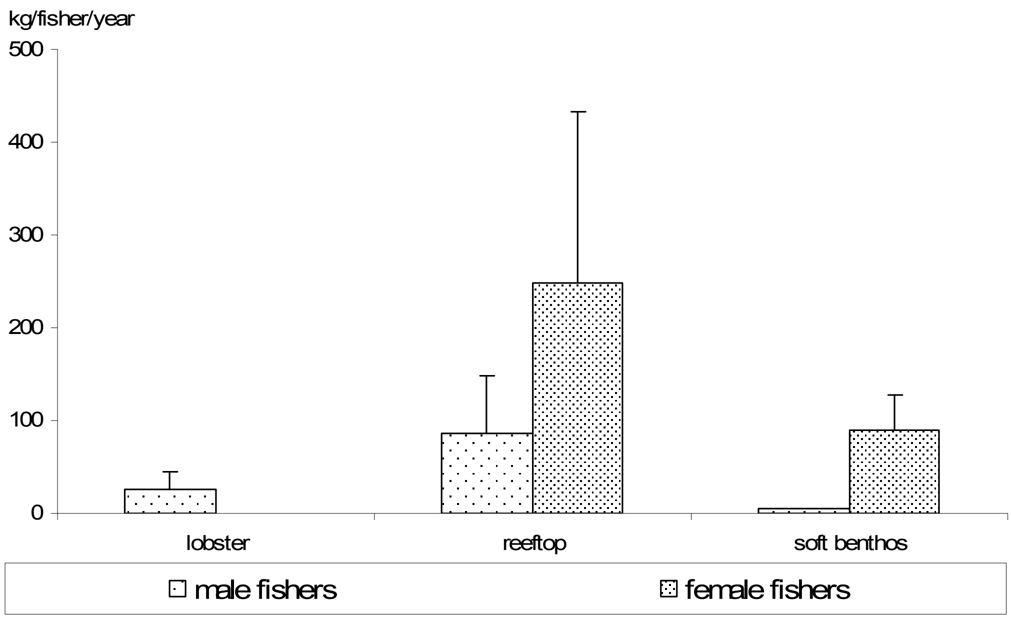


**Figure 5.17: Average annual invertebrate catch (kg wet weight/year) by fisher and gender in Rarotonga.**
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 6 for males, n = 9 for females).

Extrapolation of our survey data is somewhat restricted due to the small survey sample as compared to the total population of both communities included in the survey, i.e. 12%. This bias is magnified 10 times if taking into account Rarotonga's total population, i.e. the sample represents only 2.3% of all households surveyed (Census 2001 reports 2531 households on Rarotonga.). Resource surveys included the entire reef system of the island and, hence, the habitat areas and reef lengths presented in Table 5.4 refer to the island's total available fishing ground. Geographical distribution of the island's main reef and lagoon resources suggests, on the other hand, that both communities surveyed by the socioeconomic team have best access to most of the reef and lagoon resources. Nevertheless, it must be taken into account that the fishing ground in Rarotonga is open-access and, hence, all resources, if not under any kind of protection, are theoretically accessible by all.

Overall, all the results presented so far suggest that reef and lagoon fishing and collecting activities are practised at a very low level among Rarotongan people due to a number of reasons, including ciguatera poisoning and the urbanised lifestyle. Thus, calculations were done for both scenarios. Firstly, survey results are extrapolated to the total population of the communities surveyed only. The resulting impact assessment was done by taking into account all available reef and lagoon areas and, in the case of the lobster fishery, the total available outer-reef length. Secondly, survey results are extrapolated to the total population on Rarotonga, again using the total available reef and lagoon surface areas and outer-reef length. These figures are shown in Table 5.4.

The resulting data suggest that there is almost no current pressure on lobster resources if the total number of potential divers for lobsters are considered in relation to the total outer-reef length. The density of fishers per available km$^2$ of reef area is low in the first and moderately high in the second scenario. The highest fisher density and presumably pressure occurs if considering possible fisher densities for soft benthos, i.e. 19 fishers and 77 fishers/km$^2$ for first and second population scenarios. However, adding the average annual catch per fisher, an estimated annual impact of 1.5–6 t/km$^2$ may occur for soft benthos and 1.9–3.4 t/km$^2$ for reeftop fisheries. These figures are not as high as expected. Also, extrapolated figures for the total population of the island are likely to be overestimated given the high proportion of households living under urban rather than rural conditions that were not included in the survey. So, these figures seem to confirm the overall picture that, currently, not much fishing and collection are done in Rarotonga's reef and lagoon systems. However, the final decision as to whether these figures may or may not be detrimental depends on comparison with the resource survey results.

**Table 5.4: Parameters used in assessing fishing pressure on invertebrate resources in Rarotonga**

| Parameters | Fishery / Habitat | | |
|---|---|---|---|
| | Lobster | Reeftop | Soft benthos |
| Fishing ground area (km$^2$) | 33.7 [(3)] | 6.1 | 4.45 |
| Number of fishers (per fishery) [(1)] | 17 [76] | 64 [267] | 84 [343] |
| Density of fishers (number of fishers/km$^2$ fishing ground) | 1 [2] | 11 [44] | 19 [77] |
| Average annual invertebrate catch (kg/fisher/year) [(2)] | 26.24 (±18.74) | 176.18 (±107.56) | 78.23 (±32.07) |

Figures in brackets denote standard error; figures in square brackets have been extrapolated to cover the entire population of Rarotonga; [(1)] total number of fishers is extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only; [(3)] linear km outer reef length.

### *5.2.5 Discussion and conclusions: socioeconomics in Rarotonga*

- People in the villages surveyed frequently eat fresh fish and other seafood. These results are in accordance with the CIMRIS survey (Cahn and Tuara 2007). Results from both surveys suggest that fresh fish are consumed about twice per week. Also, the CIMRIS survey highlighted that most fresh fish consumed is either purchased or received as a gift; very little is caught. However, the CIMRIS survey did not distinguish between reef and pelagic fish. Thus, households that reported eating fish that was caught by a household may have included fish caught by trolling at the outer reef. The CIMRIS report also suggests that the percentage of fresh fish consumed on average in any of the three communities and that was caught by a member of the same household decreased from about 79% of all households interviewed in 1998 (total n = 38) to 52% in 2001 (total n = 25) and to 8% in 2006 (total n = 37).

- Reasons for the decrease in fresh-fish (and presumably also invertebrate) consumption are the deterioration of the lagoon quality, associated with a high risk of fish poisoning and, perhaps, changes in lifestyle. However, people of Rarotonga prefer reef fish and also certain invertebrates, but explained that they are less easily available and much more expensive than other protein sources.

- At the local market in town, some stands offer invertebrates prepared for sale in coconut cream (Figure 5.18) or in other traditional ways. However, the quantities marketed are low, and prices are high. As shown in Figure 5.19, a dish of raw fish is more expensive than several other meat dishes. Also, respondents of the household survey confirmed that frozen chicken and canned fish or meat are less expensive to buy and more available than fresh fish. Fresh fish can only be bought at a few fish shops, at the roadside, or at the Rarotonga market. Households further reported that relatives living on other islands may send or bring reef fish to Rarotonga; however, only very rarely.

**Figure 5.18: Locally prepared giant clam and bêche-de-mer meat in coconut cream for sale at the Rarotonga Saturday market.**


**Figure 5.19: Local prices for dishes sold at the Rarotonga Saturday market.**

- Availability and prices may explain why Rarotonga people consume much less fresh fish than the average found across all sites surveyed in Cook Islands, i.e. ~32 kg/person/year as compared to ~52 kg/person/year. Also, invertebrate consumption is extremely low (~1.4 kg/person/year edible meat), and canned fish consumption is almost as high as the average across all sites (~11 kg as compared to ~13 kg/person/year).

Taking into account the various aspects of the Rarotonga socioeconomic survey, it is concluded that:

- Rarotongan people are currently much less dependent on their reef and lagoon resources than elsewhere in the country. However, this situation is determined by health risks (ciguatera) rather than choice. Nevertheless, the change to an urbanised lifestyle and the price of various food items may also have contributed to the reduction in seafood. Most of the finfish consumed today is from commercially fished pelagic species. The proportion of reef fish imported from other islands is much lower.

- Living standards and costs on Rarotonga are high. Most households depend on salaries for income and/or social and retirement payments. No households mentioned fisheries as providing any kind of income.

- People in both communities surveyed are very aware of the fact that the quality of the lagoon system has deteriorated and that the risk of ciguatera is high. Most people also are aware of the ongoing community project to improve the lagoon quality and of the existing MPAs. However, the MPAs are mostly perceived as a venture to benefit tourism. Also, the effects of rejuvenation of stocks inside the MPAs or increased biomass are believed to spill-over into other, non-protected areas. This may be particularly valuable for the recovery of vulnerable species.

- Most respondents consider the risk of fish poisoning is too high to continue fishing. The few fishers who continue to fish target particular species that they consider of low or no risk. Accordingly, only very few species are reported for average catch rates. Overall, fishing impact is low to moderate, and much lower than expected in such a densely populated coastal area.

- For invertebrates, current fishing pressure is even lower. Data do not suggest any current pressure on lobster resources. Highest fisher density and presumably fishing pressure possibly exist for soft benthos collection; however, total annual quantities harvested are low. Again, respondents pointed out that the low catch rates and interest in collecting invertebrates is mainly due to lack of resources rather than interest. Thus, the low current fisher density and catch figures must be interpreted in response to a deteriorated and presumably decreased resource status. Urbanisation and the importance of salary-based income have opened up opportunities for greater food choices and have lowered fish and seafood consumption levels. However, the respondents' expressed interest in and preferences for reef fish and seafood highlight the fact that the poor resource status and lagoon conditions are major reasons for the currently low exploitation level.

- CoFish socioeconomic survey results support the ongoing CIMRIS pilot project's efforts to improve the lagoon conditions and its marine resources in concert between the government and communities.

## 5.3 Finfish resource surveys: Rarotonga

At 67 km², Rarotonga is the largest island in Cook Islands, located in the southwestern region of the southern group near the centre of the Cook-Austral chain of seamounts. The oval-shaped island measures 11 km in length (east to west) and has a maximum width of 8 km (north to south, Figure 5.20). It is the main population centre and administrative centre of Cook Islands.

**Figure 5.20: The island of Rarotonga.**

On this island there are two distinct reef habitats: the outer fringing reef and a small inner area in the southeast part of the island, classified as back-reef (Figure 5.21). As in Mangaia, the island experiences strong easterly winds; therefore, the sampling stations in the outer reef were restricted to the more sheltered and calmer areas in the north, west and south of the island (Figure 5.20).

Finfish resources and associated habitats were assessed in Rarotonga between 16 and 20 October 2007, from a total of 17 transects (8 back- and 9 outer-reef transects, see Figure 5.21 and Appendix 3.4.1 for transect locations and coordinates respectively).

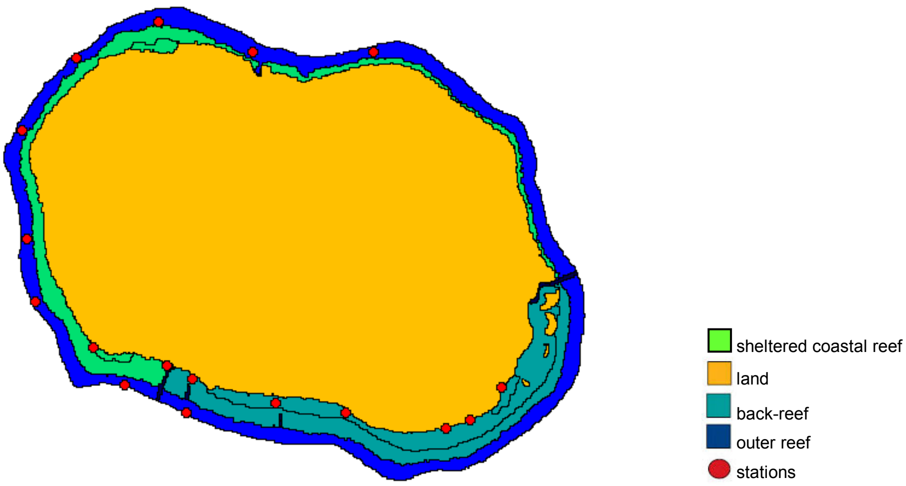


**Figure 5.21: Habitat types and transect locations for finfish assessment in Rarotonga.**

### *5.3.1 Finfish assessment results: Rarotonga*

A total of 20 families, 45 genera, 114 species and 12,500 fish were recorded in the 17 transects (See Appendix 3.4.3 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 36 genera, 104 species and 12,454 individuals.

Finfish resources differed slightly between the two reef environments found in Rarotonga (Table 5.5). The back-reef displayed higher biomass (210 g/m²), size (20 cm FL) and size ratio (64%) than the outer reef. Outer reefs had higher biodiversity (31 species/transect). Fish density was similar in the two habitats (0.9 fish/m²).

**Table 5.5: Primary finfish habitat and resource parameters recorded in Rarotonga (average values ±SE)**

| Parameters | Habitat | | |
|---|---|---|---|
| | Back-reef (1) | Outer reef (1) | All reefs (2) |
| Number of transects | 8 | 9 | 17 |
| Total habitat area ($km^2$) | 6.6 | 9.9 | 16.5 |
| Depth (m) | 1 (1-2) (3) | 9 (7-11) (3) | 6 (1-11) (3) |
| Soft bottom (% cover) | 27 ±5 | 1 ±0 | 9 |
| Rubble & boulders (% cover) | 6 ±1 | 2 ±0 | 3 |
| Hard bottom (% cover) | 44 ±6 | 79 ±3 | 67 |
| Live coral (% cover) | 20 ±4 | 7 ±2 | 13 |
| Soft coral (% cover) | 1 ±0 | 11 ±3 | 7 |
| Biodiversity (species/transect) | 23 ±4 | 31 ±2 | 27±2 |
| Density (fish/$m^2$) | 0.9 ±0.4 | 0.9 ±0.3 | 0.9 |
| Size (cm FL) (4) | 20 ±1 | 17 ±1 | 16 |
| Size ratio (%) | 64 ±3 | 58 ±3 | 59 |
| Biomass (g/$m^2$) | 210.2 ±137.0 | 120.6 ±35.8 | 113.7 |

(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.

*Back-reef environment: Rarotonga*

The back-reef environment of Rarotonga was dominated by Acanthuridae and Mullidae and, to a much lesser extent, Lethrinidae. Goatfish were more important than surgeonfish in terms of biomass (Figure 5.22). These three families were represented by 15 species; particularly high biomass and abundance were recorded for *Mulloidichthys flavolineatus*, *M. vanicolensis*, *Acanthurus triostegus*, *Ctenochaetus striatus* and *Gnathodentex aureolineatus* (Table 5.6). This reef environment presented a fairly diverse habitat with very high cover of hard bottom (44%), average cover of live coral (22%) and good cover of soft bottom (27%, Table 5.5).

**Table 5.6: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Rarotonga**

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Acanthurus triostegus* | Convict tang | 0.29 ±0.20 | 30.5 ±22.6 |
| | *Ctenochaetus striatus* | Striated surgeonfish | 0.20 ±0.07 | 22.4 ±9.9 |
| Mullidae | *Mulloidichthys flavolineatus* | Yellowstripe goatfish | 0.15 ±0.14 | 71.0 ±70.3 |
| | *Mulloidichthys vanicolensis* | Yellowfin goatfish | 0.05 ±0.04 | 40.6 ±40.5 |
| Lethrinidae | *Gnathodentex aureolineatus* | Goldlined seabream | 0.10 ±0.10 | 16.1 ±15.9 |

The density of finfish was equal to the density recorded in outer reefs. Biomass, size and size ratio were, however, higher than at outer reefs, while biodiversity was lower. When compared to the back-reefs of Aitutaki and Palmerston, Rarotonga values of density, biomass, size and size ratio were by far the highest among the sites. Biodiversity (23 species/transect) was higher than at the back-reef of Palmerston (18 species/transect) but lower than Aitutaki (29 species/transect). Trophic structure was similarly composed of herbivores and carnivores in terms of density, while carnivores dominated in terms of biomass. Acanthuridae were the main herbivores, while Mullidae and Lethrinidae were the two most important carnivore families. All size ratios were high except for Holocentridae. These back-reefs displayed a quite diverse composition of substrate, mostly hard bottom (44%) but also adequate mobile bottom (27%), offering suitable habitat for carnivores (Lethrinidae but especially Mullidae) as well as herbivore fish species.

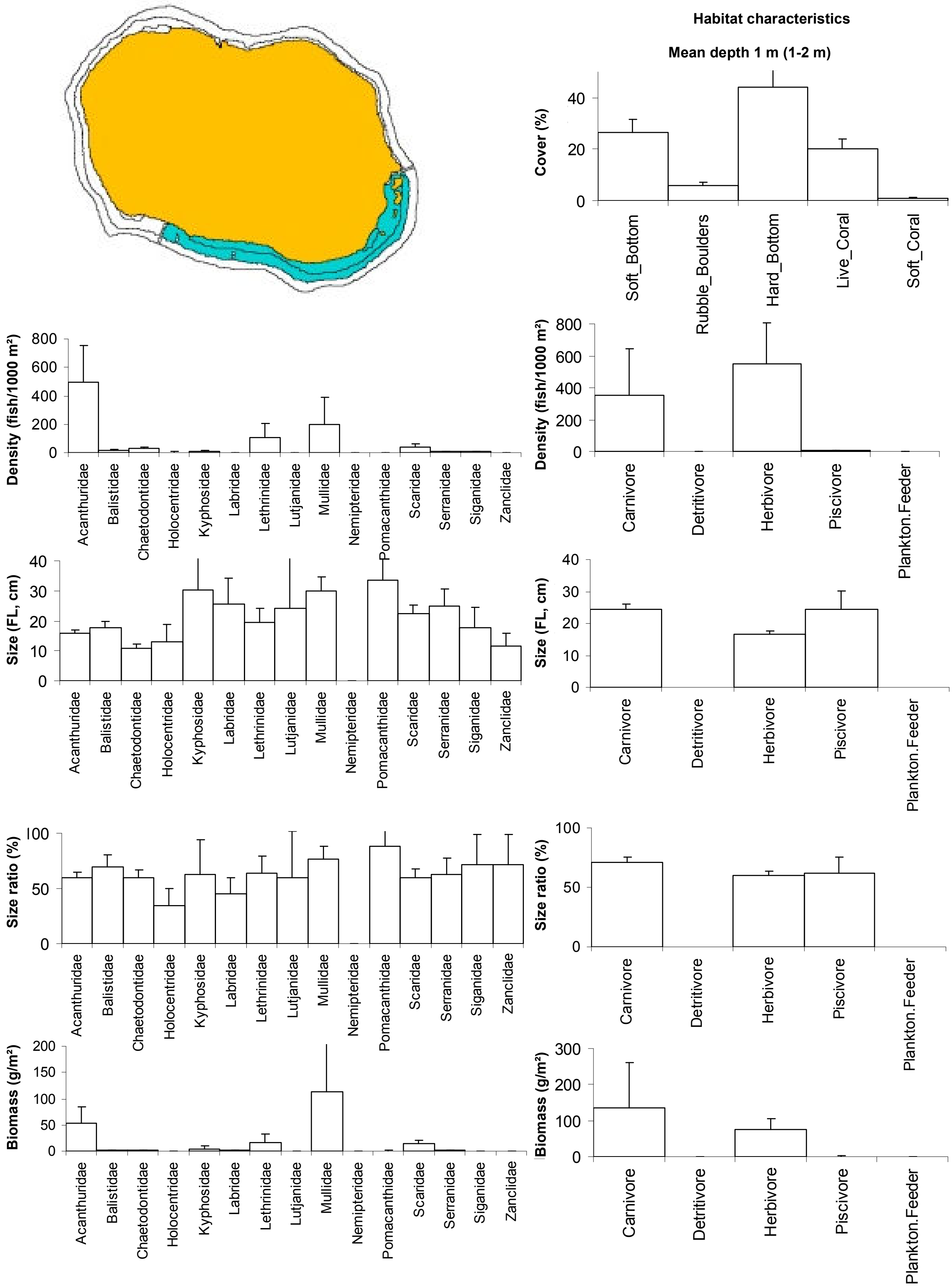


**Figure 5.22: Profile of finfish resources in the back-reef environment of Rarotonga.**
Bars represent standard error (+SE); FL = fork length.

*Outer-reef environment: Rarotonga*

The outer reef of Rarotonga was largely dominated by herbivorous Acanthuridae, with very few other fish (Figure 5.23). This family was represented by 14 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Naso lituratus*, *Acanthurus triostegus*, *A. leucopareius* and *A. olivaceus* (Table 5.7). Most of the substrate was hard bottom (79%) and only very little live coral was present (7%). Soft-coral cover was more important (11%) (Table 5.5 and Figure 5.23).

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

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.54 ±0.22 | 62.4 ±26.0 |
| | *Naso lituratus* | Orangespine unicornfish | 0.03 ±0.02 | 13.9 ±9.6 |
| | *Acanthurus triostegus* | Convict tang | 0.12 ±0.10 | 10.7 ±8.6 |
| | *Acanthurus leucopareius* | Whitebar surgeonfish | 0.07 ±0.03 | 6.66 ±4.1 |
| | *Acanthurus olivaceus* | Orangeband surgeonfish | 0.01 ±0.01 | 3.3 ±2.5 |

Fish size, size ratio and biomass in the outer reef were lower than the back-reef values. Density was equivalent in the two habitats. Biodiversity was higher in the outer reefs (31 versus 23 species/transect), but the lowest among the four country sites' outer reefs. When comparing the other biological parameters among the four sites, the density and biomass of fish in the outer reefs of Rarotonga displayed the second-highest values of density and biomass, lower only than the Aitutaki values, and the highest values of size and size ratio. Average size ratios for individual families were high, always above 50% of the maximum value for all families. Substrate composition was heavily dominated by hard bottom, with very little live coral, normally favouring herbivores, particularly browsing surgeonfish.

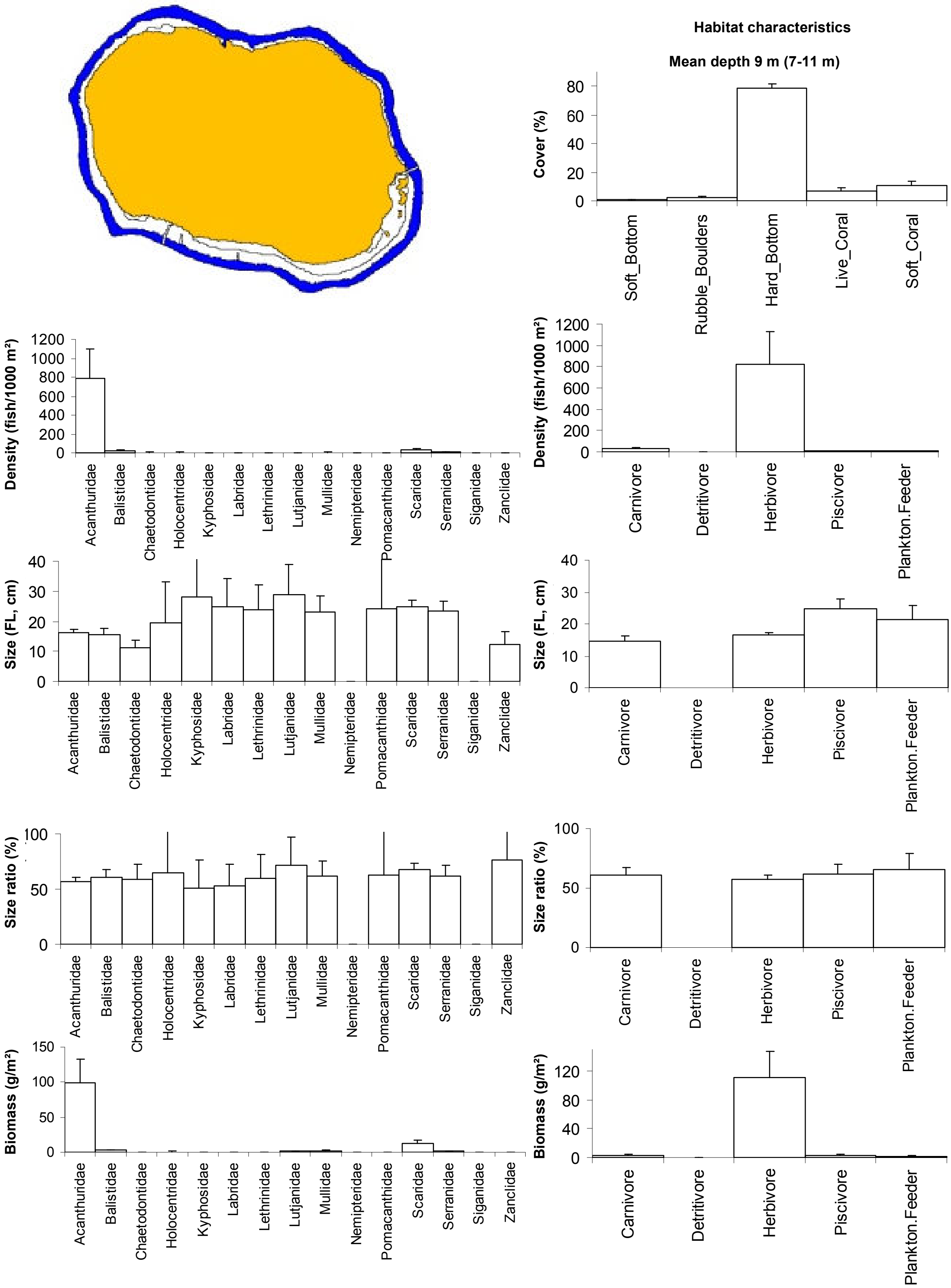


**Figure 5.23: Profile of finfish resources in the outer-reef environment of Rarotonga.**
Bars represent standard error (+SE); FL = fork length.

*Overall reef environment: Rarotonga*

Overall, the fish assemblage of Rarotonga was dominated by four main families: herbivorous Acanthuridae, in terms of density and biomass and, to a lesser extent, herbivore Scaridae and carnivore Mullidae and Lethrinidae, though mainly for biomass (Figure 5.24). These four most abundant families were represented by a total of 39 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Mulloidichthys flavolineatus*, *Acanthurus triostegus*, *M. vanicolensis*, *Naso lituratus*, *Gnathodentex aureolineatus*, *A. leucopareius*, *Scarus psittacus* and *Chlorurus sordidus* (Table 5.8). The average substrate at this site was strongly dominated by hard bottom (67%), with limited cover of live coral (13%) and a smaller proportion of mobile bottom (12%). The overall fish assemblage in Rarotonga shared characteristics of outer reefs (60% of total habitat) and back-reefs (40%).

**Table 5.8: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Rarotonga (weighted average)**

| Family | Species | Common name | Density (fish/m$^2$) | Biomass (g/m$^2$) |
|---|---|---|---|---|
| Acanthuridae | *Ctenochaetus striatus* | Striated surgeonfish | 0.403 | 46.3 |
| | *Acanthurus triostegus* | Convict tang | 0.189 | 18.7 |
| | *Naso lituratus* | Orangespine unicornfish | 0.020 | 8.5 |
| | *Acanthurus leucopareius* | Whitebar surgeonfish | 0.040 | 4.0 |
| Lethrinidae | *Gnathodentex aureolineatus* | Goldlined seabream | 0.042 | 6.5 |
| Mullidae | *Mulloidichthys flavolineatus* | Yellowstripe goatfish | 0.058 | 28.5 |
| | *Mulloidichthys vanicolensis* | Yellowfin goatfish | 0.018 | 16.3 |
| Scaridae | *Scarus psittacus* | Common parrotfish | 0.009 | 3.8 |
| | *Chlorurus sordidus* | Daisy parrotfish | 0.011 | 2.3 |

Overall, Rarotonga appeared to support a fairly good finfish resource, with highest density (0.9 fish/m$^2$), biomass (98 g/m$^2$), and size ratio (59%) in the country. Biodiversity was, however, the lowest recorded among the four sites (27 species/transect versus 36 species/transect in Aitutaki). Detailed assessment at the family level confirmed a low diversity of the fish community, composed mostly of Acanthuridae and, to a much lesser extent, Mullidae, Scaridae and Lethrinidae. Acanthuridae were very abundant in number but were represented by small-sized species. Trophic composition in terms of density was heavily dominated by herbivores, advantaged by the type of substrate, mainly bare rock. However, carnivores were more important in terms of biomass. Overall, size ratios were above the 50% threshold for all families. Fishing for reef fish is hardly practised in Rarotonga due to the serious problem with ciguatera, which affects many species. Therefore, abundance of fish is high and resources almost intact.

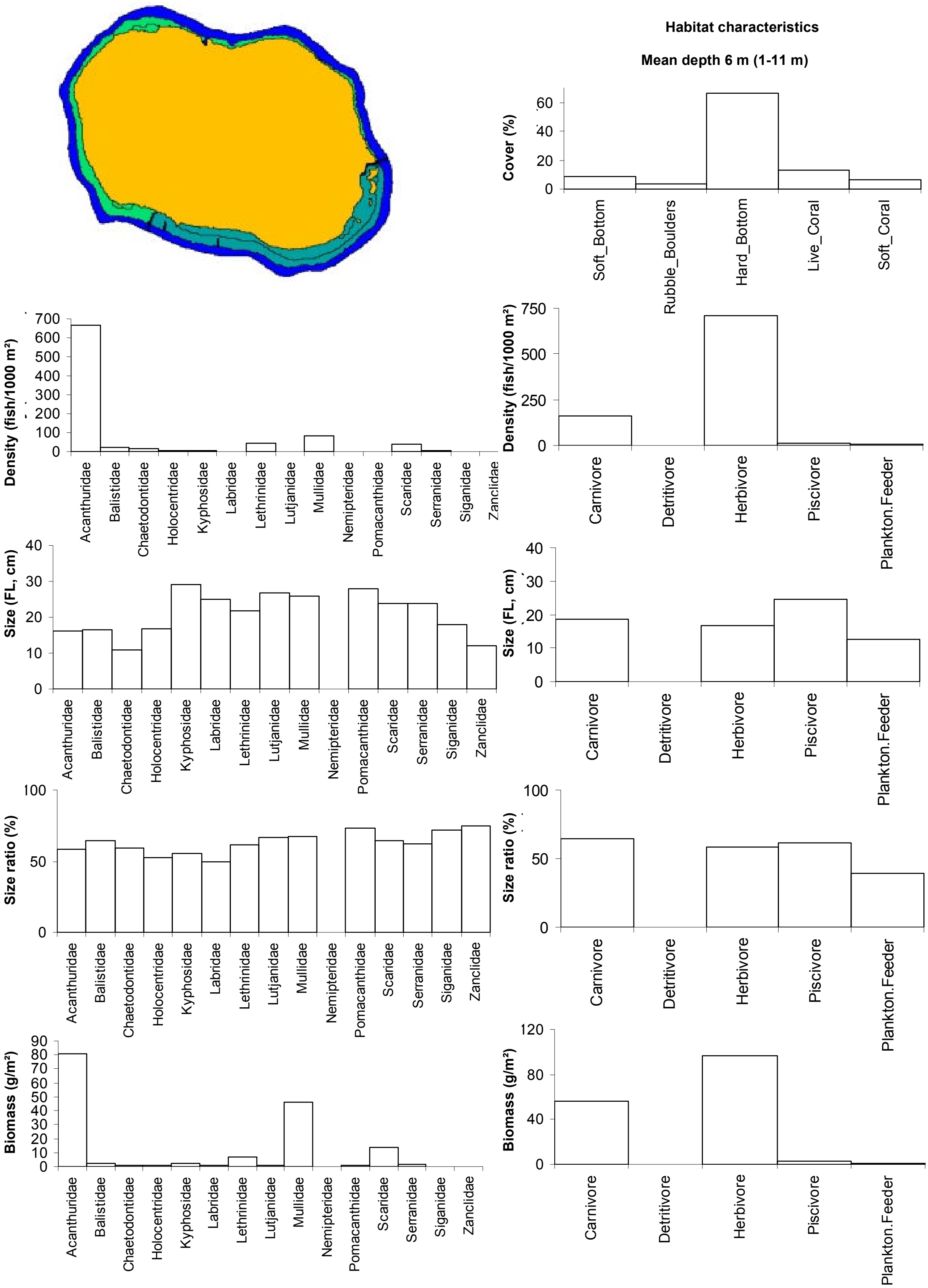


**Figure 5.24: Profile of finfish resources in the combined reef habitats of Rarotonga (weighted average).**
FL = fork length.

### *5.3.2 Discussion and conclusions: finfish resources in Rarotonga*

- All reef fish around Rarotonga are ciguatoxic so almost no reef fish are eaten or fished for consumption. The most heavily affected area is the east and southeast part of the island. Fish density and biomass were higher than at similar sites in the country, surpassed only by the values in Aitutaki. However, biodiversity in Rarotonga was particularly low in both back-reefs and outer reefs, most probably due to the natural poverty of the reef condition, made of coral slab and very little live coral.

- Overall, Rarotonga finfish resources appeared to be in good condition. The reef habitat was very poor in the outer reef and supported primarily surgeonfish (Acanthuridae) in high abundance. The back-reef environment was slightly healthier and supported higher concentrations of fish; however, species diversity was low.

- The trophic community was mainly composed of herbivores but carnivores were more important in the back-reefs, where soft bottom was available and Mullidae were relatively abundant.

- Ciguatera fish poisoning, which has become more serious in the past 10 years, is limiting fishing to a few species and for personal use only. Fishing is changing targets from reef fish to pelagic species. This is the reason why fish abundance and biomass at this site are relatively high and fishing pressure, as well as impact, is low.

## 5.4 Invertebrate resources: Rarotonga

The diversity and abundance of invertebrate species at Rarotonga were independently determined using a range of survey techniques (Table 5.9): broad-scale assessment (using the ‘manta tow’; locations shown in Figure 5.25) and finer-scale assessment of specific reef and benthic habitats (Figures 5.26 and 5.27).

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 assessments were conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

**Table 5.9: Number of stations and replicate measures completed at Rarotonga**

| Survey method | Stations | Replicate measures |
|---|---|---|
| Broad-scale transects (B-S) | 10 | 60 transects |
| Reef-benthos transects (RBt) | 13 | 78 transects |
| Soft-benthos transects (SBt) | 0 | 0 transect |
| Soft-benthos infaunal quadrats (SBq) | 0 | 0 quadrat group |
| Mother-of-pearl transects (MOPt) | 5 | 30 transects |
| Mother-of-pearl searches (MOPs) | 1 | 6 search periods |
| Reef-front searches (RFs) | 4 | 24 search periods |
| Reef-front search by walking (RFs_w) | 0 | 0 search period |
| Sea cucumber day searches (Ds) | 4 | 24 search periods |
| Sea cucumber night searches (Ns) | 2 | 12 search periods |

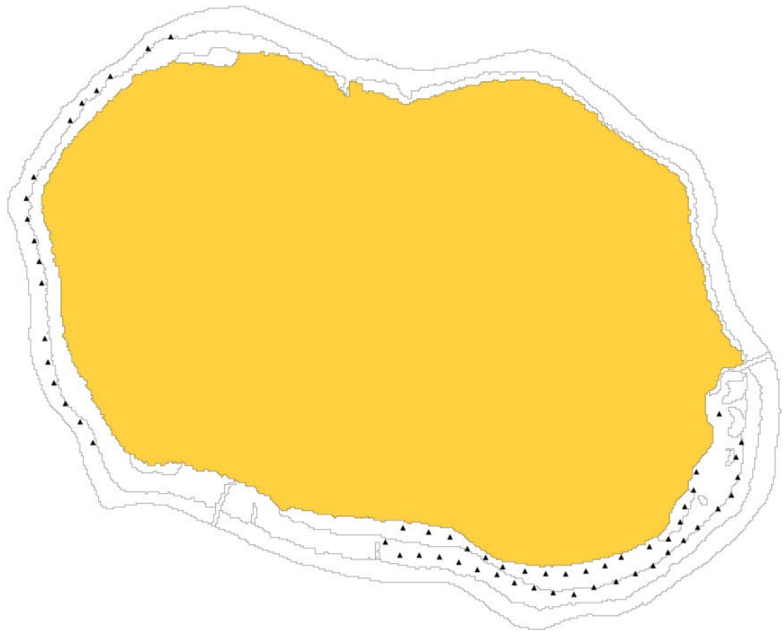

**Figure 5.25: Broad-scale survey stations for invertebrates in Rarotonga.**
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

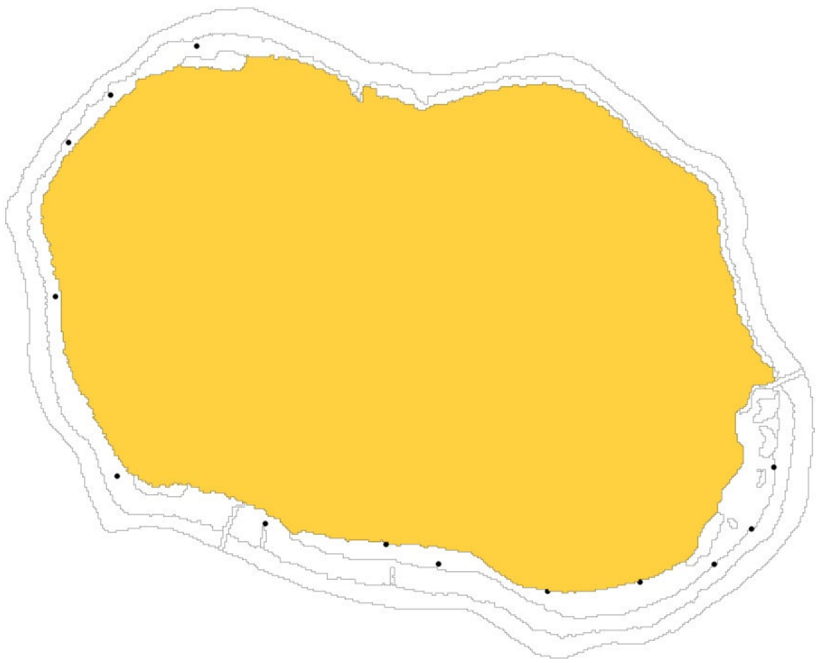

**Figure 5.26: Fine-scale reef-benthos transect survey stations for invertebrates in Rarotonga.**
Black circles: reef-benthos transect stations (RBt).

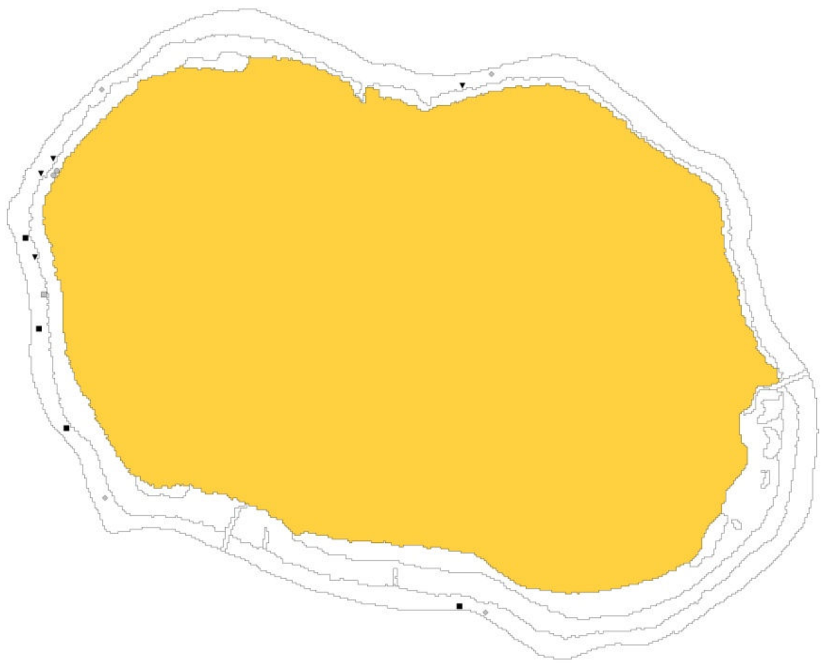

**Figure 5.27: Fine-scale survey stations for invertebrates in Rarotonga.**
Inverted black triangles: reef-front search stations (RFs);
black diamonds: reef-front search by walking stations (RFs_w);
grey squares: mother-of-pearl search stations (MOPs);
grey diamonds: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Thirty-six species or species groups (groups of species within a genus) were recorded in the Rarotonga invertebrate surveys. Among these were 5 bivalves, 11 gastropods, 7 sea cucumbers, 6 urchins, 3 sea stars, 1 cnidarian and 2 crustaceans (Appendix 4.4.1). Information on key families and species is detailed below.

### *5.4.1 Giant clams: Rarotonga*

Shallow reef habitat that is suitable for giant clams was not extensive at Rarotonga (16 km$^2$: ~6.1 km$^2$ of shallow reef inside the lagoon and 9.1 km$^2$ on the reef crest or slope). In the northeast quarter of the island there is no lagoon, only a narrow fringing reef. In the southeast quarter there is a shallow lagoon reaching a maximum of ~700 m in width. The remainder of the reef (the western part) is made of a shallow reef, with some pools.

The high-island environment influences the reef system, and riverine inputs are notable closer to shore. A full range of habitats extends seawards, and water movement is generally most dynamic in the northeast quarter of the island and around the small passages in the south, while the western reef and lagoon is more protected.

