PACIFIC REGIONAL OCEANIC AND

COASTAL FISHERIES DEVELOPMENT PROGRAMME

(PROCFish/C/CoFish)

FRENCH POLYNESIA COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT FAKARAVA, MAATEA, MATAIEA, RAIVAVAE AND TIKEHAU

(September – October 2003, January – March 2004,
April – June 2006)

by

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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 Oceanic and Coastal Fisheries Development Programme (PROCFish/C) conducted fieldwork in five locations around French Polynesia on September – October 2003, January – March 2004, and April – June 2006. French Polynesia is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by PROCFish or its associated programme CoFish (Pacific Regional 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 French Polynesia covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with two sites surveyed on the first two trips, and one site on the third trip, by a team of five programme scientists and several local attachments from the Fisheries Department and CRIOBE research institute. 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 French Polynesia, the five sites selected for the survey were Fakarava, Maatea, Mataiea, Raivavae and Tikehau. 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,

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- presenting no major logistical problems,
- having been previously investigated, and
- presenting particular interest for Vanuatu's Department of Fisheries.

Results from fieldwork at Fakarava

Fakarava is a coralline atoll with a rectangular shape, situated in the Tuamotu Archipelago at 16°19'24'S and 145°35'57'W. Its length is 54.8 km and its width is 25.8 km. The main village, Rotoava, is in the north of the atoll. Its population is 697 inhabitants, with a population density of 43.5 people/km². As often in the Tuamotu Archipelago, pearl culture is the second most developed sector after tourism.

The large lagoon, 1153 km², comprises only 16 km² of submerged area and its depth ranges between 30 and 50 m. Access to the lagoon is by the north via the Garuae passage, the largest passage in French Polynesia, and by the south via the Tumakohua passage. The area comprises only three habitats: outer reef, back-reef and intermediate reef, with a total reef area of ~77 km². This lagoon is the second largest in French Polynesia and is listed as a UNESCO biosphere reserve.

Socioeconomics: Fakarava

The Fakarava community mainly relies on reef and lagoon fisheries for subsistence purposes. Local residents eat a large amount of fresh fish (64 kg/person/year) among the highest amount of all PROCFish/C sites in French Polynesia; however, only small amounts of invertebrates and canned fish are eaten. The total subsistence demand of the Fakarava community is estimated at 65.6 t/year. Few opportunities exist for commercial reef fisheries, either for fish or for invertebrates, due to a very limited volume of air cargo freight for fresh marine produce. Only 12% of all households depend on fisheries for their first income source. Most fishers are males; the very few female fishers are all family members of the commercial *parc* fishery, and/or also collect shells for handicrafts. Current fishing pressure seems to pose no detrimental impact on any of the resources targeted. Invertebrate fisheries are far less important than finfish. Giant clam collection represented the highest impact by wet weight, followed by the collection of lobsters and shells of *Turbo* spp. Average annual catch rates of invertebrates fishers are low and may not exceed 210 kg wet weight/fisher/year.

Finfish resources: Fakarava

The finfish resource assessment indicated that the status of finfish resources in this site is relatively poor. This is reflected in the very low average fish size and size ratios for all habitats, especially back-reef. Early signs of impacts on carnivore species (especially Lethrinidae) were suggested by the low density and biomass and small sizes of these fish in all reefs. Fish traps were used in outer reefs in the past but have been abandoned in the last 4–5 years, further releasing pressure on this habitat. In fact in the outer reefs, density, biomass and fish sizes were the highest among all habitats and among the highest of the five sites, proving the resources here are in better condition compared to the more exploited habitats.

Invertebrate resources: Fakarava

Fakarava had extensive reef suitable for the elongate clam *Tridacna maxima.* Clams were common, occurring at high density in most areas of the lagoon, and not significantly impacted by fishing pressure. *T. maxima* displayed a 'full' range of size classes and the number of small clams indicates that spawning and recruitment are not generally impacted at the sites surveyed However, the largest clams were somewhat smaller than those found in other parts of the Pacific.

Trochus, *Trochus niloticus*, were common at Fakarava, but mainly limited to shallow-water reef in the lagoon. The protection of trochus broodstock (sizes ≥11 cm), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Fakarava are in the good condition found during survey. The blacklip pearl oyster, *Pinctada margaritifera*, was relatively common at Fakarava compared to other PROCFish sites in French Polynesia. There is also a restricted range of sea cucumber species at Fakarava (due to biogeographical influence), and the oceanic conditions do not offer much potential for a commercial fishery.

Recommendations for Fakarava

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

- Spear diving, especially in the lagoon, should be regulated and spear diving at night be banned.

- Considering the high quality of habitat in Fakarava, marine protected areas should be considered as a primary management tool.

- The density and size range of trochus noted in survey suggests that limited fishing could be made at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing. If trochus harvests are considered, it is suggested that some stock be moved from areas of highest density to other suitable areas within Fakarava (possibly reeftop of barrier) in order to extend the range of trochus in Fakarava.

- Surf redfish (*Actinopyga mauritiana*) abundance should be monitored around the atoll, as there may be some potential for harvests of this species if aggregations are located. Further assessment is needed for the deeper-water white teatfish stock (*Holothuria fuscogilva*), especially in the southern pass of the atoll. The preliminary investigation and fishing history of this stock suggest there is potential for small-scale harvests in the future.

Results from fieldwork at Maatea

Moorea is part of the Windward Group in the Society Islands and is only 16 km northwest of Tahiti. Its surface area is 134 km² with a population of ~15,000 people. The village of Maatea is situated at 17°35'S and 149°48'W in the south of the island, a high island, with the highest point reaching 1207 m. Its fishery area is delimited by the eastern and western reef passages.

The lagoon (~7 km²) has large back-reefs and is composed of four habitats: outer reef, back-reef, intermediate reef and sheltered coastal reef, with a total reef area of ~11 km².

Socioeconomics: Maatea

Maatea, although one of the more traditional communities on Moorea, has also largely adopted the urbanised lifestyle of nearby Papeete and Tahiti. Salaries and social fees are the main sources of income, with fisheries and agriculture both less important. The people eat a large amount of fresh fish, estimated at ~70 t/year in total, but only a small amount of invertebrates. More males than females are engaged in fishing. Fishing is still done from non-motorised boats, or by walking; handlines and fishing rods are preferred. Participation by commercial fishers is low. Average fish sizes follow the expected trend, i.e. sizes increase from the sheltered coastal reef to the outer reef. CPUEs also increase slightly from sheltered coastal reef to the outer reef. Invertebrate fisheries are limited to a few species and are far less important than finfish fisheries. Overall, the survey data suggest that fishing pressure imposed by the subsistence needs of the Maatea community alone is high. Invertebrate data also suggest that reef resources are poor.

Finfish resources: Maatea

Survey results show that the status of finfish resources in Maatea is slightly lower than the average across PROCFish/C study sites in the country. Detailed assessment at reef level also revealed a systematic, lower-than-average abundance for snappers (Lutjanidae), goatfish (Mullidae) and especially emperors (Lethrinidae). These results suggest that this trend could be due to greater-than-average impact from fishing carnivorous species. Fishing in Maatea is mostly carried out for sustenance purposes. However, the impact on fish resources is already visible: in the low average fish size shown by some families; the particular trophic structure, which is highly dominated by herbivores; and in the very low number or lack of carnivores, especially of targeted species groups, such as Lethrinidae.

Overall, Maatea finfish resources appeared to be in relatively low to poor condition, despite the relatively rich reef habitat. Populations of emperors (Lethrinidae), snappers (Lutjanidae) and goatfish (Mullidae) were systematically lower than the country average. The total fishing pressure on Maatea was found to be high and obvious impacts were revealed by the lower than average fish size and in the herbivore-dominated trophic composition of the finfish population.

Invertebrate resources: Maatea

The reefs at Maatea, especially the shallow-water back-reef habitat, were very suitable for the elongate clam, *Tridacna maxima*. The fringing reef was less suitable for giant clams, due to significant river inflows. Giant clam density was high compared to other open-lagoon, high-island sites in the Pacific, although the coverage and density were not remarkable compared to results from more enclosed atoll sites in French Polynesia. 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 shore and of large-sized clams was relatively low, supporting the assumption that clam stocks are moderately impacted by fishing.

Trochus, *Trochus niloticus,* stocks are common at Maatea, with the greatest concentrations on fringing reef opposite the main passes. Strict protection of trochus broodstock (sizes 11 cm and up), and the long 'resting' of stock since the last commercial fishing are considered the main reasons why trochus stocks at Maatea are in the healthy condition found during the survey. Periodic harvests along with strict size controls have proved a successful strategy for stock management in French Polynesia. The blacklip pearl oyster, *Pinctada margaritifera*, was uncommon at Maatea.

The potential for developing a commercial sea cucumber fishery based on stocks around Maatea is limited. A restricted range of sea cucumber species was present, mainly due to biogeographical influences, the easterly position of Moorea in the Pacific, and the limited number of protected habitats available in this largely oceanic-influenced lagoon system. High densities of the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish were recorded, but few medium-value prickly redfish (*Thelenota ananas*) were recorded.

Recommendations for Maatea

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

- The development and implementation of Moorea's marine management plan (Plan de Gestion de l'Espace Maritime (PGEM)) agrees with the perception that the lagoon resources of Maatea and Moorea are generally declining, due to increases in population and tourism. However, the effectiveness of this PGEM may need further improvement as there are a number of conflicts arising between governmental and local authorities concerning modern and traditional conservation approaches and methods.

- Spear diving is a common practice in the coastal, lagoon and outer reefs; this very selective fishing practice should be regulated and night diving banned.

- Marine protected areas could be considered as a primary management tool to enable overexploited fishing areas to recover.

- There is scope for trochus fishing at Maatea at areas where stocks are at their highest densities (500–600 /ha are required); especially if the gauntlet fishery regulation is adhered to (i.e. only shells with a basal width between 8 and 11 cm are taken).

- The green snail (*Turbo marmoratus*), is common in some places in Maatea, but the density of this species is not high across its range. No commercial fishing of *T. marmoratus* is recommended at this stage due to the limited area and distribution of this species across its potential range at Maatea.

- Interviewing older fishers to identify areas that traditionally held trochus and green snail stocks, but which are now overfished, might allow range extension of both these resources. Transplantation of adults from dense aggregations into new areas that have become depleted is advised if commercial harvests are not to go ahead in the short term.

- The high-value black teatfish (*Holothuria nobilis*) was absent around Maatea. In addition, further assessment of deeper-water white teatfish stocks (*H. fuscogilva*) is required to understand its fishery potential. Extra survey effort is recommended to ascertain the status of these stocks on Moorea, and to see if extra protection is needed to rebuild populations of this species locally.

Results from fieldwork at Mataiea

The village of Mataiea is located in the south of Tahiti Nui high-island, at the position 17°46'S and 149°24'W. This island, which is part of the Windward Group in the Society Archipelago, is the biggest island in French Polynesia (1045 km²). It comprises two dormant volcanoes linked by a natural isthmus: Tahiti Nui (big) and Tahiti Iti (small). It is also the most inhabited island, with 70% of the total population. Only the coastal band is inhabited and there are 22 districts in total. The fishery ground area is open access and extends 11.3 km x 2.2 km. The lagoon comprises four habitats: outer reef, back-reef, intermediate reef and sheltered coastal reef, with a total reef area of ~14 km². As most of the people work in the capital city, fishing is performed for food rather than income.

Socioeconomics: Mataiea

The community of Teva I Uta, Mataiea, is a large community (>7900 people), around 80 km from the country's capital city Papeete. Its peri-urban character is highlighted by the high dependency on salaries, with fisheries mainly done for subsistence and leisure purposes rather than for income generation. The average finfish consumption of ~45 kg/person/year is above the regional average, but the lowest compared to the other PROCFish/C sites in the country. In contrast, consumption of invertebrates and canned fish is very low.

Finfish fishing mainly targets the lagoon between the passages of Teavaraa and Temaraui and the sheltered coastal reef and, to a much lesser extent, the outer-reef area, mainly because most fishers use paddling canoes, sometimes equipped with small outboard engines (9–15 hp), which do not allow them to venture out to the outer reef in all conditions.

Most fishing is done by males, while females may participate in weekend and leisure fishing. Lobster diving is exclusively done by males. Invertebrate fishing is mainly for subsistence needs; less than 40% may be sold among the community's members, mainly lobsters, which are subject to the highest fishing pressure and make up 80% of all reported catches.

Finfish resources: Mataiea

Despite the relatively rich reef habitat in Mataiea, the finfish resources appeared to be in poor condition due to heavy fishing, especially in the lagoon and coastal areas. Survey results showed fish densities and biomass to be the lowest of all the survey sites. Detailed assessment at reef level also revealed a lower-than-average abundance of carnivores, especially Labridae, Lutjanidae and Lethrinidae, with Mullidae showing slightly higher abundance in coastal and intermediate reefs. Preliminary results suggest that this trend could be due to greater-than-average impact from fishing carnivorous species (Lutjanidae, Serranidae and Labridae). Populations of snappers (Lutjanidae), emperors (Lethrinidae) and goatfish (Mullidae) were systematically low and groupers (Serranidae) practically absent. Fishing in Mataiea is mostly carried out for sustenance purposes. The impact on fish resources is however already elevated due to the high population and high fisher density.

Invertebrate resources: Mataiea

The lagoon areas of Mataiea and especially the shallow-water back-reef areas were very suitable for the elongate clam, *Tridacna maxima*, and giant clam density was reasonable for *T. maxima* for a high-island, open-lagoon site. The coverage and density were not remarkable compared to densities commonly found elsewhere in French Polynesia and local reports claim clam numbers and sizes have decreased in recent years. Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the number of large-sized clams was relatively small, supporting the assumption that clam stocks are impacted by fishing pressure.

Despite blacklip pearl oysters, *Pinctada margaritifera,* being cryptic and normally sparsely distributed in open lagoon systems (such as found at Mataiea), they were still surprisingly rare, with only a single shell recorded in survey.

Trochus, *Trochus niloticus,* and green snail, *Turbo marmoratus*, although mainly limited to within the passes and lagoon were relatively common at Mataiea. Both are species of commercial value to inshore fishers. The protection of trochus broodstock (sizes 11 cm and up), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Mataiea are in the healthy condition found during the survey.

There is a restricted range of sea cucumber species at Mataiea (due to biogeographical influence), and no clear picture of pressure on stocks emerged. A good density of lower-value leopard or tigerfish (*Bohadschia argus*) was recorded, but black teatfish (*Holothuria nobilis*), a more valuable species, was only found at a single location in survey. Prickly redfish (*Thelenota ananas*), which has a slightly lower value than black teatfish, was not uncommon, but still at moderate-to-low density.

Recommendations for Mataiea

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

- Further development of reef finfish fisheries would not be sustainable and resources need to be allowed to recover if food security needs are to be met in the future.

- Recovery should be achieved through the establishment of restrictive marine resource management measures. Marine protected areas should be considered as a primary management tool. The efficiency of this trial should then be evaluated through ongoing resource monitoring.

- Use of gillnets and night spearfishing should be strictly regulated.

- Intermediate and coastal reefs should be the focus of recovery and protection since the natural poverty of the outer reefs would not release pressure on sheltered coastal and back-reefs.

- The density and size range of trochus noted in the survey suggest that limited fishing could be made at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing.

- No commercial fishing of green snail, *Turbo marmoratus*, is recommended as the range of this species is very limited.

- Older fishers could be interviewed to identify areas that traditionally held trochus and green snail stocks, but which are now overfished. This might allow the range of these resources to be extended locally, by transplanting adults to these areas.

- Further assessment is needed of the stocks of the deeper-water white teatfish (*Holothuria fuscogilva*) to assess the potential for commercial harvesting of this species.

Results from fieldwork at Raivavae

Raivavae is a high-island in the Austral Islands, situated at 23°53'S and 147°40'W. The island has an area of 16 km², and its highest point is Mount Hiro (437 m). The island is surrounded by a small lagoon with two passes, one in the north and one in the south. Four reef habitats are present: sheltered coastal reef, intermediate reef, back-reef and outer reef, with a total reef area of ~93 km². Both the eastern and the southern parts of the island are dominated by *motu*, small coralline islets. The local economy is based on agricultural produce for food, fisheries, and handicrafts. Population (1050 people) is distributed over four districts, with Rairua being the most important.

Socioeconomics: Raivavae

The community of Raivavae still enjoys a rather traditional lifestyle as it is far from Tahiti and relatively small (~1100 people). The more traditional lifestyle of the community is revealed by the high consumption of invertebrates; the very limited income generation from fisheries; the common practice of exchanging seafood without payment among community members; and a low household expenditure level. Consumption of finfish is rather low (~46 kg/person/year) compared to other communities surveyed in French Polynesia, but this is because agriculture provides a good alternative food source. Also, the consumption of pelagic fish has increased on the island due to the increased risk of ciguatera from certain reef fish.

Most fishing is done by males; females are less involved, but may participate at weekend and leisure fishing. Diving for lobsters and giant clams is exclusively performed by males, while females are the main collectors of *poupou* (small shells of marine snails) for handicrafts, from the *motu* at the barrier reef. Finfish are caught mainly for subsistence and also for sharing with other community members.

Invertebrates are targeted for export, with about half of the reported annual catch exported to Papeete. Most of the invertebrates exported are giant clams, which are exported by sea as a frozen product. Lobsters are also exported either by air or frozen and shipped by sea, but amounts vary according to seasonal demands, such as end-of-year festivities. The collection of *poupou* (shells) for artisanal purposes also provides a major income source for Raivavae households. However, this collection is considered to have no adverse environmental or resource impact because no live shellfish are taken and collection is onshore.

Finfish resources: Raivavae

Survey results indicate that the status of finfish resources in Raivavae is better than the average across French Polynesia study sites. Detailed assessment at reef level also revealed a systematic high or average abundance and biomass, except for the back-reefs (the poorest environment at this site). Average biomass of herbivores and carnivores were both the highest among the five sites, and this is even more significant when we consider Raivavae is lacking the intermediate-reef habitat. Average sizes and size ratios were the highest of all sites, suggesting a healthy status of resources. Fishing at the present rate is not impacting the resources; in fact, of all the survey sites, the Raivavae community was the least dependent on fisheries for income generation and consumed the least amount of fresh fish. Moreover, fishing for reef fish is becoming less important than fishing for pelagic fish because of the increase in ciguatera.

Invertebrate resources: Raivavae

The mid-lagoon patch-reef areas and especially the shallow-water back-reef of Raivavae were very suitable for the elongate clam *Tridacna maxima*. Clams were not present on all reefs, but densities in the south and west of the lagoon were exceptional for a high-island, open-lagoon environment. *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment. The number of large-sized clams in the stock suggests that clam stocks are only marginally impacted by fishing pressure. However clams over 22 cm shell length were rarely found.

Trochus, *Trochus niloticus*, and the great green turban, *Turbo marmoratus*, have not established viable populations in the areas where they were reported to have been introduced. The blacklip pearl oyster, *Pinctada margaritifera*, was not common at Raivavae, but was found regularly in the lagoon.

There is a restricted range of sea cucumber species at Raivavae (due to biogeographical influence), and it appears that the lack of significant numbers of leopardfish (*Bohadschia argus*) and black teatfish (*Holothuria nobilis*) is more related to the unsuitability of the habitat than to any fishing pressure. The widespread distribution and high abundance of surf redfish (*Actinopyga mauritiana*) recorded during surveys, indicate that there is a potential for commercial fishing of this stock at Raivavae. There are also significant numbers of lollyfish (*Holothuria atra*).

Recommendations for Raivavae

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

- The density and size of Serranidae in the outer reefs should be monitored to detect any decreases, as there are early signs that this fish family is decreasing in abundance.

- The current level of fishing for reef finfish for sustenance and to fulfil social obligations can be maintained, as it appears to be sustainable.

- Further assessment is needed to assess deeper-water white teatfish stocks (*Holothuria fuscogilva*); however, the preliminary investigation did not highlight any very promising options for this species.

- Although for giant clams no sustainability issues were identified and exploitation rates are below any rate critical to commercial fishing, a management plan designed to rest certain areas is recommended. A system of rotational closures (introduced with local consultation) could operate at variable time periods, depending on the state of the reef (its condition and its location), but will need to take into account the growth rate of clams, to allow clams time to reach maturity.

- Any future introductions of the commercial topshell (*Trochus niloticus*) should consider first placing the trochus on inshore reefs in the north of the island to protect them after the move until they acclimatise to local conditions, and then relocating them to reef on the northeast corner of the island. In addition, any future translocations should be made with the active support of fishers and the community, to ensure there is a general understanding of the potential benefits of these stocks becoming established.

Results from fieldwork at Tikehau

Located in the Tuamoto Archipelago near Rangiroa, this atoll has an annular shape and is positioned at 15°00'06S and 148°10'37W. It is 26 km long and 19.8 km wide. Its lagoon, which has a mean depth of about 20 m, covers an area of 400 km² and the submerged areas represent 20 km². The highest point of the *motu* is 8 m. Population is 417 people, which represents a density of ~20 people/km²; most of the population lives in the village of Tuheraera, in the southwest of the atoll. There is only one passage in the west, the Tuheiava passage. Only three habitats are represented since there is no high island and therefore no terrigenous influence: intermediate reef, back-reef and outer reef, with a total reef area of ~76 km².

People from Tikehau make their living from fisheries and operate traditional *parcs* (permanent fish traps), which allow them to better manage the export of their products in Tahiti. Pearl culture, together with tourism and copra production, also makes an important contribution to the economy.

Socioeconomics: Tikehau

People living on the atoll island of Tikehau still enjoy a more traditional lifestyle, as shown by the relatively low household expenditure level, even though the island offers hardly any potential for agricultural subsistence production. However, the daily flight services to the country's capital city, a guaranteed freight volume and the air cargo price for fresh seafood produce have prompted the substantial development of commercial reef fishery. Fisheries are the most important income source, followed by social fees and salaries.

The high dependence of the Tikehau community on their marine resources also shows in the high consumption of fresh fish (67 kg/person/year). However, the consumption of invertebrates and canned fish was found to be of minor, if any, importance. Invertebrate fisheries are less important than finfish fisheries. Very few people regularly collect invertebrates, and then only lobsters, giant clams, some *Turbo* spp. shells and other shells collected for handicrafts.

There are three major finfish fisher groups found on Tikehau: subsistence and leisure fishers; commercial fishers using spear diving, handlines and gillnets; and commercial fishers who operate *parcs* (fish traps) mainly in the passages (and also some located in the sheltered coastal reef area). Highest impact on the island's finfish resources was found to be imposed by *parc* fishers. The total annual impact may be as high as 400 t, ~96% of which is for export and ~4% for consumption by Tikehau residents only.

Finfish resources: Tikehau

The status of finfish resources in Tikehau was poorer than the average across French Polynesia study sites. Density, biomass and biodiversity were similar to values found at Mataiea, the lowest recorded in the country. Tikehau reefs displayed among the lowest values of density and biomass of all herbivores, especially Acanthuridae and Scaridae. Density of carnivores was also in the lower range, which cannot be explained by the type of habitat, since in general this is composed of a similar cover of hard and soft bottom. The low density of carnivores and, indeed, of all fish in general, is directly related to intense fishing imposed upon these reefs, especially on the internal reefs, which has impacted the fish populations in terms of abundance and size and therefore total biomass.

Overall, Tikehau finfish resources appeared to be in a rather poor condition. Although reef habitats seemed relatively rich, the finfish resources, especially those in the back- and intermediate reefs, displayed among the lowest values in the country. The populations of Lutjanidae, Lethrinidae and Mullidae were extremely low, although this is a general trend for all sites in the country. This cannot possibly be due to a lack of suitable habitats, since all types of substrate are well represented in Tikehau. This site has the highest average cover of soft bottom, which generally favours carnivores, such as Lethrinidae and Mullidae. The cause of this scarcity is related to the fishing pressure.

Invertebrate resources: Tikehau

Tikehau had extensive reef suitable for the elongate clam, *Tridacna maxima*. Clams were common and at high density in the passage area, and were also found at reasonably high density on reefs in the lagoon. *T. maxima* displayed a 'full' range of size classes, although there was no build-up of large clams. This supports the assumption that clam stocks are marginally impacted by fishing pressure. The number of small clams in the size range indicates that spawning and recruitment are not generally affected.

Trochus, *Trochus niloticus*, were relatively common at Tikehau but mainly limited to within the pass and lagoon. The protection of trochus broodstock (sizes 11 cm and up), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Tikehau are in the condition found during survey. The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Tikehau. There is a restricted range of sea cucumber species at Tikehau (due to biogeographical factors), and no real potential for commercial harvesting.

Recommendations for Tikehau

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

- Appropriate management measures need to be developed in consultation with the Service de la pêche and the local community leaders/authorities to ensure stocks are conserved for future generations as the present level of fishing for export appears to be unsustainable in the long term.

- The use of *parcs* (fish traps) should be regulated as part of management arrangements, since they are too efficient at targeting carnivorous species (snappers, emperors and goatfish in the inner reefs (back-, intermediate and coastal reefs)). Spearfishing, and the use of gillnets in the inner reefs should be banned.

- Considering the high quality of habitat in Tikehau, marine protected areas should be considered as a primary management tool.

- Limited fishing of trochus could be conducted at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing. If harvests are considered, some movement of stock from the pass to other suitable areas within Tikehau (possibly reeftop of barrier) may be beneficial to extending the range of trochus in Tikehau.

- Surf redfish (*Actinopyga mauritiana*) abundance should be monitored, as there is some potential for harvests of this species, while further assessment is needed for the deeper-water white teatfish stock (*Holothuria fuscogilva*); however the preliminary investigation did not highlight promising results for this species.

RÉSUMÉ

Les agents chargés de la composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique (PROCFish/C) ont conduit des enquêtes sur le terrain, sur cinq sites dispersés autour de la Polynésie française, de septembre à octobre 2003, de janvier à mars 2004 et d'avril à juin 2006. La Polynésie française est l'un des 17 États et Territoires insulaires océaniens qui ont fait l'objet d'enquêtes sur une période de cinq à six ans, dans le cadre du projet PROCFish ou de son projet associé CoFish (projet de développement de la pêche côtière)[3].

Le but des enquêtes était d'obtenir des données de référence sur l'état des ressources récifales et de pallier l'énorme manque d'informations qui entrave la gestion efficace des ressources récifales.

Les autres résultats recherchés étaient notamment les suivants :
- toute première évaluation exhaustive et comparative des pêcheries récifales (poissons, invertébrés et paramètres socioéconomiques de leur exploitation) de plusieurs pays de la région océanienne, suivant une méthode normalisée, appliquée sur chaque site d'étude ;
- diffusion de rapports nationaux comprenant un ensemble de « profils des ressources halieutiques récifales » pour les sites étudiés dans chaque pays, servant de base au développement de la pêche côtière et à la planification de sa gestion ;
- élaboration d'un jeu d'indicateurs (ou points de référence servant à évaluer l'état des stocks), à l'appui de l'élaboration de plans locaux et nationaux de gestion des ressources récifales, et de programmes de suivi ; et
- élaboration de systèmes de gestion des données et informations, notamment de bases de données régionales et nationales.

Les enquêtes conduites en Polynésie française concernaient trois disciplines (poissons, invertébrés et aspects socioéconomiques) sur chaque site. Une équipe composée de cinq scientifiques du Programme pêche côtière de la CPS, et plusieurs stagiaires détachés par le Service de la pêche et le Centre de recherches insulaires et observatoire de l'environnement (CRIOBE), a étudié deux sites au cours des deux premières missions, et un site au cours de la troisième. Au cours des travaux sur le terrain, l'équipe a formé ses homologues locaux aux méthodes d'enquête et de comptage employées dans chaque discipline, notamment la collecte de données et leur saisie dans la base de données du projet.

En Polynésie française, les cinq sites retenus pour le travail d'enquêtes étaient : Fakarava, Maatea, Mataiea, Raivavae et Tikehau. Ces sites ont été sélectionnés d'après des critères précis, notamment :
- existence d'une pêcherie récifale active,
- sites représentatifs du pays,
- systèmes relativement fermés (les habitants du site pêchent dans des zones bien définies),
- taille appropriée,

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[3] 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, Wallis et Futuna).