Using all survey techniques, only the elongate clam *Tridacna maxima* was noted. The fluted clam *Tridacna squamosa*, which has been noted in deeper water at other sites in the Cook Islands, was not noted in these surveys. Broad-scale sampling provided a good overview of the distribution and density of *T. maxima* on the western reef slope, as well as inside the southern lagoon. Records from broad-scale sampling revealed that *T. maxima* was relatively sparsely distributed and at a low density (recorded at 7/10 stations and 26/60 transects, a total of 55 specimens; see Figure 5.28).

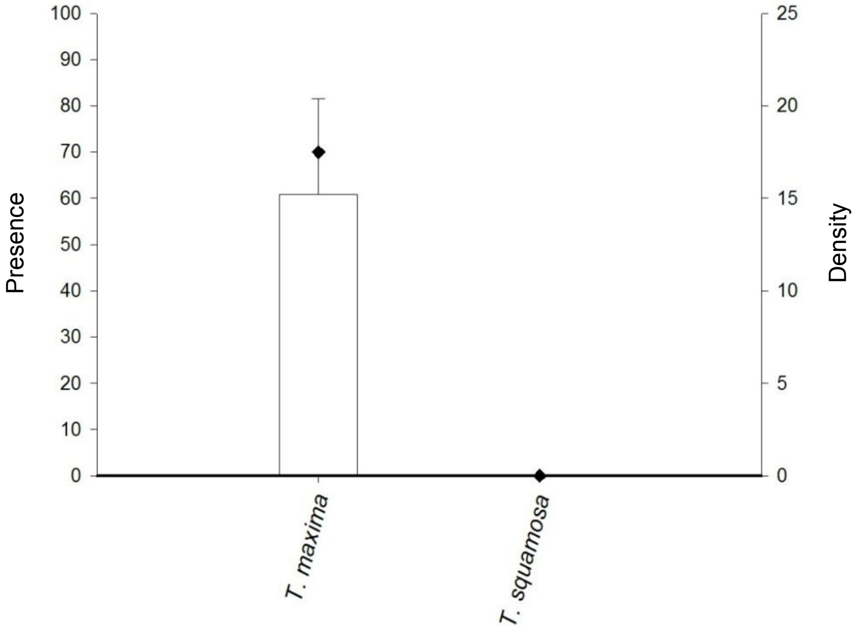


**Figure 5.28 Presence and mean density of giant clam species in Rarotonga based on broad-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Finer-scale surveys (RBt) targeted specific areas of clam habitat. In these reef-benthos assessments, mostly near the reef platform at low tide, *T. maxima* was present in 92% (12/13) of stations, with an average density of 208.3 /ha ±42.2. The station with the highest density of this small clam was on the shallow reef platform and held *T. maxima* at 500 /ha. The outer-reef slope did not hold a significant abundance of larger broodstock clams, with very few giant clams recorded (mean density 8.3 /ha in MOPt stations).

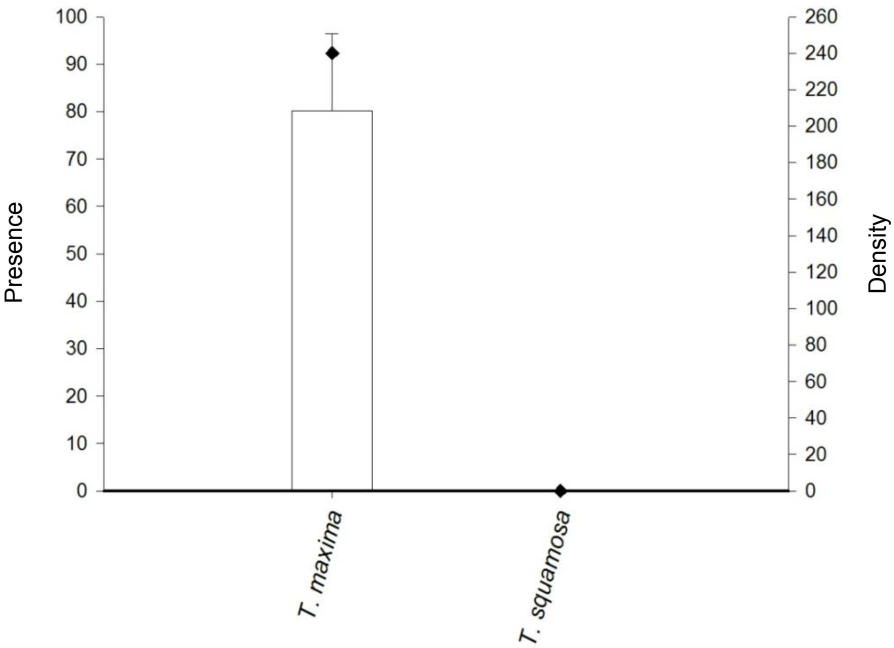


**Figure 5.29: Presence and mean density of giant clam species in Rarotonga based on fine-scale survey.**
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

The mean size of *T. maxima* was small at 9.1 cm ±0.5, but a full range of clam sizes was recorded in survey (n = 77 clams measured). *T. maxima* clams recorded in reef-benthos transect stations alone (mostly on shallow-water reef platform) were slightly smaller, with a mean size of 8.1 cm ±0.5 (n = 61).

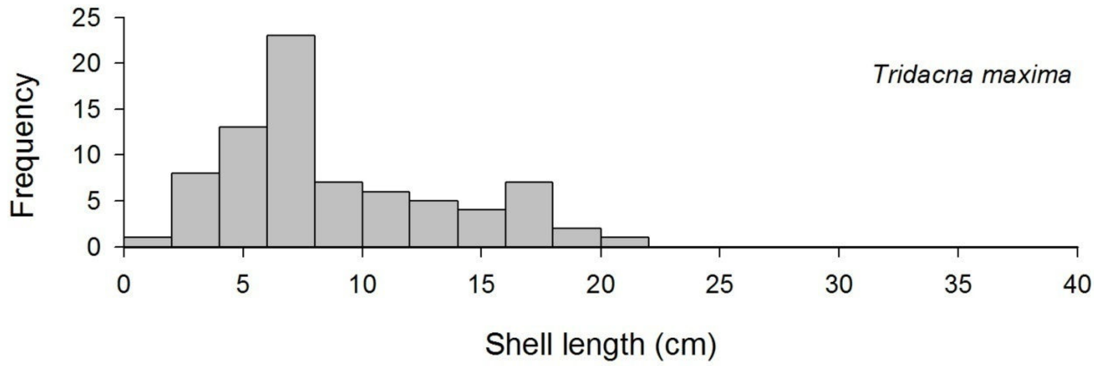


**Figure 5.30: Size frequency histogram of giant clam shell length (cm) for Rarotonga.**

### *5.4.2 Mother of pearl species (MOP) – trochus and pearl oysters: Rarotonga*

Cook Islands is not within the natural distribution range of the commercial topshell *Trochus niloticus* in the Pacific. This species was introduced by the Cook Island fishery department (MMR) to Rarotonga between 1981 and 1983 through the movement of 200 trochus from Aitutaki (The original stock was translocated from Fiji.). The first commercial harvest of trochus at Rarotonga was in 2000.

**Table 5.10: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Rarotonga**
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 | 2.8 | 1.1 | 5/10 = 50 | 6/60 = 10 |
| RBt | 1682.7 | 969.4 | 8/13 = 62 | 28/78 = 36 |
| RFs | 2.9 | 1.0 | 3/4 = 75 | 3/24 = 13 |
| MOPt | 416.7 | 141.0 | 5/5 = 100 | 28/30 = 93 |
| Ds | 22.6 | 9.6 | 4/4 = 100 | 15/24 = 63 |
| ***Tectus pyramis*** | | | | |
| | None recorded | | | |
| ***Pinctada margaritifera*** | | | | |
| B-S | 0.3 | 0.3 | 1/10 = 10 | 1/60 = 2 |
| RBt | | | 0/13 = 0 | 0/78 = 0 |
| RFs | | | 0/4 = 0 | 0/24 = 0 |
| MOPt | | | 0/5 = 0 | 0/30 = 0 |
| Ds | | | 0/4 = 0 | 0/24 = 0 |

B-S = broad-scale survey; RBt = reef-benthos transect; RFs = reef-front search; MOPt = mother-of-pearl transect; Ds = sea cucumber day search.

The habitat suitable for trochus was considered quite good on Rarotonga, with an extensive barrier reef crest and back-reef, and some shallow-water shoaling on the reef slope. CoFish work surveyed all reef zones to ascertain the distribution and density of trochus. Usually, in addition to standard broad-scale and shallow reef surveys, trochus information is collected using reef-front searches and mother-of-pearl transects (MOPt). If too few trochus are present, the dive team resorts to mother-of-pearl searches (MOPs), which allow a more comprehensive coverage of the bottom, without the need to conform to the linearity of strip transects (See Methods and Table 5.10.).

The overall densities observed in RBt and dedicated MOPt stations were among the highest recorded across CoFish sites in the Pacific. The densities recorded vary a lot from station to station and demonstrate the patchiness of the resource (Presence was recorded in 62% of RBt stations.). The density of the trochus population living on the shallow back-reef was greatest at the northwest quarter of the island (At two RBt stations density reached almost one specimen per m².), while large adults were mostly recorded at depth in the west and south.

The vertical distribution (depth profile) of the trochus population was quite different from what has been observed at many other sites visited. There were almost no trochus recorded in the surf zone or between the surface and 10 m depth. In this case, a population of large specimens was recorded, mostly living below 10 m depth and mostly between 12 and 15 m. It is interesting to note that in sea cucumber day search stations (Ds), we recorded a density of 22.6 ± 9.6 trochus/ha, while the average depth for these stations was 25.2 m. As this shows, trochus were routinely noted at depth, with the deepest trochus noted at 30.1 m. This is the deepest live specimen of trochus recorded across our CoFish/PROCFish surveys to date.

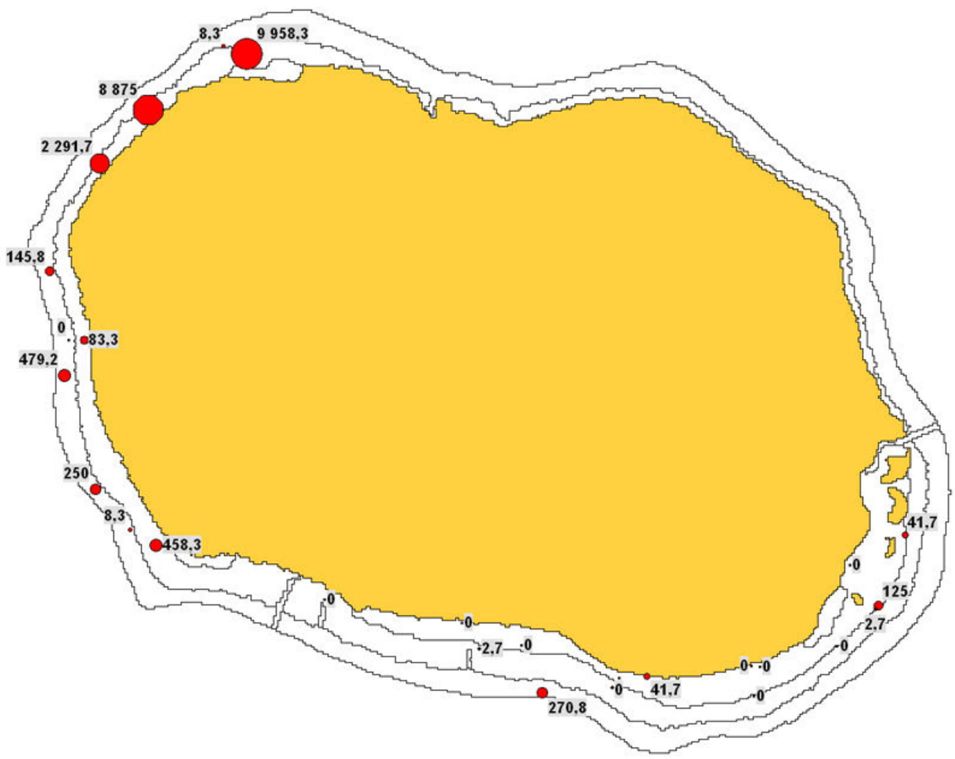


**Figure 5.31: Trochus (*Trochus niloticus*) density (individuals per ha) recorded in B-S, RBt and MOPt station surveys in Rarotonga.**

The shell sizes also give important information on the status of stocks by highlighting new recruitment into the fishery or the lack of recruitment, which could have implications for the numbers of trochus entering the capture size classes in the following two years (Figure 5.32).

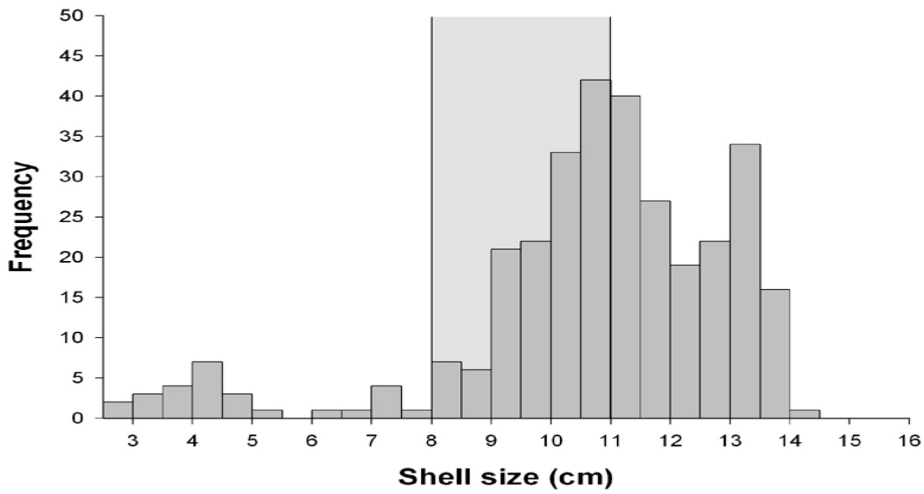


**Figure 5.32: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Rarotonga.**
The legal shell size classes fall into the grey band (8–11 cm).

Overall, 676 *Trochus niloticus* were noted during the survey. Of the 317 which were measured (mean size 10.8 cm ±0.1), 41% were from legal size classes (8–11 cm), and fully 50.1% of the stock was 'over-size' (>11 cm basal width).

This size profile describes a stock dominated by older shells, which has good implications for the 'success' of the fishery. The long closure of the fishery (The last harvest, in 2003, was 6.4 t from Nikao, and 9.5 t from Takitumu.) has allowed a large amount of the stock to reach protected size classes. However, unlike in Aitutaki, there is some indication that recruitment pulses are still arriving (The smaller number of shell recordings <6 cm are probably an underestimate of this proportion, because these small shells are very cryptic.). Nevertheless, recruitment of shells smaller than the legal-sized and smaller legal-sized trochus does not show very successful cohorts from spawning between 2004 and 2005 (The years 2002, 2004 and 2006 had extra-warm episodes over the summer, based on a threshold of +0.5°C for the Oceanic Niño Index.).

In fishery terms, it is important to maintain older, larger trochus as part of the population, as they provide by far the largest input of gametes for future generations (A 10 cm shell produces ~2 million eggs, whereas a 13 cm shell produces three times as many, i.e. ~6 million eggs.). However, some early researchers, e.g. Asano (1963), suggested that this proportion of the stock must not become 'too' dominant and that it was better for the productivity of the fishery to fish the stock periodically, maintaining a number of large shells, but not letting them build up to become the dominant size class of the population. This is due to the fact that, although larger shells need to be in high density for successful reproduction, they can also dominate the best trochus habitat, using available food sources for the maintenance rather than production of new nacre.

The other common mother-of-pearl shell, the green topshell (*Tectus pyramis*) was not recorded. Only one specimen of the blacklip pearl oyster (*Pinctada margaritifera*) was recorded.

### *5.4.3 Infaunal species and groups: Rarotonga*

Soft benthos at the coastal margins of Rarotonga was not suitable for 'shell beds' and no concentrations of arc (*Anadara* spp.) or venus (*Gafrarium* spp.) shells were noted. Therefore, no infaunal 'digging' stations (quadrat surveys) were completed at Rarotonga.

### *5.4.4 Other gastropods and bivalves: Rarotonga*

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs) was only found on the reef slope in the south during deeper-water surveys (Ds), where it reached a reasonably high density (mean density 50 /ha, average length 25.5 cm ±0.4). Other spider shells were rare (*Lambis chiragra* was recorded twice, average length 16.3 cm ±0.2.). No strawberry or red-lipped conch (*Strombus luhuanus*) was present. This species has been previously listed as absent from Cook Islands (Bishop Museum 2008) (Appendices 4.4.1 to 4.4.7).

One species of turban shell, the rough turban (*Turbo setosus*) was recorded during surveys at low density at the reef crest (its normal habitat). In RFs and MOP stations, these shells were recorded at average densities of 10.8 and 7.6 /ha, respectively. The low density of this species highlights the vulnerability of these types of stocks to gleaning when conditions are suitable. Increased management intervention of this food resource would yield greater recruitment and productivity. A moratorium of several years or the designation of small reserve areas could be considered to allow time for stocks to rebuild.

One gastropod species typically targeted for subsistence in Cook Islands is the operculate worm shell *Dendropoma maxima*. As they are often at very high density and within folds and crevices on the tops and sides of coral structures (with often only the operculum visble), it is not generally realistic to attempt to count them in multi-species assessments. However, an attempt at recording this species was made in Rarotonga, as they were at relatively low density. On broad-scale assessment, the density was roughly estimated as 272.5 /ha ±188.9. On the reef flat (RBt stations), the average density was similar at 288.5 /ha ±104.8. Greatest density was noted on the reef slope, where access for fishers was more difficult.

Other resource species targeted by fishers (e.g. *Cerithium*, *Charonia*, *Conus*, *Cypraea* and *Thais*) were also recorded during independent surveys (Appendices 4.4.1 to 4.4.7).

### *5.4.5 Lobsters: Rarotonga*

There was no dedicated night reef-front assessment of lobsters (See Methods.). However, one female *Panulirus penicillatus* was recorded at the surf zone in a western RFs station. No prawn killer (*Lysiosquillina maculata*) burrows were noted in Rarotonga.

### *5.4.6 Sea cucumbers[13]: Rarotonga*

Around Rarotonga the area of shallow- and deep-water lagoon was limited (total surface of lagoon and reef flat of 10.6 km²). Lagoon habitat was restricted to the south of the island and

[13] 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.

the depth of this protected area never exceeded 4 m, except in the channels of the small passages. In addition some mangroves existed but were very limited in area. The land mass of Rarotonga (total land area 67.6 km$^2$) influences the coastal habitat to some extent with riverine (allochthonous) inputs. Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers, which are mostly deposit feeders) were not extensive throughout the lagoon. Sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates, and the exposed nature of many of the environments around Rarotonga were not ideal for many species.

Sea cucumber species' presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.11, Appendices 4.4.2 to 4.4.7; see also Methods). Results from the full range of assessments yielded seven commercial species of sea cucumber (Table 5.11).

Sea cucumber species associated with more sheltered areas of shallow reef, such as the medium commercial value leopardfish (*Bohadschia argus*), were absent at this relatively dynamic site. High-value black teatfish (*Holothuria nobilis*), a species that is easily targeted by commercial fishing, was rare but still noted in few surveys (recorded in 8% of RBt stations, n = 4 specimens, recorded inside the lagoon and on the reef slope).

Sea cucumber species especially associated with reef crests, such as the medium commercial value surf redfish (*Actinopyga mauritiana*), was well distributed all around the island (recorded in 38% of RBt and 100% of RFs stations), at moderate density (average of 131.4 ±85.7 and 111.8 /ha ±33.5 in RBt and RFs stations respectively).

The medium/high-value species greenfish (*Stichopus chloronotus*) was recorded in all assessments. Unlike in Mangaia, where it was absent, this species was commonly distributed (found in 63% of broad-scale transects, 80–92% of RBt and MOPt stations) and even recorded regularly at depth (75% of Ds stations). The density was low at depth (Ds station average density 8.3 /ha ±14.6) and greatest at more protected inner-reef stations (1407.1 /ha ±984.4 at RBt stations).

The lollyfish (*Holothuria atra*), one of the lower-value species of sea cucumbers, was also well distributed (found in 75% of broad-scale survey transects, 100% of RBt stations) and was also noted at depth (found in 100% of Ds stations on the reef slope). Predictably, it was recorded at highest density in shallow water (average density 10,772.4 /ha for RBt stations). *Holothuria atra*, *H. cinerascens*, *H. leucospilota* and *H. pervicax* are all low-value species that have been fished for local consumption in Cook Islands. Only the first three were recorded in Rarotonga, with *H. cinerascens*, locally called *rori pua*, mostly found in areas with strong water movement. It was present in 23% of the reef-benthos transects at an average density of 105.8 /ha. The more widespread *H. leucospilota* was broadly distributed (recorded in 55% of broad-scale transects, 85% of RBt stations) and recorded at higher average density (812.8 /ha ±190.6 and 6782.1 /ha ±1904.9, in broad-scale and RBt stations respectively).

Unfortunately, no high-value sandfish *H. scabra* were found in Rarotonga. This is understandable considering the lack of available habitats and the easterly location of the Cook archipelago in the Pacific (We have not recorded sandfish east of Wallis Island.). The low-value false sandfish (*Bohadschia similis*), which uses the same habitat as sandfish, was also absent.

Deep-water assessments (24 five-minute search periods, average depth 25 m, maximum depth 32 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and elephant trunkfish (*H. fuscopunctata*). These assessments were only done on the outer slope, because the lagoon was too shallow. Unfortunately, no high-value *H. fuscogilva* were recorded. Among the more commonly recorded species, only the high-value species *T. ananas* was recorded, and it was well distributed (recorded in 100% of sea cucumber deep dives and 60% of MOPt stations). It was found at moderate density on the reef slope (average density 39.9 /ha ±14.6 on Ds). In a similar result to that given by surveys at Mangaia, the *T. ananas* recorded in Rarotonga were quite small in size, at an average length of 35.7 cm. No *T. anax* or *H. fuscopunctata* were recorded.

### *5.4.7 Other echinoderms: Rarotonga*

At Rarotonga, the edible collector urchin (*Tripneustes gratilla*) and slate urchins (*Heterocentrotus* spp.) were recorded in survey. Collector urchins were common on shallow-water reefs (recorded in 69% of RBt stations) and often at high density (especially in the southeast of the lagoon close to the back-reef, where two stations had average densities of ~1500 /ha). *Heterocentrotus* spp. (mainly *Heterocentrotus trigonarius*) were seen at high density on the surf-impacted reef crest and were also recorded in moderate density during reef-front searches (821.6 /ha ±239.7).

Urchins such as *Echinothrix* spp. (mostly *Echinothrix diadema*) were also common (recorded in all reef-front searches and 62% of RBt stations) and could be found at an average station density reaching 3167 /ha. *Echinometra mathaei* were also very common (n ≥65,000 individuals) and recorded at high densities (reaching in some stations almost 10 specimens/m²) on the outer-reef slope as well as on shallow inner reefs (Appendices 4.4.2 to 4.4.9).

Starfish, e.g. those of the genus Linckia (e.g. the blue starfish *Linckia laevigata* and *L. guildingi*) were present in small numbers (170 specimens) but at relatively high average density on the inner reef (131.4 /ha ±47.4 at RBt stations). Corallivore (coral eating) starfish were rare, with only one individual pincushion star (*Culcita novaeguineae*) and two crown-of-thorns (*Acanthaster planci*) noted in survey.

**Table 5.11: Sea cucumber species records for Rarotonga**

| Species | Common name | Commercial value [5] | B-S transects n = 60 | | | Reef-benthos stations n = 13 | | | Other stations RFs = 4; MOPs = 1; MOPt = 5 | | | 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 | 8.1 | 43.9 | 18 | 131.4 | 341.7 | 38 | 111.8<br>15.2 | 111.8<br>15.2 | 100 RFs<br>100 MOPs | 106.7 | 106.7 | 100 Ns |
| *Bohadschia argus* | Leopardfish | M | | | | | | | | | | | | |
| *Holothuria atra* | Lollyfish | L | 3179.5 | 4239.4 | 75 | 10,772.4 | 10,772.4 | 100 | 33.3 | 55.6 | 60 MOPt | 395.6<br>48.8 | 395.6<br>48.8 | 100 Ns<br>100 Ds |
| *Holothuria cinerascens* | | L | 1.1 | 31.8 | 3 | 105.8 | 458.3 | 23 | | | | 44.1 | 44.1 | 100 Ns |
| *Holothuria fuscogilva* [4] | White teatfish | H | | | | | | | | | | | | |
| *Holothuria hilla* | | L | 0.8 | 16.5 | 5 | 201.9 | 291.7 | 69 | | | | | | |
| *Holothuria impatiens* | | L | | | | 38.5 | 100.0 | 38 | | | | 66.7 | 66.7 | 100 Ns |
| *Holothuria leucospilota* | | L | 812.8 | 1477.8 | 55 | 6782.1 | 8015.2 | 85 | 8.3 | 41.7 | 20 MOPt | 871.1 | 871.1 | 100 Ns |
| *Holothuria nobilis* [4] | Black teatfish | H | | | | 6.4 | 83.3 | 8 | 4.2 | 20.8 | 20 MOPt | 4.4 | 8.9 | 50 Ns |
| *Holothuria pervicax* | | L | | | | 48.1 | 125.0 | 38 | | | | | | |
| *Stichopus chloronotus* | Greenfish | H/M | 161.6 | 255.2 | 63 | 1407.1 | 1524.3 | 92 | 1.0<br>15.2<br>412.5 | 3.9<br>15.2<br>515.6 | 25 RFs<br>100 MOPs<br>80 MOPt | 17.8<br>8.3 | 35.6<br>11.1 | 50 Ns<br>75 Ds |
| *Stichopus hermanni* | Curryfish | H/M | | | | | | | | | | | | |
| *Stichopus horrens* | Peanutfish | M/L | | | | | | | | | | | | |
| *Stichopus monotuberculatus* | | L/M | | | | 102.6 | 166.7 | 62 | | | | 240.0 | 240.0 | 100 Ns |
| *Synapta* spp. | | L | | | | | | | | | | | | |
| *Thelenota ananas* | Prickly redfish | H | 0.5 | 16.1 | 3 | 6.4 | 41.7 | 15 | 16.7 | 27.8 | 60 MOPt | 39.9 | 39.9 | 100 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; H/M is higher in value than M/H; B-S transects= broad-scale transects; RFs = reef-front search; MOPs = mother-of-pearl search; MOPt = mother-of-pearl transect; Ds = sea cucumber day search; Ns = sea cucumber night search.

### *5.4.8 Discussion and conclusions: invertebrate resources in Rarotonga*

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

Data on the shallow-water environments and giant clam distribution, density and shell size suggest the following:

- The range of reef habitats and the dynamic water-movement regime found at Rarotonga provides extensive suitable reef for giant clams.
- Only one giant clam species was present (*Tridacna maxima*), and the fluted clam (*T. squamosa*), which has been recorded at the other CoFish sites in Cook Islands, was absent. *T. squamosa* can be considered as commercially extinct[14] in Rarotonga.
- Clams are broadcast spawners, and only mature as females at larger size classes (protandric hermaphrodites). This means that the presence of large older individuals is needed for successful fertilisation of gametes and production of new generations of giant clam.
- In general, giant clams at Rarotonga were impacted by fishing, noted by the predominance of small size classes on the reef platform and the lack of larger clams on the reef slope. These larger clams can act as an important 'surrogate' reserve. Despite the high level of fishing pressure, recruitment was still occurring and clams were still at reasonable density in some areas. However, the average clam size was small, and continued fishing at this level, without protection of parts of the fishery (and aggregations of 'broodstock') jeopardises sustainability and could result in a rapid decline of stocks in the medium term.

In summary, the environment, distribution, density and length recordings give a good picture of MOP stock health, which is summarised below:

- The back-reef, reef platforms and reef slope of Rarotonga constitute an extensive and suitable benthos for the commercial topshell (*Trochus niloticus*).
- Trochus were common at many easily accessible, shallow-water reefs on the extensive barrier platform. The most abundant aggregations of trochus were recorded along reef platform in the northwest and they occurred more sparsely along the reef slope.
- Trochus distribution was not common in the surf zones of the reef slope (depth 0–10 m) but at >10 m depths they were found at reasonable abundance and live shells were recorded down to 30.1 m depth.
- There is a good abundance of commercial size classes at the moment, with more than adequate numbers of 'broodstock'. In some places, large, old individuals dominate the stock at both the reef platform and slope. Size class information reveals that there is good

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

recruitment of small trochus 3–5 cm (≥1 years old), but that there has been a lack of successful recruitment from spawning 2 years ago (current size 5 cm) and 3 years ago (current size 9 cm).

- There is no potential for commercial collection of the blacklip pearl oyster *Pinctada margaritifera* at Rarotonga and the green topshell *Tectus pyramis* was not recorded.

In summary, the environment, distribution, density and length recordings of sea cucumber species gives the following picture of stock health:

- The large high island of Rarotonga is surrounded by a full range of marine environments, although protected areas of inshore reef were limited in scale. The predominantly exposed reef was more suitable for a smaller range of sea cucumbers, and the reduced species complement also reflected the easterly position of Cook Islands in the Pacific, which is distant from the centre of biodiversity.

- The general indication from presence and density data collected in survey shows that sea cucumbers that are present locally are not under heavy fishing pressure, although previous fishing may have eliminated some species. In general, the species fished for subsistence are also not impacted.

- Sea cucumbers play an important role in 'cleaning' hard (limestone) and processing soft (sand and mud) benthic substrates. When these species are overfished, there is the potential for detritus to build up, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) or anoxic conditions (oxygen-poor areas unsuitable for life).

## 5.5 Overall recommendations for Rarotonga

- Protecting some areas of clams on the reef platform and designating some deeper-water locations as 'no-take' reserves to maintain high densities would be the best approach for successful stock management of giant clams.

- If small numbers of *T. squamosa* can be located around the reef slope of Rarotonga a recovery plan should be implemented. Identification of individuals may allow movement and aggregation of some remaining individuals to protected areas to assist successful sexual reproduction, or access for use in hatchery rearing of juveniles.

- Any proposed fishing plans for trochus (*Trochus niloticus*) may consider the option of partially raising the maximum size limit, so that large trochus can be harvested for specialist markets or some can be moved to replenish other areas by augmenting the existing broodstock or introducing new broodstock.

- Sea cucumber stocks of greenfish (*Stichopus chloronotus*) and potentially *Holothuria atra*, *Actinopyga mauritiana* and *Thelenota ananas* may offer limited potential for commercialisation if short, limited harvests (a few days) controlled by MMR could be interspersed between longer periods (several years) when the fishery remained protected from fishing, to allow stocks to recover from the harvest.

## 6. REFERENCES

Adams, T., W. Nash, P. Tuara, D. Munro, M. Amos, J. Leqata, O. Terekia, N. Mataiti, M. Teopa and J. Whitford. 1992. A practical comparison of three methods of estimating natural mortality in a Cook Islands trochus fishery. Inshore Fisheries Research Project Miscellaneous Contributions. South Pacific Commission, Noumea, New Caledonia. 18 p.

Adams, T.J.H., I. Bertram, P. Dalzell, M. Koroa, S. Matoto, J. Ngu, O. Terekia and P. Tuara. 1996. Aitutaki lagoon fishery, fisheries resources survey and management plan. South Pacific Commission, Noumea, New Caledonia.

Andrews, G.J. 1987. Marine ecological survey of Pukapuka Atoll. Final Report. Commonwealth Science Council–Australian Institute of Marine Science, Townsville, Australia. 133 p.

Anon. 1978. Report on the South Pacific Commission turtle project in the Cook Islands (21 August 1974 – 21 August 1977). South Pacific Commission, Noumea, New Caledonia. 8 p.

Anon. 1980. Country Statement – Cook Islands. Working Paper No. 6. 12th Regional Technical Meeting on Fisheries (17–21 November 1980). South Pacific Commission, Noumea, New Caledonia. 2 p.

Anon. 1984. Country Report – Cook Islands. Working Paper No. 20. 16th Regional Technical Meeting on Fisheries (13–17 August 1984). South Pacific Commission, Noumea, New Caledonia. 10 p.

Anon. 1990. SPC initiatives in remote sensing, digital image analysis and geographical information systems. Working Paper No. 16. 22nd Regional Technical Meeting on Fisheries (6–10 August 1990). South Pacific Commission, Noumea, New Caledonia. 4 p.

Anon. 1994. Country Statement – Cook Islands. Information Paper No. 5. 25th Regional Technical Meeting on Fisheries (14–18 March 1994). South Pacific Commission, Noumea, New Caledonia. 4 p.

Anon. 1998. Country Report: Cook Islands. 11th Meeting of the Standing Committee on Tuna and Billfish, SCTB 11, Ala Moana Hotel, Waikiki, Hawaii (30 May – 6 June 1998). Secretariat of the Pacific Community, Noumea, New Caledonia.

Anon. 1999. Country Statement for the Cook Islands. Information Paper No. 15. 1st Heads of Fisheries Meeting (9–13 August 1999). Secretariat of the Pacific Community, Noumea, New Caledonia. 2 p.

Anon. 2005. Research into more cost effective mooring systems for fish aggregating devices (FADs) in the Pacific region as a means to limit fishing pressure on inshore marine resources. Final report (1 June 2001 – 30 June 2004) to New Zealand under 'The Pacific Initiative for the Environment Fund'. Secretariat of the Pacific Community, Noumea, New Caledonia. 161 p.

Anon. 2007. Annual report – Part 1. Information on fisheries, research and statistics. WCPFC-SC3-AR PART 1/WP 5. Honolulu, United States of America (13–24 August 2007). Western and Central Pacific Fisheries Commission, Pohnpei, FSM.

Asano, N. 1963. Studies on trochus ecology and its propagation in Micronesia. [An abridged translation]. Paper presented at the Workshop on Trochus Assessment, Development and Management, Port Vila, Vanuatu. 56 p.

Becker, W. and E. Helsing. (eds). 1991. Food and health data: Their use in nutrition policy-making. World Health Organization Regional Office for Europe, Copenhagen.

Bertram, I. 1993. Notes on the albacore industry as it affects the Cook Islands. Working Paper No. 20. 5th South Pacific Albacore Research Workshop, Papeete, French Polynesia, 29 March – 1 April 1993. South Pacific Commission, Noumea, New Caledonia.

Bertram, I. 1995a. The Aitutaki experience in the development of management strategies for the trochus fishery. SPC Trochus Information Bulletin 4: 42–47.

Bertram, I. 1995b. The Aitutaki experience in the development of management strategies for the trochus fishery. Background Paper No. 34. Joint FFA/SPC workshop on the management of South Pacific inshore fisheries, Noumea (26 June – 7 July 1995). South Pacific Commission, Nouméa, New Caledonia.

Bertram, I. 1995c. Forum Fisheries Agency/South Pacific Commission workshop on management of South Pacific inshore fisheries, Noumea, New Caledonia (June 26 – 7 July 1995). Noumea, New Caledonia.

Bertram, I. 1996. The aquarium fishery in the Cook Islands: 'is there a need for management?'. SPC Live Reef Fish Information Bulletin 1: 10–12.

Bertram, I.G. 1999. The MIRAB model twelve years on. Contemporary Pacific 11(1): 105–138.

Bertram, I.G. and R.F. Watters. 1985. The MIRAB economy in South Pacific microstates. Pacific Viewpoint 26(3): 497–519.

Bertram, I., S. Tatuava, I. Kaitara, N. Rongo, T. Apolo, N. Roi, J. Mitchell, and N. Makikiriti. 1999. Rarotonga fish aggregating device (FAD) and coastal catch report for 1998. Miscellaneous Report: 99/18, Ministry of Marine Resources, Rarotonga, Cook Islands.

Beverly, S. and L. Chapman. 1998. Capture Section report of technical assistance to the Rarotongan-based tuna longline fleet, and demonstration of mid-water fishing techniques to artisanal male fishers in Rarotonga and Aitutaki, Cook Islands (26 January to 3 May 1997). Secretariat of the Pacific Community, Noumea, New Caledonia. 63 p.

Bishop Museum. 2008. http://www.bishopmuseum.org/, accessed 18/11/2008.

Braley, R.D. 1998. Major success for TMRC blacklip pearl oyster hatchery, Penrhyn Atoll, Northern Cook Islands. SPC Pearl Oyster Information Bulletin 11: 5.

Brandon, D. 1977. Turtle farming progress report on the South Pacific Commmission turtle farming project in the Cook Islands. Working Paper No. 21. 19th Regional Technical Meeting on Fisheries (24–28 January 1977). South Pacific Commission, Noumea, New Caledonia. 9 p.

Bullivant, J.S. and McCann. 1974. Crabs from Manihiki. Contributions to the natural history of Manihiki Atoll, Cook Islands. New Zealand Oceanographic Institute Memoir 31: 41–43.

Cahn, M. and A. Tuara. 2007. Takitunu lagoon pilot program: community input, and monitoring and evaluation. Cook Islands Marine Resource Institutional Strengthening (CIMRIS) report. New Zealand Agency for International Development (NZAID), Wellington, New Zealand.

Chambers, C. 2007. Pasua (*Tridacna maxima*) size and abundance in Tongareva Lagoon, Cook Islands. SPC Trochus Information Bulletin 13: 7–12.

Chapman, L. and P. Cusack. 1997. Report on fourth visit to the Cook Islands (Part I — 17 November 1985 to 29 July 1986; and Part II — 14 November to 23 December 1986). Unpublished report No. 6, South Pacific Commission, Noumea, New Caledonia. 51 p.

Chapman, L. 2001. Tuna fishery development strategy for the Cook Islands (17 August – 7 September 2001). Field Report No. 13, Fisheries Development Section, Secretariat of the Pacific Community, Noumea, New Caledonia.

Chapman, L. 2004. Nearshore domestic fisheries development in Pacific Island countries and territories. Information Paper 8. 4th Heads of Fisheries Meeting, Noumea, New Caledonia (30 August – 3 September 2004). Secretariat of the Pacific Community, Noumea, New Caledonia.

Central Intelligence Agency. 2008. http://www.cia.gov/library/, accessed 27/08/2008.

CIDDP. 1984. Cook Islands Development Plan 1982–1985. Cook Islands Department of Development and Planning, Government of the Cook Islands, Rarotonga, Cook Islands. 254 p.

CIMMR. 2001. Basic information on the marine resources of the Cook Islands. Cook Islands Ministry of Marine Resources, Rarotonga, Cook Islands. 54 p.

CIMMR. 2002. Status of the Cook Islands Marine Aquarium Fishery. Cook Islands Ministry of Marine Resources, Rarotonga, Cook Islands. unpublished data.

CIMOPED. 1988. Second Development Plan 1988–1992. Cook Islands Ministry of Planning and Economic Development, Government of the Cook Islands, Rarotonga, Cook Islands. 118 p.

Clerk, C.C. 1981. The animal world of the Mangaians. Ph. D. Diss. Univ. College, London. 551 p.

Clua, E., P. Legendre, L. Vigliola, F. Magron, K. Kulbicki, S. Sarramegna, P. Labrosse and Galzin. 2006. Medium-scale approach (MSA) for improved assessment of coral reef fish habitat. Journal of Experimental Marine Biology and Ecology 333: 219–230.

Commission of Political Review. 1998. Reforming the political system of the Cook Islands – Preparing for the challenges of the 21st century. Cook Islands Government, Rarotonga, Cook Islands. 114 p.

Cook Islands Government. 1994. Laws of the Cook Islands 1994. Cook Islands Government, Rarotonga, Cook Islands. pp. 198–203.

Cook Islands Government. 2008. http://www.cook-islands.gov.ck/, accessed 20/08/2008.

Cook Islands Statistics Office. 2007. Census of population and dwellings 2006, preliminary result. In: Cook Islands Statistical Bulletin. Cook Islands Government, Rarotonga, Cook Islands. 10 p.

Dahl, A.L. 1980. Report on marine surveys of Rarotonga and Aitutaki. South Pacific Commission, Noumea, New Caledonia. 14 p.

Dalzell, P. and G. Preston. 1992. Deep reef slope fishery resources of the South Pacific. A summary and analysis of the dropline fishing survey data generated by the activities of the SPC Fisheries Programme between 1974 and 1988. South Pacific Commission, Noumea, New Caledonia. pp 73–97.

Dashwood, J. 1979. Trochus survey report, Aitutaki, 18 June – 4 July 1979. Ministry of Marine Resources, Rarotonga, Cook Islands.

Dashwood, J. 1990. Drafting a management plan in the Cook Islands. SPC Pearl Oyster Information Bulletin 2: 12.

Desurmont, A. 1992. Fish Aggregating Device (FAD) Assistance Programme report of visit to the Cook Islands (23 November to 21 December 1990). South Pacific Commission, Noumea, New Caledonia. 27 p.

English, S., C. Wilkinson and V. Baker (eds). 1997. Survey manual for tropical marine resources. 2nd ed. Australian Institute of Marine Science, Townsville.

Evans, M. 2001. Persistence of the gift: Tongan tradition in transnational context. Wilfried Laurier University Press, Waterloo, Canada.

FAO. 2008. Fisheries and aquaculture country profile: Cook Islands. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/fishery/countrysector/FI-CP_CK/, accessed 24/11/2008.

Forstreuter, W. 2002. Geographic information systems and remote sensing workshop in the Cook Islands. SPC Fisheries Newsletter 101: 26–28.

Fujino, M. and T. Patia. 1993. Report of milkfish monitoring collection in Mitiaro in January 1993. Cook Islands Ministry of Marine Resources Internal Report, Rarotonga, Cook Islands. 6 p.

Gail, M. 1957. Research on trochus biology and fishing. protection and conservation of resources. SPC/FAO First South Pacific Fisheries Training Course. South Pacific Commission, Nouméa, New Caledonia. Unpublished lecture notes.