- habitat diversifié,
- absence de problèmes logistiques majeurs,
- études déjà effectuées auparavant, et
- intérêt particulier des sites pour le Service de la pêche de la Polynésie française.

Résultats des travaux de terrain effectués à Fakarava

Fakarava est un atoll corallien de forme rectangulaire, situé dans l'archipel des Tuamotu, par 16°19'24 de latitude sud et 145°35'57 de longitude ouest. Il mesure 54,8 km de long, et 25,8 km de large. Le principal village, Rotoava, se trouve au nord de l'atoll. Il compte 697 habitants, soit une densité de population est 43,5 habitants/km². Comme souvent dans l'archipel des Tuamotu, la perliculture est le deuxième secteur de l'économie après le tourisme.

Ce grand lagon de 1 153 km² ne comprend que 16 km² de terres émergées, et sa profondeur varie de 30 à 50 mètres. On accède au lagon au nord par la passe de Garuae, la plus grande de toute la Polynésie française, et au sud par celle de Tumakohua. Cette zone ne comprend que trois habitats : le tombant récifal externe, l'arrière-récif et le récif intermédiaire, qui recouvrent une superficie récifale totale de 77 km² environ. Ce lagon, deuxième de Polynésie française par la taille, a été classé « réserve de biosphère » par l'UNESCO.

Enquêtes socioéconomiques : Fakarava

La population de Fakarava tire principalement sa nourriture des ressources récifales et lagonaires. Les habitants consomment de grandes quantités de poisson frais (64 kg par personne et par an, soit l'une des plus grandes quantités consommées parmi tous les sites PROCFish/C de Polynésie française), mais aussi de petites quantités d'invertébrés et de poisson en conserve. La demande vivrière totale de la communauté de Fakarava est estimée à 65,6 tonnes par an. Les débouchés de la pêche commerciale, de poissons ou d'invertébrés, sont peu nombreux du fait du volume très limité du fret aérien réservé aux produits de la mer frais. De tous les ménages, seuls 12 pour cent tirent leurs principaux revenus de la pêche. La pêche est surtout l'affaire des hommes, les très rares femmes pratiquant la pêche étant toutes des membres de la famille de l'entreprise de pêche commerciale (parc à poissons) ; elles ramassent aussi des coquillages pour fabriquer des objets d'artisanat. La pression de pêche actuelle ne semble pas causer de dégâts sur les ressources ciblées. La pêche d'invertébrés est beaucoup moins importante que celle de poissons. C'est la collecte de bénitiers qui a le plus fort impact par poids humide, suivie de celle de langoustes et de coquilles de *Turbo* spp. Les taux moyens de prises annuelles d'invertébrés sont faibles et ne dépassent pas 210 kg de poids humide par pêcheur et par an.

Ressources en poissons : Fakarava

L'évaluation des ressources en poissons montre que l'état de celles-ci sur ce site est relativement médiocre, ce qui se traduit par une taille moyenne très faible des poissons et des rapports de tailles très réduits pour l'ensemble des habitats, surtout l'arrière-récif. La faiblesse de la densité, de la biomasse et de la taille des poissons d'espèces carnivores (lethrinidés, en particulier), est l'un des premiers signes d'impacts sur ces poissons dans tous les récifs. Autrefois, on utilisait des parcs à poissons sur les récifs extérieurs ; ils ont été abandonnés depuis 4 à 5 ans, ce qui atténue la pression sur cet habitat. De fait, sur les tombants récifaux externes, la densité, la biomasse et la taille des poissons sont les plus élevées de tous les habitats, et parmi les plus élevées des cinq sites, ce qui prouve que les ressources sont ici en meilleur état que dans les habitats plus exploités.

Ressources en invertébrés : Fakarava

Fakarava possède un vaste récif, qui convient bien au bénitier allongé *Tridacna maxima.* Les bénitiers sont présents en grand nombre et à densité élevée dans la plupart des zones du lagon et ne subissent pas d'impact significatif dû à la pression de pêche. Les individus observés sont de toutes classes de taille, et le nombre de petits bénitiers laisse à penser qu'il n'y a en général pas d'obstacle au frai ni au recrutement sur les sites étudiés. Les individus les plus grands étaient toutefois plus petits que ceux que l'on trouve dans d'autres régions du Pacifique.

Le troca *Trochus niloticus* est abondant à Fakarava, mais sa présence se limite aux eaux peu profondes du lagon. La protection du stock reproducteur (de plus de 11 cm) et le « repos » du stock entre deux périodes de pêche commerciale expliquent le bon état des stocks observé à Fakarava pendant l'enquête. L'huître perlière à lèvres noires *Pinctada margaritifera* est relativement courante à Fakarava, par rapport à d'autres sites PROCFish de Polynésie française. On trouve aussi une gamme restreinte d'espèces d'holothuries (pour des raisons biogéographiques), et les conditions océaniques n'offrent pas beaucoup de perspectives pour une exploitation commerciale.

Recommandations pour Fakarava

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

- La pêche au fusil sous-marin, particulièrement dans le lagon, devrait être réglementée et la pêche en plongée de nuit interdite.

- Compte tenu de la grande qualité de l'habitat à Fakarava, des aires marines protégées devraient être envisagées comme principal outil de gestion.

- La densité et la fourchette de tailles de trocas, observées au cours de l'enquête, suggèrent qu'une pêche limitée pourrait être pratiquée dans les zones de plus forte abondance. On ne devrait pas commencer à pêcher au-dessous du seuil de densité de 500 à 600 individus par hectare. Avant d'envisager de récolter des trocas, il conviendrait de transférer une partie du stock depuis les zones de forte densité vers d'autres zones appropriées à Fakarava (éventuellement la barrière récifale), afin d'y élargir l'aire de répartition du troca.

- Il faudrait surveiller l'abondance de l'holothurie de brisant *Actinopyga mauritiana* tout autour de l'atoll. Il existe peut-être un potentiel de récolte de cette espèce si l'on trouve des concentrations. Il faudra évaluer plus précisément le stock d'holothuries blanches à mamelles *Holothuria fuscogilva* qui vit dans des eaux plus profondes, surtout dans la passe sud de l'atoll. D'après les premières investigations et l'historique de la pêche de cette espèce, il existe des possibilités de récolte à petite échelle.

Résultats des travaux de terrain effectués à Maatea

Moorea fait partie du groupe des îles du Vent, dans l'archipel de la Société. Elle n'est qu'à 16 km au nord-ouest de Tahiti. Quelque 15 000 habitants vivent sur ses 134 km². Le village de Maatea est situé par 17°35' de latitude sud et 149°48' de longitude ouest au sud de l'île. Cette île haute culmine à 1 207 mètres. Sa pêcherie est délimitée par les passes est et ouest dans le récif. Le lagon, d'environ 7 km², comporte de grands arrière-récifs et se compose de quatre habitats : tombant récifal externe, arrière-récif, récif intermédiaire et récif côtier protégé, qui recouvrent une superficie récifale totale de 11 km² environ.

Enquêtes socioéconomiques : Maatea

Bien que peuplée d'une des communautés les plus traditionnelles de Moorea, Maatea a largement adopté le mode de vie urbanisé de Papeete et Tahiti, toutes proches. Les salaires et prestations sociales sont les principales sources de revenus, la pêche et l'agriculture étant moins importantes. Les habitants consomment une grande quantité de poisson frais, estimée à 70 tonnes par an environ, mais une petite quantité seulement d'invertébrés. Les hommes pratiquent plus souvent la pêche que les femmes. Ils pêchent encore depuis des embarcations sans moteur, ou à pied, de préférence à la ligne et à la canne. On observe peu de pêcheurs commerciaux. Les tailles moyennes des poissons suivent l'évolution attendue, c'est-à-dire qu'elles augmentent au fur et à mesure que l'on s'éloigne du récif côtier protégé en direction du tombant récifal externe. Les PUE augmentent légèrement du récif côtier protégé vers le tombant récifal externe. Les invertébrés récoltés se limitent à quelques espèces, et cette pêche est beaucoup moins importante que celle de poissons. Dans l'ensemble, il ressort des données de l'enquête que la pression de pêche imposée par les besoins de subsistance de la seule communauté de Maatea est élevée. Les données concernant les invertébrés laissent aussi à penser que les ressources récifales sont médiocres.

Ressources en poissons : Maatea

Les résultats de l'enquête montrent que l'état des ressources en poissons à Maatea est légèrement moins bon que la moyenne des sites du pays où des enquêtes PROCFish/C ont été conduites. L'évaluation détaillée, au niveau du récif, révèle aussi une abondance systématiquement inférieure à la moyenne des vivaneaux (lutjanidés), des rougets (mullidés) et surtout des empereurs (lethrinidés). D'après ces résultats, cette tendance pourrait s'expliquer par l'impact supérieur à la moyenne de la pêche d'espèces carnivores. À Maatea, la pêche est surtout pratiquée à des fins de subsistance. Cependant, l'impact de la pêche sur les ressources halieutiques se manifeste déjà par la faible taille moyenne de certaines familles de poissons, par la structure trophique particulière, dominée par des herbivores, et par le très faible nombre, voire l'absence, de carnivores, surtout ceux qui appartiennent à des groupes d'espèces ciblées comme les lethrinidés.

Dans l'ensemble, les ressources en poissons de Maatea semblent en médiocre, voire mauvais état, malgré la relative richesse de l'habitat récifal. Les populations d'empereurs (lethrinidés), de vivaneaux (lutjanidés) et de rougets (mullidés) sont systématiquement inférieures à la moyenne du pays. La pression de pêche totale à Maatea est élevée, et cela se manifeste par la taille des poissons, inférieure à la moyenne, et par la composition trophique de la population de poissons, dominée par les herbivores.

Ressources en invertébrés : Maatea

Les récifs de Maatea, en particulier l'habitat de l'arrière-récif aux eaux peu profondes, conviennent parfaitement au bénitier *Tridacna maxima*. Le récif frangeant est moins favorable, du fait des importants apports terrigènes des cours d'eau. La densité des bénitiers est élevée par rapport à d'autres lagons ouverts d'îles hautes du Pacifique, bien que la couverture et la densité ne soient pas remarquables, comparées aux résultats d'enquêtes menées sur des sites d'atolls plus fermés de Polynésie française. Bien que l'on observe toute la gamme de classes de taille chez *T. maxima*, y compris de jeunes bénitiers, ce qui traduit le succès du frai et du recrutement, l'abondance des bénitiers près du littoral et de bénitiers de grande taille est relativement faible, ce qui confirme l'hypothèse que les stocks de bénitiers sont modérément affectés par la pêche.

Les stocks de troca *Trochus niloticus* sont abondants à Maatea. Ils se concentrent surtout sur le récif frangeant, face aux passes principales. On estime qu'une stricte protection du stock reproducteur de trocas (à partir de 11 cm) et le long « repos » du stock depuis la dernière campagne de pêche commerciale expliquent la bonne santé des stocks de troca à Maatea, observée pendant l'enquête. Des récoltes périodiques et des mesures strictes de contrôle de la taille se sont révélées une stratégie fructueuse de gestion du stock en Polynésie française. L'huître perlière à lèvres noires *Pinctada margaritifera* n'est pas courante à Maatea.

Le potentiel de développement d'une pêcherie commerciale d'holothuries parmi les stocks vivant autour de Maatea est limité. Une gamme restreinte d'espèces d'holothuries est présente, du fait d'influences biogéographiques – la position orientale de Moorea dans le Pacifique et le nombre limité d'habitats protégés existant dans ce système lagonaire, largement influencé par l'océan. On a enregistré des densités élevées d'holothuries léopards (*Bohadschia argus)* et d'*Holothuria atra*, mais aussi quelques holothuries ananas (*Thelenota ananas*) de valeur marchande moyenne.

Recommandations pour Maatea

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

- L'élaboration et la mise en œuvre du plan de gestion de l'espace maritime (PGEM) de Moorea s'appuient sur le constat que les ressources du lagon de Maatea et de Moorea sont en train de décliner, en règle générale, sous l'effet de l'essor démographique et du développement touristique. L'efficacité de ce PGEM pourrait toutefois être améliorée malgré l'existence de plusieurs conflits entre les autorités gouvernementales et locales concernant les approches et méthodes modernes et traditionnelles de la conservation.

- La pêche au fusil sous-marin est couramment pratiquée dans le récif côtier, le lagon et les récifs extérieurs. Cette pratique très sélective devrait être réglementée et la pêche de nuit en plongée interdite.

- Il conviendrait d'aménager des aires marines protégées et d'en faire un outil primordial de gestion qui permettrait aux zones de pêche surexploitées de retrouver leur richesse.

- La récolte de trocas à Maatea est possible dans les zones où les stocks atteignent leur densité maximale (500 à 600 individus par hectare), surtout si le règlement halieutique est strictement respecté (seules des coquilles d'une largeur à la base de 8 à 11 cm sont prélevées).

- Le burgau *Turbo marmoratus* est courant à certains endroits de Maatea, mais la densité de cette espèce n'est pas constamment élevée. Il n'est pas recommandé de pêcher *T. marmoratus* à des fins commerciales pour l'instant, en raison de l'aire de répartition actuellement limitée de cette espèce par rapport à ce qu'elle pourrait être.

- On pourrait élargir l'aire de répartition de ces deux ressources en consultant de vieux pêcheurs, afin de déterminer les zones où vivaient autrefois des stocks de trocas et de burgaus, mais qui sont maintenant surpêchées. Il est conseillé de transplanter des adultes, depuis des zones de forte concentration vers de nouvelles zones désormais appauvries, à condition de ne pas entreprendre de prélèvements commerciaux à court terme.

- L'holothurie noire à mamelles *Holothuria nobilis*, de forte valeur marchande, est absente autour de Maatea. En outre, il faudrait commencer par évaluer les stocks d'holothuries blanches à mamelles *H. fuscogilva*, qui vivent en eaux plus profondes, pour s'assurer de l'état de ces stocks à Moorea et voir s'il convient de les protéger particulièrement afin de reconstituer les stocks de cette espèce à l'échelon local.