Gillett, R. 1988. Pacific Islands trochus introductions. Information Background Paper No. 61. SPC Workshop on Pacific Inshore Fishery Resources, Noumea, New Caledonia (14–25 March 1988). South Pacific Commission, Noumea, New Caledonia.

Gillett, R. 2002. Pacific Island fisheries: regional and country information. RAP Publication 2002/13, Asia-Pacific Fishery Commission, FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. 168 p.

Gillett, R. and J. Ianelli. 1991. Aspects of the biology and fisheries of flying fish in the Pacific Islands. Document 91/7. FAO/UNDP Regional Fisheries Support Programme, Suva, Fiji. 35 p.

Grange, K. and R. Singleton. 1985. A guide to the reef fishes of Palmerston and Suwarrow Atolls, Cook Islands. Field Report 21. New Zealand Oceanographic Institute. 24 p.

Gulland, J.A. 1983. Fish stock assessment: A manual of basic methods. John Wiley and Sons, Chichester, New York.

Heffernan, O. 2006. Pearls of wisdom. SPC Pearl Oyster Information Bulletin 17: 13–15.

Hinds, V.T. 1970. Report to the Government of the Cook Islands. Trip report by the SPC Fisheries Officer. File PRO 7/3/5. South Pacific Commission, Nouméa, New Caledonia.

Hume, H. 1976. Report on the South Pacific Commission Outer Reef Fisheries Project in the Cook Islands (1 December 1975 to 31 May 1976). South Pacific Commission, Noumea, New Caledonia. 21 p.

Jellyman, D.J. 1988. A survey of the stock of freshwater eels on Mitiaro, Southern Cook Islands. Report to the Ministry of Foreign Affairs and the Cook Islands Government. Government of the Cook Islands, Rarotonga, Cook Islands. 37 p.

Kearney, R.E., R.D. Gillett, and J.P. Hallier. 1979. Interim report of the activities of the Skipjack Survey and Assessment Programme in the waters of the Cook Islands (24 November – 5 December 1978, and 4–11 February 1979). Skipjack Survey and Assessment Programme, Preliminary Country Report No. 15. South Pacific Commission, Noumea, New Caledonia.

Kent, G. 1978. South Pacific fisheries management. Department of Political Science and Pacific Urban Studies and Planning Programme, University of Hawaii, Honolulu, Hawaii. Draft manuscript.

Kronen, M., McArdle B. and Labrosse P. 2006. Surveying seafood consumption: A methodological approach. The South Pacific Journal of Natural Science 24: 11–20.

Kulbicki, M. and S. Sarramegna. 1999. Comparison of density estimates derivated from strip transect and distance sampling for underwater visual censuses: a case study of Chaetodontidae and Pomacanthidae. Aquatic Living Resources 12: 315–325.

Kulbicki, M., Y. Letourneur and P. Labrosse. 2000. Fish stock assessment of the northern New Caledonian lagoons: 2- Stocks of lagoon bottom and reef-associated fishes. Aquatic Living Resources 13: 77–90.

Labrosse, P., M. Kulbicki and J. Ferraris. 2002. Underwater visual fish census, proper use and implementation. Reef Resources Assessment Tools (ReaT). Secretariat of the Pacific Community, Noumea, New Caledonia.

Laurent, D., B. Yeeting, P. Labrosse and J.P. Gaudechoux. 2005. Ciguatera field reference guide. Secretariat of the Pacific Community, Noumea, New Caledonia.

Lawson, T.A. and R.E. Kearney. 1982. An assessment of the skipjack and baitfish resources of the Cook Islands. Skipjack Survey and Assessment Programme Final Country Report No. 2. South Pacific Commission, Noumea, New Caledonia. 30 p.

Lawson, T. and A.D. Lewis. 1996. Distant-water longline catch and effort in the vicinity of the Cook Islands. Oceanic Fisheries Programme Internal Report No. 30. South Pacific Commission, Noumea, New Caledonia. 26 p.

Letourneur, Y., M. Kulbicki and P. Labrosse. 1998. Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: An update. Naga 21(4): 39–46.

Lewis, A. 1986. A review of fisheries research activities and plans, Ministry of Marine Resources – Cook Islands. Technical Bulletin No. 1. FAO/UNDP Regional Fishery Support Programme, Suva, Fiji. 51 p.

Lewis, A. 1987. Progress review – research activities, resource profiles and management plans, Ministry of Marine Resources – Cook Islands. FAO/UNDP Regional Fishery Support Programme, Suva, Fiji. 45 p.

Liew, G. 1980. The Cook Islands. Paper prepared as application to the Lome Convention. Government of the Cook Islands, Rarotonga, Cook Islands. 89 p.

Losacker, W. 1992. Ciguatera fish poisoning in the Cook Islands. SPC Ciguatera Information Bulletin 2: 12–14.

Marsters, T.J. 1975. Country statement – Cook Islands. Working Paper No. 20. 8th Regional Technical Meeting on Fisheries, Noumea, New Caledonia (20–24 October 1975). South Pacific Commission, Noumea, New Caledonia. 11 p.

Marsters, T.J. and T.T.Wichman. 1974. A report of a survey of *Trochus niloticus* in Aitutaki. Unpublished mimeo of a report to the Department of Fisheries, Ministry of Economic Services, Rarotonga. 15 p.

Mead, P. 1997. Report on third visit to the Cook Islands (16 February to 20 July 1983). Unpublished report No. 5. South Pacific Commission, Noumea, New Caledonia. 33 p.

Mitchell, J. 1996. Country Report: Cook Islands. 9th meeting of the Standing Committee on Tuna and Billfish (SCTB9) (22–23 July 1996). South Pacific Commission, Noumea, New Caledonia. 2 p.

Mitchell, J. 2000. Cook Islands Country Report. 13th Meeting of the Standing Committee on Tuna and Billfish (SCTB 13) Noumea, New Caledonia (5–12 July 2000). Secretariat of the Pacific Community, Noumea, New Caledonia.

Mitchell, J. 2005. Cook Islands Fishery Report. 1st Meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission WCPFC–SC1 Noumea, New Caledonia (8–19 August 2005). Western and Central Pacific Fisheries Commission, Pohnpei, FSM.

Nash, W., T. Adams, P. Tuara, O. Terekia, D. Munro, M. Amos, J. Leqata, N. Mataiti, M. Teopenga and J. Whitford. 1994. The Aitutaki trochus fishery: a case study. South Pacific Commission, Noumea, New Caledonia. 68 p.

Nelson, S.G and L.G. Eldredge. 1991. Distribution and status of introduced cichlid fishes of the Genera Oreochromis and Tilapia in the islands of the South Pacific and Micronesia. Asian Fisheries Biology 4: 11–22.

Passfield, K. 1988. Tropical Spiny Rock Lobsters (Crayfish) [Koura tai]. Cook Islands Fisheries Resource Profile No.4. Cook Islands Ministry of Marine Resources, Rarotonga, Cook Islands. 14 p.

Passfield, K. 1997. First commercial trochus harvest from Palmerston Atoll. SPC Trochus Information Bulletin 5: 25.

Passfield, K. 1997. Notes on ‘pipi’ pearl oyster, *Pinctada maculata*, fishing in Tongareva, Cook Islands, 1995. SPC Pearl Oyster Information Bulletin 10: 21.

Paulay, G. 1994. The state of the reef: Aitutaki surveys, 1994. University of Guam Marine Laboratory, Mangialao. 16 p.

PCRF. 2004. Health of the Aitutaki Atoll reef: Reef report. Planetary Coral Reef Foundation. http://www.pcrf.org/science/Aitutaki/reefreport.html/, accessed 17/11/2008.

Ponia, B. 2000. Trochus transhipment to Atiu, Mauke and Takutea Islands, Cook Islands. SPC Trochus Information Bulletin 6: 2–3.

Powell, R. 1962. Fisheries Development in the Cook Islands. South Pacific Bulletin. January 1962, pp 50–53 and 60–61.

Powell, R. 1957. The transfer of live trochus shell from Fiji to the Cook Islands – December 1956 – March 1957. Unpublished mimeo of a report to the Director of Agriculture, Rarotonga. 6 p.

Preston, G. 1990. Recent beche-de-mer surveys in the Pacific Islands. Article in SPC Bêche-de-mer Information Bulletin 1: 10.

Preston, G. 2000. Managing the ocean. Report prepared for the World Bank. Gillett, Preston and Associates Inc. Noumea, New Caledonia.

Preston, G., A. Lewis, N. Sims, I. Bertram, N. Howard, S. Maluofenua, B. Marsters, K. Passfield, T. Tearii, F. Viala, D. Wright, and B. Yeeting. 1995. The marine resources of Palmerston Island, Cook Islands. Report of a survey carried out in September 1988. Inshore Fisheries Research Project, Technical Document No. 10. South Pacific Commission, Noumea, New Caledonia. 61 p.

Raumea, K. 1992. Mangaia fisheries survey. Cook Islands Ministry of Marine Resources Internal Report, Rarotonga, Cook Islands. 11 p.

Raumea, K., N. Roi, T. Turua and N. Makikiriti. 2001. First monitoring survey for Aroa *Ra'ui*. Ministry of Marine Resources Report 2001/09, Rarotonga, Cook Islands.

Roi. N. 2003. The Raui system in the Cook Islands. Paper submitted at coastal fisheries management meeting, Nadi, Fiji (17–21 March 2003). Secretariat of the Pacific Community, Noumea, New Caledonia. 4 p.

Russ, G.R. and J. St. John. 1988. Diets, growth rates and secondary production of herbivorous coral reef fishes. Proceedings of the 6th International Coral Reef Symposium, Townsville, Australia: 37–43.

Sims, N.A. 1984. The status of *Trochus niloticus* in the Cook Islands. Ministry of Marine Resources, Rarotonga. (unpubl.).

Sims, N.A. 1985. The abundance, distribution, and exploitation of *Trochus niloticus* L. in the Cook Islands. Proceedings of the 5th International Coral Reef Congress, Tahiti, 1985, Vol. 1: 539–544.

Sims, N.A. 1988a. A cost-benefit analysis of FADs in the artisanal tuna fishery in Rarotonga. Background Paper No. 36. Workshop on Pacific Inshore Fishery Resources (14–25 March 1988). South Pacific Commission, Noumea, New Caledonia. 11 p.

Sims, N.A. 1988b. Trochus research in the Cook Islands and its implications for the management. Background Paper No. 37. Workshop on Pacific Inshore Fishery Resources (14–25 March 1988). South Pacific Commission, Noumea, New Caledonia. 13 p.

Small, C.A. and L.D. Dixon. 2004. Tonga: Migration and the homeland. http://www.migrationinformation.org/profiles/, accessed 30/03/2005.

Smith, A. 1993. Cook Islands fisheries resource profiles. FFA report No. 93/25. Forum Fisheries Agency, Honiara, Solomon Islands. 121 p.

Sokimi, W. and L. Chapman. 2003. Commercial tuna longline workshop for the development of the pelagic fresh fish export industry in the Cook Islands (24 August to 27 September 2002). Fisheries Development Section, Field Report No. 18. Secretariat of the Pacific Community, Noumea, New Caledonia. 38 p.

Tatuava, S., I. Bertram, and N. Roi. 2002. National Commercial Tuna Longline Training Workshop, Rarotonga (19 August – 25 September 2002). Ministry of Marine Resources, Rarotonga, Cook Islands.

Taumaia, P. and G. Preston. 1985. Deep Sea Fisheries Development Project Report of second visit to the Cook Islands (10 September 1981 to 29 March 1082). South Pacific Commission, Noumea, New Caledonia. 31 p.

Tiraa, A. 2006. *Ra'ui* in the Cook Islands – today's context in Rarotonga. SPC Traditional Marine Resource Management and Knowledge Information Bulletin 19: 11–15.

Tuara, P. 1992. The use of individual transferable quota as a tool for the management of *Trochus niloticus* in the Cook Islands. Paper delivered at the Expert consultation on the development of community-based coastal fishery management systems for Asia and the Pacific, Kobe, Japan (8–12 June 1992). South Pacific Commission, Noumea, New Caledonia.

Tuara, P. 1997. Trochus resource assessment, development and management in the Cook Islands. Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea, New Caledonia. pp 21–25.

Turner, B. (ed.). 2007. The Statesman's Yearbook 2008 – The politics, culture and economics of the world. MacMillan Publishers Limited, USA. pp. 861–863.

Van Pel, H. 1955. The fisheries industry of the Cook Islands. South Pacific Commission, Noumea, New Caledonia. 52 p.

Whitelaw, W. 2001. Country guide to gamefishing in the western and central Pacific. Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.

WorldFish Center. 2000. http://fishbase.org/home.htm/, accessed 17/10/2007.

Zoutendyk, D. 1989. Bêche-de-mer, Rori of the Cook Islands. Cook Islands Marine Resources Profile No.6, Ministry of Marine Resources, Rarotonga, Cook Islands. 17 p.

# 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).

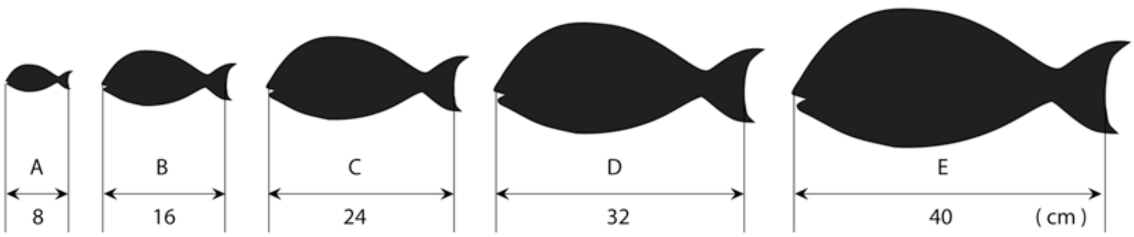


**Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).**

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.

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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$_i$

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Invertebrate per capita consumption:

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

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

Canned fish per capita consumption:

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

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

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

Total finfish consumption:

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

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

Total invertebrate consumption:

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

$Inv_{pcj}$ = invertebrate weight consumption (kg edible meat/capita/year) for household$_j$

$n_{ss}$ = number of people in sample size

$n_{pop}$ = number of people in total population

Total canned fish consumption:

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

$CF_{pcj}$ = canned fish net weight consumption (kg/capita/year) of household$_j$

$n_{ss}$ = number of people in sample size

$n_{pop}$ = number of people in total population

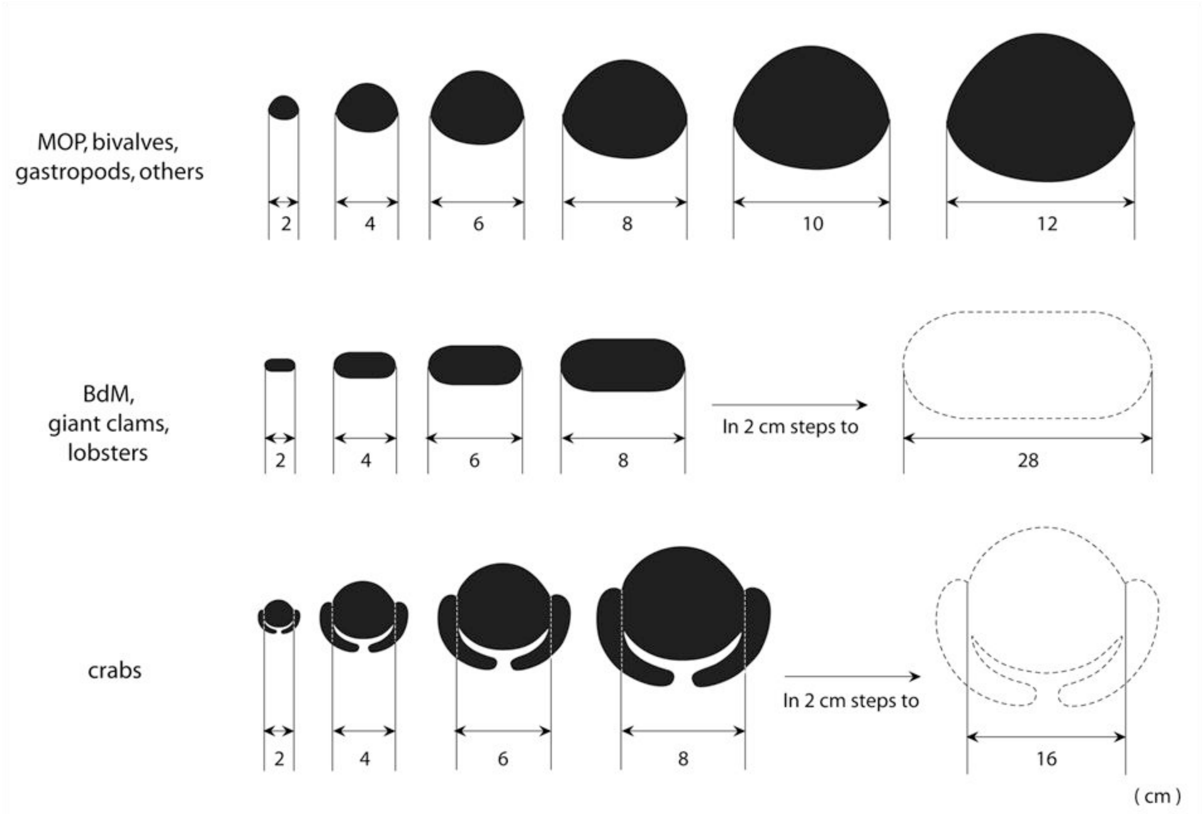


**Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).**

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*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).

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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 $\text{habitat}_h$
$Acf_h$ = average annual catch of female fishers (kg/year) for $\text{habitat}_h$
$Fim_h$ = total number of male fishers for $\text{habitat}_h$
$Acm_h$ = average annual catch of male fishers (kg/year) for $\text{habitat}_h$
$N_h$ = 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 $\text{habitat}_h$ (total number of interviews where female fishers provided detailed information for $\text{habitat}_h$)
$f_i$ = frequency of fishing trips (trips/week) as reported on $\text{interview}_i$
$Fm_i$ = number of months fished (reported in $\text{interview}_i$)
$Cf_i$ = average catch reported in $\text{interview}_i$ (all species)
$Rf_h$ = number of targeted habitats as reported by female fishers for $\text{habitat}_h$ (total numbers of interviews where female fishers reported targeting $\text{habitat}_h$ but did not necessarily provide detailed information)
$f_k$ = frequency of fishing trips (trips/week) as reported for $\text{habitat}_k$
$Fm_k$ = number of months fished for reported $\text{habitat}_k$ (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>

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

Where:

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

In order to establish <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.

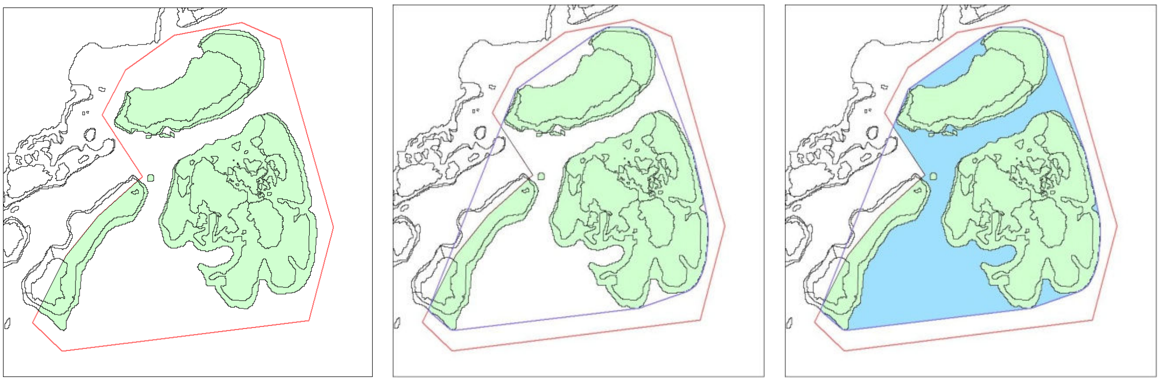

**Figure A1.1.3: Determination of lagoon area.**
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled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

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

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

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

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

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

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

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

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

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

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

Information on invertebrate fishing strategies by fishery and gender includes:

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

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

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

*Appendix 1: Survey methods*
*Socioeconomics*

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

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

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

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

Total annual catch:

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

TACj = total annual catch t/year for species$_j$
$F_{inv}f_h$ = total number of female invertebrate fishers for habitat$_h$
$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
$F_{inv}m_h$ = total number of male invertebrate fishers for habitat$_h$
$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for habitat$_h$ and species$_j$
$N_h$ = number of habitats

Where:

$$\text{Ac}_{\text{inv}}\text{f}_{\text{hj}} = \frac{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12} \bullet Cf_{ij}}{I_{inv}f_h} \bullet \frac{\sum_{k=1}^{R_{inv}f_h} f_k \bullet 52 \bullet 0.83 \bullet \frac{Fm_k}{12}}{\sum_{i=1}^{I_{inv}f_h} f_i \bullet 52 \bullet 0.83 \bullet \frac{Fm_i}{12}}$$

$I_{inv}f_h$ = number of interviews of female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for habitat$_h$)
$f_i$ = frequency of fishing trips (trips/week) as reported in interview$_i$

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

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

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

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

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

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

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

*Data entry and analysis*

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

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

### *1.1.2 Socioeconomic survey questionnaires*

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

**HOUSEHOLD CENSUS AND CONSUMPTION SURVEY**

**HH NO.** ☐

Name of head of household: ________________ Village: _________________

Name of person asked: _____________________ Date: __________________

Surveyor's ID: __________________

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

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 OR:

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

10. Do you sell fish? yes ☐ no ☐

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

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

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

kg ☐ OR:

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

and the rest you gift? yes ☐

how much? kg ☐ OR:

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

and/or sell? yes ☐

how much? kg ☐ OR:

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

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

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

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

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

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

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

*Specify the number by size*

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

20. Do you also fish invertebrates?

Yes ☐ no ☐ <u>if yes</u> for consumption? ☐ sale? ☐

**–THANK YOU–**

**INVERTEBRATE FISHING AND MARKETING SURVEY**
**FISHERS**

**HH NO.** ☐

Name: ________________________________________

Gender: ☐ female ☐ male Age: ☐

Village: ________________________________________

Date: ________________ Surveyor's name: ___________________

*Invertebrates = everything that is not a fish with fins!*

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

---

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

☐ lobster diving ☐ other, such as clams, octopus

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

☐ one only ☐ several

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

----------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------

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

| | times/week | | duration in hours<br>*(if the fisher can't specify, tick the box)*<br><2 | 2–4 | 4–6 | >6 | glean/dive at<br>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**<br>vernacular/common name and scientific code if possible | **Average quantity/trip** | | | | | | | **Used for**<br>(specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given)<br>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 | | | | |
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## *Appendix 1: Survey methods*
## *Socioeconomics*

| **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 | | | | |
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**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 |
|---|---|---|---|---|---|
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## 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 |
|---|---|---|
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**Seasonality of species**

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

| Vernacular name | Scientific name(s) | Months NOT fished |
|---|---|---|
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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?)** |
|---|---|---|
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### *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,*<br>*Donax cuneatus,*<br>*Donax cuneatus* | 2.75 | 35 | 65 | 0.96 | Bivalves |
| *Atrina vexillum,*<br>*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,*<br>*Thais aculeata,*<br>*Thais aculeata* | 20 | 25 | 75 | 5 | Gastropods |
| *Cerithium nodulosum,*<br>*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,*<br>*Strombus gibberulus gibbosus* | 240 | 25 | 75 | 60 | Gastropods |
| *Conus* sp. | 240 | 25 | 75 | 60 | Gastropods |
| *Cypraea annulus,*<br>*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.

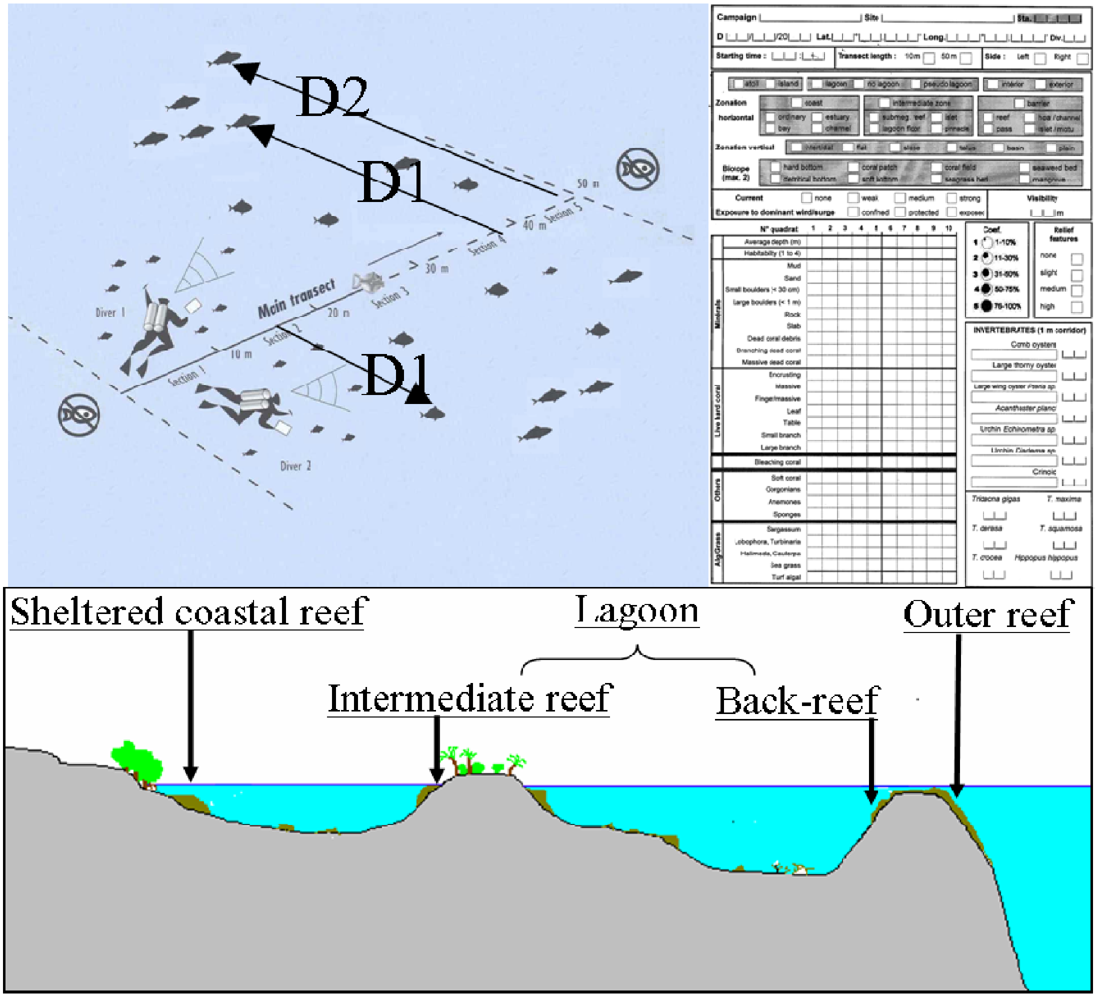



**Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).**
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys 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.

## *Appendix 1: Survey methods*
## *Finfish*

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

These are:

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

*Substrate*

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

*Parameters of interest*

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

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

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

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

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

*Sampling design*

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

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

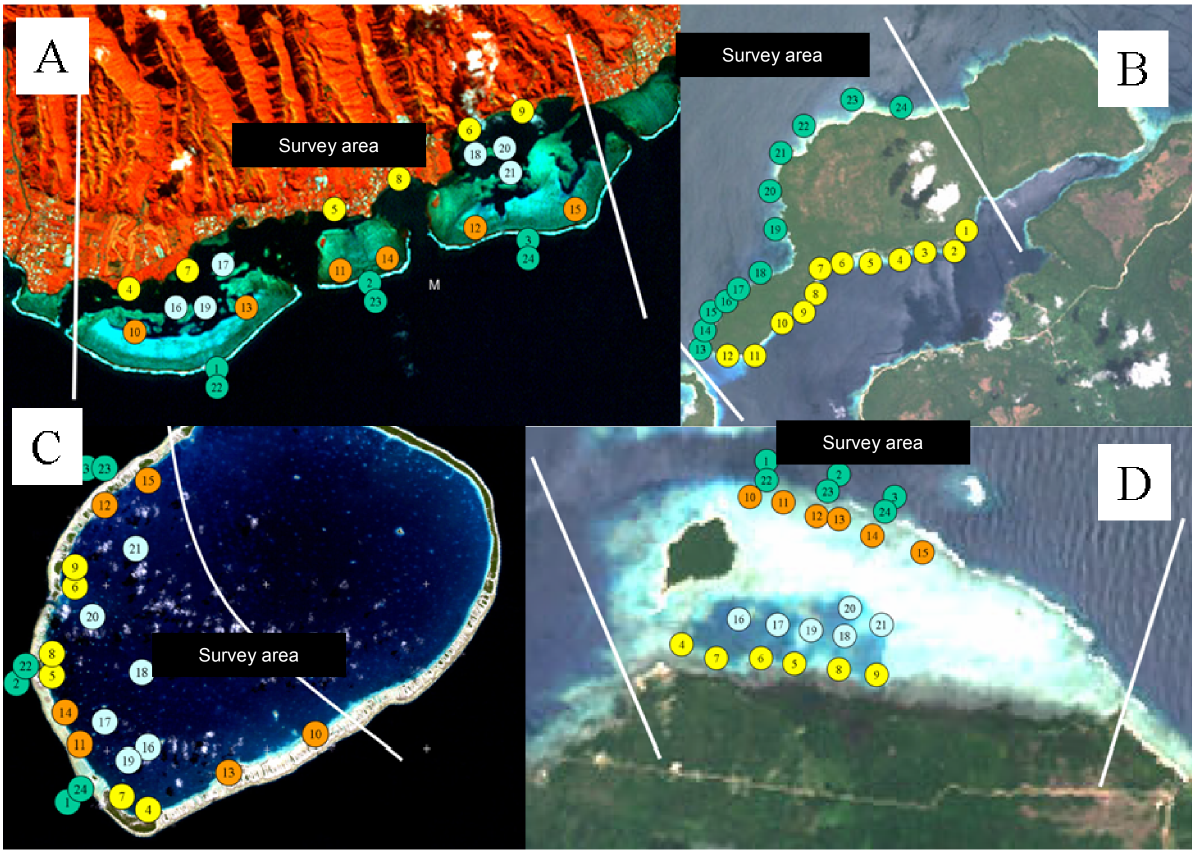



**Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.**
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, 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 |__|__|__|

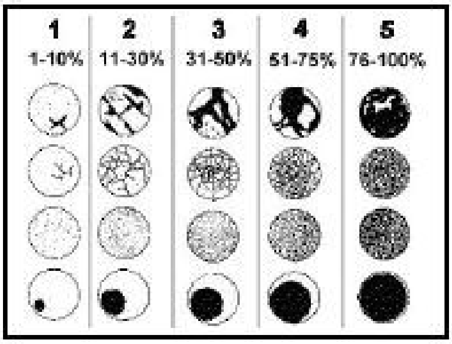
Starting time : |__|__| :|__|__| Visibility |__|__| m Side : Left ☐ Right ☐

| ☐ 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

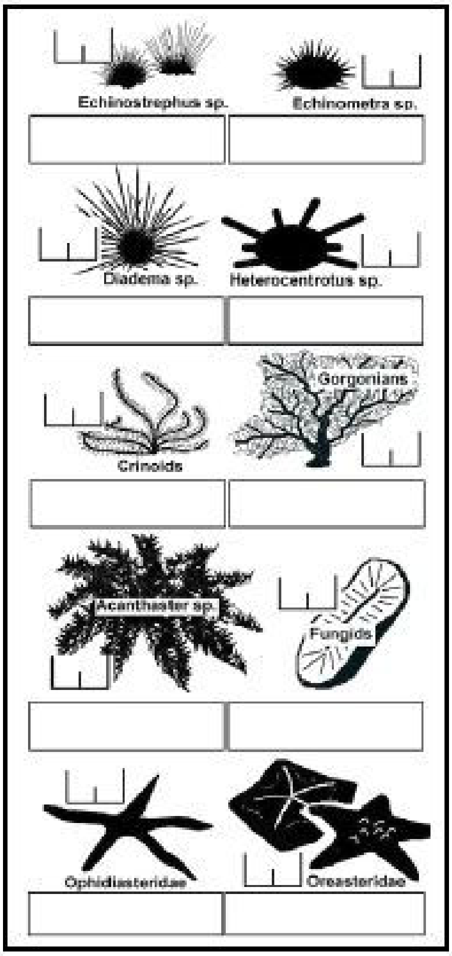
☐ hard bottom ☐ large coral patches ☐ small coral patches ☐ coral field ☐ seaweed bed
☐ detritical bottom ☐ soft bottom ☐ seagrass bed ☐ mangrove

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




Quadrat limits 0 5 10 15 20 25 30 35 40 45 50

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



*Appendix 1: Survey methods*
*Finfish*

**Campaign |_____________________| Site |________________________________| Diver |__|__| Transect |__|__|__|**

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

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## 1.3 Invertebrate resource survey methods

### *1.3.1 Methods used to assess the status of invertebrate resources*

*Introduction*

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

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

*Field methods*

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

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

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

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

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

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

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

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

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

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

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

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

[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).

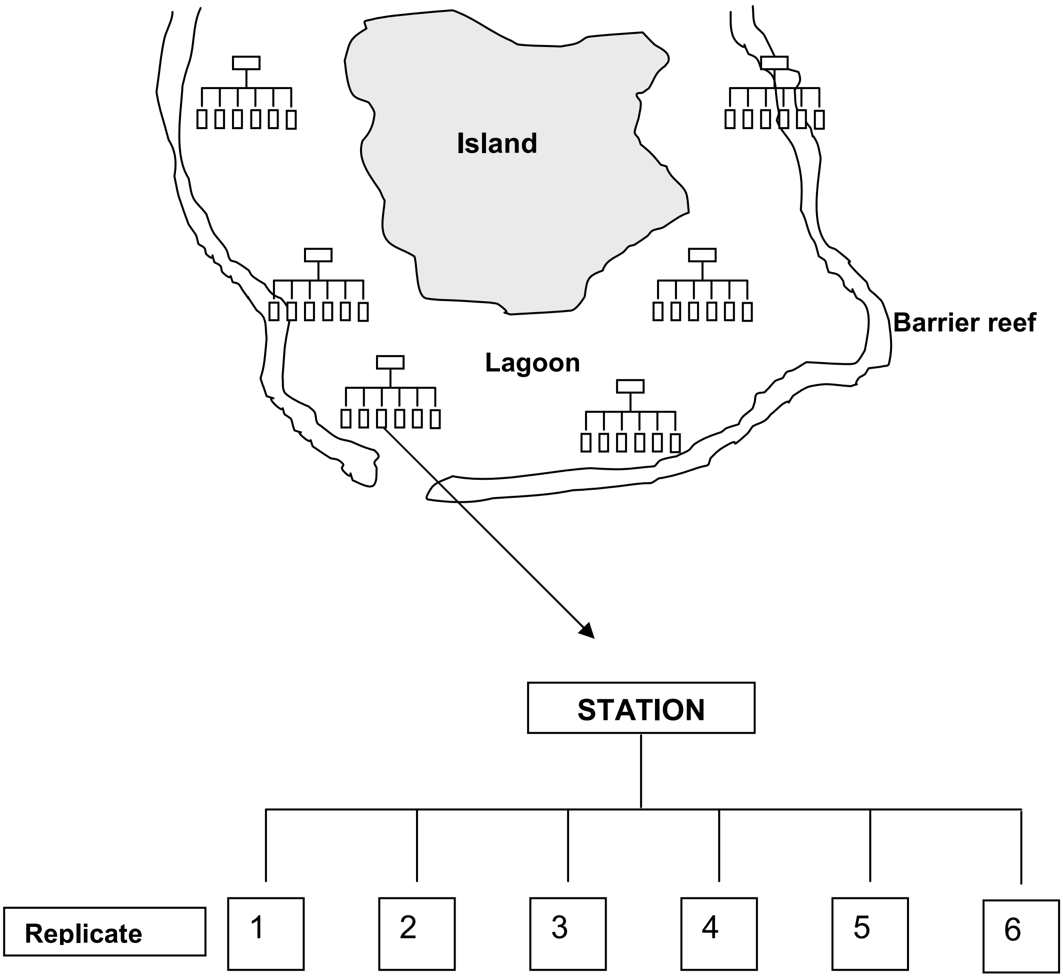


**Figure A1.3.1: Stations and replicate measures at a given site.**
A replicate measure could be a transect, search period or quadrat group.

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).

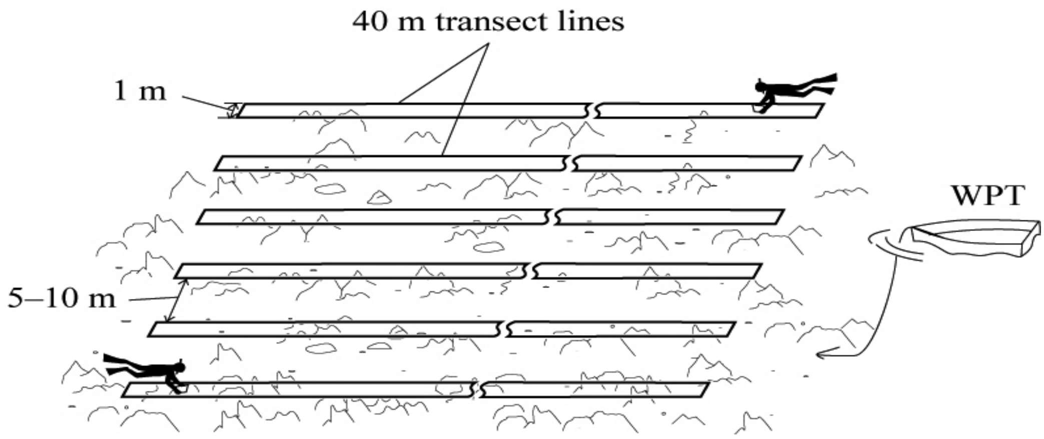


**Figure A1.3.2: Example of a reef-benthos transect station (RBt).**

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.

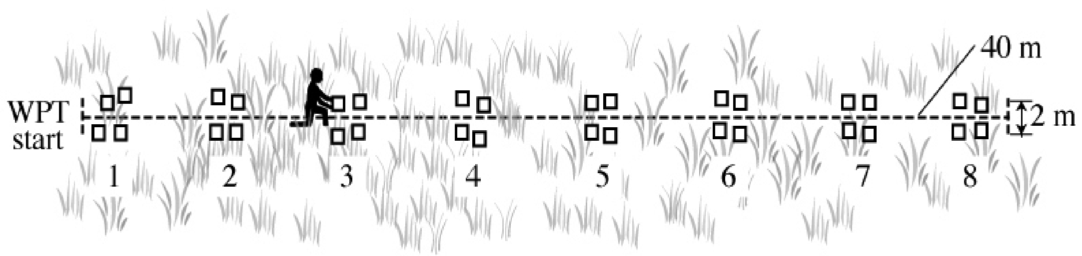


**Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).**
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<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).

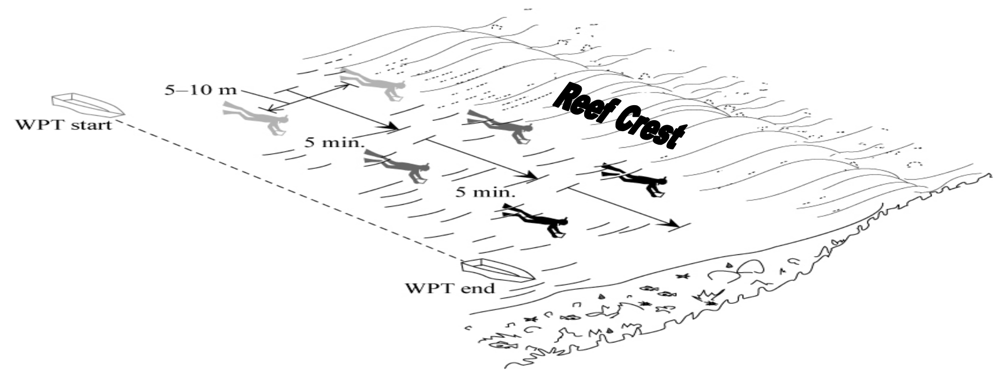


**Figure A1.3.4: Reef-front search (RFs) station.**

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.

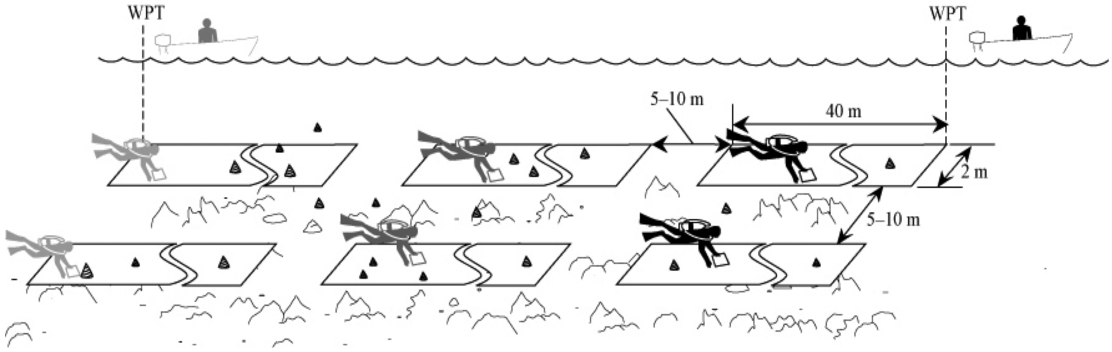


**Figure A1.3.5: Mother-of-pearl transect station (MOPt).**

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*

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| 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.