Résultats des travaux de terrain effectués à Mataiea

Le village de Mataiea est situé au sud de l'île haute de Tahiti Nui, par 17°46' de latitude sud et 149°24' de longitude ouest. Cette île fait partie du groupe du Vent, dans l'archipel de la Société. C'est la plus grande de Polynésie française (1 045 km²). Elle comprend deux volcans éteints, reliés par un isthme naturel, Tahiti Nui (le grand volcan) et Tahiti Iti (le petit). C'est aussi l'île la plus peuplée (70 pour cent de la population totale). Seule la bande côtière est peuplée, et il y a 22 districts en tout. La pêcherie, qui s'étend sur 11,3 km x 2,2 km, est libre d'accès. Le lagon comprend quatre habitats : le tombant récifal externe, l'arrière-récif, le récif intermédiaire et le récif côtier protégé, soit une surface récifale totale de 14 km² environ. La plupart des habitants travaillant dans la capitale, la pêche est surtout pratiquée à des fins vivrières, et non comme source de revenus.

Enquêtes socioéconomiques : Mataiea

Teva I Uta, Mataiea, est une grande communauté (plus de 7 900 personnes), à 80 km environ de la capitale, Papeete. Son caractère périurbain se traduit par le fait que les habitants sont fortement tributaires de leur salaire, la pêche n'étant pratiquée qu'à des fins vivrières et sportives et non économiques. La consommation moyenne de poissons – 45 kg par personne et par an environ – est supérieure à la moyenne régionale, mais la moins élevée par rapport aux autres sites PROCFish/C du pays. En revanche, la consommation d'invertébrés et de poissons en conserve est très faible.

La pêche de poissons cible principalement le lagon entre les passes de Teavaraa et Temaraui, et la plupart des pêcheurs utilisent des pirogues à rames, parfois équipées de petits moteurs hors-bord (9 à 15 cv), ce qui ne leur permet pas de s'aventurer en toute circonstance sur le tombant récifal externe.

Ce sont surtout les hommes qui vont pêcher, les femmes participant à cette activité en fin de semaine et pendant leurs loisirs. La pêche de langoustes en plongée est réservée aux hommes.

La récolte d'invertébrés est surtout destinée à la subsistance ; moins de 40 pour cent des prises sont vendues à des membres de la communauté. Il s'agit principalement de langoustes, qui sont exposées à la plus forte pression de pêche et représentent 80 pour cent des prises totales déclarées.

Ressources en poissons : Mataiea

Malgré la relative richesse de l'habitat récifal à Mataiea, les ressources en poissons semblent en mauvais état, sous l'effet de la forte pression de pêche, surtout dans le lagon et les zones côtières. Les résultats de l'enquête montrent que la densité et la biomasse des poissons sont au niveau le plus bas de tous les sites étudiés. L'évaluation détaillée au niveau du récif révèle aussi une abondance de carnivores (labridés, lutjanidés et lethrinidés) inférieure à la moyenne, les mullidés accusant une abondance légèrement supérieure sur le récif côtier et le récif intermédiaire. Les premiers résultats laissent à penser que cette évolution pourrait s'expliquer par l'impact supérieur à la moyenne de la pêche d'espèces carnivores (lutjanidés, serranidés et labridés). Les populations de vivaneaux (lutjanidés), d'empereurs (lethrinidés) et de rougets (mullidés) sont systématiquement faibles et les mérous (serranidés) pratiquement absents. À Mataiea, la pêche est le plus souvent pratiquée à des fins de subsistance. L'impact de la pêche sur les ressources halieutique est toutefois d'ores et déjà élevé, du fait de la forte population de l'île et de la grande densité de pêcheurs.

Ressources en invertébrés : Mataiea

Les zones lagonaires de Mataiea, et surtout les zones peu profondes de l'arrière-récif, conviennent très bien au bénitier *Tridacna maxima*, dont la densité est modérée pour une île haute et un lagon ouvert. La couverture et la densité ne sont pas remarquables par rapport aux densités couramment observées ailleurs en Polynésie française, et les pêcheurs locaux interrogés ont observé une diminution du nombre et de la taille des bénitiers au cours des dernières années. Bien que toutes les classes de taille soient représentées pour *T. maxima*, y compris de jeunes bénitiers – ce qui traduit le succès du frai et du recrutement – le nombre de bénitiers de grande taille est relativement faible, ce qui confirme l'hypothèse que les stocks de bénitiers sont affectés par la pression de pêche.

Malgré le comportement cryptique des huîtres perlières à lèvres noires *Pinctada margaritifera* et leur dispersion clairsemée habituelle dans les systèmes à lagon ouvert (comme celui de Mataiea), elles sont rares, ce qui est surprenant : une seule nacre a été enregistrée au cours de l'enquête.

Le troca *Trochus niloticus,* et le burgau, *Turbo marmoratus*, dont l'aire de répartition est limitée aux passes et au lagon, sont relativement abondants à Mataiea. Ce sont deux espèces d'intérêt commercial pour les pêcheurs côtiers. La bonne santé du stock reproducteur de trocas, constatée au cours de l'enquête, s'explique principalement par des mesures de protection (prélèvement à partir de 11 cm) et de « repos » des stocks entre deux périodes de pêche commerciale

Pour des raisons biogéographiques, l'aire de répartition des espèces d'holothuries à Mataiea est restreinte, et l'on ne connaît pas bien la pression qui s'exerce sur les stocks. On a noté une bonne densité d'holothuries léopards *Bohadschia argus* de moindre valeur marchande, mais les holothuries noires à mamelles (*Holothuria nobilis*), espèce de plus grande valeur, n'ont été repérées qu'en un seul endroit. Les holothuries ananas *Thelenota ananas*, de valeur légèrement inférieure à celle des holothuries noires à mamelles, n'étaient pas rares, mais à une densité modérée à faible.

Recommandations pour Mataiea

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

- Il ne faudrait pas que la pêche de poissons de récif continue de croître ; on doit donner aux ressources le temps de se reconstituer si l'on veut assurer la sécurité alimentaire à l'avenir.

- Des mesures restrictives de gestion des ressources marines devraient être prises pour faciliter la reconstitution des stocks. L'aménagement d'aires marines protégées devrait être considéré comme un outil de gestion primordial. Leur efficacité devrait ensuite être évaluée par un suivi régulier des ressources.

- L'emploi de filets maillants et la pêche au fusil de nuit devraient être strictement réglementés.

- Les mesures de repeuplement et de protection devraient se concentrer sur le récif intermédiaire et le récif côtier, car la pauvreté naturelle des récifs externes ne permet pas d'alléger la pression qui s'exerce sur le récif côtier protégé et les arrière-récifs.

- La densité et la fourchette de tailles des trocas, observées au cours de l'enquête, laissent à penser qu'une pêche limitée pourrait être pratiquée dans des zones de grande abondance. On ne devrait commencer à pêcher qu'au-dessus du seuil de densité de 500 à 600 individus par hectare.

- Il n'est pas recommandé de pêcher le burgau *Turbo marmoratus* à des fins commerciales, l'aire de répartition de cette espèce étant très limitée.

- On pourrait consulter de vieux pêcheurs, afin de déterminer les zones où vivaient autrefois des stocks de trocas et de burgaus, mais qui sont maintenant surpêchées. Cela permettrait d'élargir l'aire de répartition de ces ressources et d'y transplanter des adultes.

- Il convient d'évaluer les stocks d'holothuries blanches à mamelles *Holothuria fuscogilva* vivant dans des eaux plus profondes, pour savoir s'il existe un potentiel de récolte de cette espèce à des fins commerciales.

Résultats des travaux de terrain effectués à Raivavae

Raivavae est une île haute des Australes, située par 23°53' de latitude sud et 147°40' de longitude ouest. Elle a une superficie de 16 km² et son point culminant est le mont Hiro (437 mètres). L'île est entourée d'un petit lagon qui comporte deux passes, l'une au nord et l'autre au sud. On observe quatre habitats récifaux : le récif côtier protégé, le récif intermédiaire, l'arrière-récif et le tombant récifal externe, soit une superficie récifale de 93 km² environ. Des *motu*, petits îlots coralliens, occupent les parties est et sud de l'île. L'économie locale repose sur l'agriculture de subsistance, la pêche et l'artisanat. La population (1 050 habitants) est répartie sur quatre districts, dont Rairua est le principal.

Enquêtes socioéconomiques : Raivavae

Éloignée de Tahiti et relativement peu peuplée (~ 1 100 habitants), la communauté de Raivavae conserve un mode de vie plutôt traditionnel, qui se manifeste par la forte consommation d'invertébrés, les revenus très limités tirés de la pêche, la pratique courante consistant à troquer des produits de la mer entre membres de la communauté, et de faibles dépenses des ménages. La consommation de poissons est assez faible (~ 46 kg par personne et par an) par rapport à d'autres communautés étudiées de Polynésie française, l'agriculture constituant une bonne source différente de nourriture. La consommation de poissons pélagiques a augmenté sur l'île, du fait du risque d'intoxication ciguatérique causé par la consommation de certains poissons de récif.

Ce sont surtout les hommes qui pêchent. Les femmes ne pêchent qu'occasionnellement en fin de semaine et pendant leur temps libre. La pêche de langoustes et de bénitiers en plongée est exclusivement réservée aux hommes, tandis que les femmes ramassent des *poupou* (petits escargots de mer) pour fabriquer des objets artisanaux, sur les *motu* du récif barrière. Les poissons ne sont capturés qu'à des fins de subsistance et de partage avec d'autres membres de la communauté.

Près de la moitié des prises annuelles déclarées d'invertébrés est destinée à l'exportation vers Papeete. La plupart des invertébrés récoltés sont des bénitiers exportés par bateau sous forme congelée. Des langoustes sont également exportées, par avion ou, sous forme congelée, par bateau, mais leur quantité varie selon la demande saisonnière, pour les fêtes de fin d'année par exemple. La collecte de *poupou* à des fins artisanales est une source importante de revenus pour les ménages de Raivavae, mais elle n'est pas considérée comme ayant des effets négatifs sur l'environnement ou les ressources car l'on ne prélève pas de coquillage vivant, et la collecte se fait sur le rivage.

Ressources en poissons : Raivavae

D'après les résultats de l'enquête, l'état des ressources en poissons de Raivavae est meilleur que la moyenne des sites étudiés en Polynésie française. L'évaluation détaillée, au niveau du récif, révèle aussi une abondance et une biomasse systématiques élevées ou moyennes, sauf sur les arrière-récifs (l'environnement le plus pauvre sur ce site). La biomasse moyenne des herbivores et des carnivores est la plus élevée parmi les cinq sites, ce qui est d'autant plus important que Raivavae n'a pas d'habitat de récif intermédiaire. Les tailles moyennes et les rapports de taille étaient les plus élevés de tous les sites, ce qui dénote une bonne santé des ressources. Au rythme actuel, la pêche n'a pas d'effet négatif sur les ressources ; de fait, de tous les sites étudiés, c'est la communauté de Raivavae qui dépend le moins de la pêche sur le plan économique, et celle qui consomme le moins de poisson frais. En outre, la pêche de poissons de récif est de moins en moins importante, les habitants pêchant de plus en plus de poissons pélagiques du fait du risque accru de ciguatera.

Ressources en invertébrés : Raivavae

Les pâtés de corail, au milieu du lagon, et surtout l'arrière-récif peu profond de Raivavae conviennent très bien aux bénitiers *Tridacna maxima*. Les bénitiers ne sont pas présents sur tous les récifs, mais les densités, au sud et à l'ouest du lagon, sont exceptionnelles pour une île haute et un lagon ouvert. Toutes les classes de taille de *T. maxima* coexistent, y compris de jeunes bénitiers, ce qui dénote le succès du frai et du recrutement. Le nombre de bénitiers de grande taille dans le stock indique que celui-ci n'est que faiblement affecté par la pression de pêche. On a toutefois rarement trouvé des bénitiers de plus de 22 cm de longueur de coquille.

Le troca *Trochus niloticus* et le burgau *Turbo marmoratus* ne se sont pas stabilisés dans les zones où ils avaient été introduits. L'huître perlière à lèvres noires *Pinctada margaritifera* n'est pas abondante à Raivavae, mais on en a fréquemment trouvé dans le lagon.

Pour des raisons biogéographiques, la gamme d'espèces d'holothuries présentes à Raivavae est limitée, et il semble que l'absence de quantités importantes d'holothuries léopards ((*Bohadschia argus*) et d'holothuries noires à mamelles (*Holothuria nobilis*) s'explique davantage par un habitat inapproprié que par la pression de pêche. La répartition et l'abondance de l'holothurie de brisants *Actinopyga mauritiana* enregistrées au cours des enquêtes montrent qu'il existe un potentiel de pêche commerciale de ces espèces à Raivavae. On a observé également des quantités importantes de l'espèce *Holothuria atra*.

Recommandations pour Raivavae

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

- Il faut surveiller la densité et la taille des serranidés sur les récifs externes, afin de déceler toute diminution, premier symptôme d'appauvrissement de cette famille.

- Le niveau actuel de la pêche de poissons de récif, pratiquée à des fins vivrières et pour honorer certaines obligations sociales, peut être maintenu, tant qu'il semble acceptable à long terme.

- Il faut évaluer les stocks d'holothuries blanches à mamelles *Holothuria fuscogilva ;* la première investigation n'a toutefois pas permis de conclure à un avenir très prometteur pour cette espèce.

- Bien qu'aucun problème à long terme n'ait été envisagé en ce qui concerne les bénitiers, et que les taux d'exploitation soient inférieurs au taux critique de pêche commerciale, il est recommandé d'établir un plan de gestion pour permettre aux stocks de certaines zones de « se reposer ».Un système de fermetures par rotation (mis en place après consultation des populations locales) pourrait être institué à des périodes variables, selon l'état du récif (son état et sa situation). Il faudra toutefois tenir compte de la vitesse de croissance des bénitiers pour leur laisser le temps d'atteindre la maturité.

- Avant d'introduire des trocas d'intérêt commercial (*Trochus niloticus*), il faut commencer par transférer les trocas sur des récifs intérieurs, au nord de l'île, pour les protéger jusqu'à ce qu'ils s'adaptent aux conditions locales, puis les retransférer sur le récif au nord-est de l'île. En outre, il faut procéder à ces transferts futurs avec le soutien actif des pêcheurs et de la communauté, de manière à ce que tous comprennent bien les avantages potentiels de la fixation de ces stocks.

Résultats des travaux de terrain effectués à Tikehau

Cet atoll de forme annulaire est situé dans l'archipel des Tuamotu, près de Rangiroa, par 15°00'06 de latitude sud et 148°10'37 de longitude ouest. Il mesure 26 km de long et 19,8 km de large. Son lagon, d'une profondeur moyenne de 20 mètres environ, s'étale sur 400 km², et la superficie des terres émergées est de 20 km². Le *motu*, qui culmine à 8 mètres, compte 417 habitants, soit une densité d'environ 20 personnes au km². La majeure partie de la population habite dans le village de Tuheraera, au sud-ouest de l'atoll. Il n'y a qu'une passe, à l'ouest, celle de Tuheiava. Trois habitats seulement sont représentés, en l'absence d'île haute et par conséquent d'apports terrigènes : le récif intermédiaire, l'arrière-récif et le tombant récifal externe, soit une superficie totale du récif de 76 km² environ.

Les habitants de Tikehau vivent de la pêche et exploitent des parcs à poissons traditionnels et permanents qui leur permettent de mieux gérer l'exportation de leurs produits à Tahiti. La perliculture, ainsi que le tourisme et la production de coprah, contribuent aussi pour une part importante à l'économie.

Enquêtes socioéconomiques : Tikehau

Les habitants de l'atoll de Tikehau conservent un mode de vie plutôt traditionnel, qui se traduit par un niveau relativement bas des dépenses des ménages, bien que l'île n'offre guère de possibilité de production agricole vivrière. Toutefois, les vols quotidiens vers la capitale, un volume de fret garanti et le prix du transport de produits de la mer frais par avion ont favorisé le développement de la pêche commerciale de ressources récifales. La pêche est la principale source de revenus, suivie par les salaires et les prestations sociales.

Le fait que la population de Tikehau soit fortement tributaire des ressources marines est confirmé par la grosse consommation de poisson frais (67 kg par personne et par an). La consommation d'invertébrés et de conserves de poisson est toutefois mineure, voire négligeable. La pêche d'invertébrés est moins importante que celle de poissons. Très peu de gens collectent régulièrement des invertébrés, et, dans ce cas, il ne s'agit que de langoustes, de bénitiers, de quelques coquilles de *Turbo* spp. et d'autres coquillages ramassés à des fins artisanales.

Il y a trois grandes catégories de pêcheurs de poissons à Tikehau : ceux qui pratiquent la pêche de subsistance et de plaisance ; les pêcheurs commerciaux utilisant le fusil sous-marin, la ligne à main et les filets maillants, et les pêcheurs commerciaux exploitant des parcs à poissons), surtout dans les passes (et aussi dans la zone du récif côtier protégé). Ce sont les exploitants de parcs qui imposent la plus forte pression sur les ressources en poissons de l'île. L'impact annuel total peut s'élever à 400 tonnes, dont 96 % environ sont exportés et 4 % destinés à la consommation des seuls résidents de Tikehau.

Ressources en poissons : Tikehau

L'état des ressources en poissons de Tikehau est moins bon que sur la moyenne des sites étudiés en Polynésie française. La densité, la biomasse et la biodiversité sont similaires à celles de Mataiea, les plus faibles enregistrées dans le pays. Les récifs de Tikehau présentent les plus faibles densités et biomasses d'herbivores, en particulier des acanthuridés et des scaridés. La densité des carnivores est également en bas de l'échelle, ce qui ne peut s'expliquer par le type d'habitat, qui est en général composé d'un fond dur et meuble. La faible densité de carnivores et, en fait, de poissons en général, est directement liée à l'intensité de la pêche sur ces récifs, en particulier les récifs intérieurs, qui explique la diminution de l'abondance et de la taille des populations de poissons et, par conséquent, de la biomasse totale.

Dans l'ensemble, les ressources en poissons de Tikehau sont apparemment en assez mauvais état. Bien que les habitats récifaux semblent relativement riches, les ressources en poissons, surtout sur l'arrière-récif et le récif intermédiaire, sont parmi les plus faibles du pays. Les populations de lutjanidés, lethrinidés et mullidés sont extrêmement peu nombreuses, bien que ce soit une tendance générale observée sur tous les sites du pays. Cela ne saurait s'expliquer par l'absence d'habitats appropriés, car tous les types de substrats sont bien représentés à Tikehau. Ce site a la plus grande couverture moyenne de fonds meubles, généralement propices aux carnivores tels que lethrinidés et mullidés. La cause de cette rareté est liée à la pression de pêche.

Ressources en invertébrés : Tikehau

Tikehau possède un vaste récif favorable au bénitier *Tridacna maxima*. On trouve couramment une forte densité de bénitiers dans la passe, et une densité modérée sur les récifs du lagon. Toutes les classes de taille de *T. maxima* sont présentes, sans que l'on observe de grandes quantités de bénitiers de grande taille, ce qui confirme l'hypothèse que les stocks de bénitiers sont faiblement affectés par la pression de pêche. Le nombre de petits bénitiers d'une même classe de taille indique que la reproduction et le recrutement ne sont généralement pas affectés.

On trouve assez couramment des trocas *Trochus niloticus* à Tikehau, mais surtout limités à la passe et au lagon. La protection du stock reproducteur (à partir de 11 cm) et le « repos » du stock entre deux périodes de pêche commerciale sont les principales raisons de la bonne santé des stocks de Tikehau, constatée au cours de l'enquête. L'huître perlière à lèvres noires *Pinctada margaritifera* est relativement peu courante à Tikehau. On note une gamme limitée d'espèces d'holothuries (pour des raisons biogéographiques), et aucun potentiel réel de récolte commerciale.

Recommandations pour Tikehau

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

- Il faut mettre au point des mesures de gestion appropriées, en concertation avec le Service de la pêche, les chefs de communauté et les autorités locales, pour faire en sorte que les stocks soient préservés au profit des générations futures, la pêche de ressources destinées à l'exportation ne semblant pas pouvoir perdurer à son niveau actuel.

- Le recours à des *parcs* devrait être réglementé, dans le cadre de mesures de gestion, car ils contribuent trop efficacement à la pêche de carnivores (vivaneaux, empereurs et rougets sur les récifs intérieurs (arrière-récif, récif intermédiaire et récif côtier). La pêche au fusil sous-marin et l'emploi de filets maillants dans les récifs intérieurs devraient être interdits.

- Vu la qualité de l'habitat à Tikehau, l'aménagement d'aires marines protégées devrait être considéré comme un outil primordial de gestion.

- Une pêche limitée de trocas pourrait être conduite dans des zones d'abondance maximale. On ne devrait pas commencer à pêcher en deçà du seuil de densité de 500 à 600 individus par hectare. Si l'on envisage de récolter des trocas, le transfert d'une certaine partie du stock de la passe vers d'autres zones appropriées de Tikehau (éventuellement le platier du récif barrière) pourrait s'avérer avantageux et permettre d'élargir l'aire de répartition du troca à Tikehau.

- Il faudrait surveiller l'abondance de l'holothurie de brisants *Actinopyga mauritiana*, car il existe des possibilités de récolte de cette espèce. Il faudra en revanche évaluer le stock d'holothuries blanches à mamelles *Holothuria fuscogilva* qui vivent en eaux plus profondes, bien que les premières enquêtes n'aient pas laissé entrevoir d'exploitation prometteuse de cette espèce.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
AIMS	Australian Institute of Marine Science
AQUACOP	Aquaculture au Centre Océanologique du Pacifique
BdM	bêche-de-mer (or sea cucumber)
B-S	broad-scale
CoFish	Pacific Regional Coastal Fisheries Development Programme
COTS	crown of thorns starfish
CPUE	catch per unit effort
CRIOBE	Centre de Recherches Insulaires et Observatoire de l'Environnement
Ds	day search
D-UVC	distance-sampling underwater visual census
EDF	European Development Fund
EEZ	exclusive economic zone
EU/EC	European Union/European Commission
EVAAM	Établissement pour la Valorisation des Activités Aquacoles et Maritimes
FAO	Food and Agricultural Organization (UN)
FL	fork length
GPS	global positioning system
ha	hectare
HH	household
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer
IFREMER-COP	Institut Français de Recherche pour l'Exploitation de la Mer – Centre Océanologique du Pacifique
IRD	Institut de Recherche pour le Développement
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MOP	mother-of-pearl
MOPs	mother-of-pearl search
MOPt	mother-of-pearl transect
MPA	marine protected area
MSA	medium-scale approach
NASA	National Aeronautics and Space Administration (USA)
NCA	nongeniculate coralline algae
Ns	night search
OCT	Overseas Countries and Territories
PATA	Pacific Asia Travel Association
PGEM	Plan de Gestion de l'Espace Maritime
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 by walking
PGEM	Plan de Gestion de l'Espace Maritime
SBq	soft-benthos quadrat
SBt	soft-benthos transect
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SPC	Secretariat of the Pacific Community
Service de la pêche	Service de la pêche
USD	United States dollar(s)
WHO	World Health Organization

1. INTRODUCTION AND BACKGROUND

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

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

1.1 The PROCFish and CoFish programmes

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

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

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

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

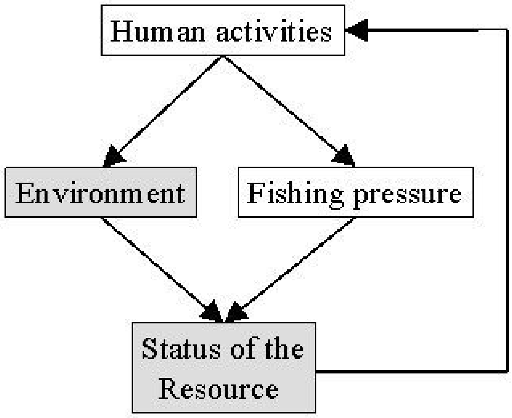

Figure 1.1: Synopsis of the PROCFish/C* multidisciplinary approach.
PROCFish/C conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the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

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

Expected outputs of the project include:

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

1.2 PROCFish/C and CoFish methodologies

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

1.2.1 Socioeconomic assessment

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

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

Socioeconomic assessments also relied on additional complementary data, including:

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

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

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

1.2.2 Finfish resource assessment

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

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

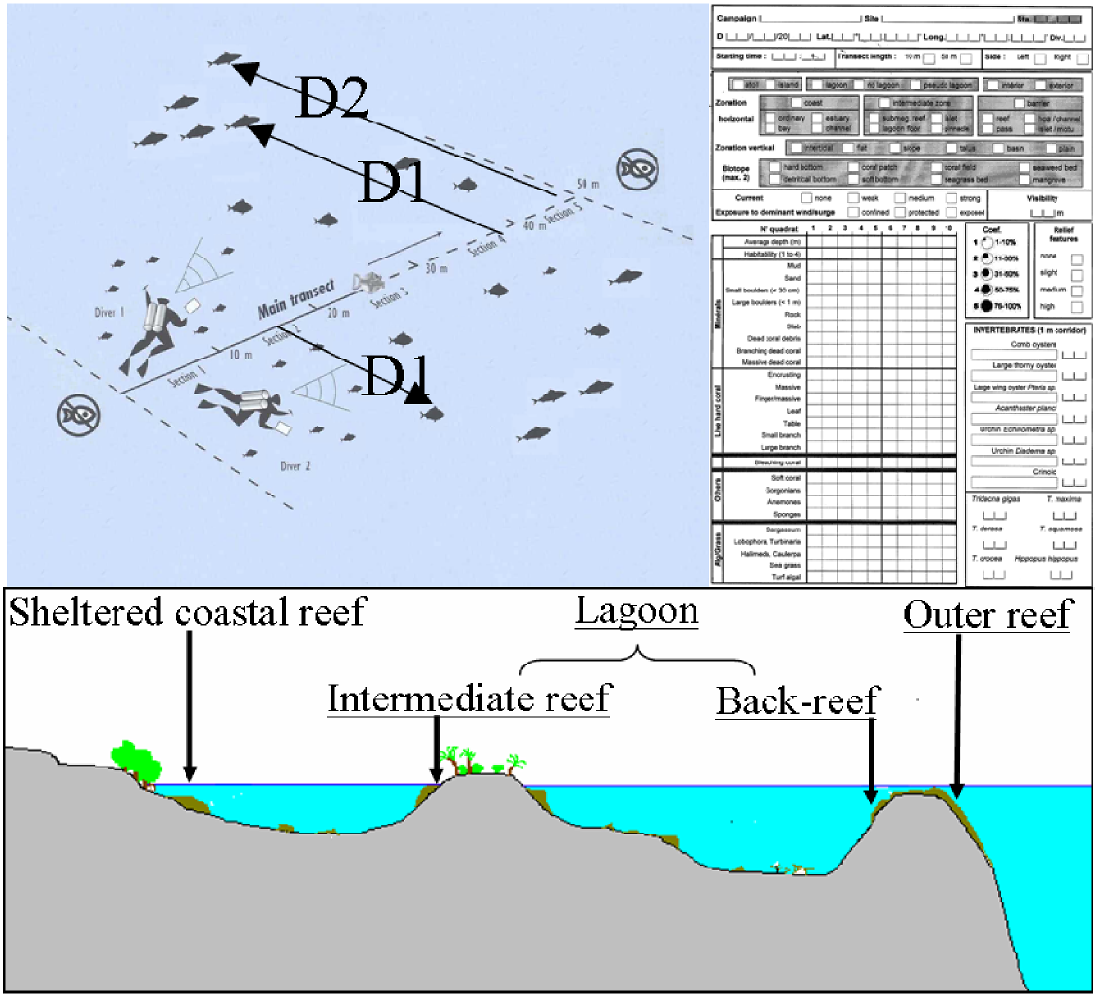

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

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

1.2.3 Invertebrate resource assessment

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

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

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

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

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

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

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

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

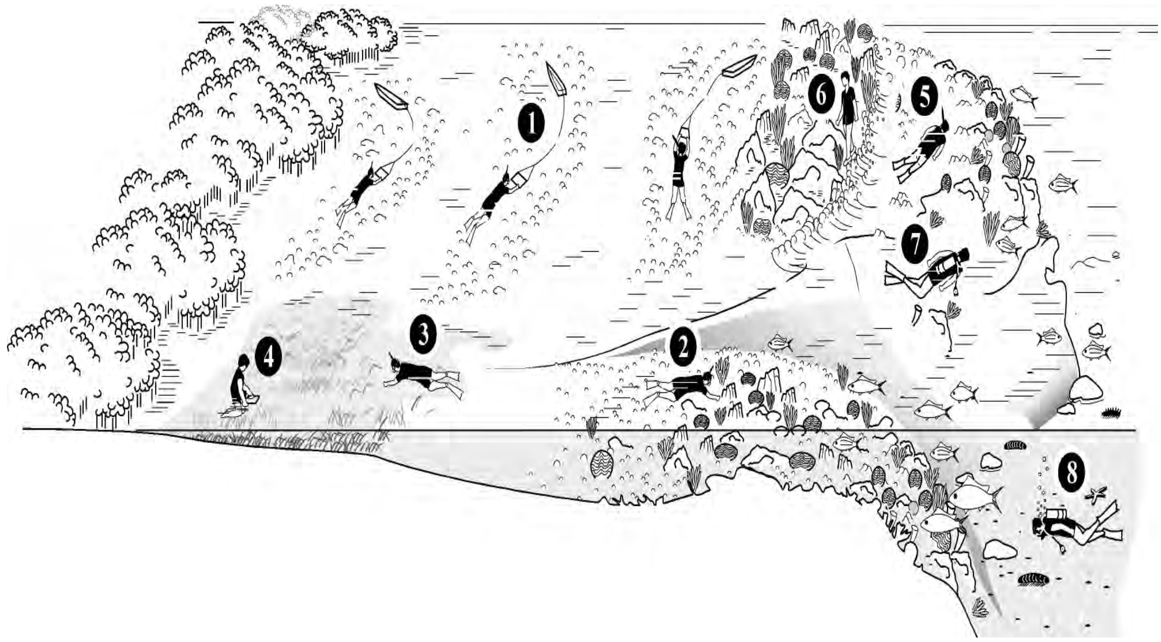

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal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