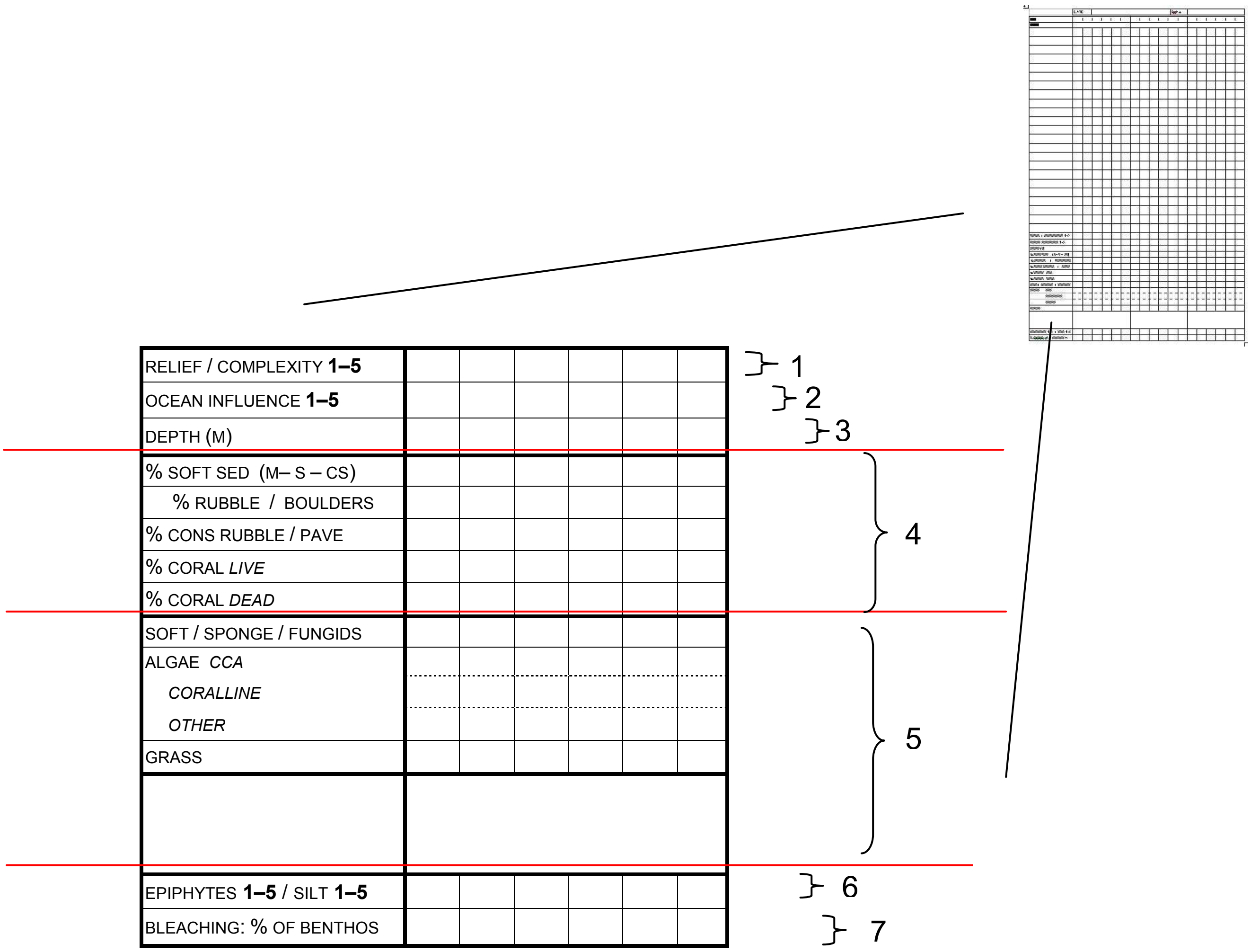



**Figure A1.3.7: Sample of the invertebrate habitat part of survey form.**

*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.

## *Appendix 1: Survey methods*
## *Invertebrates*

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

*Coral live* is any live hard coral.

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

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

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

Elements to consider:

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

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

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

*Fungids* are fungids.

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

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

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

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

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

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

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

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

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

*Bleaching (section 7 of form)*

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

# APPENDIX 2: SOCIOECONOMIC SURVEY DATA

## 2.1 Aitutaki socioeconomic survey data

### *2.1.1 Annual catch (kg) of fish groups per habitat – Aitutaki*
(includes only reported catch data by interviewed finfish fishers)

| Vernacular name | Family | Scientific name | Total weight (kg) | % of reported catch |
|---|---|---|---|---|
| **Lagoon** | | | | |
| Ume | Acanthuridae | *Naso unicornis* | 1515 | 11.6 |
| U'u | Scaridae | *Chlorurus microrhinos* | 1362 | 10.4 |
| Vete | Mullidae | *Mulloidichthys flavolineatus* | 1239 | 9.5 |
| Au'maori | Scaridae | *Scarus altipinnis* | 1005 | 7.7 |
| Paopao | Scaridae | *Scarus forsteni* | 876 | 6.7 |
| Rei | Scaridae | *Hipposcarus longiceps* | 803 | 6.1 |
| Mamaringa | Scaridae | *Scarus ghobban* | 720 | 5.5 |
| Roro | Scaridae | *Scarus oviceps* | 714 | 5.5 |
| Mu | Lethrinidae | *Monotaxis grandoculis* | 607 | 4.6 |
| Rotea | Scaridae | *Scarus* spp. | 550 | 4.2 |
| Kaa | Mugilidae | *Liza vaigiensis* | 482 | 3.7 |
| Kiokio | Albulidae | *Albula neoguinaicus* | 457 | 3.5 |
| Parangi | Acanthuridae | *Acanthurus blochii* | 439 | 3.4 |
| Au'uru | Mullidae | *Parupeneus barberinus* | 414 | 3.2 |
| Kanae | Mugilidae | *Crenimugil crenilabis* | 388 | 3.0 |
| Ripo pao'a | Serranidae | *Cephalopholis sexmaculata* | 261 | 2.0 |
| Ava | Chanidae | *Chanos chanos* | 252 | 1.9 |
| Aroa | Serranidae | *Epinephelus coioides* | 208 | 1.6 |
| Pipinanue | Kyphosidae | *Kyphosus bigibbus* | 208 | 1.6 |
| Tangau | Lutjanidae | *Lutjanus fulvus* | 111 | 0.8 |
| Maito | Acanthuridae | *Acanthurus olivaceus* | 106 | 0.8 |
| Taraoa | Serranidae | *Epinephelus merra* | 79 | 0.6 |
| Tarakii | Lethrinidae | *Gnathodentex aureolineatus* | 61 | 0.5 |
| Paru Marau | Lutjanidae | *Etelis carbunculus* | 56 | 0.4 |
| Kupa | Priacanthidae | *Priacanthus blochii* | 39 | 0.3 |
| Totara | Diodontidae | *Diodon hystrix* | 28 | 0.2 |
| Ku | Holocentridae | *Myripristis* spp. | 26 | 0.2 |
| Kuta | Holocentridae | *Sargocentron spiniferum* | 23 | 0.2 |
| Rakoa | Mullidae | *Parupeneus trifasciatus* | 22 | 0.2 |
| Ikutoto | Acanthuridae | *Acanthurus achilles* | 17 | 0.1 |
| Ature | Carangidae | *Selar crumenophthalmus* | 2 | 0.0 |
| **Total:** | | | **13,069** | **100** |
| **Passage** | | | | |
| U'u | Scaridae | Chlorurus microrhinos | 30 | 15.0 |
| Au'maori | Scaridae | *Scarus altipinnis*, *Scarus ghobban*, *Scarus frenatus* | 50 | 25.0 |
| Paopao | Scaridae | *Scarus forsteni* | 20 | 10.0 |
| Mamaringa | Scaridae | *Scarus ghobban* | 30 | 15.0 |
| Kiokio | Albulidae | *Albula vulpes* | 20 | 10.0 |
| Au'uru | Mullidae | *Parupeneus barberinus* | 50 | 25.0 |
| **Total:** | | | **200** | **100** |

### *2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Aitutaki*

| Fishery | Vernacular name | Scientific name | % annual catch (weight) | Recorded | | Extrapolated | |
|---|---|---|---|---|---|---|---|
| | | | | no/year | kg/year | no/year | kg/year |
| Lobster | Koura | *Panulirus longipes*, *Panulirus penicillatus* | 100.0 | | | 12,708.2 | 12,708.2 |
| Mangrove | Upaki | *Scylla serrata* | 100.0 | | | 4434 | 3103.6 |
| Reeftop | Paua | *Tridacna maxima* | 35.4 | | | 70,163 | 35,081.4 |
| | Ariri | *Turbo setosus* | 26.8 | | | 1317,279 | 26,345.6 |
| | Matu rori | *Holothuria* spp. | 23.2 | | | 13,201 | 23,761.0 |
| | Koura | *Panulirus longipes*, *Panulirus penicillatus* | 7.1 | | | included in above figure | |
| | Kai | *Asaphis violascens* | 1.9 | | | 29,945 | 1996.3 |
| | Coconut crab | *Birgus latro* | 0.5 | | | 513 | 512.8 |
| | Kina | *Tripneustes gratilla* | 0.3 | | | 3568 | 356.8 |
| | Vana | *Echinothrix diadema* | 0.3 | | | 3568 | 356.8 |
| | Atuke | *Heterocentrotus mammillatus* | 0.3 | | | 3568 | 356.8 |
| | Trochus | *Trochus niloticus* | 0.3 | | | 1590 | 318.1 |
| | Ungakoa | *Dendropoma maxima* | n/a | n/a | n/a | n/a | n/a |
| Intertidal | Tupa | *Cardisoma* spp. | 100.0 | | | 19,547 | 4453.3 |
| Soft benthos | Rimu, seaweed | *Caulerpa racemosa* | n/a | n/a | n/a | n/a | n/a |

n/a = no information available.

### *2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Aitutaki*

| Vernacular name | Scientific name | Size class | % of total catch (weight) |
|---|---|---|---|
| Ariri | *Turbo setosus* | 04 cm | 0.2 |
| | | 04-08 cm | 0.2 |
| | | 06 cm | 2.9 |
| | | 06-08 cm | 81.9 |
| | | 08 cm | 1.3 |
| | | 08-10 cm | 0.2 |
| | | 10 cm | 3.5 |
| | | 10-12 cm | 9.9 |
| Atuke | *Heterocentrotus mammillatus* | 06-08 cm | 100.0 |
| Coconut crab | *Birgus latro* | 24 cm | 100.0 |
| Kai | *Asaphis violascens* | 06-08 cm | 87.9 |
| | | 08 cm | 12.1 |
| Kina | *Tripneustes gratilla* | 10-12 cm | 100.0 |
| Koura | *Panulirus longipes*, *Panulirus penicillatus* | 14-18 cm | 100.0 |
| Matu rori | *Holothuria* spp. | 12 cm | 85.6 |
| | | 14 cm | 14.4 |
| Paua | *Tridacna maxima* | 06-08 cm | 19.5 |
| | | 08 cm | 1.9 |
| | | 10-12 cm | 2.6 |
| | | 12 cm | 24.7 |
| | | 14 cm | 3.7 |
| | | 14-16 cm | 7.5 |
| | | 16 cm | 32.6 |
| | | 16-18 cm | 7.5 |
| Trochus | *Trochus niloticus* | 12 cm | 100.0 |
| Tupa | *Cardisoma* spp. | 08-10 cm | 17.0 |
| | | 10 cm | 83.0 |
| Ungakoa | *Dendropoma maxima* | 08-10 cm | |
| | | 10 cm | |
| Upaki | *Scylla serrata* | 12-18 cm | 78.3 |
| | | 14-16 cm | 7.2 |
| | | 16-18 cm | 14.5 |
| Vana | *Echinothrix diadema* | 10-12 cm | 100.0 |

## 2.2 Palmerston socioeconomic survey data

### 2.2.1 *Annual catch (kg) of fish groups per habitat – Palmerston*
(includes only reported catch data by interviewed finfish fishers)

| Vernacular name | Family | Scientific name | Total weight (kg) | % of reported catch |
|---|---|---|---|---|
| **Lagoon** | | | | |
| Rei | Scaridae | *Hipposcarus longiceps* | 3376 | 24.5 |
| Greenfish (poshow) | Scaridae | *Chlorurus microrhinos* | 2866 | 20.8 |
| Show | Scaridae | *Scarus altipinnis* | 1990 | 14.4 |
| Akau | Scaridae | *Chlorurus frontalis* | 1091 | 7.9 |
| Rui | Carangidae | *Caranx lugubris* | 0 | 0.0 |
| Taiva | Lutjanidae (1) | *Lutjanus monostigma* | 965 | 7.0 |
| Taraoa | Serranidae (1) | *Epinephelus merra* | 887 | 6.4 |
| Kaka tavake | Scaridae | *Cetoscarus bicolor* | 372 | 2.7 |
| Api | Acanthuridae | *Acanthurus guttatus* | 248 | 1.8 |
| Kanae | Mugilidae | *Crenimugil crenilabis*, *Mugil cephalus* | 248 | 1.8 |
| Mamaringa | Scaridae | *Scarus ghobban* | 248 | 1.8 |
| Kaa | Mugilidae | *Liza vaigiensis* | 248 | 1.8 |
| Black show (show) | Scaridae | *Scarus altipinnis* | 248 | 1.8 |
| Pipinanue | Kyphosidae | *Kyphosus bigibbus* | 248 | 1.8 |
| Tokoro | Holocentridae | *Sargocentron tiere* | 145 | 1.1 |
| Ta | Holocentridae | *Sargocentron spiniferum* | 130 | 0.9 |
| Rotea | Scaridae | *Scarus* spp. | 124 | 0.9 |
| Marao | Holocentridae | *Myripristis* spp. | 105 | 0.8 |
| Ku | Holocentridae | *Myripristis* spp. | 71 | 0.5 |
| Aroa | Serranidae (1) | *Epinephelus tauvina* | 59 | 0.4 |
| Ngatara | Serranidae | *Epinephelus socialis* | 59 | 0.4 |
| Patuki | Serranidae | *Epinephelus hexagonatus* | 35 | 0.3 |
| Vete | Mullidae | *Mulloidichthys flavolineatus* | 28 | 0.2 |
| Uoa (wowa) | Mugilidae (1) | *Neomyxus leuciscus* (*Mugil cephalus*) | 7 | 0.1 |
| **Total:** | | | **13,794** | **100.0** |
| **Outer reef** | | | | |
| Rui | Carangidae | *Caranx lugubris* | 1032 | 100 |
| **Total:** | | | **1032** | **100** |

(1) McCormack, Gerald (2005) Cook Islands Biodiversity Database, Version 2005.6.2. Cook Islands Natural Heritage Trust, Rarotonga

### *2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Palmerston*

| Fishery | Vernacular name | Scientific name | % annual catch (weight) | Recorded | | Extrapolated | |
|---|---|---|---|---|---|---|---|
| | | | | no/year | kg/year | no/year | kg/year |
| Lobster | Koura | *Panulirus longipes*, *Panulirus penicillatus* | 100.0 | 8 | 8.3 | 8 | 8.3 |
| Reef top | Koura | *Panulirus longipes*, *Panulirus penicillatus* | 43.1 | 501 | 500.8 | 574 | 574.0 |
| | Paua | *Tridacna maxima* | 42.8 | 994 | 497.1 | 1554 | 776.9 |
| | Octopus | *Octopus* spp. | 6.2 | 130 | 71.7 | 205 | 112.6 |
| | Tupa | *Cardisoma* spp. | 5.5 | 280 | 63.8 | 440 | 100.2 |
| | Ariri | *Turbo setosus* | 2.5 | 1462 | 29.2 | 2081 | 41.6 |
| Soft benthos | Kai | *Asaphis violascens* | 100.0 | 32,813 | 492.2 | 10,671 | 711.4 |

### *2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Palmerston*

| Vernacular name | Scientific name | Size class | % of total catch (weight) |
|---|---|---|---|
| Ariri | *Turbo setosus* | 04 cm | 35.3 |
| | | 04-06 cm | 22.2 |
| | | 05 cm | 35.6 |
| | | 06 cm | 5.7 |
| | | 08 cm | 1.1 |
| Kai | *Asaphis violascens* | 04-06 cm | 70.6 |
| | | 06 cm | 29.4 |
| Koura | *Panulirus longipes*, *Panulirus penicillatus* | 20-28 cm | 11.8 |
| | | 22-24 cm | 9.8 |
| | | 24 cm | 1.6 |
| | | 26 cm | 76.8 |
| Octopus | *Octopus* spp. | 12 cm | 100.0 |
| Paua | *Tridacna maxima* | 12 cm | 84.6 |
| | | 16 cm | 5.0 |
| | | 16-18 cm | 5.4 |
| | | 18 cm | 5.0 |
| Tupa | *Cardisoma* spp. | 12-14 cm | 100.0 |

## 2.3 Mangaia socioeconomic survey data

### *2.3.1 Annual catch (kg) of fish groups per habitat – Mangaia*
(includes only reported catch data by interviewed finfish fishers)

| Vernacular name | Family | Scientific name | Total weight (kg) | % of reported catch |
|---|---|---|---|---|
| **Lagoon** | | | | |
| Tiotio | Kyphosidae | *Kyphosus cinerascens* | 537 | 30.1 |
| Ume | Acanthuridae | *Naso unicornis* | 176 | 9.9 |
| Pipi | Kyphosidae | *Kyphosus cinerascens* | 142 | 7.9 |
| Api | Acanthuridae | *Acanthurus guttatus* | 121 | 6.8 |
| Pakati | Scaridae | *Scarus* spp. | 121 | 6.8 |
| Akau | Scaridae | *Chlorurus frontalis* | 91 | 5.1 |
| Kauru (goatfish) | Mullidae | *Parupeneus* spp. | 76 | 4.3 |
| Marau | Holocentridae | *Myripristis* spp. | 63 | 3.5 |
| Maito | Acanthuridae | *Acanthurus olivaceus* | 63 | 3.5 |
| Atea | Serranidae | *Epinephelus fasciatus* | 60 | 3.3 |
| Moi | Polynemidae | *Polydactylus sexfilis* | 60 | 3.3 |
| Aua (mullet) | Mullidae | *Parupeneus* spp. | 50 | 2.8 |
| Kanae | Mugilidae | *Crenimugil crenilabis*, *Mugil cephalus* | 45 | 2.5 |
| Patuki | Serranidae | *Epinephelus hexagonatus* | 33 | 1.9 |
| Manini | Acanthuridae | *Acanthurus triostegus* | 25 | 1.4 |
| Pipi nanue | Kyphosidae | *Kyphosus bigibbus* | 24 | 1.3 |
| Paoro | Labridae | *Thalassoma* spp. | 12 | 0.7 |
| Ripo pao'a | Carangidae | *Caranx* spp. | 12 | 0.7 |
| Karakarao | Serranidae | *Epinephelus merra* | 9 | 0.5 |
| Aore | Kuhliidae | *Kuhlia mugil* | 9 | 0.5 |
| Tupauru | Pomacentridae | *Abudefduf sordidus* | 9 | 0.5 |
| Ature | Carangidae | *Selar crumenophthalmus* | 9 | 0.5 |
| Tiove | Acanthuridae | *Acanthurus triostegus* | 8 | 0.4 |
| Morava | Siganidae | *Siganus argenteus* | 8 | 0.4 |
| Vete | Mullidae | *Mulloidichthys flavolineatus* | 5 | 0.3 |
| Koma | Mullidae | *Mulloidichthys flavolineatus* | 5 | 0.3 |
| Paara | Scombridae | *Acanthocybium solandri* | 5 | 0.3 |
| Pui | Congridae | *Conger cinereus* | 1 | 0.1 |
| Kuku | Holocentridae | *Sargocentron* spp. | 1 | 0.1 |
| Kerikeri | Muraenidae | *Gymnothorax eurostus* | 1 | 0.1 |
| **Total:** | | | **1783** | **100.0** |

### *2.3.1 Annual catch (kg) of fish groups per habitat – Mangaia (continued)*

(includes only reported catch data by interviewed finfish fishers)

| Vernacular name | Family | Scientific name | Total weight (kg) | % of reported catch |
|---|---|---|---|---|
| **Outer reef** | | | | |
| Tiotio | Kyphosidae | *Kyphosus cinerascens* | 1303 | 23.1 |
| Patuki | Serranidae | *Epinephelus hexagonatus* | 725 | 12.8 |
| Marau | Holocentridae | *Myripristis* spp. | 686 | 12.1 |
| Paoro | Labridae | *Thalassoma* spp. | 673 | 11.9 |
| Karakarao | Serranidae | *Epinephelus merra* | 609 | 10.8 |
| Ume | Acanthuridae | *Naso unicornis* | 413 | 7.3 |
| Api | Acanthuridae | *Acanthurus guttatus* | 208 | 3.7 |
| Atea | Serranidae | *Epinephelus fasciatus* | 180 | 3.2 |
| Akau | Scaridae | *Chlorurus frontalis* | 167 | 3.0 |
| Pipi | Kyphosidae | *Kyphosus cinerascens* | 135 | 2.4 |
| Vaavaa | Serranidae | *Epinephelus tauvina* | 99 | 1.7 |
| Aore | Kuhliidae | *Kuhlia mugil* | 69 | 1.2 |
| Titiara | Carangidae | *Caranx ignobilis* | 66 | 1.2 |
| Pui | Congridae | *Conger cinereus* | 60 | 1.1 |
| Ripo pao'a | Carangidae | *Caranx* spp. | 53 | 0.9 |
| Aputu | Kuhliidae | *Kuhlia marginata* | 33 | 0.6 |
| Manga | Gempylidae | *Promethichthys Prometheus* | 33 | 0.6 |
| Raupipi | Kyphosidae | *Kyphosus cinerascens* | 29 | 0.5 |
| Manini | Acanthuridae | *Acanthurus triostegus* | 25 | 0.4 |
| Tupauru | Pomacentridae | *Abudefduf sordidus* | 25 | 0.4 |
| Kuku | Holocentridae | *Sargocentron* spp. | 24 | 0.4 |
| Maito | Acanthuridae | *Acanthurus olivaceus* | 18 | 0.3 |
| Kauru (goatfish) | Mullidae | *Parupeneus* spp. | 15 | 0.3 |
| Kokiri | Balistidae | *Rhinecanthus* spp. | 1 | 0.0 |
| **Total:** | | | **5650** | **100.0** |

## *2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Mangaia*

| Fishery | Vernacular name | Scientific name | % annual catch (weight) | Recorded | | Extrapolated | |
|---|---|---|---|---|---|---|---|
| | | | | no/year | kg/year | no/year | kg/year |
| Lobster | Koura | *Panulirus longipes*, *Panulirus ornatus*, *Panulirus penicillatus* | 100.0 | 500 | 500 | 6343 | 6343 |
| Reef Top | Matu rori | *Holothuria* spp. | 46.6 | 3039 | 5470 | 27,712 | 49,881 |
| | Ariri | *Turbo marmoratus*, *Turbo setosus* | 1.8 | 10,857 | 217 | 96,671 | 1933 |
| | Atuke | *Heterocentrotus mammillatus* | 2.9 | 3423 | 342 | 33,013 | 3301 |
| | Avake | *Tripneustes gratilla* | 1.3 | 1577 | 158 | 16,709 | 1671 |
| | Kina | *Echinometra mathaei*, *Tripneustes gratilla* | 1.3 | 1513 | 151 | 14,220 | 1422 |
| | Mikia | *Grapsus albolineatus*, *Grapsus grapsus* | 0.0 | 120 | 3 | 932 | 27 |
| | Eke | *Octopus* spp. | 0.5 | 117 | 64 | 1335 | 735 |
| | Papaka | *Carpilius maculatus*, *Grapsus albolineatus*, *Grapsus grapsus* | 0.0 | 100 | 3 | 777 | 22 |
| | Paua | *Tridacna maxima* | 21.4 | 5021 | 2511 | 40,639 | 20,320 |
| | Rimu | *Vexillum* spp. | n/a | 239 | n/a | 2283 | n/a |
| | Tioro | *Scylla serrata* | n/a | 35 | n/a | 272 | n/a |
| | Ungakoa | *Dendropoma maximum*, *Dendropoma* spp., *Serpulorbis* spp. | 21.3 | 166,372 | 2496 | 1310,107 | 19,652 |
| | Upaki | *Carpilius maculatus*, *Scylla serrata* | 0.2 | 40 | 28 | 311 | 218 |
| | Vana | *Echinothrix diadema* | 2.5 | 2993 | 299 | 23,637 | 2364 |

n/a = no information available.

### *2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Mangaia*

| Vernacular name | Scientific name | Size class | % of total catch (weight) |
|---|---|---|---|
| Ariri | *Turbo marmoratus*, *Turbo setosus* | 02-04 cm | 0.3 |
| | | 04-06 cm | 0.0 |
| | | 06 cm | 80.4 |
| | | 06-08 cm | 19.2 |
| Atuke | *Heterocentrotus mammillatus* | 01-10 cm | 38.1 |
| | | 08-10 cm | 38.1 |
| | | 10 cm | 14.0 |
| | | 10-12 cm | 9.8 |
| Avake | *Tripneustes gratilla* | 06 cm | 13.3 |
| | | 08-12 cm | 44.1 |
| | | 10 cm | 42.6 |
| Kina | *Echinometra mathaei*, *Tripneustes gratilla*, *Tripneustes gratilla* | 10 cm | 80.2 |
| | | 12 cm | 19.8 |
| Koura | *Panulirus longipes*, *Panulirus longipes*, *Panulirus ornatus*, *Panulirus penicillatus*, *Panulirus penicillatus* | 20 cm | 60.0 |
| | | 24 cm | 40.0 |
| Matu rori | *Holothuria* spp. | 24-26 cm | 31.4 |
| | | 24-28 cm | 62.5 |
| | | 26-28 cm | 3.6 |
| | | 28 cm | 2.5 |
| Mikia | *Grapsus albolineatus*, *Grapsus grapsus* | 08-10 cm | 100.0 |
| Eke | *Octopus* spp. | 08-10 cm | 74.3 |
| | | 10 cm | 25.7 |
| Papaka | *Carpilius maculatus*, *Grapsus albolineatus*, *Grapsus grapsus* | 08-10 cm | 100.0 |
| Paua | *Tridacna maxima* | 04-06 cm | 2.0 |
| | | 05-08 cm | 1.7 |
| | | 06-08 cm | 37.2 |
| | | 06-10 cm | 7.2 |
| | | 07-10 cm | 9.6 |
| | | 08 cm | 0.2 |
| | | 08-10 cm | 20.3 |
| | | 09 cm | 17.4 |
| | | 10 cm | 0.8 |
| | | 12-14 cm | 2.5 |
| | | 14 cm | 1.2 |
| Tioro | *Scylla serrata* | 10-12 cm | |
| Ungakoa | *Dendropoma maximum*, *Dendropoma* spp., *Serpulorbis* spp. | 04 cm | 99.9 |
| | | 06-08 cm | 0.1 |
| Upaki | *Carpilius maculatus*, *Scylla serrata* | 12 cm | 100.0 |
| Vana | *Echinothrix diadema* | 06-08 cm | 2.5 |
| | | 10 cm | 88.9 |
| | | 10-12 cm | 0.6 |
| | | 12 cm | 8.0 |

## 2.4 Rarotonga socioeconomic survey data

### *2.4.1 Annual catch (kg) of fish groups per habitat – Rarotonga*
(includes only reported catch data by interviewed finfish fishers)

| Vernacular name | Family | Scientific name | Total weight (kg) | % of reported catch |
|---|---|---|---|---|
| **Sheltered coastal reef** | | | | |
| Koma | Mullidae | *Mulloidichthys flavolineatus* | 43 | 33.3 |
| Kokokino (small trevally) | Carangidae | *Caranx sexfasciatus* | 43 | 33.3 |
| Tumaro | | | 22 | 16.7 |
| Ature | Carangidae | *Selar crumenophthalmus* | 22 | 16.7 |
| **Total:** | | | **130** | **100.0** |
| **Lagoon** | | | | |
| Morava | Siganidae | *Siganus argenteus* | 216 | 33.9 |
| Pipi | Kyphosidae | *Kyphosus cinerascens* | 162 | 25.5 |
| Rarotonga (Takitumu district) | Holocentridae | *Myripristis* spp. | 118 | 18.5 |
| Pipi nanue | Kyphosidae | *Kyphosus bigibbus* | 117 | 18.3 |
| Ripo pao'a | Carangidae | *Caranx* spp. | 10 | 1.6 |
| Greenfish (poshow) | Scaridae | *Chlorurus gibbus* | 6 | 0.9 |
| Uoa | Mugilidae | *Neomyxus leuciscus* | 4 | 0.6 |
| Ume | Acanthuridae | *Naso unicornis* | 2 | 0.4 |
| Akau | Scaridae | *Chlorurus frontalis* | 1 | 0.2 |
| Manini | Acanthuridae | *Acanthurus triostegus* | 1 | 0.2 |
| **Total:** | | | **638** | **100.0** |
| **Outer reef** | | | | |
| Akau | Scaridae | *Chlorurus frontalis* | 342 | 25.5 |
| Morava | Siganidae | *Siganus argenteus* | 172 | 12.8 |
| Ume | Acanthuridae | *Naso unicornis* | 171 | 12.7 |
| Pipi | Kyphosidae | *Kyphosus cinerascens* | 165 | 12.3 |
| Patuki | Serranidae | *Epinephelus hexagonatus* | 157 | 11.7 |
| Mu | Lethrinidae | *Monotaxis grandoculis* | 110 | 8.2 |
| Pipi nanue | Kyphosidae | *Kyphosus bigibbus* | 69 | 5.1 |
| Tangau | Lutjanidae | *Lutjanus fulvus* | 65 | 4.9 |
| Greenfish (poshow) | Scaridae | *Chlorurus gibbus* | 32 | 2.4 |
| Manini | Acanthuridae | *Acanthurus triostegus* | 16 | 1.2 |
| Nanue | Kyphosidae | *Kyphosus* spp. | 14 | 1.0 |
| Moi | Polynemidae | *Polydactylus sexfilis* | 14 | 1.0 |
| Marao | Holocentridae | *Myripristis* spp. | 9 | 0.7 |
| Taraoa | Serranidae | *Epinephelus merra* | 8 | 0.6 |
| **Total:** | | | **1344** | **100.0** |

### *2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Rarotonga*

| Fishery | Vernacular name | Scientific name | % annual catch (weight) | Recorded | | Extrapolated | |
|---|---|---|---|---|---|---|---|
| | | | | no/year | kg/year | no/year | kg/year |
| Lobster | Koura | *Panulirus longipes*, *Panulirus ornatus*, *Panulirus penicillatus* | 99.9 | 52.5 | | 451.8 | 451.8 |
| | Papapapa | *Parribacus antarcticus*, *Parribacus caledonicus* | 0.1 | 22.5 | | 193.6 | 0.3 |
| Reeftop & soft benthos | Matu rori | *Holothuria* spp. | 66.2 | 687.0 | 1236.6 | 6787.3 | 12,217.1 |
| | Paua | *Tridacna maxima* | 13.2 | 332.3 | 166.2 | 3064.5 | 1532.2 |
| | Vana | *Echinothrix diadema* | 6.6 | 819.5 | 82.0 | 7152.1 | 715.2 |
| | Atuke | *Heterocentrotus mammillatus* | 6.0 | 749.6 | 75.0 | 6454.1 | 645.4 |
| | Kai | *Asaphis violascens* | 2.3 | 993.5 | 66.2 | 9504.7 | 633.6 |
| | Kina | *Echinometra mathaei*, *Tripneustes gratilla* | 1.7 | 397.0 | 39.7 | 3798.5 | 379.8 |
| | Octopus | *Octopus* spp. | 1.2 | 38.0 | 20.9 | 347.6 | 191.2 |
| | Ariri | *Turbo marmoratus*, *T. setosus* | 0.9 | 538.1 | 10.8 | 5088.1 | 101.8 |
| | Patito | *Dendropoma* spp. | 0.8 | 159.3 | 10.6 | 1523.9 | 101.6 |
| | Avake | *Tripneustes gratilla* | 0.4 | 50.0 | 5.0 | 478.1 | 47.8 |
| | Trochus | *Trochus niloticus* | 0.1 | 154.3 | 30.9 | 1471.9 | 294.4 |
| | Ungakoa | *Dendropoma maximum*, *Dendropoma* spp., *Serpulorbis* spp. | 0.6 | 520.4 | 7.8 | 4979.1 | 74.7 |
| | Tioro | *Scylla serrata* | n/a | 30.0 | 0.0 | 258.2 | |

n/a = no information available.

### *2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Rarotonga*

| Vernacular name | Scientific name | Size class | % of total catch (weight) |
|---|---|---|---|
| Ariri | *Turbo marmoratus*, *Turbo setosus* | 06 cm | 27.9 |
| | | 08 cm | 72.1 |
| Atuke | *Heterocentrotus mammillatus* | 12 cm | 100.0 |
| Avake | *Tripneustes gratilla* | 10 cm | 100.0 |
| Kai | *Asaphis violascens* | 06 cm | 12.6 |
| | | 06-08 cm | 87.4 |
| Kina | *Echinometra mathaei*, *Tripneustes gratilla* | 08-10 cm | 54.7 |
| | | 12 cm | 45.3 |
| Koura | *Panulirus longipes*, *Panulirus ornatus*, *Panulirus penicillatus* | 18-24 cm | 14.3 |
| | | 20 cm | 85.7 |
| Matu rori | *Holothuria* spp. | 16 cm | 3.5 |
| | | 20 cm | 61.0 |
| | | 20-28 cm | 14.0 |
| | | 24 cm | 16.3 |
| | | 26 cm | 5.1 |
| | | 28 cm | 0.1 |
| Eke | *Octopus* spp. | 10-12 cm | 83.5 |
| | | 12 cm | 16.5 |
| Papapapa | *Parribacus antarcticus*, *Parribacus caledonicus* | 18 cm | 66.7 |
| | | 20-22 cm | 33.3 |
| Patito | *Dendropoma* spp. | 06 cm | 100.0 |
| Paua | *Tridacna maxima* | 10-14 cm | 30.1 |
| | | 12 cm | 0.8 |
| | | 14 cm | 36.1 |
| | | 14-16 cm | 33.1 |
| Tioro | *Scylla serrata* | 16 cm | |
| Trochus | *Trochus niloticus* | 10 cm | 97.2 |
| | | 12 cm | 2.8 |
| Ungakoa | *Dendropoma maximum*, *Dendropoma* spp., *Serpulorbis* spp. | 04 cm | 27.8 |
| | | 04-06 cm | 62.6 |
| | | 06 cm | 9.6 |
| Vana | *Echinothrix diadema* | 10 cm | 100.0 |

# APPENDIX 3: FINFISH SURVEY DATA

## 3.1 Aitutaki finfish survey data

### *3.1.1 Coordinates (WGS84) of the 18 D-UVC transects used to assess finfish resource status in Aitutaki*

| Station name | Habitat | Latitude | Longitude |
|---|---|---|---|
| TRA01 | Lagoon | 18º53'50.1612" S | 159º48'53.1" W |
| TRA02 | Back-reef | 18º53'35.9988" S | 159º49'30" W |
| TRA03 | Back-reef | 18º55'14.7612" S | 159º49'14.0412" W |
| TRA04 | Lagoon | 18º52'13.3788" S | 159º48'16.9812" W |
| TRA05 | Outer reef | 18º52'02.0388" S | 159º44'46.7988" W |
| TRA06 | Outer reef | 18º54'43.38" S | 159º43'30" W |
| TRA07 | Lagoon | 18º56'28.14" S | 159º44'33.2412" W |
| TRA08 | Lagoon | 18º53'05.64" S | 159º48'29.2212" W |
| TRA09 | Lagoon | 18º54'22.0212" S | 159º48'51.7788" W |
| TRA10 | Lagoon | 18º53'59.3412" S | 159º48'22.3812" W |
| TRA11 | Back-reef | 18º56'36.3012" S | 159º44'43.8" W |
| TRA12 | Back-reef | 18º55'49.8" S | 159º46'04.62" W |
| TRA13 | Outer reef | 18º56'31.4988" S | 159º45'15.0012" W |
| TRA14 | Outer reef | 18º57'06.4188" S | 159º43'43.7988" W |
| TRA15 | Back-reef | 18º52'30.54" S | 159º48'53.46" W |
| TRA16 | Back-reef | 18º52'04.98" S | 159º48'54.4212" W |
| TRA17 | Outer reef | 18º55'21.2412" S | 159º50'04.4988" W |
| TRA18 | Outer reef | 18º55'42.24" S | 159º47'46.0788" W |

### *3.1.2 Weighted average density and biomass of all finfish species recorded in Aitutaki* (using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Acanthuridae | *Acanthurus nigricauda* | 0.0037 | 1.961 |
| Back-reef | Acanthuridae | *Acanthurus triostegus* | 0.0667 | 6.124 |
| Back-reef | Acanthuridae | *Ctenochaetus striatus* | 0.1488 | 24.331 |
| Back-reef | Acanthuridae | *Naso lituratus* | 0.0097 | 3.047 |
| Back-reef | Acanthuridae | *Naso unicornis* | 0.0007 | 1.008 |
| Back-reef | Acanthuridae | *Zebrasoma scopas* | 0.0003 | 0.021 |
| Back-reef | Acanthuridae | *Zebrasoma veliferum* | 0.0013 | 0.289 |
| Back-reef | Balistidae | *Rhinecanthus aculeatus* | 0.0013 | 0.109 |
| Back-reef | Balistidae | *Rhinecanthus rectangulus* | 0.0007 | 0.068 |
| Back-reef | Chaetodontidae | *Chaetodon auriga* | 0.0103 | 1.190 |
| Back-reef | Chaetodontidae | *Chaetodon bennetti* | 0.0007 | 0.043 |
| Back-reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0023 | 0.057 |
| Back-reef | Chaetodontidae | *Chaetodon ephippium* | 0.0047 | 0.721 |
| Back-reef | Chaetodontidae | *Chaetodon lunula* | 0.0027 | 0.291 |
| Back-reef | Chaetodontidae | *Chaetodon lunulatus* | 0.0017 | 0.070 |
| Back-reef | Chaetodontidae | *Chaetodon ornatissimus* | 0.0007 | 0.041 |
| Back-reef | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0010 | 0.049 |
| Back-reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0003 | 0.013 |
| Back-reef | Chaetodontidae | *Chaetodon vagabundus* | 0.0003 | 0.019 |
| Back-reef | Chaetodontidae | *Heniochus varius* | 0.0003 | 0.010 |
| Back-reef | Holocentridae | *Myripristis kuntee* | 0.0013 | 0.173 |

### *3.1.2 Weighted average density and biomass of all finfish species recorded in Aitutaki (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Holocentridae | *Myripristis* spp. | 0.0017 | 0.293 |
| Back-reef | Holocentridae | *Neoniphon sammara* | 0.0003 | 0.039 |
| Back-reef | Holocentridae | *Sargocentron diadema* | 0.0003 | 0.020 |
| Back-reef | Holocentridae | *Sargocentron spiniferum* | 0.0003 | 0.079 |
| Back-reef | Labridae | *Cheilinus chlorourus* | 0.0053 | 1.017 |
| Back-reef | Labridae | *Cheilinus fasciatus* | 0.0003 | 0.003 |
| Back-reef | Labridae | *Cheilinus undulatus* | 0.0003 | 5.073 |
| Back-reef | Labridae | *Coris aygula* | 0.0020 | 0.334 |
| Back-reef | Labridae | *Epibulus insidiator* | 0.0003 | 0.074 |
| Back-reef | Lethrinidae | *Gnathodentex aureolineatus* | 0.0103 | 2.245 |
| Back-reef | Lethrinidae | *Monotaxis grandoculis* | 0.0003 | 0.297 |
| Back-reef | Lutjanidae | *Lutjanus fulvus* | 0.0057 | 1.714 |
| Back-reef | Mullidae | *Parupeneus barberinoides* | 0.0003 | 0.088 |
| Back-reef | Mullidae | *Parupeneus barberinus* | 0.0053 | 1.494 |
| Back-reef | Mullidae | *Parupeneus cyclostomus* | 0.0017 | 0.610 |
| Back-reef | Mullidae | *Parupeneus multifasciatus* | 0.0060 | 0.857 |
| Back-reef | Mullidae | *Parupeneus trifasciatus* | 0.0020 | 0.337 |
| Back-reef | Scaridae | *Chlorurus frontalis* | 0.0070 | 0.931 |
| Back-reef | Scaridae | *Chlorurus sordidus* | 0.0120 | 1.129 |
| Back-reef | Scaridae | *Scarus frenatus* | 0.0030 | 0.511 |
| Back-reef | Scaridae | *Scarus ghobban* | 0.0067 | 2.147 |
| Back-reef | Scaridae | *Scarus globiceps* | 0.0017 | 0.604 |
| Back-reef | Scaridae | *Scarus psittacus* | 0.0597 | 10.444 |
| Back-reef | Scaridae | *Scarus* spp. | 0.0423 | 1.646 |
| Back-reef | Serranidae | *Cephalopholis argus* | 0.0023 | 0.774 |
| Back-reef | Serranidae | *Cephalopholis miniata* | 0.0003 | 0.080 |
| Back-reef | Serranidae | *Epinephelus merra* | 0.0057 | 0.469 |
| Back-reef | Zanclidae | *Zanclus cornutus* | 0.0037 | 0.583 |
| Lagoon | Acanthuridae | *Acanthurus achilles* | 0.0003 | 0.037 |
| Lagoon | Acanthuridae | *Acanthurus blochii* | 0.0007 | 0.000 |
| Lagoon | Acanthuridae | *Acanthurus triostegus* | 0.0296 | 2.004 |
| Lagoon | Acanthuridae | *Acanthurus xanthopterus* | 0.0007 | 0.000 |
| Lagoon | Acanthuridae | *Ctenochaetus striatus* | 0.1051 | 16.900 |
| Lagoon | Acanthuridae | *Naso annulatus* | 0.0003 | 0.095 |
| Lagoon | Acanthuridae | *Naso lituratus* | 0.0097 | 3.856 |
| Lagoon | Acanthuridae | *Naso unicornis* | 0.0035 | 2.482 |
| Lagoon | Acanthuridae | *Zebrasoma scopas* | 0.0013 | 0.124 |
| Lagoon | Acanthuridae | *Zebrasoma veliferum* | 0.0010 | 0.259 |
| Lagoon | Balistidae | *Rhinecanthus aculeatus* | 0.0040 | 0.349 |
| Lagoon | Carangidae | *Caranx melampygus* | 0.0030 | 1.449 |
| Lagoon | Chaetodontidae | *Chaetodon auriga* | 0.0110 | 1.341 |
| Lagoon | Chaetodontidae | *Chaetodon bennetti* | 0.0013 | 0.040 |
| Lagoon | Chaetodontidae | *Chaetodon citrinellus* | 0.0020 | 0.014 |
| Lagoon | Chaetodontidae | *Chaetodon ephippium* | 0.0037 | 0.603 |
| Lagoon | Chaetodontidae | *Chaetodon lunula* | 0.0003 | 0.000 |
| Lagoon | Chaetodontidae | *Chaetodon lunulatus* | 0.0130 | 0.433 |
| Lagoon | Chaetodontidae | *Chaetodon reticulatus* | 0.0013 | 0.147 |

### *3.1.2 Weighted average density and biomass of all finfish species recorded in Aitutaki (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Lagoon | Chaetodontidae | *Chaetodon trifascialis* | 0.0013 | 0.107 |
| Lagoon | Chaetodontidae | *Chaetodon ulietensis* | 0.0027 | 0.091 |
| Lagoon | Chaetodontidae | *Chaetodon unimaculatus* | 0.0043 | 0.249 |
| Lagoon | Chaetodontidae | *Forcipiger flavissimus* | 0.0003 | 0.061 |
| Lagoon | Chaetodontidae | *Forcipiger longirostris* | 0.0003 | 0.017 |
| Lagoon | Holocentridae | *Sargocentron spiniferum* | 0.0020 | 0.281 |
| Lagoon | Kyphosidae | *Kyphosus cinerascens* | 0.0003 | 0.193 |
| Lagoon | Kyphosidae | *Kyphosus vaigiensis* | 0.0007 | 0.396 |
| Lagoon | Labridae | *Cheilinus chlorourus* | 0.0103 | 1.280 |
| Lagoon | Labridae | *Cheilinus undulatus* | 0.0007 | 0.622 |
| Lagoon | Labridae | *Coris aygula* | 0.0003 | 0.099 |
| Lagoon | Labridae | *Epibulus insidiator* | 0.0063 | 0.620 |
| Lagoon | Lethrinidae | *Gnathodentex aureolineatus* | 0.0100 | 0.778 |
| Lagoon | Lethrinidae | *Monotaxis grandoculis* | 0.0047 | 2.248 |
| Lagoon | Lutjanidae | *Lutjanus fulvus* | 0.0063 | 1.128 |
| Lagoon | Lutjanidae | *Lutjanus monostigma* | 0.0023 | 0.842 |
| Lagoon | Mugilidae | *Liza vaigiensis* | 0.0040 | 0.000 |
| Lagoon | Mullidae | *Parupeneus barberinus* | 0.0007 | 0.288 |
| Lagoon | Mullidae | *Parupeneus cyclostomus* | 0.0010 | 0.391 |
| Lagoon | Mullidae | *Parupeneus multifasciatus* | 0.0030 | 0.460 |
| Lagoon | Scaridae | *Chlorurus microrhinos* | 0.0010 | 0.617 |
| Lagoon | Scaridae | *Chlorurus sordidus* | 0.0415 | 4.321 |
| Lagoon | Scaridae | *Hipposcarus longiceps* | 0.0010 | 0.951 |
| Lagoon | Scaridae | *Scarus altipinnis* | 0.0113 | 7.012 |
| Lagoon | Scaridae | *Scarus frenatus* | 0.0023 | 1.078 |
| Lagoon | Scaridae | *Scarus ghobban* | 0.0027 | 0.718 |
| Lagoon | Scaridae | *Scarus psittacus* | 0.0077 | 0.872 |
| Lagoon | Scaridae | *Scarus rivulatus* | 0.0003 | 0.058 |
| Lagoon | Scaridae | *Scarus schlegeli* | 0.0020 | 0.276 |
| Lagoon | Scaridae | *Scarus* spp. | 0.0158 | 2.378 |
| Lagoon | Serranidae | *Cephalopholis argus* | 0.0050 | 1.050 |
| Lagoon | Serranidae | *Epinephelus hexagonatus* | 0.0003 | 0.028 |
| Lagoon | Serranidae | *Epinephelus merra* | 0.0110 | 1.121 |
| Lagoon | Serranidae | *Epinephelus* spp. | 0.0003 | 0.051 |
| Lagoon | Serranidae | *Plectropomus laevis* | 0.0003 | 1.855 |
| Lagoon | Serranidae | *Plectropomus leopardus* | 0.0003 | 0.094 |
| Lagoon | Siganidae | *Siganus argenteus* | 0.0007 | 0.125 |
| Lagoon | Zanclidae | *Zanclus cornutus* | 0.0057 | 0.829 |
| Outer reef | Acanthuridae | *Acanthurus achilles* | 0.0087 | 1.466 |
| Outer reef | Acanthuridae | *Acanthurus guttatus* | 0.0023 | 0.382 |
| Outer reef | Acanthuridae | *Acanthurus lineatus* | 0.0054 | 1.728 |
| Outer reef | Acanthuridae | *Acanthurus nigricans* | 0.0050 | 0.564 |
| Outer reef | Acanthuridae | *Acanthurus nigrofuscus* | 0.0420 | 1.189 |
| Outer reef | Acanthuridae | *Acanthurus* spp. | 0.0160 | 1.735 |
| Outer reef | Acanthuridae | *Acanthurus triostegus* | 0.1333 | 8.069 |
| Outer reef | Acanthuridae | *Ctenochaetus striatus* | 0.5095 | 60.144 |
| Outer reef | Acanthuridae | *Ctenochaetus strigosus* | 0.0013 | 0.101 |

### *3.1.2 Weighted average density and biomass of all finfish species recorded in Aitutaki (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Acanthuridae | *Naso annulatus* | 0.0010 | 0.678 |
| Outer reef | Acanthuridae | *Naso lituratus* | 0.0258 | 7.018 |
| Outer reef | Acanthuridae | *Zebrasoma veliferum* | 0.0033 | 0.690 |
| Outer reef | Balistidae | *Balistapus undulatus* | 0.0030 | 0.442 |
| Outer reef | Balistidae | *Melichthys niger* | 0.0267 | 4.577 |
| Outer reef | Balistidae | *Melichthys vidua* | 0.0224 | 3.071 |
| Outer reef | Balistidae | *Rhinecanthus rectangulus* | 0.0010 | 0.075 |
| Outer reef | Balistidae | *Sufflamen bursa* | 0.0013 | 0.179 |
| Outer reef | Chaetodontidae | *Chaetodon auriga* | 0.0007 | 0.069 |
| Outer reef | Chaetodontidae | *Chaetodon bennetti* | 0.0003 | 0.021 |
| Outer reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0007 | 0.002 |
| Outer reef | Chaetodontidae | *Chaetodon ephippium* | 0.0007 | 0.073 |
| Outer reef | Chaetodontidae | *Chaetodon lunula* | 0.0007 | 0.061 |
| Outer reef | Chaetodontidae | *Chaetodon lunulatus* | 0.0023 | 0.097 |
| Outer reef | Chaetodontidae | *Chaetodon ornatissimus* | 0.0003 | 0.037 |
| Outer reef | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0087 | 0.388 |
| Outer reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0023 | 0.100 |
| Outer reef | Chaetodontidae | *Chaetodon trifascialis* | 0.0010 | 0.065 |
| Outer reef | Chaetodontidae | *Chaetodon ulietensis* | 0.0013 | 0.100 |
| Outer reef | Chaetodontidae | *Chaetodon unimaculatus* | 0.0017 | 0.203 |
| Outer reef | Chaetodontidae | *Heniochus monoceros* | 0.0017 | 0.327 |
| Outer reef | Holocentridae | *Myripristis berndti* | 0.0020 | 0.843 |
| Outer reef | Holocentridae | *Myripristis murdjan* | 0.0037 | 0.917 |
| Outer reef | Holocentridae | *Sargocentron* spp. | 0.0007 | 0.068 |
| Outer reef | Holocentridae | *Sargocentron spiniferum* | 0.0007 | 0.210 |
| Outer reef | Holocentridae | *Sargocentron tiere* | 0.0007 | 0.068 |
| Outer reef | Labridae | *Cheilinus chlorourus* | 0.0017 | 0.273 |
| Outer reef | Labridae | *Cheilinus fasciatus* | 0.0010 | 0.107 |
| Outer reef | Labridae | *Coris aygula* | 0.0003 | 0.067 |
| Outer reef | Labridae | *Coris gaimard* | 0.0003 | 0.111 |
| Outer reef | Labridae | *Epibulus insidiator* | 0.0013 | 0.258 |
| Outer reef | Labridae | *Hemigymnus fasciatus* | 0.0007 | 0.126 |
| Outer reef | Lethrinidae | *Gnathodentex aureolineatus* | 0.0037 | 1.343 |
| Outer reef | Lethrinidae | *Lethrinus xanthochilus* | 0.0007 | 1.062 |
| Outer reef | Lethrinidae | *Monotaxis grandoculis* | 0.0004 | 0.199 |
| Outer reef | Lutjanidae | *Aphareus furca* | 0.0003 | 0.118 |
| Outer reef | Lutjanidae | *Lutjanus fulvus* | 0.0007 | 0.148 |
| Outer reef | Mullidae | *Parupeneus cyclostomus* | 0.0010 | 0.343 |
| Outer reef | Mullidae | *Parupeneus multifasciatus* | 0.0027 | 0.380 |
| Outer reef | Mullidae | *Parupeneus trifasciatus* | 0.0020 | 0.508 |
| Outer reef | Pomacanthidae | *Pomacanthus imperator* | 0.0010 | 0.839 |
| Outer reef | Scaridae | *Chlorurus frontalis* | 0.0010 | 0.247 |
| Outer reef | Scaridae | *Chlorurus sordidus* | 0.0687 | 7.655 |
| Outer reef | Scaridae | *Hipposcarus longiceps* | 0.0007 | 0.265 |
| Outer reef | Scaridae | *Scarus altipinnis* | 0.0007 | 0.143 |
| Outer reef | Scaridae | *Scarus dimidiatus* | 0.0027 | 0.285 |
| Outer reef | Scaridae | *Scarus frenatus* | 0.0057 | 1.972 |

### *3.1.2 Weighted average density and biomass of all finfish species recorded in Aitutaki (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Scaridae | *Scarus ghobban* | 0.0007 | 0.143 |
| Outer reef | Scaridae | *Scarus globiceps* | 0.0030 | 0.523 |
| Outer reef | Scaridae | *Scarus longipinnis* | 0.0007 | 0.109 |
| Outer reef | Scaridae | *Scarus psittacus* | 0.0107 | 1.377 |
| Outer reef | Scaridae | *Scarus rivulatus* | 0.0003 | 0.130 |
| Outer reef | Scaridae | *Scarus* spp. | 0.0183 | 3.198 |
| Outer reef | Scaridae | *Scarus tricolor* | 0.0003 | 0.286 |
| Outer reef | Serranidae | *Cephalopholis argus* | 0.0433 | 9.013 |
| Outer reef | Serranidae | *Cephalopholis urodeta* | 0.0070 | 0.742 |
| Outer reef | Serranidae | *Epinephelus hexagonatus* | 0.0050 | 0.287 |
| Outer reef | Serranidae | *Epinephelus merra* | 0.0013 | 0.099 |
| Outer reef | Serranidae | *Plectropomus laevis* | 0.0003 | 0.257 |
| Outer reef | Zanclidae | *Zanclus cornutus* | 0.0003 | 0.036 |

## 3.2 Palmerston finfish survey data

### *3.2.1 Coordinates (WGS84) of the 18 D-UVC transects used to assess finfish resource status in Palmerston*

| Station name | Habitat | Latitude | Longitude |
|---|---|---|---|
| TRA01 | Outer reef | 18º02'44.88" S | 163º11'29.2812" W |
| TRA02 | Outer reef | 18º03'36.4212" S | 163º11'55.5" W |
| TRA03 | Outer reef | 18º03'47.0988" S | 163º07'31.0188" W |
| TRA04 | Outer reef | 18º04'57.7812" S | 163º08'50.3988" W |
| TRA05 | Outer reef | 18º00'06.5988" S | 163º08'55.5" W |
| TRA06 | Outer reef | 18º00'24.66" S | 163º10'29.7012" W |
| TRA07 | Back-reef | 18º02'50.5788" S | 163º11'08.2788" W |
| TRA08 | Back-reef | 18º02'39.84" S | 163º11'03.3612" W |
| TRA09 | Lagoon | 18º02'16.0188" S | 163º10'22.1412" W |
| TRA10 | Lagoon | 18º00'41.2812" S | 163º09'51.9588" W |
| TRA11 | Lagoon | 18º00'24.7212" S | 163º09'54.7812" W |
| TRA12 | Back-reef | 18º00'52.3188" S | 163º10'02.9388" W |
| TRA13 | Lagoon | 18º04'52.2012" S | 163º09'32.1588" W |
| TRA14 | Lagoon | 18º04'43.2588" S | 163º10'09.66" W |
| TRA15 | Back-reef | 18º04'47.82" S | 163º10'25.7988" W |
| TRA16 | Lagoon | 18º03'38.9988" S | 163º10'47.2188" W |
| TRA17 | Back-reef | 18º03'46.62" S | 163º10'51.3012" W |
| TRA18 | Back-reef | 18º03'59.8212" S | 163º10'45.3612" W |

### *3.2.2 Weighted average density and biomass of all finfish species recorded in Palmerston* (using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Acanthuridae | *Acanthurus nigrofuscus* | 0.0007 | 0.058 |
| Back-reef | Acanthuridae | *Acanthurus olivaceus* | 0.0087 | 2.062 |
| Back-reef | Acanthuridae | *Acanthurus triostegus* | 0.0730 | 3.927 |
| Back-reef | Acanthuridae | *Ctenochaetus striatus* | 0.2084 | 4.247 |
| Back-reef | Acanthuridae | *Ctenochaetus strigosus* | 0.0003 | 0.007 |
| Back-reef | Acanthuridae | *Naso lituratus* | 0.0023 | 0.517 |
| Back-reef | Acanthuridae | *Naso unicornis* | 0.0013 | 3.024 |
| Back-reef | Balistidae | *Rhinecanthus aculeatus* | 0.0010 | 0.155 |
| Back-reef | Carangidae | *Carangoides orthogrammus* | 0.0010 | 1.083 |
| Back-reef | Carangidae | *Caranx lugubris* | 0.0010 | 0.511 |
| Back-reef | Carangidae | *Caranx melampygus* | 0.0020 | 1.074 |
| Back-reef | Chaetodontidae | *Chaetodon auriga* | 0.0080 | 0.868 |
| Back-reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0013 | 0.018 |
| Back-reef | Chaetodontidae | *Chaetodon ephippium* | 0.0030 | 0.527 |
| Back-reef | Chaetodontidae | *Chaetodon lunulatus* | 0.0027 | 0.062 |
| Back-reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0010 | 0.031 |
| Back-reef | Chaetodontidae | *Chaetodon ulietensis* | 0.0013 | 0.053 |
| Back-reef | Holocentridae | *Myripristis murdjan* | 0.0013 | 0.235 |
| Back-reef | Holocentridae | *Sargocentron spiniferum* | 0.0003 | 0.024 |
| Back-reef | Labridae | *Cheilinus chlorourus* | 0.0017 | 0.206 |
| Back-reef | Labridae | *Epibulus insidiator* | 0.0003 | 0.006 |
| Back-reef | Lethrinidae | *Monotaxis grandoculis* | 0.0013 | 1.560 |
| Back-reef | Lutjanidae | *Lutjanus monostigma* | 0.0003 | 0.232 |

### *3.2.2 Weighted average density and biomass of all finfish species recorded in Palmerston (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Mullidae | *Mulloidichthys flavolineatus* | 0.0013 | 0.035 |
| Back-reef | Mullidae | *Parupeneus barberinus* | 0.0003 | 0.068 |
| Back-reef | Mullidae | *Parupeneus multifasciatus* | 0.0030 | 0.051 |
| Back-reef | Mullidae | *Parupeneus pleurostigma* | 0.0007 | 0.064 |
| Back-reef | Mullidae | *Parupeneus trifasciatus* | 0.0010 | 0.100 |
| Back-reef | Scaridae | *Cetoscarus bicolor* | 0.0007 | 0.573 |
| Back-reef | Scaridae | *Chlorurus microrhinos* | 0.0050 | 9.547 |
| Back-reef | Scaridae | *Chlorurus sordidus* | 0.0263 | 0.412 |
| Back-reef | Scaridae | *Hipposcarus longiceps* | 0.0098 | 6.107 |
| Back-reef | Scaridae | *Scarus altipinnis* | 0.0040 | 0.706 |
| Back-reef | Scaridae | *Scarus frenatus* | 0.0007 | 0.068 |
| Back-reef | Scaridae | *Scarus psittacus* | 0.0067 | 0.312 |
| Back-reef | Scaridae | *Scarus schlegeli* | 0.0017 | 0.195 |
| Back-reef | Scaridae | *Scarus* spp. | 0.0113 | 0.310 |
| Back-reef | Serranidae | *Cephalopholis argus* | 0.0003 | 0.098 |
| Back-reef | Serranidae | *Plectropomus laevis* | 0.0007 | 7.043 |
| Back-reef | Zanclidae | *Zanclus cornutus* | 0.0003 | 0.045 |
| Lagoon | Acanthuridae | *Acanthurus achilles* | 0.0099 | 1.021 |
| Lagoon | Acanthuridae | *Acanthurus blochii* | 0.0003 | 0.074 |
| Lagoon | Acanthuridae | *Acanthurus nigrofuscus* | 0.0043 | 0.074 |
| Lagoon | Acanthuridae | *Acanthurus triostegus* | 0.0477 | 3.265 |
| Lagoon | Acanthuridae | *Ctenochaetus striatus* | 0.1750 | 28.675 |
| Lagoon | Acanthuridae | *Naso lituratus* | 0.0003 | 0.099 |
| Lagoon | Acanthuridae | *Naso unicornis* | 0.0003 | 0.092 |
| Lagoon | Acanthuridae | *Zebrasoma veliferum* | 0.0003 | 0.091 |
| Lagoon | Balistidae | *Rhinecanthus aculeatus* | 0.0027 | 0.457 |
| Lagoon | Balistidae | *Rhinecanthus rectangulus* | 0.0010 | 0.227 |
| Lagoon | Carangidae | *Caranx melampygus* | 0.0067 | 10.920 |
| Lagoon | Carcharhinidae | *Carcharhinus amblyrhynchos* | 0.0010 | 32.039 |
| Lagoon | Carcharhinidae | *Triaenodon obesus* | 0.0003 | 7.021 |
| Lagoon | Chaetodontidae | *Chaetodon auriga* | 0.0153 | 2.302 |
| Lagoon | Chaetodontidae | *Chaetodon citrinellus* | 0.0030 | 0.020 |
| Lagoon | Chaetodontidae | *Chaetodon ephippium* | 0.0053 | 0.724 |
| Lagoon | Chaetodontidae | *Chaetodon lunula* | 0.0007 | 0.138 |
| Lagoon | Chaetodontidae | *Chaetodon lunulatus* | 0.0083 | 0.248 |
| Lagoon | Chaetodontidae | *Chaetodon ornatissimus* | 0.0003 | 0.002 |
| Lagoon | Chaetodontidae | *Chaetodon pelewensis* | 0.0017 | 0.008 |
| Lagoon | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0013 | 0.052 |
| Lagoon | Chaetodontidae | *Chaetodon reticulatus* | 0.0003 | 0.013 |
| Lagoon | Chaetodontidae | *Chaetodon ulietensis* | 0.0082 | 0.332 |
| Lagoon | Chaetodontidae | *Chaetodon vagabundus* | 0.0017 | 0.151 |
| Lagoon | Chaetodontidae | *Forcipiger longirostris* | 0.0017 | 0.103 |
| Lagoon | Chaetodontidae | *Heniochus chrysostomus* | 0.0003 | 0.037 |
| Lagoon | Fistulariidae | *Fistularia commersonii* | 0.0007 | 0.131 |
| Lagoon | Holocentridae | *Myripristis murdjan* | 0.0030 | 0.528 |
| Lagoon | Holocentridae | *Neoniphon argenteus* | 0.0013 | 0.199 |
| Lagoon | Holocentridae | *Sargocentron spiniferum* | 0.0077 | 2.445 |

### *3.2.2 Weighted average density and biomass of all finfish species recorded in Palmerston (continued)*
(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Lagoon | Labridae | *Cheilinus chlorourus* | 0.0030 | 0.265 |
| Lagoon | Labridae | *Coris aygula* | 0.0003 | 0.050 |
| Lagoon | Labridae | *Epibulus insidiator* | 0.0010 | 0.050 |
| Lagoon | Lethrinidae | *Gnathodentex aureolineatus* | 0.0013 | 0.351 |
| Lagoon | Lethrinidae | *Lethrinus atkinsoni* | 0.0003 | 0.312 |
| Lagoon | Lethrinidae | *Lethrinus xanthochilus* | 0.0007 | 1.062 |
| Lagoon | Lethrinidae | *Monotaxis grandoculis* | 0.0167 | 17.626 |
| Lagoon | Lutjanidae | *Lutjanus monostigma* | 0.0140 | 5.495 |
| Lagoon | Mullidae | *Parupeneus barberinus* | 0.0013 | 0.463 |
| Lagoon | Mullidae | *Parupeneus cyclostomus* | 0.0007 | 0.240 |
| Lagoon | Mullidae | *Parupeneus multifasciatus* | 0.0040 | 0.236 |
| Lagoon | Mullidae | *Parupeneus trifasciatus* | 0.0010 | 0.407 |
| Lagoon | Muraenidae | *Gymnothorax javanicus* | 0.0003 | 0.697 |
| Lagoon | Scaridae | *Cetoscarus bicolor* | 0.0013 | 1.989 |
| Lagoon | Scaridae | *Chlorurus microrhinos* | 0.0022 | 1.491 |
| Lagoon | Scaridae | *Chlorurus sordidus* | 0.0429 | 1.535 |
| Lagoon | Scaridae | *Hipposcarus longiceps* | 0.0353 | 16.562 |
| Lagoon | Scaridae | *Scarus altipinnis* | 0.0406 | 11.346 |
| Lagoon | Scaridae | *Scarus psittacus* | 0.0013 | 0.290 |
| Lagoon | Scaridae | *Scarus schlegeli* | 0.0100 | 1.878 |
| Lagoon | Scaridae | *Scarus* spp. | 0.0007 | 0.024 |
| Lagoon | Serranidae | *Cephalopholis argus* | 0.0190 | 7.408 |
| Lagoon | Serranidae | *Epinephelus areolatus* | 0.0003 | 0.041 |
| Lagoon | Serranidae | *Epinephelus maculatus* | 0.0017 | 0.223 |
| Lagoon | Serranidae | *Epinephelus merra* | 0.0060 | 0.863 |
| Lagoon | Serranidae | *Plectropomus laevis* | 0.0030 | 8.054 |
| Lagoon | Siganidae | *Siganus argenteus* | 0.0037 | 1.026 |
| Lagoon | Tetraodontidae | *Arothron meleagris* | 0.0003 | 0.030 |
| Lagoon | Zanclidae | *Zanclus cornutus* | 0.0020 | 0.247 |
| Outer reef | Acanthuridae | *Acanthurus achilles* | 0.0439 | 5.040 |
| Outer reef | Acanthuridae | *Acanthurus nigricans* | 0.0179 | 2.657 |
| Outer reef | Acanthuridae | *Acanthurus nigricauda* | 0.0017 | 0.145 |
| Outer reef | Acanthuridae | *Acanthurus nigrofuscus* | 0.0764 | 3.429 |
| Outer reef | Acanthuridae | *Acanthurus* spp. | 0.0113 | 0.394 |
| Outer reef | Acanthuridae | *Acanthurus triostegus* | 0.0017 | 0.122 |
| Outer reef | Acanthuridae | *Ctenochaetus striatus* | 0.1874 | 23.189 |
| Outer reef | Acanthuridae | *Ctenochaetus strigosus* | 0.0197 | 1.013 |
| Outer reef | Acanthuridae | *Naso annulatus* | 0.0020 | 0.348 |
| Outer reef | Acanthuridae | *Naso lituratus* | 0.0157 | 4.145 |
| Outer reef | Acanthuridae | *Naso thynnoides* | 0.0017 | 0.239 |
| Outer reef | Acanthuridae | *Zebrasoma scopas* | 0.0007 | 0.064 |
| Outer reef | Balistidae | *Balistapus undulatus* | 0.0010 | 0.262 |
| Outer reef | Balistidae | *Melichthys niger* | 0.0126 | 1.384 |
| Outer reef | Balistidae | *Melichthys vidua* | 0.0172 | 2.838 |
| Outer reef | Balistidae | *Rhinecanthus aculeatus* | 0.0003 | 0.023 |
| Outer reef | Balistidae | *Rhinecanthus rectangulus* | 0.0010 | 0.072 |
| Outer reef | Balistidae | *Sufflamen bursa* | 0.0040 | 0.450 |

### *3.2.2 Weighted average density and biomass of all finfish species recorded in Palmerston (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Balistidae | *Sufflamen* spp. | 0.0003 | 0.060 |
| Outer reef | Carangidae | *Carangoides orthogrammus* | 0.0010 | 0.348 |
| Outer reef | Carangidae | *Caranx lugubris* | 0.0003 | 0.139 |
| Outer reef | Carangidae | *Caranx melampygus* | 0.0050 | 5.324 |
| Outer reef | Carangidae | *Trachinotus baillonii* | 0.0007 | 0.164 |
| Outer reef | Carcharhinidae | *Triaenodon obesus* | 0.0007 | 8.032 |
| Outer reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0073 | 0.184 |
| Outer reef | Chaetodontidae | *Chaetodon lunulatus* | 0.0043 | 0.129 |
| Outer reef | Chaetodontidae | *Chaetodon ornatissimus* | 0.0010 | 0.069 |
| Outer reef | Chaetodontidae | *Chaetodon pelewensis* | 0.0023 | 0.033 |
| Outer reef | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0067 | 0.303 |
| Outer reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0047 | 0.215 |
| Outer reef | Chaetodontidae | *Chaetodon ulietensis* | 0.0030 | 0.143 |
| Outer reef | Chaetodontidae | *Chaetodon unimaculatus* | 0.0030 | 0.081 |
| Outer reef | Labridae | *Cheilinus chlorourus* | 0.0057 | 0.625 |
| Outer reef | Labridae | *Coris gaimard* | 0.0003 | 0.077 |
| Outer reef | Labridae | *Epibulus insidiator* | 0.0033 | 0.614 |
| Outer reef | Labridae | *Oxycheilinus digramma* | 0.0003 | 0.029 |
| Outer reef | Mullidae | *Parupeneus multifasciatus* | 0.0027 | 0.251 |
| Outer reef | Mullidae | *Parupeneus trifasciatus* | 0.0020 | 0.170 |
| Outer reef | Scaridae | *Chlorurus microrhinos* | 0.0011 | 2.554 |
| Outer reef | Scaridae | *Chlorurus sordidus* | 0.1857 | 12.605 |
| Outer reef | Scaridae | *Hipposcarus longiceps* | 0.0018 | 1.556 |
| Outer reef | Scaridae | *Scarus altipinnis* | 0.0027 | 3.085 |
| Outer reef | Scaridae | *Scarus frenatus* | 0.0037 | 0.345 |
| Outer reef | Scaridae | *Scarus ghobban* | 0.0007 | 0.085 |
| Outer reef | Scaridae | *Scarus globiceps* | 0.0023 | 0.395 |
| Outer reef | Scaridae | *Scarus oviceps* | 0.0003 | 0.063 |
| Outer reef | Scaridae | *Scarus psittacus* | 0.0110 | 0.958 |
| Outer reef | Scaridae | *Scarus schlegeli* | 0.0073 | 0.681 |
| Outer reef | Scaridae | *Scarus* spp. | 0.0063 | 0.218 |
| Outer reef | Serranidae | *Cephalopholis argus* | 0.0067 | 1.226 |
| Outer reef | Serranidae | *Cephalopholis urodeta* | 0.0097 | 0.757 |
| Outer reef | Serranidae | *Epinephelus hexagonatus* | 0.0007 | 0.047 |
| Outer reef | Serranidae | *Plectropomus laevis* | 0.0017 | 6.281 |
| Outer reef | Zanclidae | *Zanclus cornutus* | 0.0013 | 0.135 |

## 3.3 Mangaia finfish survey data

### *3.3.1 Coordinates (WGS84) of the 13 D-UVC transects used to assess finfish resource status in Mangaia*

| Station name | Habitat | Latitude | Longitude |
|---|---|---|---|
| TRA12 | Outer reef | 21º54'40.7412" S | 157º57'11.2788" W |
| TRA13 | Outer reef | 21º54'41.58" S | 157º57'20.9412" W |
| TRA06 | Outer reef | 21º56'11.2812" S | 157º57'47.4588" W |
| TRA09 | Outer reef | 21º57'24.7788" S | 157º54'23.8212" W |
| TRA05 | Outer reef | 21º57'00.7812" S | 157º57'08.46" W |
| TRA07 | Outer reef | 21º57'30.1788" S | 157º55'08.2812" W |
| TRA01 | Outer reef | 21º53'35.4588" S | 157º56'14.1612" W |
| TRA10 | Outer reef | 21º55'38.3412" S | 157º57'42.0012" W |
| TRA02 | Outer reef | 21º53'45.78" S | 157º56'44.4012" W |
| TRA03 | Outer reef | 21º54'10.08" S | 157º57'08.7588" W |
| TRA04 | Outer reef | 21º57'28.1988" S | 157º56'25.5012" W |
| TRA11 | Outer reef | 21º55'12.4212" S | 157º57'33.0012" W |
| TRA08 | Outer reef | 21º57'26.5212" S | 157º53'27.6" W |

### *3.3.2 Weighted average density and biomass of all finfish species recorded in Mangaia* (using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Acanthuridae | *Acanthurus achilles* | 0.0168 | 2.357 |
| Outer reef | Acanthuridae | *Acanthurus auranticavus* | 0.0316 | 2.638 |
| Outer reef | Acanthuridae | *Acanthurus guttatus* | 0.0267 | 3.502 |
| Outer reef | Acanthuridae | *Acanthurus leucopareius* | 0.1922 | 27.227 |
| Outer reef | Acanthuridae | *Acanthurus nigricans* | 0.0361 | 4.569 |
| Outer reef | Acanthuridae | *Acanthurus nigrofuscus* | 0.0005 | 0.117 |
| Outer reef | Acanthuridae | *Acanthurus olivaceus* | 0.0015 | 0.313 |
| Outer reef | Acanthuridae | *Acanthurus* spp. | 0.0114 | 1.018 |
| Outer reef | Acanthuridae | *Acanthurus thompsoni* | 0.0112 | 0.832 |
| Outer reef | Acanthuridae | *Acanthurus triostegus* | 0.0198 | 1.568 |
| Outer reef | Acanthuridae | *Ctenochaetus flavicauda* | 0.0116 | 0.437 |
| Outer reef | Acanthuridae | *Ctenochaetus hawaiiensis* | 0.0217 | 2.255 |
| Outer reef | Acanthuridae | *Ctenochaetus striatus* | 0.3231 | 36.086 |
| Outer reef | Acanthuridae | *Ctenochaetus strigosus* | 0.0020 | 0.074 |
| Outer reef | Acanthuridae | *Naso lituratus* | 0.0304 | 5.598 |
| Outer reef | Acanthuridae | *Naso unicornis* | 0.0255 | 3.632 |
| Outer reef | Acanthuridae | *Zebrasoma rostratum* | 0.0003 | 0.038 |
| Outer reef | Acanthuridae | *Zebrasoma scopas* | 0.0057 | 0.461 |
| Outer reef | Balistidae | *Balistapus undulatus* | 0.0002 | 0.016 |
| Outer reef | Balistidae | *Melichthys niger* | 0.0018 | 0.938 |
| Outer reef | Balistidae | *Melichthys vidua* | 0.0012 | 0.234 |
| Outer reef | Balistidae | *Rhinecanthus rectangulus* | 0.0005 | 0.045 |
| Outer reef | Balistidae | *Sufflamen bursa* | 0.0035 | 0.296 |
| Outer reef | Balistidae | *Sufflamen chrysopterum* | 0.0006 | 0.029 |
| Outer reef | Carangidae | *Selar* spp. | 0.0385 | 8.335 |
| Outer reef | Carangidae | *Seriola rivoliana* | 0.0002 | 0.802 |
| Outer reef | Chaetodontidae | *Chaetodon auriga* | 0.0011 | 0.041 |
| Outer reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0003 | 0.007 |

### *3.3.2 Weighted average density and biomass of all finfish species recorded in Mangaia (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Chaetodontidae | *Chaetodon lunula* | 0.0023 | 0.127 |
| Outer reef | Chaetodontidae | *Chaetodon pelewensis* | 0.0002 | 0.001 |
| Outer reef | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0022 | 0.051 |
| Outer reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0011 | 0.033 |
| Outer reef | Chaetodontidae | *Chaetodon unimaculatus* | 0.0012 | 0.053 |
| Outer reef | Chaetodontidae | *Forcipiger longirostris* | 0.0011 | 0.052 |
| Outer reef | Holocentridae | *Myripristis berndti* | 0.0017 | 0.559 |
| Outer reef | Holocentridae | *Myripristis kuntee* | 0.0003 | 0.029 |
| Outer reef | Holocentridae | *Myripristis murdjan* | 0.0003 | 0.064 |
| Outer reef | Holocentridae | *Myripristis* spp. | 0.0002 | 0.010 |
| Outer reef | Holocentridae | *Sargocentron tiere* | 0.0017 | 0.232 |
| Outer reef | Kyphosidae | *Kyphosus cinerascens* | 0.0002 | 0.034 |
| Outer reef | Labridae | *Coris aygula* | 0.0029 | 1.992 |
| Outer reef | Labridae | *Coris gaimard* | 0.0003 | 0.143 |
| Outer reef | Labridae | *Hemigymnus fasciatus* | 0.0012 | 0.297 |
| Outer reef | Labridae | *Oxycheilinus digramma* | 0.0002 | 0.030 |
| Outer reef | Lethrinidae | *Gnathodentex aureolineatus* | 0.0021 | 0.330 |
| Outer reef | Lutjanidae | *Aphareus furca* | 0.0055 | 1.847 |
| Outer reef | Mullidae | *Mulloidichthys flavolineatus* | 0.0006 | 0.227 |
| Outer reef | Mullidae | *Mulloidichthys vanicolensis* | 0.0003 | 0.079 |
| Outer reef | Mullidae | *Parupeneus barberinoides* | 0.0006 | 0.122 |
| Outer reef | Mullidae | *Parupeneus bifasciatus* | 0.0065 | 2.628 |
| Outer reef | Mullidae | *Parupeneus cyclostomus* | 0.0009 | 0.156 |
| Outer reef | Mullidae | *Parupeneus indicus* | 0.0009 | 0.505 |
| Outer reef | Mullidae | *Parupeneus multifasciatus* | 0.0043 | 0.555 |
| Outer reef | Pomacanthidae | *Pomacanthus imperator* | 0.0017 | 0.808 |
| Outer reef | Scaridae | *Calotomus carolinus* | 0.0002 | 0.061 |
| Outer reef | Scaridae | *Hipposcarus longiceps* | 0.0002 | 0.279 |
| Outer reef | Scaridae | *Scarus forsteni* | 0.0030 | 1.827 |
| Outer reef | Scaridae | *Scarus frenatus* | 0.0026 | 1.258 |
| Outer reef | Scaridae | *Scarus psittacus* | 0.0003 | 0.079 |
| Outer reef | Scaridae | *Scarus* spp. | 0.0014 | 0.913 |
| Outer reef | Serranidae | *Cephalopholis argus* | 0.0018 | 0.516 |
| Outer reef | Serranidae | *Cephalopholis urodeta* | 0.0069 | 0.510 |
| Outer reef | Serranidae | *Epinephelus fasciatus* | 0.0026 | 0.629 |
| Outer reef | Serranidae | *Epinephelus tauvina* | 0.0002 | 0.081 |
| Outer reef | Siganidae | *Siganus argenteus* | 0.0012 | 0.117 |
| Outer reef | Siganidae | *Siganus* spp. | 0.0059 | 0.517 |
| Outer reef | Siganidae | *Siganus spinus* | 0.0028 | 0.266 |
| Outer reef | Zanclidae | *Zanclus cornutus* | 0.0011 | 0.042 |

## 3.4 Rarotonga finfish survey data

### *3.4.1 Coordinates (WGS84) of the 17 D-UVC transects used to assess finfish resource status in Rarotonga*

| Station name | Habitat | Latitude | Longitude |
|---|---|---|---|
| TRA04 | Outer reef | 21º12'00.72" S | 159º45'38.7612" W |
| TRA13 | Back-reef | 21º16'08.4" S | 159º45'59.4" W |
| TRA16 | Back-reef | 21º15'35.82" S | 159º48'10.8612" W |
| TRA17 | Back-reef | 21º15'23.58" S | 159º49'04.7388" W |
| TRA07 | Outer reef | 21º16'07.9788" S | 159º47'56.4" W |
| TRA09 | Outer reef | 21º14'51.9612" S | 159º49'47.64" W |
| TRA10 | Back-reef | 21º15'50.4612" S | 159º44'05.3412" W |
| TRA05 | Outer reef | 21º12'00.7812" S | 159º47'07.5012" W |
| TRA03 | Outer reef | 21º12'54.9" S | 159º49'57.2988" W |
| TRA14 | Back-reef | 21º16'01.0812" S | 159º46'50.6388" W |
| TRA06 | Outer reef | 21º11'40.38" S | 159º48'16.6212" W |
| TRA02 | Outer reef | 21º14'09.42" S | 159º49'53.1588" W |
| TRA15 | Back-reef | 21º15'45.0612" S | 159º47'52.08" W |
| TRA11 | Back-reef | 21º16'12.8388" S | 159º44'27.7188" W |
| TRA12 | Back-reef | 21º16'18.7788" S | 159º44'45.4812" W |
| TRA01 | Outer reef | 21º12'04.9788" S | 159º49'17.3388" W |
| TRA08 | Outer reef | 21º15'49.0788" S | 159º48'41.6988" W |

### *3.4.2 Weighted average density and biomass of all finfish species recorded in Rarotonga* (using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Acanthuridae | *Acanthurus nigricans* | 0.0005 | 0.073 |
| Back-reef | Acanthuridae | *Acanthurus triostegus* | 0.2868 | 30.505 |
| Back-reef | Acanthuridae | *Ctenochaetus striatus* | 0.1979 | 22.419 |
| Back-reef | Acanthuridae | *Naso lituratus* | 0.0063 | 0.482 |
| Back-reef | Acanthuridae | *Naso unicornis* | 0.0018 | 0.278 |
| Back-reef | Acanthuridae | *Zebrasoma scopas* | 0.0010 | 0.029 |
| Back-reef | Acanthuridae | *Zebrasoma veliferum* | 0.0003 | 0.016 |
| Back-reef | Balistidae | *Rhinecanthus aculeatus* | 0.0133 | 1.521 |
| Back-reef | Carangidae | *Caranx ignobilis* | 0.0003 | 1.069 |
| Back-reef | Chaetodontidae | *Chaetodon aureofasciatus* | 0.0005 | 0.027 |
| Back-reef | Chaetodontidae | *Chaetodon auriga* | 0.0163 | 0.910 |
| Back-reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0060 | 0.064 |
| Back-reef | Chaetodontidae | *Chaetodon lunula* | 0.0008 | 0.032 |
| Back-reef | Chaetodontidae | *Chaetodon ornatissimus* | 0.0010 | 0.057 |
| Back-reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0005 | 0.008 |
| Back-reef | Chaetodontidae | *Chaetodon ulietensis* | 0.0010 | 0.018 |
| Back-reef | Chaetodontidae | *Chaetodon unimaculatus* | 0.0008 | 0.012 |
| Back-reef | Chaetodontidae | *Chaetodon vagabundus* | 0.0008 | 0.040 |
| Back-reef | Chaetodontidae | *Forcipiger longirostris* | 0.0008 | 0.037 |
| Back-reef | Chaetodontidae | *Heniochus acuminatus* | 0.0003 | 0.018 |
| Back-reef | Chaetodontidae | *Heniochus chrysostomus* | 0.0015 | 0.044 |
| Back-reef | Diodontidae | *Diodon hystrix* | 0.0003 | 0.441 |
| Back-reef | Holocentridae | *Myripristis* spp. | 0.0010 | 0.101 |
| Back-reef | Holocentridae | *Sargocentron diadema* | 0.0010 | 0.061 |