1.3 French Polynesia

1.3.1 General

French Polynesia (Figure 1.4) is made up of five main island groups; Marquesas Islands, Tuamotu Archipelago, Society Islands (comprising the Windward Group, including Tahiti and Moorea, and the Leeward Group, including Raiatea and Bora Bora), Gambier Islands, and Austral Islands (Whitelaw 2001), with a mix of high and low basaltic islands, and raised and low coral atolls (Anon. 1986). The capital, Papeete, is on Tahiti, the territory's largest island (1043 km²) in the Society Islands (Encylopedia Britannica 2008, Wikipedia 2008).The islands and atolls are located between 8º and 28ºS latitude, and 134º and 155ºW longitude. French Polynesia has an exclusive economic zone (EEZ) of ~5,030,000 km², with a land area of only 3521 km². French Polynesia has around 70% of its EEZ bordering on international waters, with the remaining EEZ bordering three Pacific countries: Cook Islands to the west, the Republic of Kiribati to the northwest, and Pitcairn Islands to the southeast (Chapman 2004).

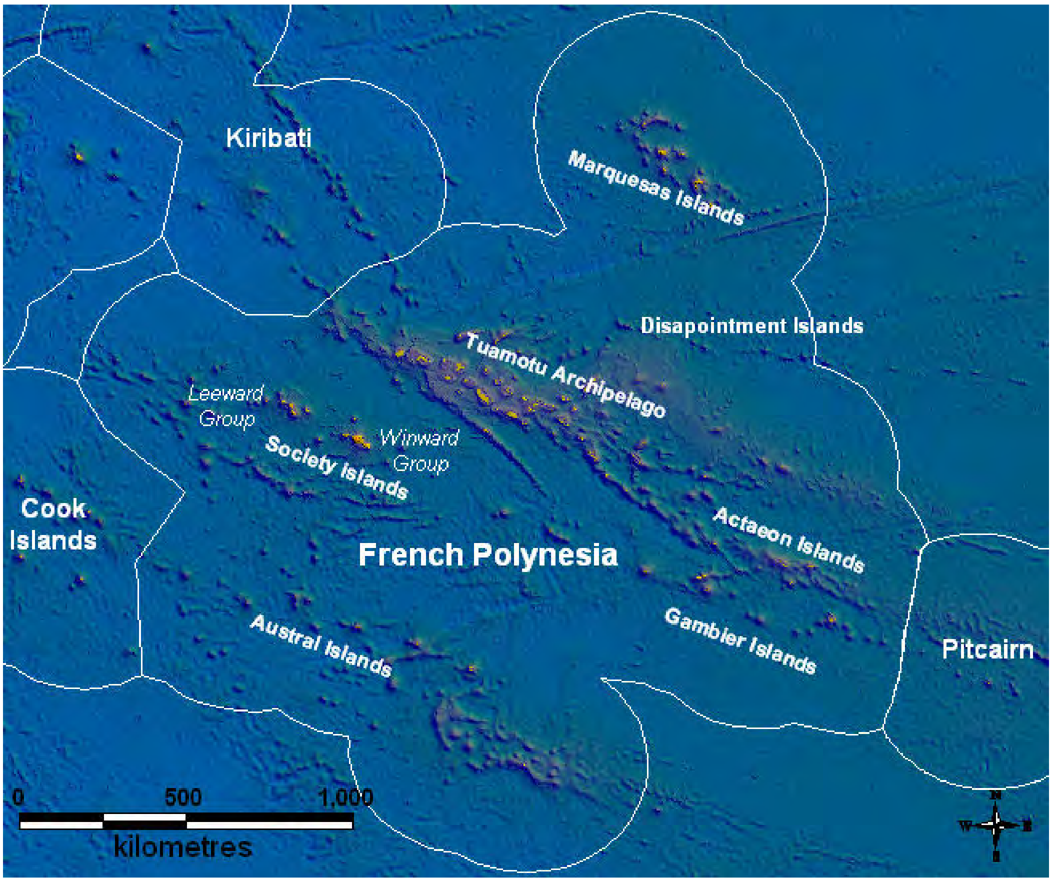

Figure 1.4: Map of French Polynesia.

The climate is tropical, warm and humid. However there are occasional cyclonic storms in January. A warm, rainy season lasts from November to April and a relatively cool, dry season from May to October. The temperature varies only slightly throughout the year. At Papeete, the average annual temperature is 26°C; the average high is 33°C in March and the average low 21°C in August. The Austral Islands, farther south, have a cooler climate; the average low can go down to 18°C in September. The relative humidity is always high, generally between 80 and 90%. Annual rainfall is 2106 mm in Papeete, but can be as much as 3050 mm on the coastal areas (Encylopedia Britannica 2008, CIA 2008, Turner 2008).

Provisional figures for the 2007 French Polynesia population census provide an estimate of 259,596 people. At the 2007 census, 68.6% of the population of French Polynesia lived on the island of Tahiti alone. The urban area of Papeete, the capital city, has 131,695 inhabitants (2007 census). The annual growth rate from 2002 to 2007 was 1.2% (Institut Statistique de Polynésie Française 2008). The population density for 2008 is estimated to be 75 persons per km² (SPC 2008).

Between 1946 and 2003, French Polynesia had the status of an overseas territory of France. In 2003 it became an overseas collectivity, whereby the President of French Polynesia is the head of government and of a multi-party system. Executive power is exercised by the government. Legislative power is vested in both the government and the Assembly of French Polynesia (the Territorial Assembly). A high commissioner, appointed by the French government, represents the French president as head of state and is in charge of matters including defence, foreign relations, and justice (Encylopedia Britannica 2008, Wikipedia 2008). Tourism is the country's main economic activity. Many resources are used for local subsistence, including fruits, products from fishing and planting, and materials for the construction of traditional types of houses and canoes (Encylopedia Britannica 2008). Agriculture and fisheries products are: fish, coconuts, vanilla, vegetables, fruits, coffee, poultry, beef and dairy products. Industries are: tourism, pearls, agricultural processing, handicrafts and phosphates. In 2005 the Gross Domestic Product (GDP) was made up of agriculture (3.1%), industry (19%) and services (77.8%). In terms of the labour force the 2002 figures reveal that 13% were employed in agriculture, 19% in industry, and 68% in services. French Polynesia imports a great deal and exports very little. In 2005, the estimated import cost was USD 1.706 billion f.o.b. for fuels, foodstuffs, machinery and equipment. Import markets in 2006 were France (52.7%), Singapore (14.9%), New Zealand (6.8%), and the United States of America (6.6%). In 2005 exports earning was USD 211 million f.o.b. derived from the sale of cultured pearls, coconut products, mother-of-pearl, vanilla, and shark meat (CIA 2008). Production has increased in recent years. Representing 27% of the world market, French Polynesia is the world's second-largest producer of pearls after Australia. It is the second-largest industry in the country after tourism and employs about 4000 islanders (Turner 2008). Export markets in 2006 were France (46.3%), Japan (20.8%), Niger (12.8%), and United States of America (12.5%) (CIA 2008).

1.3.2 The fisheries sector

French Polynesia's fisheries comprise the offshore fishery for tuna and other pelagic species; several small-scale tuna fisheries, some in association with fish aggregating devices (FADs); the deep-water snapper fishery; reef fisheries for a range of fish and invertebrate species; and aquaculture and/or mariculture of a range of species.

Offshore tuna fishery

The people of French Polynesia have only become involved in domestic offshore tuna fishing since the late 1980s. Prior to this, offshore tuna fishing trials or fishing activities were conducted by foreign fishing vessels. Japanese, Taiwanese and Korean longliners fished in the waters around French Polynesia in 1975 and 1976, catching 7044 and 7264 t respectively (Klawe 1978). With the declaration of the EEZ and the issuing of fishing licences in 1979, only Japanese longliners operated in the French Polynesian EEZ (Gillett and Kearney 1983). Japanese and Korean vessels were licensed to fish in the early 1980s. Japan ceased its access agreement with French Polynesia in 1992 (Anon. 1996), while 65 Korean longline vessels were licensed under their access agreement in 1995 (Dauphin 1996). In December 2000, all access agreements with foreign fishing fleets ceased (Ponsonnet *et al*. 2007).

Trials were also undertaken for surface tunas using the pole-and-line method, but these were limited because French Polynesia was outside the range of the distant-water fleets (Gillett and Kearney 1983). Two trials were undertaken by Japanese pole-and-line vessels in the mid-1970s. The SPC Skipjack Survey and Assessment Programme conducted several tagging cruises in the French Polynesian EEZ in 1978/1979 (Kearney *et al.* 1979) and 1979/1980 (Gillett and Kearney 1980). During the first tagging cruise of 60 days, 8148 skipjack and 98 yellowfin tuna were tagged and released (Kearney *et al*. 1979). During the second tagging cruise of 65 days, 20,827 tuna were tagged and released, with the vast majority (18,815 fish) tagged in the Marquesas Islands (Gillett and Kearney 1980).

Domestic, semi-industrial oceanic fisheries in French Polynesia, the basis of the drifting tuna longline technique, began in 1989 with five vessels landing 53 t of fish (Josse and Bach

1994). The optimal exploitation level for French Polynesia's EEZ has been estimated at 13,000 t. From 1996 to 2001, total oceanic production steadily increased, going from 3373 t to 7811 t in 2001 (Misselis 2003). French Polynesia then decided to begin construction of a new longliner, banking on an increase in albacore tuna catches (Anon. 1998, Beverly 1998). Unfortunately, beginning in 2001, production steadily decreased to reach some 5268 t in 2006, a figure that corresponds to a 40% decrease in the volume of catches over five years (Buestel and Iltis 2004, Ponsonnet *et al*. 2007). These poor results, which mainly involved albacore tuna (the fleet's target species), were associated with climate fluctuations (El Niño), which made access to this resource more complicated for French Polynesian vessels, which have limited ranges (Service de la Pêche 2007).

In 2006, the number of active fishing vessels was 71, made up of 39 fresh tuna boats (ice boats), 6 mixed tuna vessels (capable of processing both fresh and frozen product) and 26 freezer tuna ships. The fleet's activity fluctuated widely throughout the year; on average only 55 ships were working at the same time in 2006 and only 43 ships were active for more than 10 months. In 2007, the landed catch increased to 6309 t, even though overall effort decreased, and a net recovery of albacore tuna yields allowed the fleet to increase production by 20% in comparison to the previous year (Service de la Pêche 2007).

Research was also undertaken throughout the EEZ from 1995 to 1999 to study tuna behaviour through the use of acoustics and fishing. The results provided good knowledge of deep-swimming tunas' habitat and behaviours in a view to optimising exploitation (Service de la Pêche 2005). Since then, the Service de la Pêche has conducted exploration work through the use of commercial vessels in the most poorly known parts of the EEZ. The first exploratory campaign took place in 2005 in the north-eastern part of the EEZ, east of the Marquesas Islands; the second took place in 2006 in the southern part of the EEZ. The Service de la Pêche was trying to develop a predictive model that would incorporate environmental and historical fishing data so as to predict zones of yellowfin, bigeye and albacore tuna concentrations. The goal of locating albacore and bigeye tuna concentrations was not attained (Service de la Pêche 2008).

Small-scale tuna fisheries including the use of fish aggregating devices (FADs)

Tuna fishing, mainly for skipjack tuna, has always been an important fishery in French Polynesia. Traditionally, fishing for surface tuna was conducted from large, double-hull canoes equipped with floating baskets that stored live bait, which was thrown to attract the tuna to the canoe (Nordhoff 1930). These canoes fished in tuna holes close to the reef and used a long, crane-like pole that was attached at the base to the canoe. Two lines are attached to the top of the pole, each with a hook. A live bait is attached to one hook and the pole extended so the bait is in the water. When a fish is hooked, the pole is raised, swinging the tuna into the boat; the other hook is then baited and lowered into the water from the pole, while the first fish is attended to (Nordhoff 1930).

Two other forms of tuna fishing have also been used traditionally around French Polynesia, one using pearl-shell lures on the surface, and the other in mid-water using a line with baited hook. The use of pearl-shell lures on short poles from outrigger sailing or paddling canoes has been used extensively throughout Polynesia, targeting surface schools of tunas, especially skipjack tuna. The mid-water fishing method is used from smaller, 4–5 m outrigger canoes, which drift over tuna holes close to the reef and use stones to take the baited hook to the desired fishing depth, with the stone released once the depth has been reached (Nordhoff 1930, Pel and Devambez 1957).