### *3.4.2 Weighted average density and biomass of all finfish species recorded in Rarotonga (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Back-reef | Holocentridae | *Sargocentron spiniferum* | 0.0013 | 0.032 |
| Back-reef | Kyphosidae | *Kyphosus cinerascens* | 0.0063 | 3.620 |
| Back-reef | Kyphosidae | *Kyphosus vaigiensis* | 0.0023 | 1.505 |
| Back-reef | Labridae | *Cheilinus chlorourus* | 0.0015 | 0.150 |
| Back-reef | Labridae | *Cheilinus trilobatus* | 0.0003 | 0.077 |
| Back-reef | Labridae | *Coris aygula* | 0.0010 | 1.065 |
| Back-reef | Lethrinidae | *Gnathodentex aureolineatus* | 0.1038 | 16.147 |
| Back-reef | Lethrinidae | *Monotaxis grandoculis* | 0.0010 | 0.339 |
| Back-reef | Lutjanidae | *Lutjanus fulvus* | 0.0005 | 0.134 |
| Back-reef | Mugilidae | *Liza vaigiensis* | 0.0003 | 0.573 |
| Back-reef | Mullidae | *Mulloidichthys flavolineatus* | 0.1455 | 71.007 |
| Back-reef | Mullidae | *Mulloidichthys vanicolensis* | 0.0450 | 40.581 |
| Back-reef | Mullidae | *Parupeneus barberinus* | 0.0003 | 0.329 |
| Back-reef | Mullidae | *Parupeneus bifasciatus* | 0.0018 | 0.498 |
| Back-reef | Mullidae | *Parupeneus cyclostomus* | 0.0003 | 0.026 |
| Back-reef | Mullidae | *Parupeneus multifasciatus* | 0.0063 | 0.423 |
| Back-reef | Pomacanthidae | *Pomacanthus imperator* | 0.0010 | 0.974 |
| Back-reef | Scaridae | *Calotomus carolinus* | 0.0003 | 0.041 |
| Back-reef | Scaridae | *Chlorurus frontalis* | 0.0085 | 3.772 |
| Back-reef | Scaridae | *Chlorurus microrhinos* | 0.0008 | 0.430 |
| Back-reef | Scaridae | *Chlorurus sordidus* | 0.0108 | 0.675 |
| Back-reef | Scaridae | *Scarus altipinnis* | 0.0013 | 1.011 |
| Back-reef | Scaridae | *Scarus frenatus* | 0.0008 | 0.233 |
| Back-reef | Scaridae | *Scarus globiceps* | 0.0013 | 0.498 |
| Back-reef | Scaridae | *Scarus psittacus* | 0.0138 | 5.859 |
| Back-reef | Scaridae | *Scarus rivulatus* | 0.0005 | 0.445 |
| Back-reef | Scaridae | *Scarus schlegeli* | 0.0003 | 0.283 |
| Back-reef | Scaridae | *Scarus spinus* | 0.0035 | 1.188 |
| Back-reef | Serranidae | *Cephalopholis argus* | 0.0038 | 1.322 |
| Back-reef | Serranidae | *Epinephelus hexagonatus* | 0.0003 | 0.029 |
| Back-reef | Serranidae | *Epinephelus merra* | 0.0003 | 0.049 |
| Back-reef | Serranidae | *Epinephelus tauvina* | 0.0003 | 0.050 |
| Back-reef | Siganidae | *Siganus argenteus* | 0.0005 | 0.028 |
| Back-reef | Siganidae | *Siganus spinus* | 0.0038 | 0.445 |
| Back-reef | Zanclidae | *Zanclus cornutus* | 0.0025 | 0.149 |
| Outer reef | Acanthuridae | *Acanthurus achilles* | 0.0013 | 0.230 |
| Outer reef | Acanthuridae | *Acanthurus auranticavus* | 0.0007 | 0.087 |
| Outer reef | Acanthuridae | *Acanthurus guttatus* | 0.0044 | 0.490 |
| Outer reef | Acanthuridae | *Acanthurus leucopareius* | 0.0673 | 6.666 |
| Outer reef | Acanthuridae | *Acanthurus nigricans* | 0.0013 | 0.123 |
| Outer reef | Acanthuridae | *Acanthurus nigricauda* | 0.0011 | 0.384 |
| Outer reef | Acanthuridae | *Acanthurus olivaceus* | 0.0067 | 3.348 |
| Outer reef | Acanthuridae | *Acanthurus triostegus* | 0.1236 | 10.707 |
| Outer reef | Acanthuridae | *Ctenochaetus hawaiiensis* | 0.0009 | 0.286 |
| Outer reef | Acanthuridae | *Ctenochaetus striatus* | 0.5416 | 62.354 |
| Outer reef | Acanthuridae | *Ctenochaetus strigosus* | 0.0087 | 0.184 |
| Outer reef | Acanthuridae | *Naso lituratus* | 0.0284 | 13.926 |

### *3.4.2 Weighted average density and biomass of all finfish species recorded in Rarotonga (continued)*

(using distance-sampling underwater visual censuses (D-UVC))

| Habitat | Family | Species | Density (fish/m²) | Biomass (g/m²) |
|---|---|---|---|---|
| Outer reef | Acanthuridae | *Zebrasoma scopas* | 0.0002 | 0.011 |
| Outer reef | Balistidae | *Melichthys vidua* | 0.0031 | 0.894 |
| Outer reef | Balistidae | *Rhinecanthus aculeatus* | 0.0022 | 0.192 |
| Outer reef | Balistidae | *Rhinecanthus rectangulus* | 0.0029 | 0.233 |
| Outer reef | Balistidae | *Sufflamen bursa* | 0.0159 | 1.262 |
| Outer reef | Chaetodontidae | *Chaetodon citrinellus* | 0.0002 | 0.000 |
| Outer reef | Chaetodontidae | *Chaetodon ornatissimus* | 0.0018 | 0.074 |
| Outer reef | Chaetodontidae | *Chaetodon quadrimaculatus* | 0.0002 | 0.002 |
| Outer reef | Chaetodontidae | *Chaetodon reticulatus* | 0.0004 | 0.022 |
| Outer reef | Chaetodontidae | *Chaetodon ulietensis* | 0.0004 | 0.010 |
| Outer reef | Chaetodontidae | *Chaetodon unimaculatus* | 0.0007 | 0.035 |
| Outer reef | Chaetodontidae | *Forcipiger longirostris* | 0.0004 | 0.028 |
| Outer reef | Chaetodontidae | *Heniochus acuminatus* | 0.0004 | 0.040 |
| Outer reef | Chaetodontidae | *Heniochus varius* | 0.0002 | 0.007 |
| Outer reef | Holocentridae | *Myripristis berndti* | 0.0036 | 0.742 |
| Outer reef | Kyphosidae | *Kyphosus cinerascens* | 0.0002 | 0.104 |
| Outer reef | Kyphosidae | *Kyphosus vaigiensis* | 0.0007 | 0.362 |
| Outer reef | Labridae | *Cheilinus chlorourus* | 0.0004 | 0.115 |
| Outer reef | Labridae | *Coris aygula* | 0.0004 | 0.123 |
| Outer reef | Labridae | *Oxycheilinus digramma* | 0.0002 | 0.066 |
| Outer reef | Lethrinidae | *Gnathodentex aureolineatus* | 0.0004 | 0.061 |
| Outer reef | Lethrinidae | *Monotaxis grandoculis* | 0.0002 | 0.217 |
| Outer reef | Lutjanidae | *Aphareus furca* | 0.0027 | 1.166 |
| Outer reef | Mullidae | *Parupeneus bifasciatus* | 0.0009 | 0.476 |
| Outer reef | Mullidae | *Parupeneus cyclostomus* | 0.0020 | 0.664 |
| Outer reef | Mullidae | *Parupeneus multifasciatus* | 0.0020 | 0.518 |
| Outer reef | Muraenidae | *Gymnothorax* spp. | 0.0002 | 0.086 |
| Outer reef | Pomacanthidae | *Pomacanthus imperator* | 0.0002 | 0.085 |
| Outer reef | Scaridae | *Calotomus carolinus* | 0.0002 | 0.079 |
| Outer reef | Scaridae | *Chlorurus frontalis* | 0.0002 | 0.121 |
| Outer reef | Scaridae | *Chlorurus sordidus* | 0.0116 | 3.413 |
| Outer reef | Scaridae | *Scarus altipinnis* | 0.0013 | 1.707 |
| Outer reef | Scaridae | *Scarus forsteni* | 0.0007 | 0.405 |
| Outer reef | Scaridae | *Scarus frenatus* | 0.0013 | 0.594 |
| Outer reef | Scaridae | *Scarus globiceps* | 0.0053 | 1.596 |
| Outer reef | Scaridae | *Scarus niger* | 0.0002 | 0.052 |
| Outer reef | Scaridae | *Scarus oviceps* | 0.0002 | 0.099 |
| Outer reef | Scaridae | *Scarus psittacus* | 0.0060 | 2.384 |
| Outer reef | Scaridae | *Scarus schlegeli* | 0.0053 | 1.673 |
| Outer reef | Scaridae | *Scarus* spp. | 0.0009 | 0.317 |
| Outer reef | Scaridae | *Scarus spinus* | 0.0002 | 0.048 |
| Outer reef | Serranidae | *Cephalopholis argus* | 0.0053 | 1.428 |
| Outer reef | Serranidae | *Cephalopholis urodeta* | 0.0013 | 0.145 |
| Outer reef | Serranidae | *Epinephelus areolatus* | 0.0002 | 0.059 |
| Outer reef | Serranidae | *Epinephelus fasciatus* | 0.0002 | 0.077 |
| Outer reef | Zanclidae | *Zanclus cornutus* | 0.0022 | 0.154 |

# APPENDIX 4: INVERTEBRATE SURVEY DATA

## 4.1 Aitutaki invertebrate survey data

### *4.1.1 Invertebrate species recorded in different assessments in Aitutaki*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Bêche-de-mer | *Actinopyga mauritiana* | + | + | | + |
| Bêche-de-mer | *Bohadschia argus* | + | | | |
| Bêche-de-mer | *Holothuria atra* | + | + | | + |
| Bêche-de-mer | *Holothuria leucospilota* | + | + | | + |
| Bêche-de-mer | *Stichopus chloronotus* | + | + | | + |
| Bêche-de-mer | *Stichopus horrens* | | | | + |
| Bêche-de-mer | *Synapta* spp. | + | | | |
| Bêche-de-mer | *Thelenota ananas* | | | | + |
| Bivalve | *Chama* spp. | + | + | | |
| Bivalve | *Pinctada margaritifera* | + | + | | |
| Bivalve | *Spondylus* spp. | + | + | | |
| Bivalve | *Tridacna maxima* | + | + | | + |
| Cnidarian | *Heteractis* spp. | | | | + |
| Cnidarian | *Stichodactyla* spp. | | | | + |
| Crustacean | *Parribacus caledonicus* | | | | + |
| Gastropod | *Astralium* spp. | | + | | + |
| Gastropod | *Cerithium nodulosum* | + | + | | |
| Gastropod | *Conus ebraeus* | | + | | |
| Gastropod | *Conus* spp. | | + | | + |
| Gastropod | *Conus vexillum* | | + | | |
| Gastropod | *Cypraea annulus* | | + | | |
| Gastropod | *Cypraea caputserpensis* | | + | | |
| Gastropod | *Cypraea moneta* | | + | | |
| Gastropod | *Cypraea tigris* | + | + | | + |
| Gastropod | *Lambis truncata* | | | | + |
| Gastropod | *Strombus lentiginosus* | | + | | |
| Gastropod | *Thais aculeata* | | + | | |
| Gastropod | *Thais* spp. | | + | | |
| Gastropod | *Trochus niloticus* | + | + | | + |
| Gastropod | *Trochus* spp. | | + | | |
| Gastropod | *Turbo argyrostomus* | | | | + |
| Gastropod | *Turbo setosus* | | | | + |
| Star | *Acanthaster planci* | + | + | | + |
| Star | *Linckia laevigata* | + | + | | + |
| Urchin | *Diadema savignyi* | + | | | |
| Urchin | *Diadema* spp. | + | + | | + |
| Urchin | *Echinometra mathaei* | + | + | | + |
| Urchin | *Echinothrix calamaris* | | + | | |
| Urchin | *Echinothrix diadema* | + | + | | + |
| Urchin | *Heterocentrotus mammillatus* | | | | + |
| Urchin | *Tripneustes gratilla* | + | + | | + |

+ = presence of the species.

### *4.1.2 Aitutaki 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 |
| *Acanthaster planci* | 0.2 | 0.2 | 72 | 16.7 | | 1 | 0.2 | 0.2 | 12 | 2.8 | | 1 |
| *Actinopyga mauritiana* | 10.5 | 5.9 | 72 | 68.4 | 35.2 | 11 | 10.4 | 7.7 | 12 | 25.0 | 17.4 | 5 |
| *Bohadschia argus* | 0.7 | 0.7 | 72 | 50.0 | | 1 | 0.7 | 0.7 | 12 | 8.3 | | 1 |
| *Cerithium nodulosum* | 8.0 | 3.4 | 72 | 52.7 | 17.0 | 11 | 7.9 | 3.8 | 12 | 19.0 | 6.6 | 5 |
| *Chama* spp. | 47.8 | 16.2 | 72 | 114.7 | 35.7 | 30 | 47.8 | 21.4 | 12 | 57.3 | 24.7 | 10 |
| *Cypraea tigris* | 1.9 | 0.8 | 72 | 22.6 | 3.4 | 6 | 1.9 | 0.9 | 12 | 5.6 | 1.6 | 4 |
| *Diadema savignyi* | 0.2 | 0.2 | 72 | 16.7 | | 1 | 0.2 | 0.2 | 12 | 2.8 | | 1 |
| *Diadema* spp. | 1.4 | 0.6 | 72 | 20.0 | 3.3 | 5 | 1.4 | 0.7 | 12 | 4.2 | 1.4 | 4 |
| *Echinometra mathaei* | 721.2 | 196.2 | 72 | 911.0 | 242.0 | 57 | 721.2 | 391.5 | 12 | 721.2 | 391.5 | 12 |
| *Echinothrix diadema* | 20.4 | 7.7 | 72 | 112.8 | 32.9 | 13 | 20.4 | 16.4 | 12 | 61.1 | 46.1 | 4 |
| *Holothuria atra* | 10,032.8 | 1431.0 | 72 | 12,454.5 | 1623.9 | 58 | 10,016.7 | 2942.6 | 12 | 10,016.7 | 2,942.6 | 12 |
| *Holothuria leucospilota* | 82.2 | 26.6 | 72 | 295.8 | 78.9 | 20 | 82.0 | 40.3 | 12 | 163.9 | 66.8 | 6 |
| *Linckia laevigata* | 79.3 | 13.0 | 72 | 103.8 | 15.6 | 55 | 79.3 | 19.1 | 12 | 86.5 | 19.4 | 11 |
| *Pinctada margaritifera* | 0.5 | 0.3 | 72 | 16.7 | 0.0 | 2 | 0.5 | 0.3 | 12 | 2.8 | 0.0 | 2 |
| *Spondylus* spp. | 0.2 | 0.2 | 72 | 16.7 | | 1 | 0.2 | 0.2 | 12 | 2.8 | | 1 |
| *Stichopus chloronotus* | 93.1 | 14.3 | 72 | 121.8 | 16.9 | 55 | 93.1 | 28.9 | 12 | 93.1 | 28.9 | 12 |
| *Synapta* spp. | 0.7 | 0.5 | 72 | 25.0 | 8.3 | 2 | 0.7 | 0.7 | 12 | 8.3 | | 1 |
| *Tridacna maxima* | 143.3 | 44.0 | 72 | 210.6 | 62.6 | 49 | 143.2 | 60.9 | 12 | 156.2 | 65.2 | 11 |
| *Tripneustes gratilla* | 5.1 | 2.0 | 72 | 30.6 | 8.9 | 12 | 5.1 | 2.7 | 12 | 8.7 | 4.2 | 7 |
| *Trochus niloticus* | 38.4 | 16.1 | 72 | 197.6 | 69.8 | 14 | 38.5 | 34.2 | 12 | 65.9 | 58.1 | 7 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.3 Aitutaki 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 |
| *Acanthaster planci* | 1.9 | 1.9 | 129 | 250.0 | | 1 | 2.0 | 2.0 | 21 | 41.7 | | 1 |
| *Actinopyga mauritiana* | 34.9 | 12.8 | 129 | 500.0 | 93.2 | 9 | 26.5 | 18.7 | 21 | 138.9 | 83.9 | 4 |
| *Astralium* spp. | 42.6 | 9.6 | 129 | 289.5 | 21.5 | 19 | 42.3 | 13.5 | 21 | 88.9 | 19.8 | 10 |
| *Cerithium nodulosum* | 3.9 | 3.9 | 129 | 500.0 | | 1 | 4.0 | 4.0 | 21 | 83.3 | | 1 |
| *Chama* spp. | 182.2 | 82.4 | 129 | 1382.4 | 555.4 | 17 | 186.5 | 84.8 | 21 | 435.2 | 168.7 | 9 |
| *Conus ebraeus* | 1.9 | 1.9 | 129 | 250.0 | | 1 | 2.0 | 2.0 | 21 | 41.7 | | 1 |
| *Conus* spp. | 81.4 | 17.9 | 129 | 420.0 | 53.5 | 25 | 82.7 | 19.4 | 21 | 144.7 | 19.5 | 12 |
| *Conus vexillum* | 1.9 | 1.9 | 129 | 250.0 | | 1 | 2.0 | 2.0 | 21 | 41.7 | | 1 |
| *Cypraea annulus* | 5.8 | 3.3 | 129 | 250.0 | 0.0 | 3 | 6.0 | 3.3 | 21 | 41.7 | 0.0 | 3 |
| *Cypraea caputserpensis* | 7.8 | 3.8 | 129 | 250.0 | 0.0 | 4 | 7.9 | 4.7 | 21 | 55.6 | 13.9 | 3 |
| *Cypraea moneta* | 17.4 | 5.6 | 129 | 250.0 | 0.0 | 9 | 17.9 | 5.4 | 21 | 46.9 | 5.2 | 8 |
| *Cypraea tigris* | 5.8 | 3.3 | 129 | 250.0 | 0.0 | 3 | 6.0 | 4.3 | 21 | 62.5 | 20.8 | 2 |
| *Diadema* spp. | 110.5 | 29.1 | 129 | 712.5 | 119.3 | 20 | 113.1 | 53.0 | 21 | 339.3 | 123.5 | 7 |
| *Echinometra mathaei* | 4038.8 | 370.5 | 129 | 5371.1 | 410.9 | 97 | 4121.7 | 596.8 | 21 | 4327.8 | 588.8 | 20 |
| *Echinothrix calamaris* | 1.9 | 1.9 | 129 | 250.0 | | 1 | 2.0 | 2.0 | 21 | 41.7 | | 1 |
| *Echinothrix diadema* | 1596.9 | 435.0 | 129 | 3491.5 | 893.9 | 59 | 1490.7 | 669.4 | 21 | 1841.5 | 807.2 | 17 |
| *Holothuria atra* | 20,945.7 | 3271.8 | 129 | 23,094.0 | 3549.1 | 117 | 21,341.9 | 5432.2 | 21 | 22,409.0 | 5599.7 | 20 |
| *Holothuria leucospilota* | 1151.2 | 206.5 | 129 | 3453.5 | 448.0 | 43 | 1175.3 | 503.7 | 21 | 2243.7 | 853.9 | 11 |
| *Linckia laevigata* | 220.9 | 24.7 | 129 | 425.4 | 31.0 | 67 | 226.2 | 36.9 | 21 | 250.0 | 36.6 | 19 |
| *Pinctada margaritifera* | 1.9 | 1.9 | 129 | 250.0 | | 1 | 2.0 | 2.0 | 21 | 41.7 | | 1 |
| *Spondylus* spp. | 3.9 | 2.7 | 129 | 250.0 | 0.0 | 2 | 4.0 | 2.7 | 21 | 41.7 | 0.0 | 2 |
| *Stichopus chloronotus* | 441.9 | 102.2 | 129 | 760.0 | 166.8 | 75 | 447.8 | 112.6 | 21 | 470.1 | 116.0 | 20 |
| *Strombus lentiginosus* | 3.9 | 3.9 | 129 | 500.0 | | 1 | 4.0 | 4.0 | 21 | 83.3 | | 1 |
| *Thais aculeata* | 7.8 | 4.7 | 129 | 333.3 | 83.3 | 3 | 7.3 | 4.5 | 21 | 50.9 | 16.7 | 3 |
| *Thais* spp. | 3.9 | 2.7 | 129 | 250.0 | 0.0 | 2 | 4.0 | 2.7 | 21 | 41.7 | 0.0 | 2 |
| *Tridacna maxima* | 864.3 | 127.6 | 129 | 1343.4 | 177.9 | 83 | 876.3 | 276.6 | 21 | 920.1 | 287.1 | 20 |
| *Tripneustes gratilla* | 211.2 | 62.0 | 129 | 1513.9 | 302.1 | 18 | 216.3 | 121.9 | 21 | 908.3 | 393.4 | 5 |
| *Trochus niloticus* | 866.3 | 147.0 | 129 | 2149.0 | 283.6 | 52 | 857.1 | 315.4 | 21 | 1500.0 | 478.4 | 12 |
| *Trochus* spp. | 38.8 | 36.9 | 129 | 2500.0 | 2250.0 | 2 | 39.7 | 37.7 | 21 | 416.7 | 375.0 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.4 Aitutaki 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 |
| *Acanthaster planci* | 0.5 | 0.5 | 48 | 23.5 | | 1 | 0.5 | 0.5 | 8 | 3.9 | | 1 |
| *Actinopyga mauritiana* | 74.5 | 28.9 | 48 | 132.5 | 48.9 | 27 | 74.5 | 50.1 | 8 | 85.2 | 56.5 | 7 |
| *Echinometra mathaei* | 413.2 | 130.2 | 48 | 1102.0 | 283.6 | 18 | 413.2 | 164.7 | 8 | 661.2 | 187.0 | 5 |
| *Heterocentrotus mammillatus* | 17.2 | 9.5 | 48 | 117.6 | 53.6 | 7 | 17.2 | 16.0 | 8 | 45.8 | 41.8 | 3 |
| *Holothuria atra* | 1.0 | 0.7 | 48 | 23.5 | 0.0 | 2 | 1.0 | 0.6 | 8 | 3.9 | 0.0 | 2 |
| *Tridacna maxima* | 0.5 | 0.5 | 48 | 23.5 | | 1 | 0.5 | 0.5 | 8 | 3.9 | | 1 |
| *Trochus niloticus* | 27.9 | 5.2 | 48 | 51.6 | 6.8 | 26 | 27.9 | 10.0 | 8 | 31.9 | 10.6 | 7 |
| *Turbo setosus* | 0.5 | 0.5 | 48 | 23.5 | | 1 | 0.5 | 0.5 | 8 | 3.9 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.5 Aitutaki 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 |
| *Acanthaster planci* | 0.5 | 0.3 | 48 | 11.1 | 0.0 | 2 | 0.5 | 0.5 | 8 | 3.7 | | 1 |
| *Actinopyga mauritiana* | 197.5 | 27.9 | 48 | 201.7 | 28.1 | 47 | 197.5 | 36.7 | 8 | 197.5 | 36.7 | 8 |
| *Astralium* spp. | 40.3 | 40.3 | 48 | 1933.3 | | 1 | 40.3 | 40.3 | 8 | 322.2 | | 1 |
| *Echinometra mathaei* | 59.5 | 19.1 | 48 | 190.4 | 46.2 | 15 | 59.5 | 22.2 | 8 | 68.0 | 23.7 | 7 |
| *Echinothrix diadema* | 1276.2 | 235.2 | 48 | 1750.2 | 283.7 | 35 | 1276.2 | 419.8 | 8 | 1458.5 | 436.6 | 7 |
| *Heteractis* spp. | 0.2 | 0.2 | 48 | 11.1 | | 1 | 0.2 | 0.2 | 8 | 1.9 | | 1 |
| *Heterocentrotus mammillatus* | 5.8 | 3.2 | 48 | 69.4 | 21.0 | 4 | 5.8 | 5.8 | 8 | 46.3 | | 1 |
| *Holothuria atra* | 893.5 | 163.5 | 48 | 974.7 | | 44 | 893.5 | 206.6 | 8 | 893.5 | 206.6 | 8 |
| *Holothuria leucospilota* | 0.2 | 0.2 | 48 | 11.1 | | 1 | 0.2 | 0.2 | 8 | 1.9 | | 1 |
| *Linckia laevigata* | 27.1 | 7.4 | 48 | 59.1 | 13.3 | 22 | 27.1 | 16.8 | 8 | 31.0 | 18.9 | 7 |
| *Stichopus chloronotus* | 8.1 | 3.0 | 48 | 35.4 | 9.5 | 11 | 8.1 | 4.7 | 8 | 16.2 | 7.8 | 4 |
| *Thelenota ananas* | 0.5 | 0.5 | 48 | 22.2 | | 1 | 0.5 | 0.5 | 8 | 3.7 | | 1 |
| *Tridacna maxima* | 2.1 | 0.7 | 48 | 12.5 | 1.4 | 8 | 2.1 | 1.0 | 8 | 4.2 | 1.4 | 4 |
| *Tripneustes gratilla* | 0.2 | 0.2 | 48 | 11.1 | | 1 | 0.2 | 0.2 | 8 | 1.9 | | 1 |
| *Trochus niloticus* | 66.0 | 15.0 | 48 | 83.3 | 18.0 | 38 | 66.0 | 27.4 | 8 | 75.4 | 29.7 | 7 |
| *Turbo setosus* | 7.4 | 3.8 | 48 | 44.4 | 18.7 | 8 | 7.4 | 5.7 | 8 | 14.8 | 10.6 | 4 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.6 Aitutaki 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 |
| *Holothuria atra* | 7.6 | 7.6 | 6 | 45.5 | | 1 | 7.6 | | 1 | 7.6 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.7 Aitutaki mother-of-pearl transect (MOPt) assessment data review*

Station: Six 1 m x 40 m.

| Species | Transect | | | Transect _P | | | Station | | | Station _P | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SE | n | Mean | SE | n | Mean | SE | n | Mean | SE | n |
| *Actinopyga mauritiana* | 114.6 | 32.7 | 24 | 275.0 | 40.8 | 10 | 114.6 | 62.8 | 4 | 152.8 | 70.5 | 3 |
| *Conus* spp. | 5.2 | 5.2 | 24 | 125.0 | | 1 | 5.2 | 5.2 | 4 | 20.8 | | 1 |
| *Echinometra mathaei* | 4255.2 | 1310.8 | 24 | 6007.4 | 1681.9 | 17 | 4255.2 | 3089.8 | 4 | 4255.2 | 3089.8 | 4 |
| *Stichodactyla* spp. | 5.2 | 5.2 | 24 | 125.0 | | 1 | 5.2 | 5.2 | 4 | 20.8 | | 1 |
| *Tridacna maxima* | 15.6 | 8.6 | 24 | 125.0 | 0.0 | 3 | 15.6 | 10.0 | 4 | 31.3 | 10.4 | 2 |
| *Trochus niloticus* | 599.0 | 119.4 | 24 | 718.8 | 127.2 | 20 | 599.0 | 265.6 | 4 | 599.0 | 265.6 | 4 |
| *Turbo argyrostomus* | 5.2 | 5.2 | 24 | 125.0 | | 1 | 5.2 | 5.2 | 4 | 20.8 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.8 Aitutaki 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* | 1248.9 | 206.6 | 12 | 1248.9 | 206.6 | 12 | 1248.9 | 342.2 | 2 | 1248.9 | 342.2 | 2 |
| *Cypraea tigris* | 8.9 | 8.9 | 12 | 106.7 | | 1 | 8.9 | 8.9 | 2 | 17.8 | | 1 |
| *Diadema* spp. | 8.9 | 6.0 | 12 | 53.3 | 0.0 | 2 | 8.9 | 0.0 | 2 | 8.9 | 0.0 | 2 |
| *Echinothrix diadema* | 13.3 | 7.0 | 12 | 53.3 | 0.0 | 3 | 13.3 | 4.4 | 2 | 13.3 | 4.4 | 2 |
| *Holothuria atra* | 11,111.1 | 3502.1 | 12 | 22,222.2 | 2140.7 | 6 | 11,111.1 | 2222.2 | 2 | 11,111.1 | 2222.2 | 2 |
| *Holothuria leucospilota* | 2733.3 | 1439.1 | 12 | 5466.7 | 2474.6 | 6 | 2733.3 | 2333.3 | 2 | 2733.3 | 2333.3 | 2 |
| *Linckia laevigata* | 17.8 | 12.0 | 12 | 106.7 | 0.0 | 2 | 17.8 | 17.8 | 2 | 35.6 | | 1 |
| *Parribacus caledonicus* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Stichopus chloronotus* | 26.7 | 12.3 | 12 | 80.0 | 15.4 | 4 | 26.7 | 8.9 | 2 | 26.7 | 8.9 | 2 |
| *Stichopus horrens* | 195.6 | 46.6 | 12 | 234.7 | 46.5 | 10 | 195.6 | 80.0 | 2 | 195.6 | 80.0 | 2 |
| *Tripneustes gratilla* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Trochus niloticus* | 57.8 | 17.9 | 12 | 86.7 | 20.0 | 8 | 57.8 | 22.2 | 2 | 57.8 | 22.2 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.1.9 Aitutaki 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 |
| *Acanthaster planci* | 11.9 | 4.0 | 18 | 30.6 | 4.9 | 7 | 11.9 | 6.9 | 3 | 17.9 | 6.0 | 2 |
| *Lambis truncata* | 4.0 | 4.0 | 18 | 71.4 | | 1 | 4.0 | 4.0 | 3 | 11.9 | | 1 |
| *Thelenota ananas* | 11.9 | 3.7 | 18 | 26.8 | 4.2 | 8 | 11.9 | 6.3 | 3 | 17.9 | 3.6 | 2 |
| *Trochus niloticus* | 11.9 | 6.2 | 18 | 53.6 | | 4 | 11.9 | 11.9 | 3 | 35.7 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

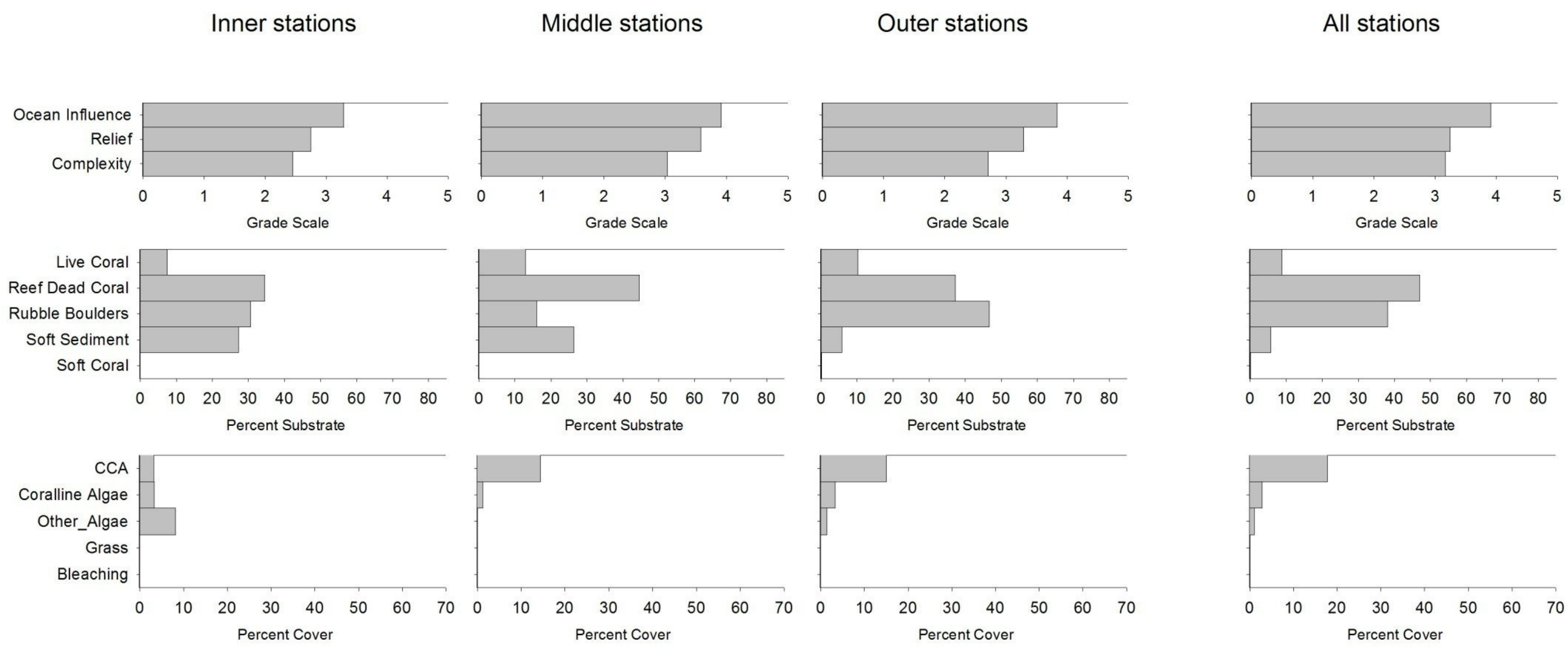
### *4.1.10 Aitutaki species size review – all survey methods*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Holothuria atra* | 19.0 | 0.4 | 60,402 |
| *Actinopyga mauritiana* | 18.3 | 0.4 | 1371 |
| *Trochus niloticus* | 10.8 | 0.1 | 1098 |
| *Tridacna maxima* | 8.0 | 0.2 | 1077 |
| *Stichopus chloronotus* | 17.3 | 0.3 | 671 |
| *Linckia laevigata* | 6.0 | 0.0 | 577 |
| *Astralium* spp. | 3.9 | 0.2 | 196 |
| *Tripneustes gratilla* | 9.2 | 0.6 | 133 |
| *Stichopus horrens* | 14.2 | 1.7 | 44 |
| *Conus* spp. | 3.7 | 0.2 | 43 |
| *Cerithium nodulosum* | 9.7 | 0.0 | 36 |
| *Thelenota ananas* | 44.1 | 1.3 | 17 |
| *Cypraea tigris* | 8.1 | 0.6 | 13 |
| *Lambis truncata* | 29.0 | 0.3 | 5 |
| *Pinctada margaritifera* | 14.3 | 1.2 | 3 |
| *Thais* spp. | 7.0 | 0.8 | 2 |
| *Strombus lentiginosus* | 9.5 | 0.0 | 2 |
| *Trochus* spp. | 1.4 | | 20 |
| *Bohadschia argus* | 37.0 | | 3 |
| *Parribacus caledonicus* | 15.0 | | 1 |
| *Conus vexillum* | 3.9 | | 1 |
| *Echinometra mathaei* | | | 7116 |
| *Echinothrix diadema* | | | 6428 |
| *Holothuria leucospilota* | | | 1561 |
| *Chama* spp. | | | 300 |
| *Diadema* spp. | | | 65 |
| *Heterocentrotus mammillatus* | | | 60 |
| *Turbo setosus* | | | 33 |
| *Acanthaster planci* | | | 20 |
| *Cypraea moneta* | | | 9 |
| *Thais aculeata* | | | 4 |
| *Cypraea caputserpensis* | | | 4 |
| *Synapta* spp. | | | 3 |
| *Cypraea annulus* | | | 3 |
| *Spondylus* spp. | | | 3 |
| *Echinothrix calamaris* | | | 1 |
| *Turbo argyrostomus* | | | 1 |
| *Heteractis* spp. | | | 1 |
| *Stichodactyla* spp. | | | 1 |
| *Conus ebraeus* | | | 1 |
| *Diadema savignyi* | | | 1 |

### *4.1.11 Habitat descriptors for independent assessment – Aitutaki*

**Broad-scale stations**

**Reef-benthos transect stations**



## 4.2 Palmerston invertebrate survey data

### *4.2.1 Invertebrate species recorded in different assessments in Palmerston*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Bêche-de-mer | *Actinopyga mauritiana* | + | + | | + |
| Bêche-de-mer | *Bohadschia argus* | + | + | | + |
| Bêche-de-mer | *Holothuria atra* | + | + | | + |
| Bêche-de-mer | *Holothuria fuscogilva* | + | | | |
| Bêche-de-mer | *Holothuria leucospilota* | + | + | | |
| Bêche-de-mer | *Holothuria nobilis* | | + | | |
| Bêche-de-mer | *Stichopus chloronotus* | + | + | | + |
| Bêche-de-mer | *Stichopus horrens* | | + | | + |
| Bivalve | *Chama* spp. | + | + | | + |
| Bivalve | *Modiolus* spp. | | + | | |
| Bivalve | *Pinctada margaritifera* | | | | + |
| Bivalve | *Spondylus* spp. | | | | + |
| Bivalve | *Tridacna maxima* | + | + | | + |
| Bivalve | *Tridacna squamosa* | | | | + |
| Crustacean | *Panulirus penicillatus* | | + | | |
| Crustacean | *Parribacus caledonicus* | | | | + |
| Gastropod | *Astralium* spp. | | + | | + |
| Gastropod | *Cantharus* spp. | | + | | |
| Gastropod | *Cerithium nodulosum* | + | + | | |
| Gastropod | *Conus* spp. | | + | | + |
| Gastropod | *Cymatium* spp. | | + | | |
| Gastropod | *Cypraea annulus* | | + | | |
| Gastropod | *Cypraea caputserpensis* | | + | | |
| Gastropod | *Cypraea moneta* | | + | | |
| Gastropod | *Cypraea tigris* | + | | | |
| Gastropod | *Lambis chiragra* | | | | + |
| Gastropod | *Lambis truncata* | + | | | |
| Gastropod | *Pleuroploca filamentosa* | | + | | |
| Gastropod | *Thais aculeata* | | + | | + |
| Gastropod | *Thais* spp. | + | + | | + |
| Gastropod | *Trochus niloticus* | + | + | | + |
| Gastropod | *Turbo argyrostomus* | | | | + |
| Gastropod | *Turbo setosus* | | | | + |
| Octopus | *Octopus* spp. | | + | | + |
| Star | *Acanthaster planci* | + | + | | |
| Star | *Linckia laevigata* | + | + | | + |
| Urchin | *Diadema* spp. | | + | | + |
| Urchin | *Echinometra mathaei* | + | + | | + |
| Urchin | *Echinothrix diadema* | + | + | | + |

+ = presence of the species.

### *4.2.2 Palmerston 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 |
| *Acanthaster planci* | 0.3 | 0.3 | 54 | 16.7 | | 1 | 0.3 | 0.3 | 9 | 2.8 | | 1 |
| *Actinopyga mauritiana* | 0.6 | 0.4 | 54 | 16.7 | 0.0 | 2 | 0.6 | 0.6 | 9 | 5.6 | | 1 |
| *Bohadschia argus* | 0.9 | 0.7 | 54 | 25.0 | 8.3 | 2 | 0.9 | 0.9 | 9 | 8.3 | | 1 |
| *Cerithium nodulosum* | 10.2 | 4.8 | 54 | 91.7 | 26.1 | 6 | 10.2 | 6.8 | 9 | 45.8 | 6.9 | 2 |
| *Chama* spp. | 1644.1 | 609.9 | 54 | 1675.2 | 620.7 | 53 | 1644.1 | 969.7 | 9 | 1644.1 | 969.7 | 9 |
| *Cypraea tigris* | 0.6 | 0.4 | 54 | 16.7 | 0.0 | 2 | 0.6 | 0.4 | 9 | 2.8 | 0.0 | 2 |
| *Echinometra mathaei* | 56.5 | 14.9 | 54 | 190.6 | 30.7 | 16 | 56.5 | 31.7 | 9 | 169.4 | 50.0 | 3 |
| *Echinothrix diadema* | 8.3 | 2.7 | 54 | 37.5 | 7.4 | 12 | 8.3 | 5.7 | 9 | 25.0 | 13.7 | 3 |
| *Holothuria atra* | 1468.8 | 692.1 | 54 | 2558.6 | 1175.3 | 31 | 1468.8 | 1042.9 | 9 | 1652.4 | 1164.1 | 8 |
| *Holothuria fuscogilva* | 0.3 | 0.3 | 54 | 16.7 | | 1 | 0.3 | 0.3 | 9 | 2.8 | | 1 |
| *Holothuria leucospilota* | 0.3 | 0.3 | 54 | 16.7 | | 1 | 0.3 | 0.3 | 9 | 2.8 | | 1 |
| *Lambis truncata* | 0.9 | 0.9 | 54 | 50.0 | | 1 | 0.9 | 0.9 | 9 | 8.3 | | 1 |
| *Linckia laevigata* | 1.2 | 0.6 | 54 | 16.7 | 0.0 | 4 | 1.2 | 0.5 | 9 | 2.8 | 0.0 | 4 |
| *Stichopus chloronotus* | 856.8 | 137.8 | 54 | 856.8 | 137.8 | 54 | 856.8 | 272.6 | 9 | 856.8 | 272.6 | 9 |
| *Thais* spp. | 2.8 | 1.3 | 54 | 30.0 | 6.2 | 5 | 2.8 | 2.4 | 9 | 12.5 | 9.7 | 2 |
| *Tridacna maxima* | 153.1 | 26.9 | 54 | 162.1 | 28.0 | 51 | 153.1 | 36.7 | 9 | 153.1 | 36.7 | 9 |
| *Trochus niloticus* | 0.6 | 0.4 | 54 | 16.7 | 0.0 | 2 | 0.6 | 0.6 | 9 | 5.6 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.3 Palmerston 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 |
| *Acanthaster planci* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Actinopyga mauritiana* | 7.4 | 4.2 | 102 | 250.0 | 0.0 | 3 | 7.4 | 5.3 | 17 | 62.5 | 20.8 | 2 |
| *Astralium* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Bohadschia argus* | 22.9 | 8.9 | 102 | 333.3 | 44.5 | 7 | 22.9 | 8.2 | 17 | 64.8 | 8.5 | 6 |
| *Cantharus* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Cerithium nodulosum* | 7.4 | 4.2 | 102 | 250.0 | 0.0 | 3 | 7.4 | 7.4 | 17 | 125.0 | | 1 |
| *Chama* spp. | 3946.9 | 659.6 | 102 | 4970.2 | 792.5 | 81 | 3946.9 | 1283.1 | 17 | 3946.9 | 1283.1 | 17 |
| *Conus* spp. | 25.3 | 7.7 | 102 | 258.3 | 8.3 | 10 | 25.3 | 11.4 | 17 | 86.1 | 21.7 | 5 |
| *Cymatium* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Cypraea annulus* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Cypraea caputserpensis* | 14.7 | 5.9 | 102 | 250.0 | 0.0 | 6 | 14.7 | 8.7 | 17 | 83.3 | 24.1 | 3 |
| *Cypraea moneta* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Diadema* spp. | 8.2 | 4.7 | 102 | 277.8 | 27.8 | 3 | 8.2 | 5.7 | 17 | 69.4 | 13.9 | 2 |
| *Echinometra mathaei* | 553.9 | 115.1 | 102 | 1086.5 | 200.3 | 52 | 553.9 | 205.9 | 17 | 627.8 | 227.1 | 15 |
| *Echinothrix diadema* | 53.9 | 16.2 | 102 | 423.1 | 65.7 | 13 | 53.9 | 22.8 | 17 | 101.9 | 36.8 | 9 |
| *Holothuria atra* | 3442.8 | 641.9 | 102 | 5574.1 | 946.1 | 63 | 3442.8 | 1437.2 | 17 | 3658.0 | 1512.8 | 16 |
| *Holothuria leucospilota* | 66.2 | 18.4 | 102 | 482.1 | 61.3 | 14 | 66.2 | 32.8 | 17 | 225.0 | 75.2 | 5 |
| *Holothuria nobilis* | 8.2 | 5.9 | 102 | 416.7 | 83.3 | 2 | 8.2 | 5.7 | 17 | 69.4 | 13.9 | 2 |
| *Linckia laevigata* | 14.7 | 8.4 | 102 | 375.0 | 125.0 | 4 | 14.7 | 7.9 | 17 | 62.5 | 20.8 | 4 |
| *Modiolus* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Octopus* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Panulirus penicillatus* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Pleuroploca filamentosa* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Stichopus chloronotus* | 3399.5 | 432.0 | 102 | 3985.6 | 479.4 | 87 | 3399.5 | 951.9 | 17 | 3612.0 | 987.8 | 16 |
| *Stichopus horrens* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Thais aculeata* | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Thais* spp. | 2.5 | 2.5 | 102 | 250.0 | | 1 | 2.5 | 2.5 | 17 | 41.7 | | 1 |
| *Tridacna maxima* | 738.6 | 65.1 | 102 | 876.0 | 67.6 | 86 | 738.6 | 101.4 | 17 | 738.6 | 101.4 | 17 |
| *Trochus niloticus* | 53.9 | 17.3 | 102 | 458.3 | 80.4 | 12 | 53.9 | 23.9 | 17 | 152.8 | 46.5 | 6 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.4 Palmerston 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* | 20.2 | 6.6 | 42 | 70.6 | 15.6 | 12 | 20.2 | 13.7 | 7 | 47.1 | 26.1 | 3 |
| *Echinometra mathaei* | 13.4 | 6.7 | 42 | 94.1 | | 6 | 13.4 | 10.3 | 7 | 23.5 | 17.1 | 4 |
| *Holothuria atra* | 0.6 | 0.6 | 42 | 23.5 | | 1 | 0.6 | 0.6 | 7 | 3.9 | | 1 |
| *Octopus* spp. | 0.6 | 0.6 | 42 | 23.5 | | 1 | 0.6 | 0.6 | 7 | 3.9 | | 1 |
| *Stichopus chloronotus* | 2.2 | 1.8 | 42 | 47.1 | 23.5 | 2 | 2.2 | 1.7 | 7 | 7.8 | 3.9 | 2 |
| *Tridacna maxima* | 0.6 | 0.6 | 42 | 23.5 | | 1 | 0.6 | 0.6 | 7 | 3.9 | | 1 |
| *Trochus niloticus* | 1.7 | 0.9 | 42 | 23.5 | 0.0 | 3 | 1.7 | 1.2 | 7 | 5.9 | 2.0 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.5 Palmerston 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* | 154.8 | 27.4 | 30 | 178.6 | 28.9 | 26 | 154.8 | 51.9 | 5 | 154.8 | 51.9 | 5 |
| *Chama* spp. | 24.8 | 16.8 | 30 | 248.1 | 115.2 | 3 | 24.8 | 24.8 | 5 | 124.1 | | 1 |
| *Echinothrix diadema* | 6.7 | 4.9 | 30 | 100.0 | 33.3 | 2 | 6.7 | 6.7 | 5 | 33.3 | | 1 |
| *Holothuria atra* | 808.1 | 218.9 | 30 | 897.9 | 237.3 | 27 | 808.1 | 401.0 | 5 | 808.1 | 401.0 | 5 |
| *Stichopus chloronotus* | 401.1 | 175.5 | 30 | 752.1 | 306.7 | 16 | 401.1 | 272.0 | 5 | 501.4 | 326.4 | 4 |
| *Thais aculeata* | 1.9 | 1.2 | 30 | 18.5 | 7.4 | 3 | 1.9 | 1.2 | 5 | 4.6 | 0.9 | 2 |
| *Thais* spp. | 1.1 | 1.1 | 30 | 33.3 | | 1 | 1.1 | 1.1 | 5 | 5.6 | | 1 |
| *Tridacna maxima* | 3.3 | 1.3 | 30 | 16.7 | 2.5 | 6 | 3.3 | 0.9 | 5 | 4.2 | 0.5 | 4 |
| *Turbo setosus* | 4.1 | 2.5 | 30 | 40.7 | 13.4 | 3 | 4.1 | 3.2 | 5 | 10.2 | 6.5 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.6 Palmerston 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* | 3.8 | 2.1 | 36 | 45.5 | 0.0 | 3 | 3.8 | | 6 | 11.4 | 3.8 | 2 |
| *Astralium* spp. | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Chama* spp. | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Conus* spp. | 2.5 | 2.5 | 36 | 90.9 | | 1 | 2.5 | 2.5 | 6 | 15.2 | | 1 |
| *Echinometra mathaei* | 137.6 | 49.1 | 36 | 495.5 | 118.6 | 10 | 137.6 | 101.4 | 6 | 275.3 | 180.1 | 3 |
| *Lambis chiragra* | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Linckia laevigata* | 2.5 | 1.8 | 36 | 45.5 | 0.0 | 2 | 2.5 | 2.5 | 6 | 15.2 | | 1 |
| *Stichopus chloronotus* | 35.4 | 15.6 | 36 | 212.1 | 52.0 | 6 | 35.4 | 35.4 | 6 | 212.1 | | 1 |
| *Thais* spp. | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Tridacna maxima* | 7.6 | 2.9 | 36 | 45.5 | 0.0 | 6 | 7.6 | 2.8 | 6 | 11.4 | 2.2 | 4 |
| *Tridacna squamosa* | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Trochus niloticus* | 10.1 | 5.2 | 36 | 90.9 | 18.6 | 4 | 10.1 | 6.7 | 6 | 30.3 | 7.6 | 2 |
| *Turbo argyrostomus* | 1.3 | 1.3 | 36 | 45.5 | | 1 | 1.3 | 1.3 | 6 | 7.6 | | 1 |
| *Turbo setosus* | 3.8 | 2.1 | 36 | 45.5 | 0.0 | 3 | 3.8 | 1.7 | 6 | 7.6 | 0.0 | 3 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.7 Palmerston 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* | 31.1 | 19.1 | 12 | 124.4 | 47.0 | 3 | 31.1 | 31.1 | 2 | 62.2 | | 1 |
| *Diadema* spp. | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Echinothrix diadema* | 26.7 | 18.0 | 12 | 106.7 | 53.3 | 3 | 26.7 | 26.7 | 2 | 53.3 | | 1 |
| *Parribacus caledonicus* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Stichopus horrens* | 57.8 | 17.9 | 12 | 99.0 | 18.1 | 7 | 57.8 | 13.3 | 2 | 57.8 | 13.3 | 2 |
| *Trochus niloticus* | 26.7 | 15.4 | 12 | 106.7 | 30.8 | 3 | 26.7 | 26.7 | 2 | 53.3 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.8 Palmerston sea cucumber day search (Ds) assessment data review*

Station: Six 5-min search periods.

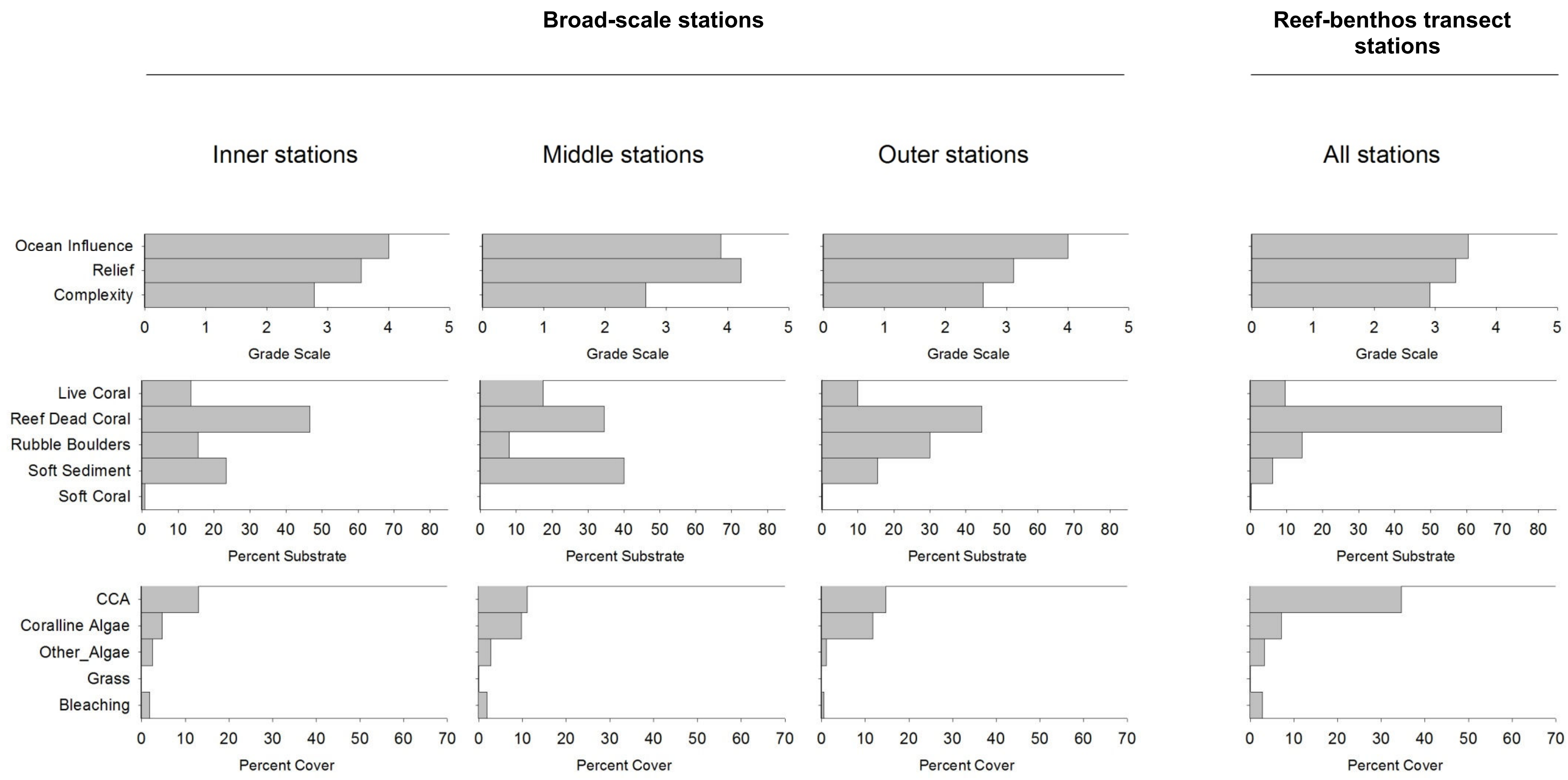
| Species | Search period | | | Search period _P | | | Station | | | Station _P | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | SE | n | Mean | SE | n | Mean | SE | n | Mean | SE | n |
| *Chama* spp. | 1640.5 | 533.9 | 24 | 3281.0 | 838.3 | 12 | 1640.5 | 1029.5 | 4 | 2187.3 | 1233.6 | 3 |
| *Pinctada margaritifera* | 0.6 | 0.6 | 24 | 14.3 | | 1 | 0.6 | 0.6 | 4 | 2.4 | | 1 |
| *Spondylus* spp. | 2.4 | 1.4 | 24 | 19.0 | | 3 | 2.4 | 1.7 | 4 | 4.8 | 2.4 | 2 |
| *Stichopus chloronotus* | 1555.4 | 367.0 | 24 | 1964.7 | 415.7 | 19 | 1555.4 | 997.5 | 4 | 1555.4 | 997.5 | 4 |
| *Stichopus horrens* | 0.6 | 0.6 | 24 | 14.3 | | 1 | 0.6 | 0.6 | 4 | 2.4 | | 1 |
| *Tridacna maxima* | 57.1 | 55.9 | 24 | 685.7 | 657.1 | 2 | 57.1 | 55.6 | 4 | 114.3 | 109.5 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.2.9 Palmerston species size review – all survey methods*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Holothuria atra* | 22.1 | 0.9 | 8345 |
| *Stichopus chloronotus* | 15.2 | 0.2 | 7891 |
| *Tridacna maxima* | 11.2 | 0.2 | 901 |
| *Trochus niloticus* | 10.6 | 0.3 | 41 |
| *Bohadschia argus* | 33.4 | 1.7 | 19 |
| *Turbo setosus* | 5.3 | 1.0 | 14 |
| *Thais* spp. | 8.4 | 0.3 | 14 |
| *Conus* spp. | 3.6 | 0.3 | 12 |
| *Lambis truncata* | 24.3 | 1.2 | 3 |
| *Astralium* spp. | 4.6 | 1.3 | 2 |
| *Chama* spp. | 18.0 | | 9670 |
| *Cerithium nodulosum* | 11.2 | | 36 |
| *Stichopus horrens* | 18.0 | | 15 |
| *Thais aculeata* | 7.6 | | 6 |
| *Holothuria nobilis* | 29.0 | | 3 |
| *Cymatium* spp. | 4.0 | | 1 |
| *Pinctada margaritifera* | 19.0 | | 1 |
| *Tridacna squamosa* | 26.0 | | 1 |
| *Holothuria fuscogilva* | 32.0 | | 1 |
| *Echinometra mathaei* | | | 539 |
| *Actinopyga mauritiana* | | | 462 |
| *Echinothrix diadema* | | | 73 |
| *Holothuria leucospilota* | | | 28 |
| *Linckia laevigata* | | | 12 |
| *Cypraea caputserpensis* | | | 6 |
| *Diadema* spp. | | | 4 |
| *Spondylus* spp. | | | 4 |
| *Acanthaster planci* | | | 2 |
| *Cypraea tigris* | | | 2 |
| *Octopus* spp. | | | 2 |
| *Turbo argyrostomus* | | | 1 |
| *Panulirus penicillatus* | | | 1 |
| *Modiolus* spp. | | | 1 |
| *Lambis chiragra* | | | 1 |
| *Pleuroploca filamentosa* | | | 1 |
| *Cypraea moneta* | | | 1 |
| *Cypraea annulus* | | | 1 |
| *Parribacus caledonicus* | | | 1 |
| *Cantharus* spp. | | | 1 |

### *4.2.10 Habitat descriptors for independent assessment – Palmerston*



## 4.3 Mangaia invertebrate survey data

### *4.3.1 Invertebrate species recorded in different assessments in Mangaia*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Bêche-de-mer | *Actinopyga mauritiana* | + | + | | + |
| Bêche-de-mer | *Holothuria atra* | + | + | | + |
| Bêche-de-mer | *Holothuria cinerascens* | | + | | + |
| Bêche-de-mer | *Holothuria difficilis* | | + | | + |
| Bêche-de-mer | *Holothuria hilla* | | + | | + |
| Bêche-de-mer | *Holothuria impatiens* | | + | | + |
| Bêche-de-mer | *Holothuria leucospilota* | | + | | + |
| Bêche-de-mer | *Holothuria nobilis* | + | | | + |
| Bêche-de-mer | *Holothuria pervicax* | | + | | + |
| Bêche-de-mer | *Holothuria* spp. | | + | | + |
| Bêche-de-mer | *Stichopus monotuberculatus* | | + | | + |
| Bêche-de-mer | *Thelenota ananas* | + | | | + |
| Bivalve | *Chama* spp. | | + | | + |
| Bivalve | *Spondylus* spp. | | + | | + |
| Bivalve | *Tridacna maxima* | + | + | | + |
| Bivalve | *Tridacna squamosa* | | | | + |
| Cnidarian | *Stichodactyla* spp. | | | | + |
| Crustacean | *Gonodactylus* spp. | | | | + |
| Crustacean | *Grapsus grapsus* | | + | | + |
| Crustacean | *Saron* spp. | | + | | |
| Crustacean | *Zozymus aeneus* | | + | | + |
| Gastropod | *Astralium* spp. | | + | | + |
| Gastropod | *Cerithium nodulosum* | | + | | |
| Gastropod | *Charonia tritonis* | | | | + |
| Gastropod | *Conus chaldeus* | | + | | |
| Gastropod | *Conus ebraeus* | | + | | |
| Gastropod | *Conus emaciatus* | | + | | |
| Gastropod | *Conus flavidus* | | + | | |
| Gastropod | *Conus frigidus* | | + | | |
| Gastropod | *Conus lividus* | | + | | |
| Gastropod | *Conus miliaris* | | + | | |
| Gastropod | *Conus pulicarius* | | + | | |
| Gastropod | *Conus rattus* | | + | | |
| Gastropod | *Conus sanguinolentus* | | + | | |
| Gastropod | *Conus* spp. | | + | | |
| Gastropod | *Conus sponsalis* | | + | | |
| Gastropod | *Cypraea caputserpensis* | | + | | |
| Gastropod | *Cypraea moneta* | | + | | |
| Gastropod | *Cypraea tigris* | + | | | |
| Gastropod | *Dendropoma maximum* | | + | | |
| Gastropod | *Dendropoma* spp. | + | + | | + |
| Gastropod | *Distorsio anus* | | + | | |
| Gastropod | *Dolabella* spp. | | | | + |
| Gastropod | *Drupa rubusidaeus* | | + | | + |
| Gastropod | *Drupa* spp. | | | | + |
| Gastropod | *Drupella* spp. | | | | + |

+ = presence of the species.

### *4.3.1 Invertebrate species recorded in different assessments in Mangaia (continued)*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Gastropod | *Lambis chiragra* | | | | + |
| Gastropod | *Lambis truncata* | | | | + |
| Gastropod | *Thais aculeata* | + | + | | |
| Gastropod | *Thais armigera* | + | + | | + |
| Gastropod | *Trochus niloticus* | | + | | + |
| Gastropod | *Turbo argyrostomus* | | | | + |
| Gastropod | *Turbo setosus* | | + | | + |
| Octopus | *Octopus* spp. | + | | | + |
| Star | *Acanthaster planci* | + | | | |
| Star | *Linckia guildingi* | | + | | + |
| Star | *Linckia laevigata* | + | + | | + |
| Urchin | *Diadema savignyi* | | | | + |
| Urchin | *Diadema* spp. | | | | + |
| Urchin | *Echinometra mathaei* | + | + | | + |
| Urchin | *Echinothrix calamaris* | | | | + |
| Urchin | *Echinothrix diadema* | + | + | | + |
| Urchin | *Heterocentrotus mammillatus* | + | + | | + |
| Urchin | *Heterocentrotus trigonarius* | + | + | | + |
| Urchin | *Tripneustes gratilla* | + | + | | + |

+ = presence of the species.

### *4.3.2 Mangaia 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 |
| *Acanthaster planci* | 0.4 | 0.4 | 42 | 16.7 | | 1 | 0.4 | 0.4 | 7 | 2.8 | | 1 |
| *Actinopyga mauritiana* | 3.2 | 1.0 | 42 | 16.7 | 0.0 | 8 | 3.2 | 1.4 | 7 | 5.6 | 1.6 | 4 |
| *Cypraea tigris* | 0.4 | 0.4 | 42 | 16.7 | | 1 | 0.4 | 0.4 | 7 | 2.7 | | 1 |
| *Dendropoma* spp. | 2274.9 | 511.1 | 42 | 2985.8 | 620.5 | 32 | 2275.0 | 1090.1 | 7 | 2654.2 | 1209.3 | 6 |
| *Echinometra mathaei* | 1562.6 | 460.5 | 42 | 2625.2 | 701.7 | 25 | 1560.1 | 788.5 | 7 | 1820.1 | 880.8 | 6 |
| *Echinothrix diadema* | 1404.1 | 417.4 | 42 | 2268.2 | 619.0 | 26 | 1399.6 | 773.9 | 7 | 1959.5 | 991.7 | 5 |
| *Heterocentrotus mammillatus* | 0.4 | 0.4 | 42 | 16.7 | | 1 | 0.4 | 0.4 | 7 | 2.8 | | 1 |
| *Heterocentrotus trigonarius* | 69.0 | 30.8 | 42 | 193.3 | 77.9 | 15 | 69.0 | 52.5 | 7 | 96.7 | 71.6 | 5 |
| *Holothuria atra* | 6.3 | 2.3 | 42 | 29.6 | 6.1 | 9 | 6.3 | 2.7 | 7 | 11.0 | 3.0 | 4 |
| *Holothuria nobilis* | 0.4 | 0.4 | 42 | 15.4 | | 1 | 0.4 | 0.4 | 7 | 2.7 | | 1 |
| *Linckia laevigata* | 0.8 | 0.6 | 42 | 16.7 | 0.0 | 2 | 0.8 | 0.8 | 7 | 5.5 | | 1 |
| *Octopus* spp. | 1.6 | 0.8 | 42 | 16.7 | 0.0 | 4 | 1.6 | 1.2 | 7 | 5.6 | 2.8 | 2 |
| *Thais aculeata* | 0.8 | 0.8 | 42 | 33.3 | | 1 | 0.8 | 0.8 | 7 | 5.5 | | 1 |
| *Thais armigera* | 2.0 | 1.0 | 42 | 20.8 | 4.2 | 4 | 2.0 | 1.6 | 7 | 6.9 | 4.2 | 2 |
| *Thelenota ananas* | 7.9 | 4.3 | 42 | 47.6 | 20.7 | 7 | 7.8 | 5.9 | 7 | 27.5 | 13.6 | 2 |
| *Tridacna maxima* | 7.9 | 2.3 | 42 | 27.6 | 4.7 | 12 | 7.9 | 3.8 | 7 | 13.8 | 4.9 | 4 |
| *Tripneustes gratilla* | 2.8 | 2.4 | 42 | 58.3 | 41.7 | 2 | 2.7 | 2.7 | 7 | 19.2 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.3 Mangaia 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 |
| *Actinopyga mauritiana* | 386.1 | 67.4 | 90 | 868.8 | 112.2 | 40 | 386.1 | 113.5 | 15 | 579.2 | 132.7 | 10 |
| *Astralium* spp. | 44.4 | 16.6 | 90 | 500.0 | 81.8 | 8 | 44.4 | 26.5 | 15 | 166.7 | 74.1 | 4 |
| *Cerithium nodulosum* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Chama* spp. | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Conus chaldeus* | 33.3 | 12.0 | 90 | 333.3 | 58.9 | 9 | 33.3 | 13.0 | 15 | 83.3 | 18.6 | 6 |
| *Conus ebraeus* | 52.8 | 14.5 | 90 | 339.3 | 42.3 | 14 | 52.8 | 15.5 | 15 | 88.0 | 17.6 | 9 |
| *Conus emaciatus* | 8.3 | 6.2 | 90 | 375.0 | 125.0 | 2 | 8.3 | 6.0 | 15 | 62.5 | 20.8 | 2 |
| *Conus flavidus* | 25.0 | 11.2 | 90 | 375.0 | 85.4 | 6 | 25.0 | 13.4 | 15 | 93.8 | 31.3 | 4 |
| *Conus frigidus* | 16.7 | 9.5 | 90 | 375.0 | 125.0 | 4 | 16.7 | 11.4 | 15 | 83.3 | 41.7 | 3 |
| *Conus lividus* | 36.1 | 13.4 | 90 | 406.3 | 65.8 | 8 | 36.1 | 15.1 | 15 | 108.3 | 21.2 | 5 |
| *Conus miliaris* | 83.3 | 33.1 | 90 | 681.8 | 196.8 | 11 | 83.3 | 54.7 | 15 | 208.3 | 125.5 | 6 |
| *Conus pulicarius* | 8.3 | 8.3 | 90 | 750.0 | | 1 | 8.3 | 8.3 | 15 | 125.0 | | 1 |
| *Conus rattus* | 8.3 | 4.8 | 90 | 250.0 | 0.0 | 3 | 8.3 | 4.5 | 15 | 41.7 | 0.0 | 3 |
| *Conus sanguinolentus* | 8.3 | 6.2 | 90 | 375.0 | 125.0 | 2 | 8.3 | 6.0 | 15 | 62.5 | 20.8 | 2 |
| *Conus* spp. | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Conus sponsalis* | 80.6 | 32.3 | 90 | 906.3 | 205.6 | 8 | 80.6 | 52.5 | 15 | 402.8 | 177.3 | 3 |
| *Cypraea caputserpensis* | 19.4 | 8.1 | 90 | 291.7 | 41.7 | 6 | 19.4 | 12.1 | 15 | 97.2 | 36.7 | 3 |
| *Cypraea moneta* | 22.2 | 13.5 | 90 | 666.7 | 166.7 | 3 | 22.2 | 17.2 | 15 | 166.7 | 83.3 | 2 |
| *Dendropoma maximum* | 622.2 | 365.4 | 90 | 11,200.0 | 4885.2 | 5 | 622.2 | 604.6 | 15 | 4666.7 | 4416.7 | 2 |
| *Dendropoma* spp. | 27,472.2 | 6097.5 | 90 | 44,954.5 | 9258.4 | 55 | 27,472.2 | 12,648.3 | 15 | 29,434.5 | 13,422.0 | 14 |
| *Distorsio anus* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Drupa rubusidaeus* | 16.7 | 11.7 | 90 | 500.0 | 250.0 | 3 | 16.7 | 11.4 | 15 | 83.3 | 41.7 | 3 |
| *Echinometra mathaei* | 20,480.6 | 3535.4 | 90 | 24,576.7 | 4084.0 | 75 | 20,480.6 | 7318.6 | 15 | 23,631.4 | 8117.7 | 13 |
| *Echinothrix diadema* | 883.3 | 185.0 | 90 | 2092.1 | 355.7 | 38 | 883.3 | 366.5 | 15 | 1104.2 | 437.6 | 12 |
| *Grapsus grapsus* | 33.3 | 33.3 | 90 | 3000.0 | | 1 | 33.3 | 33.3 | 15 | 500.0 | | 1 |
| *Heterocentrotus mammillatus* | 16.7 | 6.6 | 90 | 250.0 | 0.0 | 6 | 16.7 | 6.8 | 15 | 50.0 | 8.3 | 5 |
| *Heterocentrotus trigonarius* | 11.1 | 6.7 | 90 | 333.3 | 83.3 | 3 | 11.1 | 6.4 | 15 | 55.6 | 13.9 | 3 |
| *Holothuria atra* | 3769.4 | 374.0 | 90 | 3899.4 | 379.3 | 87 | 3769.4 | 676.1 | 15 | 3769.4 | 676.1 | 15 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.3 Mangaia reef-benthos transect (RBt) assessment data review (continued)*

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 |
| *Holothuria cinerascens* | 597.2 | 160.0 | 90 | 1791.7 | 402.4 | 30 | 597.2 | 241.7 | 15 | 814.4 | 306.4 | 11 |
| *Holothuria difficilis* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Holothuria hilla* | 11.1 | 11.1 | 90 | 1000.0 | | 1 | 11.1 | 11.1 | 15 | 166.7 | | 1 |
| *Holothuria impatiens* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Holothuria leucospilota* | 269.4 | 53.6 | 90 | 638.2 | 100.1 | 38 | 269.4 | 80.4 | 15 | 310.9 | 87.3 | 13 |
| *Holothuria pervicax* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Holothuria* spp. | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Linckia guildingi* | 5.6 | 3.9 | 90 | 250.0 | 0.0 | 2 | 5.6 | 5.6 | 15 | 83.3 | | 1 |
| *Linckia laevigata* | 5.6 | 5.6 | 90 | 500.0 | | 1 | 5.6 | 5.6 | 15 | 83.3 | | 1 |
| *Saron* spp. | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Spondylus* spp. | 180.6 | 180.6 | 90 | 16,250.0 | | 1 | 180.6 | 180.6 | 15 | 2708.3 | | 1 |
| *Stichopus monotuberculatus* | 5.6 | 3.9 | 90 | 250.0 | 0.0 | 2 | 5.6 | 3.8 | 15 | 41.7 | 0.0 | 2 |
| *Thais aculeata* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Thais armigera* | 13.9 | 8.2 | 90 | 416.7 | 83.3 | 3 | 13.9 | 7.8 | 15 | 69.4 | 13.9 | 3 |
| *Tridacna maxima* | 550.0 | 90.7 | 90 | 1053.2 | 137.7 | 47 | 550.0 | 188.3 | 15 | 589.3 | 197.9 | 14 |
| *Tripneustes gratilla* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Trochus niloticus* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |
| *Turbo setosus* | 5.6 | 3.9 | 90 | 250.0 | 0.0 | 2 | 5.6 | 5.6 | 15 | 83.3 | | 1 |
| *Zozymus aeneus* | 2.8 | 2.8 | 90 | 250.0 | | 1 | 2.8 | 2.8 | 15 | 41.7 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.4 Mangaia 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* | 283.5 | 27.8 | 60 | 283.5 | 27.8 | 60 | 283.5 | 25.1 | 10 | 283.5 | 25.1 | 10 |
| *Astralium* spp. | 1.1 | 0.6 | 60 | 16.7 | 5.6 | 4 | 1.1 | 0.7 | 10 | 3.7 | 1.9 | 3 |
| *Chama* spp. | 0.7 | 0.4 | 60 | 14.8 | 3.7 | 3 | 0.7 | 0.6 | 10 | 3.7 | 1.9 | 2 |
| *Dendropoma* spp. | 32.8 | 27.9 | 60 | 491.7 | 392.8 | 4 | 32.8 | 30.4 | 10 | 109.3 | 98.2 | 3 |
| *Drupa rubusidaeus* | 0.6 | 0.6 | 60 | 33.3 | | 1 | 0.6 | 0.6 | 10 | 5.6 | | 1 |
| *Drupa* spp. | 0.6 | 0.6 | 60 | 33.3 | | 1 | 0.6 | 0.6 | 10 | 5.6 | | 1 |
| *Drupella* spp. | 12.0 | 12.0 | 60 | 722.2 | | 1 | 12.0 | 12.0 | 10 | 120.4 | | 1 |
| *Echinometra mathaei* | 2721.3 | 419.1 | 60 | 4186.6 | | 39 | 2721.3 | 509.0 | 10 | 2721.3 | 509.0 | 10 |
| *Echinothrix diadema* | 195.2 | 43.8 | 60 | 254.6 | 54.3 | 46 | 195.2 | 55.9 | 10 | 195.2 | 55.9 | 10 |
| *Gonodactylus* spp. | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Grapsus grapsus* | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Heterocentrotus mammillatus* | 2.2 | 0.8 | 60 | 19.0 | 2.0 | 7 | 2.2 | 0.9 | 10 | 4.4 | 0.9 | 5 |
| *Heterocentrotus trigonarius* | 230.9 | 87.4 | 60 | 602.4 | 208.1 | 23 | 230.9 | 141.1 | 10 | 256.6 | 155.1 | 9 |
| *Holothuria atra* | 522.6 | 103.5 | 60 | 681.6 | 126.1 | 46 | 522.6 | 117.4 | 10 | 522.6 | 117.4 | 10 |
| *Holothuria cinerascens* | 804.4 | 231.2 | 60 | 1856.4 | 461.4 | 26 | 804.4 | 345.2 | 10 | 804.4 | 345.2 | 10 |
| *Holothuria leucospilota* | 30.4 | 12.2 | 60 | 107.2 | 37.8 | 17 | 30.4 | 19.0 | 10 | 50.6 | 29.7 | 6 |
| *Holothuria* spp. | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Linckia laevigata* | 0.6 | 0.4 | 60 | 16.7 | 5.6 | 2 | 0.6 | 0.6 | 10 | 5.6 | | 1 |
| *Stichodactyla* spp. | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Thais armigera* | 0.4 | 0.3 | 60 | 11.1 | 0.0 | 2 | 0.4 | 0.2 | 10 | 1.9 | 0.0 | 2 |
| *Tridacna maxima* | 8.3 | 2.5 | 60 | 31.3 | 6.4 | 16 | 8.3 | 2.8 | 10 | 11.9 | 3.2 | 7 |
| *Tripneustes gratilla* | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Turbo argyrostomus* | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |
| *Turbo setosus* | 3.5 | 0.9 | 60 | 14.1 | 1.3 | 15 | 3.5 | 1.0 | 10 | 5.0 | 0.9 | 7 |
| *Zozymus aeneus* | 0.2 | 0.2 | 60 | 11.1 | | 1 | 0.2 | 0.2 | 10 | 1.9 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.5 Mangaia 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 |
| *Charonia tritonis* | 3.8 | 2.6 | 24 | 45.5 | 0.0 | 2 | 3.8 | 2.2 | 4 | 7.6 | 0.0 | 2 |
| *Dendropoma* spp. | 429.9 | 149.4 | 24 | 737.0 | 224.3 | 14 | 429.9 | - | 4 | 429.9 | 305.8 | 4 |
| *Diadema savignyi* | 1770.8 | 1042.4 | 24 | 14,166.7 | 3487.3 | 3 | 1770.8 | 1344.9 | 4 | 3541.7 | 2140.2 | 2 |
| *Diadema* spp. | 1837.1 | 1117.6 | 24 | 11,022.7 | 4868.7 | 4 | 1837.1 | 1092.8 | 4 | 3674.2 | 643.9 | 2 |
| *Echinometra mathaei* | 11.4 | 5.6 | 24 | 68.2 | 13.1 | 4 | 11.4 | 6.6 | 4 | 15.2 | 7.6 | 3 |
| *Echinothrix calamaris* | 28.4 | 18.5 | 24 | 227.3 | 94.6 | 3 | 28.4 | 28.4 | 4 | 113.6 | | 1 |
| *Echinothrix diadema* | 12,225.4 | 2735.9 | 24 | 13,336.8 | 2870.1 | 22 | 12,225.4 | 4679.1 | 4 | 12,225.4 | 4679.1 | 4 |
| *Heterocentrotus mammillatus* | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |
| *Holothuria atra* | 13.3 | 6.4 | 24 | 63.6 | 18.2 | 5 | 13.3 | 8.4 | 4 | 17.7 | 10.1 | 3 |
| *Holothuria nobilis* | 3.8 | 2.6 | 24 | 45.5 | 0.0 | 2 | 3.8 | 2.2 | 4 | 7.6 | 0.0 | 2 |
| *Holothuria* spp. | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |
| *Lambis truncata* | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |
| *Linckia guildingi* | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |
| *Octopus* spp. | 3.8 | 3.8 | 24 | 90.9 | | 1 | 3.8 | 3.8 | 4 | 15.2 | | 1 |
| *Spondylus* spp. | 18.9 | 11.3 | 24 | 151.5 | 40.1 | 3 | 18.9 | 18.9 | 4 | 75.8 | | 1 |
| *Thelenota ananas* | 45.5 | 21.4 | 24 | 121.2 | 48.5 | 9 | 45.5 | 35.7 | 4 | 60.6 | 45.7 | 3 |
| *Tridacna maxima* | 24.6 | 7.7 | 24 | 65.7 | 11.0 | 9 | 24.6 | 15.3 | 4 | 32.8 | 18.2 | 3 |
| *Tridacna squamosa* | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |
| *Tripneustes gratilla* | 58.7 | 36.6 | 24 | 281.8 | 145.5 | 5 | 58.7 | 58.7 | 4 | 234.8 | | 1 |
| *Trochus niloticus* | 18.9 | 6.7 | 24 | 56.8 | 11.4 | 8 | 18.9 | 10.0 | 4 | 25.3 | 11.0 | 3 |
| *Turbo argyrostomus* | 3.8 | 2.6 | 24 | 45.5 | 0.0 | 2 | 3.8 | 2.2 | 4 | 7.6 | 0.0 | 2 |
| *Turbo setosus* | 1.9 | 1.9 | 24 | 45.5 | | 1 | 1.9 | 1.9 | 4 | 7.6 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.6 Mangaia 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* | 53.3 | 22.7 | 12 | 128.0 | 32.0 | 5 | 53.3 | 44.4 | 2 | 53.3 | 44.4 | 2 |
| *Diadema* spp. | 155.6 | 114.5 | 12 | 466.7 | 309.7 | 4 | 155.6 | 111.1 | 2 | 155.6 | 111.1 | 2 |
| *Dolabella* spp. | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Echinothrix diadema* | 124.4 | 70.5 | 12 | 248.9 | 125.2 | 6 | 124.4 | 35.6 | 2 | 124.4 | 35.6 | 2 |
| *Heterocentrotus mammillatus* | 8.9 | 6.0 | 12 | 53.3 | 0.0 | 2 | 8.9 | 0.0 | 2 | 8.9 | 0.0 | 2 |
| *Heterocentrotus trigonarius* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Holothuria atra* | 777.8 | 134.1 | 12 | 777.8 | | 12 | 777.8 | 13.3 | 2 | 777.8 | 13.3 | 2 |
| *Holothuria cinerascens* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Holothuria difficilis* | 373.3 | 254.6 | 12 | 1120.0 | 659.0 | 4 | 373.3 | 364.4 | 2 | 373.3 | 364.4 | 2 |
| *Holothuria hilla* | 8.9 | 6.0 | 12 | 53.3 | 0.0 | 2 | 8.9 | 0.0 | 2 | 8.9 | 0.0 | 2 |
| *Holothuria impatiens* | 53.3 | 28.6 | 12 | 213.3 | 30.8 | 3 | 53.3 | 53.3 | 2 | 106.7 | | 1 |
| *Holothuria leucospilota* | 1831.1 | 260.9 | 12 | 1831.1 | 260.9 | 12 | 1831.1 | 640.0 | 2 | 1831.1 | 640.0 | 2 |
| *Holothuria pervicax* | 115.6 | 62.6 | 12 | 277.3 | 120.9 | 5 | 115.6 | 115.6 | 2 | 231.1 | | 1 |
| *Linckia laevigata* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Stichopus monotuberculatus* | 431.1 | 111.5 | 12 | 431.1 | 111.5 | 12 | 431.1 | 280.0 | 2 | 431.1 | 280.0 | 2 |
| *Tridacna maxima* | 17.8 | 10.0 | 12 | 71.1 | 17.8 | 3 | 17.8 | 8.9 | 2 | 17.8 | 8.9 | 2 |
| *Tripneustes gratilla* | 26.7 | 19.1 | 12 | 160.0 | 53.3 | 2 | 26.7 | 26.7 | 2 | 53.3 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.7 Mangaia 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* | 0.6 | 0.6 | 24 | 14.3 | | 1 | 0.6 | 0.6 | 4 | 2.4 | | 1 |
| *Diadema* spp. | 0.6 | 0.6 | 24 | 14.3 | | 1 | 0.6 | 0.6 | 4 | 2.4 | | 1 |
| *Echinothrix calamaris* | 2.4 | 1.4 | 24 | 19.0 | 4.8 | 3 | 2.4 | 1.4 | 4 | 4.8 | 0.0 | 2 |
| *Echinothrix diadema* | 1414.3 | 134.0 | 24 | 1414.3 | | 24 | 1414.3 | 104.4 | 4 | 1414.3 | 104.4 | 4 |
| *Holothuria atra* | 28.0 | 7.5 | 24 | 33.6 | 8.5 | 20 | 28.0 | 12.2 | 4 | 28.0 | 12.2 | 4 |
| *Lambis chiragra* | 2.4 | 1.9 | 24 | 28.6 | 14.3 | 2 | 2.4 | 1.7 | 4 | 4.8 | 2.4 | 2 |
| *Lambis truncata* | 6.0 | 2.4 | 24 | 23.8 | 4.8 | 6 | 6.0 | 5.2 | 4 | 11.9 | 9.5 | 2 |
| *Thelenota ananas* | 51.8 | 4.9 | 24 | 51.8 | 4.9 | 24 | 51.8 | 5.4 | 4 | 51.8 | 5.4 | 4 |
| *Tridacna maxima* | 1.2 | 0.8 | 24 | 14.3 | 0.0 | 2 | 1.2 | 0.7 | 4 | 2.4 | 0.0 | 2 |
| *Tridacna squamosa* | 3.6 | 1.3 | 24 | 14.3 | 0.0 | 6 | 3.6 | 2.1 | 4 | 4.8 | 2.4 | 3 |
| *Tripneustes gratilla* | 94.0 | 35.3 | 24 | 205.2 | 63.2 | 11 | 94.0 | 86.3 | 4 | 188.1 | 164.3 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.3.8 Mangaia species size review – all survey methods*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Holothuria cinerascens* | 7.9 | 1.6 | 4560 |
| *Holothuria atra* | 18.0 | 0.3 | 4424 |
| *Actinopyga mauritiana* | 17.8 | 0.5 | 1690 |
| *Holothuria leucospilota* | 19.7 | 2.3 | 673 |
| *Tridacna maxima* | 6.1 | 0.3 | 282 |
| *Tripneustes gratilla* | 12.6 | 0.5 | 204 |
| *Thelenota ananas* | 33.3 | 0.6 | 131 |
| *Stichopus monotuberculatus* | 24.2 | 0.6 | 99 |
| *Conus miliaris* | 2.2 | 0.1 | 30 |
| *Conus sponsalis* | 1.5 | 0.1 | 29 |
| *Astralium* spp. | 3.9 | 0.1 | 22 |
| *Turbo setosus* | 7.4 | 0.5 | 22 |
| *Conus ebraeus* | 2.3 | 0.1 | 19 |
| *Conus lividus* | 3.7 | 0.3 | 13 |
| *Thais armigera* | 7.8 | 0.7 | 12 |
| *Conus chaldeus* | 2.2 | 0.2 | 12 |
| *Trochus niloticus* | 12.1 | 0.8 | 11 |
| *Lambis truncata* | 23.5 | 0.8 | 11 |
| *Conus flavidus* | 3.2 | 0.1 | 9 |
| *Tridacna squamosa* | 30.8 | 1.1 | 7 |
| *Cypraea caputserpensis* | 3.0 | 0.2 | 7 |
| *Conus frigidus* | 2.9 | 0.2 | 6 |
| *Lambis chiragra* | 11.3 | 2.6 | 4 |
| *Conus rattus* | 3.3 | 0.1 | 3 |
| *Turbo argyrostomus* | 5.1 | 1.1 | 3 |
| *Holothuria nobilis* | 21.3 | 2.3 | 3 |
| *Charonia tritonis* | 29.4 | 2.2 | 3 |
| *Conus emaciatus* | 2.5 | 0.1 | 3 |
| *Conus sanguinolentus* | 3.3 | 0.7 | 3 |
| *Holothuria* spp. | 10.5 | 1.6 | 3 |
| *Holothuria difficilis* | 4.6 | | 85 |
| *Holothuria pervicax* | 13.0 | | 27 |
| *Drupa rubusidaeus* | 4.0 | | 9 |
| *Thais aculeata* | 4.5 | | 3 |
| *Conus* spp. | 5.5 | | 1 |
| *Dolabella* spp. | 19.0 | | 1 |
| *Echinometra mathaei* | | | 26,020 |
| *Dendropoma* spp. | | | 16,037 |
| *Echinothrix diadema* | | | 13,791 |
| *Heterocentrotus trigonarius* | | | 1426 |
| *Diadema* spp. | | | 1006 |
| *Diadema savignyi* | | | 935 |
| *Dendropoma maximum* | | | 224 |
| *Spondylus* spp. | | | 75 |
| *Drupella* spp. | | | 65 |
| *Heterocentrotus mammillatus* | | | 22 |
| *Echinothrix calamaris* | | | 19 |
| *Holothuria impatiens* | | | 13 |