By the 1950s, small, diesel-powered (15–20 hp) vessels 6–8 m in length were being used primarily for fishing surface skipjack schools. A pole, short length of cotton line, wire trace and pearl-shell lure were used for fishing, although some fishers used other lures made of metal and feathers (Pel and Devambez 1957). By 1970, the boats used for fishing skipjack had increased in length to 9–10 m and were called *bonitiers* but, more importantly, engines of up to 250 hp were used. There were around 100 of these vessels in operation around French Polynesia in 1970, 72 of which were based in Tahiti (Anon. 1970). The number of *bonitiers* remained consistent at around 100 during the 1970s and into the early 1980s, although the engine size continued to increase, with most vessels having engines of 200–375 hp (Chapman and Cusack 1998).

In 1981, the first FAD was deployed by the Service de la Pêche in French Polynesia, with five deployed in that year (Anon. 1981). From June 1981 to July 1990, 130 FADs were deployed (Yen *et al*. 1990) to assist the *bonitier* fishers to reduce operational costs and increase catches (Borel 1990).

The development of *poti-marara* vessels changed the way many fishers targeted tuna (See the section 'Scoop-netting of flyingfish, below.). This multi-purpose, outboard-powered vessel, originally designed for catching flyingfish at night, could be used by a single fisher for trolling for surface tuna and mid-water handlining for the larger, deep-swimming tuna (Borel 1990, Dauphin 1996). A variation of the mid-water handlining technique was also developed in the late 1980s, where a boat could carry up to five buoys, each with a mid-water line attached. The lines could be set, with the fisher just watching the buoys until a fish was hooked (Borel 1990). These lines could be used around reef passages or FADs. When fishing around FADs, conflicts were encountered between the *bonitier* fishers, who were poling tuna on the surface, and the *poti-marara* fishers, who were fishing mid-water. As a result, FADs for the *bonitier* fishers were deployed as far as 15 nm off the coast in order to separate the two groups of fishers (Yen *et al.* 1990).

Also in the 1980s, *ika-shibi*, a night-fishing method for tuna, became popular in some areas. This method used a small underwater light to attract baitfish to the boat, which in turn attracted larger fish, such as tuna. Heavy lines in buckets were used, with the lines set at different depths by a light, break-away line. Chum was thrown as well to attract tuna, and light lines were used to catch some of the baitfish attracted to the boat, so that these could be used for bait (Chapman and Cusack 1998).

The fleet of *bonitier* and *poti-marara* vessels expanded a great deal during the 1990s, from 215 to >300 vessels between 1990 and 2000 (Anon. 2001). However, production did not increase over the same time period, averaging about 2000 t/year. The fleet underwent significant changes with the number of active *bonitiers* steadily decreasing, while the fleet of *poti-marara* continued to grow in numbers over the 1990s (Anon. 2001). The *bonitiers*, which accounted for half of all coastal fishing vessels in 1990, only accounted for 15% in 2007 (Service de la pêche 2007). Since 2000, the coastal fleet has remained steady at about 300 active vessels (250 *poti-marara* and 50 *bonitiers*) with a mean annual production level of 2300 t (Service de la pêche 2007). Also during this period, 40 FADs were maintained around the Society Islands, with 40.5% of the landings from *poti-marara* in 2002 coming from fishing around FADs, while 70% of the *bonitiers* did not fish around FADs at all (Misselis 2003).

Catch from the *bonitier* and *poti-marara* fleets has remained at between 1900 and 2800 t since 2002, without any marked trends. From 2005 to 2006, it increased significantly (nearly 50%), i.e. 2810 t in 2006 as compared to 1883 t in 2005 (Ponsonnet *et al*. 2007). In 2007, decreases in both yields and effort had an effect on the ships' individual production levels, which decreased some 23% on average for *bonitiers* and 16% for the lighter *poti-marara* vessels (Service de la pêche 2007). Total production was 2332 t in 2007.

In French Polynesia, gamefishing and charter fishing is carried out mainly from Tahiti and Bora Bora in the Society Islands. There were around 15 charter vessels in 2001, four of these operating full-time (Whitelaw 2001). In all there was estimated to be around 450 private fishing vessels of 6–8 m in length and another 50 of 8–13 m in length. There is one annual international gamefishing tournament held in February and over 30 other tournaments held throughout French Polynesia each year (Whitelaw 2001). Gamefishers come to French Polynesia to fish for marlin, with January to June being the main fishing months.

Scoop-netting of flyingfish

The traditional method of catching flyingfish involved two fishers in a paddling outrigger canoe at night. Once at the area to be fished, torches were lit on the canoe to attract the flyingfish, which one fisher caught with a dipnet while the other kept paddling the canoe (Borel 1990). This form of fishing changed in the early 1950s, when small, powered launches appeared in Tahiti. In 1956, small plywood vessels powered by a 7.5 hp outboard engine were used, using a driver and a flyingfish catcher. During the late 1950s, fishers and boat builders experimented with the hull shape and found that the 'V' hull was the best shape. This was the first of the new design called *poti-marara* or 'boat for flyingfish' (Borel 1990).

The design of the *poti-marara* was further developed in 1960, when a forward driving system was developed to allow one person to both drive and catch at the same time. As the boats developed, so did the fishing technique, with fishers mounting lights so they could be worn on their heads. This allowed the fisher to steer with one hand and use the other to catch the flyingfish with the scoop or dipnet. The same design was used during the 1980s, although the *poti-marara* were then around 4–4.5 m long and powered by 20–25 hp outboards (Borel 1990).

Fishing for mahi mahi

Another traditional coastal fishery in French Polynesia is fishing for *mahi mahi* or dolphin fish (*Coryphaena hippurus*). Single-hulled outrigger sailing canoes ~8 m long were used to troll for *mahi mahi* (Nordhoff 1930). The traditional wooden hooks gave way to hooks made of steel and bronze in the very early 1900s, although the circular shape of the hooks was retained. Hooks were baited with either saltwater crayfish flesh from the tail (tied to the hook) or flyingfish. Usually, up to four lines were trolled from a sailing canoe, with the lines hauled by hand when a fish struck and was hooked. This fishing method died out by 1920, in part because there were no suitable trees left from which to make the canoes (Nordhoff 1930).

Fishing for *mahi mahi* was rejuvenated in the 1980s with the development of the highly manoeuvrable *poti-marara* fishing vessel. The *poti-marara* was lengthened to ~5.3–5.5 m, and the outboard size increased to 55–75 hp by the mid 1980s. Once a *mahi mahi* was spotted under some birds, the boat was manoeuvred to chase and harass the fish until it tired, at which time the fisher would harpoon the exhausted fish and bring it on board (Borel 1990).

Deep-water snapper fishery

There is no real history of fishers in French Polynesia targeting deep-water snappers, although these species were taken for subsistence purposes by fishers as part of other general fishing activities when weather permitted. Up until 1985, most of the deep-water snapper catch was taken by recreational fishers using pleasure craft fitted with echo sounders and electric reels (Wrobel 1988). In the mid-1980s, some commercial targeting of deep-water snappers began around the Society Islands; however, there were concerns that some of the species may be overfished, due to targeting of the more highly prized species (Wrobel 1988).

SPC conducted some deep-water snapper fishing trials in four locations around French Polynesia: Rurutu and Tubuai in the Austral Islands, Mehetia in the Society Islands, and Ua Pou in the Marquesas Islands. Catch rates ranged from 2.3 to 6.7 kg/line-hour across the sites. (Chapman and Cusack 1998). An assessment was made of the SPC catch data in Dalzell and Preston (1992), with the biomass for all islands in French Polynesia being estimated at 3427 t, from which a potential annual yield of 343–1028 t/year could be expected. However, the authors advised caution in using this estimate because it was based on low catch rates.

Wrobel (1988) also reported on research undertaken by scientists on Moruroa (1985) and by Japanese scientists on seamounts in the Austral Islands and Marquesas Islands (1987), which confirmed the low fishing potential for deep-water snappers in these areas and possibly French Polynesia as a whole. In 2003, there was very little targeting of deep-water snappers, although ~300 boats were fishing around the country using handlines, handreels and electric reels (Chapman 2004).

Aquaculture

Aquaculture was first considered in French Polynesia in the 1950s, when a local farmer considered building ponds for tilapia in some of the swampy land on his cattle estate. The tilapia were kept at the time in a small concrete tank (Pel and Devambez 1957). Over the years, aquaculture production has grown in a number of areas and, in 2007, total production yielded 46 t, 97% of which consisted of the introduced marine shrimp (*Litopenaeus stylirostris*): the major part of the remaining 3% was of non-indigenous fish species. Aquaculture in French Polynesia now covers both marine and freshwater activities. Until now, cultured fish species were mostly the Asian seabass (*Lates calcarifer*, also known as 'barramundi'), golden tilapia or sunfish (*Oreochromis* sp.), and some indigenous lagoon fish species (trevally and rabbitfish), whose fingerlings were obtained directly from the wild. Recently, Pacific threadfin (*Polydactylus sexfilis*) and batfish (*Platax orbicularis*) were reared under hatchery conditions; the latter showing good promise for the future, being a Polynesian reef-fish delicacy (Service de la pêche 2007).

However, the main activity, which provides French Polynesia's second-largest foreign exchange resource (XPF 13 billion in 2005), continues to be pearl-oyster farming, mainly done in the Tuamotu Islands (Service de la pêche 2007). This activity also plays an important social role by allowing French Polynesians to remain on or even to return to the outer islands.

Pearls and pearl oysters

Pearl oyster, *Pinctada margaritifera,* was initially used for its nacre. However, the local pearl oyster has now become one of French Polynesia's main economic resources thanks to cultured pearls. In the early 1960s, the Service de la pêche called on the services of Japanese specialists to try to graft the mother-of-pearl blacklip oysters in Bora Bora (Tisdell and Poirine 2000). In the early 1970s, Service de la pêche implemented a programme to establish the breeding and culture of mother-or-pearl with spat and pearl grafting (Anon. 1970). By 1981, the pearl industry was French Polynesia's second-largest export, and new methods of collecting and rearing the pearl oyster in the natural environment were developed (Coeroli 1982).

After slowly increasing over the 1980s, production and export volumes increased, with 575 kg of pearls exported in 1990, 786 kg in 1991, and 1069 kg in 1993 (Coeroli 1993). However, the export value of the pearls dropped by 38% over the same period. A liberalisation of maritime leases in the early 1990s, followed by extension of grafting techniques, led to a boom in the number of pearl oyster farms and to a rapid increase in production. Pearl production took off in the mid-1990s (Tisdell and Poirine 2000); exports practically quadrupled from 1995 to 2000, going from 3.4 t to nearly 12 t. Pearl-oyster farming also played a significant social role by contributing to a better balance of economic activities among island groups through the creation of a large number of jobs in the outlying islands (Tisdell and Poirine 2000).

In 2001 it was estimated that there were around 1000 pearl farms, directly or indirectly generating close to 7000 jobs (Anon. 2001). This employment was spread among the Society, Tuamotu and Gambier Islands groups and slowed down the exodus of the population towards Tahiti. The general lagoon census carried out in 2001–2003 revealed that 31 islands hosted pearl-oyster farming activities. Some 21,358 ha of leases were granted between 1995 and 2006. The Pearl Oyster Farming Department listed 830 maritime leases (for collecting, farming and raising pearl oysters) covering a total surface area of 10,847 ha in 2007. The Tuamotu Islands (712 leases) and Gambier Islands (118 leases) account for nearly 10,596 ha of pearl-oyster farm area, while the Leeward Islands, where there are 60 leases, account for 251 ha. According to GIE Perles de Tahiti (2008), this activity generates more than 1300 salaried jobs and provides income for 7000 islanders.

In the early 2000s, pearl prices decreased significantly, in 2002 reaching their lowest levels for eight years. The worldwide economic crisis and a production that was higher than demand were the main reasons behind this. The pearl crisis now seems to be over, with the export values once again at 1995–1996 levels. Raw pearl sales abroad were slightly higher in 2007 than in 2006 (1.6%), but their overall value was down by 3.3% (Service de la pêche 2007).

In addition to its pearl, the *Pinctada margaritifera* oyster is exploited for its shell. In its raw form, Tahitian pearl-oyster shell is in very high demand on the Asian markets, in spite of a poorly organised supply chain and weak local opening (lack of promotion and development). In 1999, the volume exported exclusively to Asia was 858 t, increasing from 1268 t in 2002 to 2878 t in 2005, before decreasing to 2410 t in 2006 (Service de la pêche 2007). However, in spite of a spectacular increase in export volumes, the average price of mother-of-pearl shells decreased sharply (30%) in 2002 following the overproduction of pearls and mother-of-pearl shell.

Trochus and green snails

Trochus (*Trochus niloticus*) and green snail (*Turbo marmoratus*) were introduced from Vanuatu to French Polynesia in 1957 and 1967 respectively (Yen 1991). Both introductions to the reefs of Tahiti were successful, especially of trochus, whose stocks increased rapidly. From November 1971 to June 1973, around 350 t of trochus shell was marketed for a value of USD ~70,000 (Anon. 1973b). Green snail, on the other hand, was slower to multiply and spread out. Surveys undertaken in 1979 and 1980, 13 years after introduction, recorded the presence of green snail along the whole length of the east coast of Tahiti, at a depth range of 1–15 m (Yen 1991). Some harvesting of green snail was done in the early 1990s. Harvests of green snail need to be authorised; however, some people collect this species illegally as a highly prized food and, sometimes, for making handicrafts.

During the 1990s, regular fishing of trochus occurred; 329 t were harvested between 1990 and 1994, although there was no harvest in 1995 (Anon. 1996). The fishing of green snail was less frequent, with 57 t harvested in 1993 and 43 t harvested in 1995 (Anon. 1996). From the mid-1990s, fishing of trochus and green snail became sporadic and has been prohibited since 2000. One trochus fishing trip was authorised in 2006 on the three islands in the township of Arutua, bringing in a total shell weight of 117,893 kg (Service de la pêche 2007). Now, regular and controlled harvests are programmed by Service de la pêche, the French Polynesian fisheries agency (Georges Remoissenet pers. comm. September 2008).