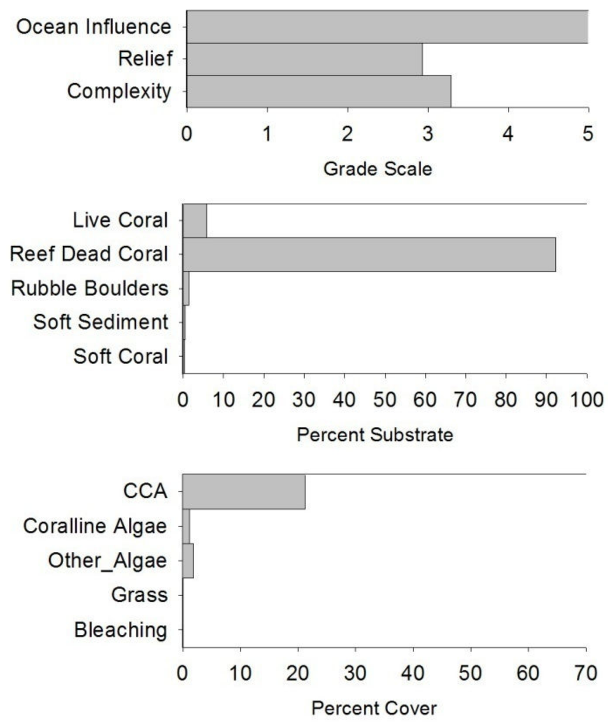
### *4.3.8 Mangaia species size review – all survey methods (continued)*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Grapsus grapsus* | | | 13 |
| *Cypraea moneta* | | | 8 |
| *Linckia laevigata* | | | 8 |
| *Octopus* spp. | | | 6 |
| *Holothuria hilla* | | | 6 |
| *Chama* spp. | | | 5 |
| *Linckia guildingi* | | | 3 |
| *Drupa* spp. | | | 3 |
| *Conus pulicarius* | | | 3 |
| *Zozymus aeneus* | | | 2 |
| *Saron* spp. | | | 1 |
| *Gonodactylus* spp. | | | 1 |
| *Cerithium nodulosum* | | | 1 |
| *Cypraea tigris* | | | 1 |
| *Acanthaster planci* | | | 1 |
| *Distorsio anus* | | | 1 |
| *Stichodactyla* spp. | | | 1 |

## *4.3.9 Habitat descriptors for independent assessment – Mangaia*

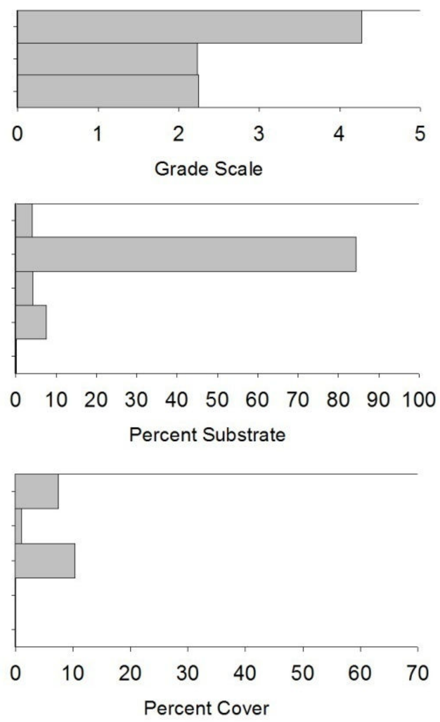
**Broad-scale stations**

All stations




**Reef-benthos transect stations**

All stations



## 4.4 Rarotonga invertebrate survey data

### 4.4.1 *Invertebrate species recorded in different assessments in Rarotonga*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Bêche-de-mer | *Actinopyga mauritiana* | + | + | | + |
| Bêche-de-mer | *Holothuria atra* | + | + | | + |
| Bêche-de-mer | *Holothuria cinerascens* | + | + | | + |
| Bêche-de-mer | *Holothuria hilla* | + | + | | |
| Bêche-de-mer | *Holothuria impatiens* | | + | | + |
| Bêche-de-mer | *Holothuria leucospilota* | + | + | | + |
| Bêche-de-mer | *Holothuria nobilis* | | + | | + |
| Bêche-de-mer | *Holothuria pervicax* | | + | | |
| Bêche-de-mer | *Stichopus chloronotus* | + | + | | + |
| Bêche-de-mer | *Stichopus monotuberculatus* | | + | | + |
| Bêche-de-mer | *Thelenota ananas* | + | + | | + |
| Bivalve | *Chama* spp. | + | | | |
| Bivalve | *Pinctada margaritifera* | + | | | |
| Bivalve | *Pinna* spp. | | + | | |
| Bivalve | *Tellina scobinata* | | + | | |
| Bivalve | *Tridacna maxima* | + | + | | + |
| Cnidarians | *Entacmaea quadricolor* | | + | | |
| Cnidarians | *Heteractis* spp. | | + | | |
| Cnidarians | *Stichodactyla* spp. | + | | | |
| Crustacean | *Carpilius maculatus* | | + | | |
| Crustacean | *Panulirus penicillatus* | | | | + |
| Crustacean | *Stenopus hispidus* | | + | | |
| Gastropod | *Astralium* spp. | | | | + |
| Gastropod | *Bursa bufonia* | | + | | |
| Gastropod | *Bursa granularis* | | + | | |
| Gastropod | *Cerithium nodulosum* | + | + | | |
| Gastropod | *Conus coronatus* | | + | | |
| Gastropod | *Conus flavidus* | | + | | |
| Gastropod | *Conus frigidus* | | + | | |
| Gastropod | *Conus lividus* | | + | | |
| Gastropod | *Conus miliaris* | | + | | |
| Gastropod | *Conus rattus* | | + | | |
| Gastropod | *Conus sanguinolentus* | | + | | + |
| Gastropod | *Conus sponsalis* | | + | | |
| Gastropod | *Conus vexillum* | | | | + |
| Gastropod | *Cypraea caputserpensis* | | + | | + |
| Gastropod | *Cypraea maculifera* | | + | | |
| Gastropod | *Cypraea moneta* | | + | | |
| Gastropod | *Cypraea schilderorum* | | + | | |
| Gastropod | *Dendropoma* spp. | + | + | | + |
| Gastropod | *Drupa* spp. | | + | | |
| Gastropod | *Lambis chiragra* | | | | + |
| Gastropod | *Lambis truncata* | | | | + |
| Gastropod | *Latirus nodatus* | | + | | |
| Gastropod | *Thais aculeata* | | + | | |
| Gastropod | *Thais armigera* | | + | | + |

+ = presence of the species.

### *4.4.1 Invertebrate species recorded in different assessments in Rarotonga (continued)*

| Group | Species | Broad scale | Reef benthos | Soft benthos | Others |
|---|---|---|---|---|---|
| Gastropod | *Trochus niloticus* | + | + | | + |
| Gastropod | *Turbo setosus* | | | | + |
| Octopus | *Octopus* spp. | | + | | + |
| Star | *Acanthaster planci* | + | | | |
| Star | *Culcita novaeguineae* | | | | + |
| Star | *Linckia guildingi* | | | | + |
| Star | *Linckia laevigata* | + | + | | + |
| Urchin | *Diadema* spp. | + | + | | + |
| Urchin | *Echinometra mathaei* | + | + | | + |
| Urchin | *Echinothrix diadema* | + | + | | + |
| Urchin | *Heterocentrotus mammillatus* | | + | | |
| Urchin | *Heterocentrotus trigonarius* | + | + | | + |
| Urchin | *Tripneustes gratilla* | + | + | | |

+ = presence of the species.

### *4.4.2 Rarotonga 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 |
| *Acanthaster planci* | 0.6 | 0.4 | 60 | 16.7 | 0.0 | 2 | 0.6 | 0.4 | 10 | 2.8 | 0.0 | 2 |
| *Actinopyga mauritiana* | 8.1 | 2.7 | 60 | 43.9 | 8.8 | 11 | 8.1 | 5.4 | 10 | 20.1 | 11.8 | 4 |
| *Cerithium nodulosum* | 1.1 | 0.5 | 60 | 16.7 | 0.0 | 4 | 1.1 | 0.6 | 10 | 3.7 | 0.9 | 3 |
| *Chama* spp. | 0.3 | 0.3 | 60 | 16.7 | | 1 | 0.3 | 0.3 | 10 | 2.7 | | 1 |
| *Dendropoma* spp. | 271.8 | 140.8 | 60 | 543.7 | 274.8 | 30 | 272.5 | 188.9 | 10 | 272.5 | 188.9 | 10 |
| *Diadema* spp. | 6.9 | 3.0 | 60 | 46.2 | 14.7 | 9 | 6.9 | 5.6 | 10 | 34.6 | 20.9 | 2 |
| *Echinometra mathaei* | 7113.6 | 2678.0 | 60 | 10,162.3 | 3739.9 | 42 | 7107.8 | 4088.6 | 10 | 7107.8 | 4088.6 | 10 |
| *Echinothrix diadema* | 874.3 | 213.1 | 60 | 1417.8 | 315.1 | 37 | 874.2 | 460.8 | 10 | 1248.8 | 614.0 | 7 |
| *Heterocentrotus trigonarius* | 6.7 | 3.9 | 60 | 66.7 | 31.6 | 6 | 6.7 | 4.4 | 10 | 33.3 | 0.0 | 2 |
| *Holothuria atra* | 3179.5 | 576.5 | 60 | 4239.4 | 701.5 | 45 | 3182.3 | 1232.5 | 10 | 3535.8 | 1320.0 | 9 |
| *Holothuria cinerascens* | 1.1 | 0.8 | 60 | 31.8 | 15.1 | 2 | 1.1 | 1.1 | 10 | 11.0 | | 1 |
| *Holothuria hilla* | 0.8 | 0.5 | 60 | 16.5 | 0.2 | 3 | 0.8 | 0.4 | 10 | 2.8 | 0.0 | 3 |
| *Holothuria leucospilota* | 812.8 | 190.6 | 60 | 1477.8 | 301.8 | 33 | 814.1 | 376.0 | 10 | 1163.0 | 485.2 | 7 |
| *Linckia laevigata* | 34.3 | 7.5 | 60 | 76.2 | 12.7 | 27 | 34.2 | 15.7 | 10 | 48.9 | 20.2 | 7 |
| *Pinctada margaritifera* | 0.3 | 0.3 | 60 | 15.4 | | 1 | 0.3 | 0.3 | 10 | 2.7 | | 1 |
| *Stichodactyla* spp. | 0.3 | 0.3 | 60 | 16.7 | | 1 | 0.3 | 0.3 | 10 | 2.8 | | 1 |
| *Stichopus chloronotus* | 161.6 | 40.6 | 60 | 255.2 | 59.2 | 38 | 161.9 | 69.4 | 10 | 161.9 | 69.4 | 10 |
| *Thelenota ananas* | 0.5 | 0.4 | 60 | 16.1 | 0.5 | 2 | 0.6 | 0.4 | 10 | 2.8 | 0.0 | 2 |
| *Tridacna maxima* | 15.2 | 2.9 | 60 | 35.2 | 4.1 | 26 | 15.2 | 5.2 | 10 | 21.7 | 5.9 | 7 |
| *Tripneustes gratilla* | 80.4 | 23.7 | 60 | 229.8 | 55.1 | 21 | 81.1 | 37.9 | 10 | 162.1 | 56.4 | 5 |
| *Trochus niloticus* | 2.8 | 1.3 | 60 | 27.6 | 7.1 | 6 | 2.8 | 1.1 | 10 | 5.5 | 1.2 | 5 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.3 Rarotonga 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 |
| *Actinopyga mauritiana* | 131.4 | 51.8 | 78 | 640.6 | 212.8 | 16 | 131.4 | 85.7 | 13 | 341.7 | 198.3 | 5 |
| *Bursa bufonia* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 4.3 | 13 | 41.7 | 0.0 | 2 |
| *Bursa granularis* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Carpilius maculatus* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Cerithium nodulosum* | 9.6 | 5.5 | 78 | 250.0 | 0.0 | 3 | 9.6 | 5.1 | 13 | 41.7 | 0.0 | 3 |
| *Conus coronatus* | 9.6 | 5.5 | 78 | 250.0 | 0.0 | 3 | 9.6 | 5.1 | 13 | 41.7 | 0.0 | 3 |
| *Conus flavidus* | 32.1 | 16.0 | 78 | 500.0 | 136.9 | 5 | 32.1 | 19.5 | 13 | 104.2 | 49.6 | 4 |
| *Conus frigidus* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Conus lividus* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 4.3 | 13 | 41.7 | 0.0 | 2 |
| *Conus miliaris* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 6.4 | 13 | 83.3 | | 1 |
| *Conus rattus* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Conus sanguinolentus* | 9.6 | 5.5 | 78 | 250.0 | 0.0 | 3 | 9.6 | 6.9 | 13 | 62.5 | 20.8 | 2 |
| *Conus sponsalis* | 9.6 | 7.1 | 78 | 375.0 | 125.0 | 2 | 9.6 | 9.6 | 13 | 125.0 | | 1 |
| *Cypraea caputserpensis* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 4.3 | 13 | 41.7 | 0.0 | 2 |
| *Cypraea maculifera* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Cypraea moneta* | 16.0 | 10.5 | 78 | 416.7 | 166.7 | 3 | 16.0 | 10.1 | 13 | 69.4 | 27.8 | 3 |
| *Cypraea schilderorum* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Dendropoma* spp. | 288.5 | 65.8 | 78 | 750.0 | 134.0 | 30 | 288.5 | 104.8 | 13 | 375.0 | 124.2 | 10 |
| *Diadema* spp. | 131.4 | 77.5 | 78 | 1138.9 | 598.2 | 9 | 131.4 | 95.6 | 13 | 427.1 | 277.1 | 4 |
| *Drupa* spp. | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Echinometra mathaei* | 18,368.6 | 3509.0 | 78 | 20,179.6 | 3789.2 | 71 | 18,368.6 | 7945.4 | 13 | 18,368.6 | 7945.4 | 13 |
| *Echinothrix diadema* | 538.5 | 126.6 | 78 | 1500.0 | 271.9 | 28 | 538.5 | 253.0 | 13 | 875.0 | 369.2 | 8 |
| *Entacmaea quadricolor* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Heteractis* spp. | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Heterocentrotus mammillatus* | 9.6 | 7.1 | 78 | 375.0 | 125.0 | 2 | 9.6 | 6.9 | 13 | 62.5 | 20.8 | 2 |
| *Heterocentrotus trigonarius* | 19.2 | 11.0 | 78 | 500.0 | 0.0 | 3 | 19.2 | 13.8 | 13 | 125.0 | 41.7 | 2 |
| *Holothuria atra* | 10,772.4 | 2606.8 | 78 | 10,912.3 | 2637.1 | 77 | 10,772.4 | 6236.2 | 13 | 10,772.4 | 6236.2 | 13 |
| *Holothuria cinerascens* | 105.8 | 38.8 | 78 | 825.0 | 186.5 | 10 | 105.8 | 67.2 | 13 | 458.3 | 190.9 | 3 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.3 Rarotonga reef-benthos transect (RBt) assessment data review (continued)*

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 |
| *Holothuria hilla* | 201.9 | 50.0 | 78 | 605.8 | 115.3 | 26 | 201.9 | 82.5 | 13 | 291.7 | 107.1 | 9 |
| *Holothuria impatiens* | 38.5 | 13.7 | 78 | 333.3 | 58.9 | 9 | 38.5 | 16.0 | 13 | 100.0 | 21.2 | 5 |
| *Holothuria leucospilota* | 6782.1 | 862.6 | 78 | 8672.1 | 973.6 | 61 | 6782.1 | 1904.9 | 13 | 8015.2 | 2039.1 | 11 |
| *Holothuria nobilis* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 6.4 | 13 | 83.3 | | 1 |
| *Holothuria pervicax* | 48.1 | 15.8 | 78 | 375.0 | 55.9 | 10 | 48.1 | 20.5 | 13 | 125.0 | 29.5 | 5 |
| *Latirus nodatus* | 19.2 | 11.0 | 78 | 375.0 | 125.0 | 4 | 19.2 | 11.2 | 13 | 83.3 | 24.1 | 3 |
| *Linckia laevigata* | 131.4 | 28.8 | 78 | 445.7 | 58.7 | 23 | 131.4 | 47.4 | 13 | 155.3 | 53.0 | 11 |
| *Octopus* spp. | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Pinna* spp. | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 6.4 | 13 | 83.3 | | 1 |
| *Stenopus hispidus* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Stichopus chloronotus* | 1407.1 | 406.4 | 78 | 2438.9 | 666.1 | 45 | 1407.1 | 984.4 | 13 | 1524.3 | 1062.6 | 12 |
| *Stichopus monotuberculatus* | 102.6 | 27.2 | 78 | 444.4 | 74.4 | 18 | 102.6 | 36.7 | 13 | 166.7 | 47.2 | 8 |
| *Tellina scobinata* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 4.3 | 13 | 41.7 | 0.0 | 2 |
| *Thais aculeata* | 3.2 | 3.2 | 78 | 250.0 | | 1 | 3.2 | 3.2 | 13 | 41.7 | | 1 |
| *Thais armigera* | 6.4 | 6.4 | 78 | 500.0 | | 1 | 6.4 | 6.4 | 13 | 83.3 | | 1 |
| *Thelenota ananas* | 6.4 | 4.5 | 78 | 250.0 | 0.0 | 2 | 6.4 | 4.3 | 13 | 41.7 | 0.0 | 2 |
| *Tridacna maxima* | 208.3 | 32.1 | 78 | 427.6 | 43.1 | 38 | 208.3 | 42.2 | 13 | 225.7 | 41.8 | 12 |
| *Tripneustes gratilla* | 448.7 | 89.2 | 78 | 921.1 | 149.1 | 38 | 448.7 | 148.3 | 13 | 648.1 | 177.5 | 9 |
| *Trochus niloticus* | 1682.7 | 420.5 | 78 | 4687.5 | 939.9 | 28 | 1682.7 | 969.4 | 13 | 2734.4 | 1485.7 | 8 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.4 Rarotonga 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* | 111.8 | 26.0 | 24 | 141.2 | 29.3 | 19 | 111.8 | 33.5 | 4 | 111.8 | 33.5 | 4 |
| *Astralium* spp. | 3.9 | 2.3 | 24 | 31.4 | | 3 | 3.9 | 2.3 | 4 | 7.8 | 0.0 | 2 |
| *Conus vexillum* | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Cypraea caputserpensis* | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Dendropoma* spp. | 41.2 | 15.1 | 24 | 123.5 | 28.4 | 8 | 41.2 | 20.7 | 4 | 54.9 | 21.8 | 3 |
| *Echinometra mathaei* | 20,831.4 | 9052.2 | 24 | 38,457.9 | 15,279.3 | 13 | 20,831.4 | 13,809.4 | 4 | 20,831.4 | 13,809.4 | 4 |
| *Echinothrix diadema* | 652.0 | 182.1 | 24 | 869.3 | 220.7 | 18 | 652.0 | 315.1 | 4 | 652.0 | 315.1 | 4 |
| *Heterocentrotus trigonarius* | 821.6 | 150.9 | 24 | 857.3 | 153.1 | 23 | 821.6 | 239.7 | 4 | 821.6 | 239.7 | 4 |
| *Octopus* spp. | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Panulirus penicillatus* | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Stichopus chloronotus* | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Thais armigera* | 2.0 | 1.4 | 24 | 23.5 | 0.0 | 2 | 2.0 | 1.1 | 4 | 3.9 | 0.0 | 2 |
| *Tridacna maxima* | 1.0 | 1.0 | 24 | 23.5 | | 1 | 1.0 | 1.0 | 4 | 3.9 | | 1 |
| *Trochus niloticus* | 2.9 | 1.6 | 24 | 23.5 | 0.0 | 3 | 2.9 | 1.0 | 4 | 3.9 | 0.0 | 3 |
| *Turbo setosus* | 10.8 | 4.2 | 24 | 43.1 | 7.2 | 6 | 10.8 | 4.3 | 4 | 14.4 | 3.5 | 3 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.5 Rarotonga 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* | 15.2 | 9.6 | 6 | 45.5 | 0.0 | 2 | 15.2 | | 1 | 15.2 | | 1 |
| *Cypraea caputserpensis* | 15.2 | 9.6 | 6 | 45.5 | 0.0 | 2 | 15.2 | | 1 | 15.2 | | 1 |
| *Dendropoma* spp. | 1583.3 | 429.0 | 6 | 1583.3 | 429.0 | 6 | 1583.3 | | 1 | 1583.3 | | 1 |
| *Echinometra mathaei* | 96,666.7 | 41,422.1 | 6 | 96,666.7 | 41,422.1 | 6 | 96,666.7 | | 1 | 96,666.7 | | 1 |
| *Echinothrix diadema* | 2204.5 | 1158.3 | 6 | 2204.5 | 1158.3 | 6 | 2204.5 | | 1 | 2204.5 | | 1 |
| *Heterocentrotus trigonarius* | 53.0 | 21.7 | 6 | 79.5 | 21.8 | 4 | 53.0 | | 1 | 53.0 | | 1 |
| *Stichopus chloronotus* | 15.2 | 9.6 | 6 | 45.5 | 0.0 | 2 | 15.2 | | 1 | 15.2 | | 1 |
| *Tridacna maxima* | 7.6 | 7.6 | 6 | 45.5 | | 1 | 7.6 | | 1 | 7.6 | | 1 |
| *Turbo setosus* | 7.6 | 7.6 | 6 | 45.5 | | 1 | 7.6 | | 1 | 7.6 | | 1 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.6 Rarotonga mother-of-pearl transect (MOPt) 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. | 4.2 | 4.2 | 30 | 125.0 | | 1 | 4.2 | 4.2 | 5 | 20.8 | | 1 |
| *Conus sanguinolentus* | 4.2 | 4.2 | 30 | 125.0 | | 1 | 4.2 | 4.2 | 5 | 20.8 | | 1 |
| *Dendropoma* spp. | 16.7 | 9.9 | 30 | 166.7 | 41.7 | 3 | 16.7 | 7.8 | 5 | 27.8 | 6.9 | 3 |
| *Echinometra mathaei* | 125.0 | 125.0 | 30 | 3750.0 | | 1 | 125.0 | 125.0 | 5 | 625.0 | | 1 |
| *Echinothrix diadema* | 2979.2 | 683.9 | 30 | 3310.2 | 733.2 | 27 | 2979.2 | 1452.5 | 5 | 2 979.2 | 1452.5 | 5 |
| *Holothuria atra* | 33.3 | 14.6 | 30 | 200.0 | 30.6 | 5 | 33.3 | 19.3 | 5 | 55.6 | 25.0 | 3 |
| *Holothuria leucospilota* | 8.3 | 8.3 | 30 | 250.0 | | 1 | 8.3 | 8.3 | 5 | 41.7 | | 1 |
| *Holothuria nobilis* | 4.2 | 4.2 | 30 | 125.0 | | 1 | 4.2 | 4.2 | 5 | 20.8 | | 1 |
| *Linckia guildingi* | 4.2 | 4.2 | 30 | 125.0 | | 1 | 4.2 | 4.2 | 5 | 20.8 | | 1 |
| *Stichopus chloronotus* | 412.5 | 122.8 | 30 | 618.8 | 166.8 | 20 | 412.5 | 198.3 | 5 | 515.6 | 218.7 | 4 |
| *Thelenota ananas* | 16.7 | 9.9 | 30 | 166.7 | 41.7 | 3 | 16.7 | 7.8 | 5 | 27.8 | 6.9 | 3 |
| *Tridacna maxima* | 8.3 | 5.8 | 30 | 125.0 | 0.0 | 2 | 8.3 | 8.3 | 5 | 41.7 | | 1 |
| *Trochus niloticus* | 416.7 | 65.7 | 30 | 446.4 | 66.9 | 28 | 416.7 | 141.0 | 5 | 416.7 | 141.0 | 5 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.7 Rarotonga 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* | 106.7 | 29.4 | 12 | 142.2 | 30.8 | 9 | 106.7 | 17.8 | 2 | 106.7 | 17.8 | 2 |
| *Echinothrix diadema* | 191.1 | 50.6 | 12 | 229.3 | 52.8 | 10 | 191.1 | 22.2 | 2 | 191.1 | 22.2 | 2 |
| *Holothuria atra* | 395.6 | 127.5 | 12 | 395.6 | 127.5 | 12 | 395.6 | 31.1 | 2 | 395.6 | 31.1 | 2 |
| *Holothuria cinerascens* | 44.4 | 32.7 | 12 | 266.7 | 106.7 | 2 | 44.4 | 17.8 | 2 | 44.4 | 17.8 | 2 |
| *Holothuria impatiens* | 66.7 | 24.7 | 12 | 133.3 | 30.0 | 6 | 66.7 | 22.2 | 2 | 66.7 | 22.2 | 2 |
| *Holothuria leucospilota* | 871.1 | 212.8 | 12 | 950.3 | 216.3 | 11 | 871.1 | 355.6 | 2 | 871.1 | 355.6 | 2 |
| *Holothuria nobilis* | 4.4 | 4.4 | 12 | 53.3 | | 1 | 4.4 | 4.4 | 2 | 8.9 | | 1 |
| *Linckia laevigata* | 17.8 | 10.0 | 12 | 71.1 | 17.8 | 3 | 17.8 | 0.0 | 2 | 17.8 | 0.0 | 2 |
| *Stichopus chloronotus* | 17.8 | 12.0 | 12 | 106.7 | 0.0 | 2 | 17.8 | 17.8 | 2 | 35.6 | | 1 |
| *Stichopus monotuberculatus* | 240.0 | 40.2 | 12 | 261.8 | 37.0 | 11 | 240.0 | 53.3 | 2 | 240.0 | 53.3 | 2 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

### *4.4.8 Rarotonga 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* | 0.6 | 0.6 | 24 | 14.3 | | 1 | 0.6 | 0.6 | 4 | 2.4 | | 1 |
| *Diadema* spp. | 16.1 | 11.0 | 24 | 77.1 | 46.2 | 5 | 16.1 | 13.1 | 4 | 32.1 | 22.6 | 2 |
| *Echinothrix diadema* | 413.1 | 63.9 | 24 | 413.1 | 63.9 | 24 | 413.1 | 118.9 | 4 | 413.1 | 118.9 | 4 |
| *Heterocentrotus trigonarius* | 1.8 | 1.8 | 24 | 42.9 | | 1 | 1.8 | 1.8 | 4 | 7.1 | | 1 |
| *Holothuria atra* | 48.8 | 12.2 | 24 | 78.1 | 15.2 | 15 | 48.8 | 27.2 | 4 | 48.8 | 27.2 | 4 |
| *Lambis chiragra* | 1.2 | 1.2 | 24 | 28.6 | | 1 | 1.2 | 1.2 | 4 | 4.8 | | 1 |
| *Lambis truncata* | 12.5 | 5.4 | 24 | 50.0 | 12.6 | 6 | 12.5 | 12.5 | 4 | 50.0 | | 1 |
| *Stichopus chloronotus* | 8.3 | 3.0 | 24 | 28.6 | 4.4 | 7 | 8.3 | 4.1 | 4 | 11.1 | 4.2 | 3 |
| *Thelenota ananas* | 39.9 | 7.7 | 24 | 43.5 | 7.9 | 22 | 39.9 | 14.6 | 4 | 39.9 | 14.6 | 4 |
| *Trochus niloticus* | 22.6 | 6.4 | 24 | 36.2 | 8.6 | 15 | 22.6 | 9.6 | 4 | 22.6 | 9.6 | 4 |

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

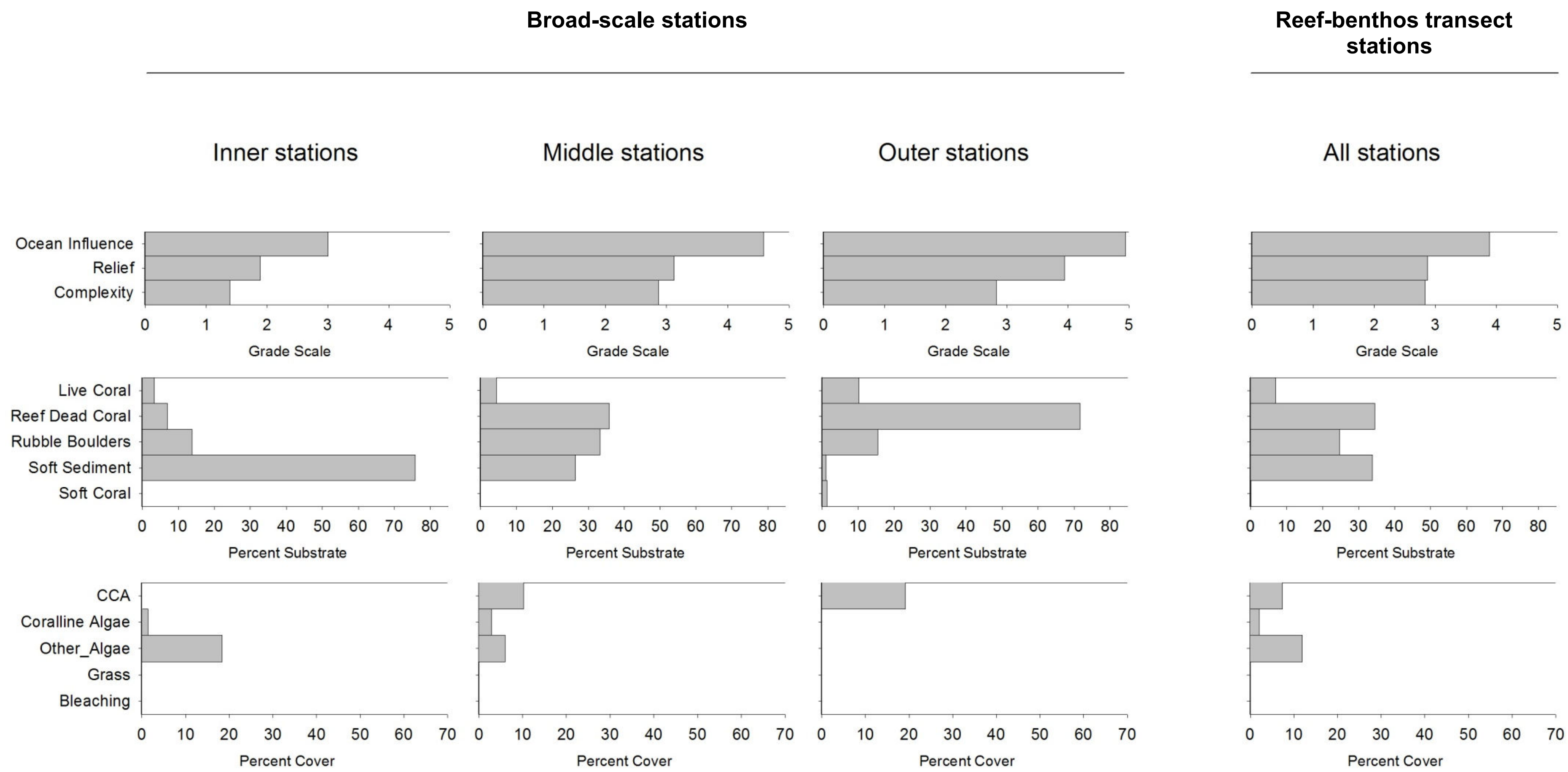
### *4.4.9 Rarotonga species size review – all survey methods*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Holothuria atra* | 17.4 | 0.4 | 15,068 |
| *Stichopus chloronotus* | 14.1 | 0.3 | 1146 |
| *Trochus niloticus* | 10.5 | 0.1 | 631 |
| *Tripneustes gratilla* | 9.5 | 0.1 | 434 |
| *Actinopyga mauritiana* | 16.5 | 0.5 | 210 |
| *Tridacna maxima* | 9.1 | 0.5 | 124 |
| *Stichopus monotuberculatus* | 13.6 | 0.4 | 86 |
| *Thelenota ananas* | 35.7 | 1.2 | 75 |
| *Lambis truncata* | 25.5 | 0.4 | 21 |
| *Turbo setosus* | 6.4 | 0.5 | 12 |
| *Conus flavidus* | 4.0 | 0.1 | 10 |
| *Cerithium nodulosum* | 8.5 | 0.5 | 7 |
| *Latirus nodatus* | 7.4 | 0.6 | 6 |
| *Thais armigera* | 8.4 | 1.0 | 4 |
| *Conus sanguinolentus* | 4.2 | 0.3 | 4 |
| *Holothuria nobilis* | 23.2 | 3.1 | 4 |
| *Bursa bufonia* | 6.9 | 0.3 | 2 |
| *Tellina scobinata* | 5.0 | 0.5 | 2 |
| *Lambis chiragra* | 16.3 | 0.2 | 2 |
| *Cypraea caputserpensis* | 2.6 | | 5 |
| *Pinna* spp. | 14.5 | | 2 |
| *Conus lividus* | 8.9 | | 2 |
| *Conus frigidus* | 2.7 | | 1 |
| *Cypraea schilderorum* | 3.3 | | 1 |
| *Bursa granularis* | 3.9 | | 1 |
| *Cypraea maculifera* | 7.0 | | 1 |
| *Conus rattus* | 3.6 | | 1 |
| *Thais aculeata* | 5.5 | | 1 |
| *Conus vexillum* | 12.5 | | 1 |
| *Echinometra mathaei* | | | 65,388 |
| *Echinothrix diadema* | | | 5648 |
| *Holothuria leucospilota* | | | 5266 |
| *Dendropoma* spp. | | | 1326 |
| *Heterocentrotus trigonarius* | | | 878 |
| *Linckia laevigata* | | | 169 |
| *Diadema* spp. | | | 93 |
| *Holothuria hilla* | | | 66 |
| *Holothuria cinerascens* | | | 47 |
| *Holothuria impatiens* | | | 27 |
| *Holothuria pervicax* | | | 15 |
| *Astralium* spp. | | | 5 |
| *Cypraea moneta* | | | 5 |
| *Conus coronatus* | | | 3 |
| *Heterocentrotus mammillatus* | | | 3 |
| *Conus sponsalis* | | | 3 |
| *Acanthaster planci* | | | 2 |
| *Octopus* spp. | | | 2 |
| *Conus miliaris* | | | 2 |

### *4.4.9 Rarotonga species size review – all survey methods (continued)*

| Species | Mean length (cm) | SE | n |
|---|---|---|---|
| *Stichodactyla* spp. | | | 1 |
| *Heteractis* spp. | | | 1 |
| *Culcita novaeguineae* | | | 1 |
| *Drupa* spp. | | | 1 |
| *Carpilius maculatus* | | | 1 |
| *Panulirus penicillatus* | | | 1 |
| *Stenopus hispidus* | | | 1 |
| *Pinctada margaritifera* | | | 1 |
| *Linckia guildingi* | | | 1 |
| *Chama* spp. | | | 1 |
| *Entacmaea quadricolor* | | | 1 |

## *4.4.10 Habitat descriptors for independent assessment – Rarotonga*

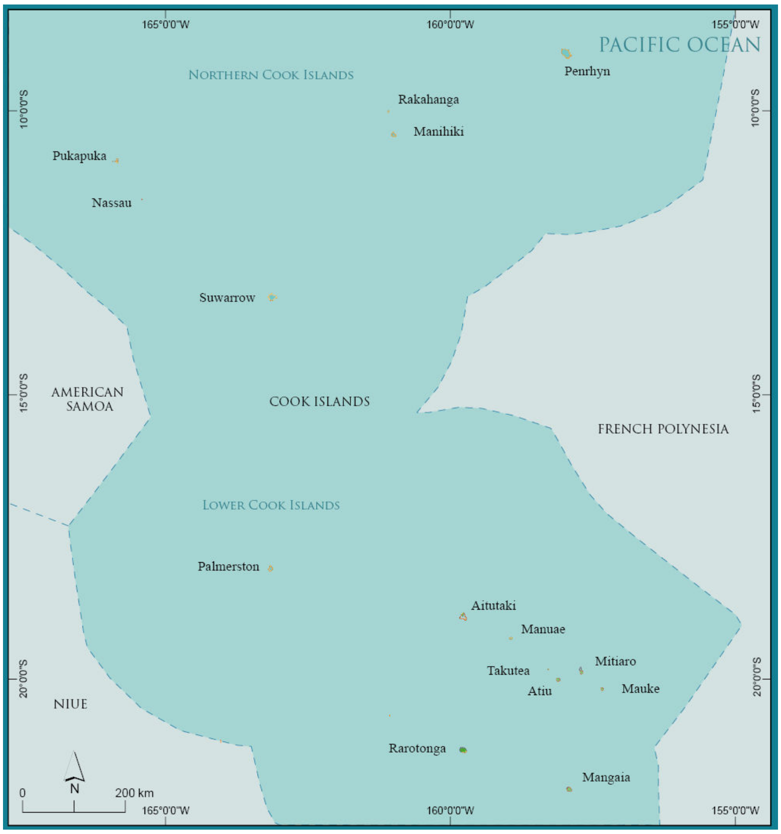


## APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – COOK ISLANDS

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*
### *Cook Islands*

*(May 2009)*




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 characterize, map and estimate the extent of shallow coral reef ecosystems worldwide using high-resolution satellite imagery (Landsat 7 images at 30 meters resolution). Since mid-2003, the project is a partnership between Institut de Recherche Pour le Développement (IRD, France) and USF. 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. It provides a reliable, spatially well constrained data set for biogeochemical budgets, biodiversity assessment, coral reef conservation programs and fisheries. The PROCFish/Coastal project has been using Millennium products in the last four years to optimize sampling strategy, access reliable reef maps, and further help in fishery data interpretation for all targeted countries. 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 the Federated States of Micronesia and data availability, please contact:

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Reference: Andréfouët S *et al.* (2006), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th Int. Coral Reef Symposium, Okinawa 2004, Japan: pp. 1732-1745.