Penaeid prawn culture and freshwater prawns

Research on the aquaculture of penaeid prawn species began in the 1970s (Anon. 1975) at the Pacific Oceanological Centre (COP) in Vairao, with the introduction of about a dozen species from South America and Asia. Five species (*Metapenaeus ensis*, *Penaeus merguiensis*, *P. semisulcatus*, *P. aztecus* and *P. japonicus*) were the focus of adaptation and growth trials, with the aim of producing post-larval shrimps in French Polynesia (Anon. 1975). The results of this work were encouraging, with three species successfully bred in captivity and one species, *P. merguiensis*, displaying year-round maturation and spawning. Also during this time, research was underway on the freshwater prawn *Macrobrachium rosenbergii*. In the early 1980s, it was in Tahiti that management of reared broodstocks (maturation, fertilisation and spawning) and production of post larvae were first controlled on major commercial species, such as *Penaeus monodon*, *Litopenaeus vannamei* and *L. stylirostris* (Georges Remoissenet pers. comm. September 2008).

In 1990, a public hatchery for marine and freshwater prawns was built and managed by Établissement pour la Valorisation des Activités Aquacoles et Maritimes (EVAAM), the government fisheries development agency. In 1994, EVAAM concentrated efforts on the species *Macrobrachium rosenbergii*, *Litopenaeus stylirostris* and *L. vannamei*, which seemed to have promising growth and yield performances. Since 1994, the prawn-farming sector has stagnated, with harvests of both freshwater and saltwater prawns staying around 50 t in the 1990s (Anon. 2001) with a maximum of 60 t recorded in 2004 (Service de la pêche 2007). That same year, production of freshwater prawns ceased due to lower yields than those from marine-shrimp culture.

After renewed activity in 2001, the territorial multi-purpose hatchery was leased out and a technical assistance programme (Service de la pêche-IFREMER) set up in 2004. Since then, production dropped by more than 25% as a result of high competition from imported shrimps, as well as the obsolescence of the facilities, production equipment, and methods. Furthermore, other circumstances contributed to the decrease of production, i.e. a breakdown in feed supplies and a flood that affected one farm. The current potential of the three farms in operation has been estimated at >70 t without any investment and probably ~100 t if farm equipment and ponds were renewed. A new, modern hatchery is being built and aims to begin production by the end of 2010 (Georges Remoissenet pers. comm. September 2008).

Fish farming and culture

The first attempts at fish farming go back to the early 1980s with the launching of an IFREMER-COP fish-farming project using a few selected species: *mahi mahi* (*Coryphaena hippurus*), European seabass (*Dicentrarchus labrax*), camouflage grouper (*Epinephelus polyphekadion*), giant trevally (*Caranx ignobilis*) and others. After some trials, the focus moved to *Lates calcarifer* (barramundi). In November 1990, the first natural spawning of barramundi occurred (Preston 1990). Despite the fact that this species was found to have nodavirus, breeding and production were considered to have been mastered overall by 1993. IFREMER then transferred the technology to the private sector in 1994. In 2000, 10 t of barramundi was farmed and two private hatcheries and three farms were under development (Anon. 2001). Problems of consistency in production (in supplying fry to farms and fish to the market) and competition with local finfish from the local fishery were the major causes of failure in farming this species (Georges Remoissenet pers. comm. September 2008).

A second introduced species, the golden tilapia (*Oreochromis* spp.), was produced at the initiative of a few farms. Unfortunately, given the limited local market, species that were not very popular locally, high production costs (XPF 800–1000 per kg, compared to XPF ≤800 for grouper fillets from outer islands) and low and sporadic production, the sector was in economic failure by 2000. Over that same period of time, the Service de la pêche began grow-out trials using local species. These involved fish larvae taken from the wild by crest nets or *hoa* nets in Rangiroa from 1995 to 1999. Then, in 2001, two species, the Pacific threadfish (*Polydactylus sexfilis*) and batfish (*Platax orbicularis*), were selected for their technical (hatchery and grow-out) and economic potentials (for local markets).

Fish-farming production is subject to highs and lows depending on the species farmed. This activity, mainly based in Tahiti and Bora Bora and currently relatively modest in scale, is still expanding. Currently, production has reached its lowest level since the first farms started operating 20 years ago. Tilapia production is only a quarter of what it once was, due to the difficulties in marketing this product. Barramundi production is also only a quarter of what it was in 2006 due to a lack of supplies of juveniles and accidental losses during grow-out. In 2007, there was practically no fish production at all, i.e. only 1.5 t as compared to 14.9 t in 2006 (Service de la pêche 2007). Techniques for reproducing and rearing batfish (*Platax orbicularis*) are currently being developed by the Service de la pêche and IFREMER; it should be possible to gradually transfer these technologies to the private sector in late 2009 (Georges Remoissenet pers. comm. September 2008).

Post-larval capture and culture

Harvesting lagoon fish larvae is a more recent activity. These larvae, most of which would suffer high predation during settlement on the reef, are collected from the wild using crest and *hoa* nets, reared and then used for restocking reefs for aquaculture, eco-tourism, or the aquarium trade. Experiments involving these techniques for harvesting and rearing were conducted by CRIOBE from 1988 onwards (Dufour and Galzin 1993) and then developed for production purposes with the Service de la pêche 10 years later, on Moorea and Rangiroa (CRIOBE 2004).

The export of 34,000 specimens for aquarium trade purposes was recorded in 2007, i.e. an increase of 10% in comparison to 2006. However, the total value of exports decreased by 10%, mainly due to the weakening United States dollar, as the US is the main market for these fish (Service de la pêche 2007). Post-larval exports ceased in 2007 because the tools used (different types of nets and light traps) to obtain valuable species were inefficient (<10% captured).

Although the capture of post-larvae for aquarium trade purposes shows an interesting potential for development (Ministère de la pêche 2005; Lecchini *et al*. 2006), its application in the trade is currently limited. Tourism and resource management show a brighter future for these techniques. Over the long term, using reef fish to reseed areas damaged by overfishing and destructive human activities or other marine areas that are regulated and protected for tourism (e.g. Moorea and Bora Bora) might emerge as a viable activity. However, it is still in the experimental phase at a fishery level, but it is currently developed in Bora Bora for eco-tourism (Georges Remoissenet pers. comm. September 2008).

Culture of green mussels

The first importation of green mussel (*Perna viridis*) to French Polynesia occurred in 1978, with broodstock coming from New Caledonia, which in turn had introduced these as spat from the Philippines (AQUACOP and De Gaillande 1978). The mussels were successfully spawned, with the broodstock kept in 15 m^3 ponds, which had water from the penaeid-shrimp culture ponds flowing through them. The green mussel seed were held at the hatchery until they reached 1 cm long, and then were sold on to the grow-out site, where they were reared in a natural, semi-enclosed lagoon (Preston 1990). It was estimated that the 3-ha lagoon could produce 8 t of mussels/year; however, that target was never reached. The activity stopped in 1992, mostly because of cheap imports from New Zealand. Furthermore, it was assessed as having limited adaptability for French Polynesia, as there were very few brackish-water sites, and areas available were mostly oligotrophic and very unsuitable because of floods, with negative impacts on the farmed mussels (Georges Remoissenet pers. comm. September 2008).

Sea turtle tagging and rearing

The Service de la pêche of French Polynesia began a tagging programme for green sea turtles (*Chelonia mydas*) in April 1972, with 67 female turtles tagged and released. During the period October to December 1972, a further 166 female and 13 male green sea turtles were caught, held and fed, tagged and all released in December. The third tagging operation commenced in mid-December 1972, with 107 female green sea turtles caught, penned, tagged, and all released in mid-February 1973 (Anon. 1973a, Anon. 1979). Two tagged turtles were recovered from the first group released, one in Fiji in July 1972 and the other in Tonga in August 1972. There were also two tag recoveries from the 2973 released, one recovered in Fiji and the other in Wallis (Anon. 1973a).

Rearing trials were also undertaken at Scilly and Rangiroa. The Scilly trials involved caging newly hatched green sea turtles in the lagoon and feeding them on fish and clam meat. These turtles were released after 9–12 months, although they were not tagged (Anon. 1979). The Rangiroa trials were conducted in 1971 and 1972, when ~50 green sea turtle hatchlings were also caged and fed on fish and clam meat over a 12-month period. The turtles grew to 5.6 kg in weight and a shell length of 33.5 cm. However, once they had reached a certain size, it was noticed that their diet was deficient in plant material, and attempts to feed them land plants and algae were unsuccessful. The rearing trials ceased at this time (Anon. 1979).

Another rearing programme was conducted in the late 1980s, in the same lagoon as the green mussel grow-out. Here green sea turtles were obtained from two sources: some brought in as juveniles by private individuals, and some collected as eggs by the staff and hatched. The aim of this project was to grow the turtles, release half into the wild, and grow the other half to 40 kg in weight and then sell them on the domestic market for food (Preston 1990).

Between 1989 and 1992, recovered sea turtles were reared in the lagoon but it was a temporary situation waiting for the building of caging in the external lagoon. In fact, the lagoon is not appropriate for this kind of rearing since it is a confined area. Between 1992 and 1993, green sea turtles were reared; they were mostly hatched from the eggs collected in Scilly. This program stopped at the end of 1993, due to budget restrictions; beforehand, the section “rearing to provide turtle meat for the local market” was rejected due to the observations made by an SPC official as well as to the ecological reasons linked to this species (Arsène Stein pers. Comm. December 2008).

Reef and reef fisheries (finfish and invertebrates)

Reef and lagoon fisheries, which are carried out in all the inhabited islands of the island groups, are an inseparable part of French Polynesian culture (Charles 2005). Pel and Devambez (1957) recorded that the main fishing gears used in the lagoon included fixed traps made of stone, nets and wire; wire and bamboo bottom traps; handlines; trolling lines; scarelines; crabnets; gillnets; castnets; dipnets; seines; spearguns; and hand spears. Diving and hand collection are other common methods of fishing. When large catches of fish, especially bigeye scad and blue mackerel, were taken in large surrounding nets, they were kept alive in pounds improvised from old fishnets or chicken wire and stakes, or rock or bamboo enclosures and live boxes, so that they could be marketed fresh over a period of time (Pel and Devambez 1957).

Lagoon fisheries, originally family-based and artisanal in nature, have tended to change with the improvement of maritime and air transport and the development of marketing channels (Vieux 2002). Fish and invertebrates can now be easily shipped to markets in Tahiti, where some 90% of the country’s population is located (Ferraris *et al*. 2005, Service de la pêche 2006a). The size of the fisher population is very difficult to estimate and monitor given that reef fishing is an unreported activity. Gabrié and You (2006) estimated that ~3000–4000 people are involved overall in these fisheries on a regular basis.

The catch from lagoon fisheries was estimated at 4300 t in 2006 (Gabrié and You 2006; Stein 2006), and this plays a major role both economically and socially, since lagoon resources account for a large part of the community's food supply, particularly in terms of protein at 100 kg/inhabitant/year (Ferraris *et al*. 2004). The Society and Tuamotu Island groups provide 81% of this production. Production was estimated to be distributed in the following way: 3400 t of lagoon fish; 700 t of small pelagic species caught in the lagoon, and 200 t of other seafood (molluscs, crustaceans, echinoderms) (Service de la pêche 2006).

The catch from the islands of Tahiti and Moorea in the Windward Islands and Raiatea and Tahaa in the Leeward Islands make the Society Islands group the largest producer of lagoon fish in French Polynesia (43% of total production). On Raiatea and Tahaa, the annual mean production for the period 2002–2005 was estimated at 305 t of lagoon products, including 290 t of fish (Anon. 2006; Gabrié and You 2006). The Tuamotu Islands group came in a close second (38%) with production mainly coming from the western atolls: Tikehau, Kaukura, Arutua, Apataki, Faaite and Rangiroa. For the past 10–15 years, commercial fisheries production in the Tuamotu Islands has remained stable at about 1200 t/year (Gabrié and You 2006). Given transport constraints and a limited market, Tahiti is the sole outlet.

Fishing in the other atolls is mainly for subsistence purposes and the scant data about these extensive catches are deduced empirically from national home-consumption surveys (Dalzell *et al*. 1996). The most recent data about the island of Tikehau estimate fisheries production at 217–435 t/year based on consumption, exports and imports. Lagoon fish account for 90% of this, with the remainder coming from coastal fisheries (tuna, skipjack, *mahi mahi*, and *wahoo*). Marketed production was 100–200 t/year. The sales of lagoon products at the municipal markets in Papeete, Pirae and Uturoa have decreased by ~80% since the 1980s, and totalled ~230 t in 2005. Lagoon fisheries produce from the Tuamotu Islands has decreased from ~80% of total lagoon fisheries recorded previously to 25–30% today. This trend probably reflects an overall decrease in production but also and, more importantly, a change in marketing channels, i.e. municipal markets today only sell about 25–30% of lagoon production; the remainder is sold directly at roadside outlets, stores and restaurants, and to private individuals or fish processors.

A wide range of information points to a depletion of reef fish resources at the principle atolls (Gabrié and You 2006). The overall production data for the Tuamotu Islands went from 1600 t in the 1980s to about 1200 t in 2006, i.e. a decrease of 20% over 20 years (Stein pers. comm.). Intensive fishing campaigns during spawning periods, the activities of occasional fishers, a lack of respect for restrictions on net sizes and lengths and harvesting egg-bearing rock lobsters are all possible causes for the apparent decline in reef and lagoon fisheries.

Oceanic and, to a lesser degree, coastal fisheries have the support of public authorities, with lagoon fisheries maintained at the local subsistence level (Gabrié and You 2006). However, they play a fundamental role in subsistence diets, providing both local protein supplies and social cohesion (Vieux 2002).

The ornamental fish export or aquarium fish trade, which began in 1998, has expanded very rapidly; from <5 t in 1998, production reached ~47.3 t in 2005, with a maximum of ~55 t in 2003 and in 2004. Most exports go to the United States. A small decline was recorded in 2005 as compared to 2004 but the value more than quadrupled, reaching XPF 82.3 million in 2005 compared to XPF 19.2 million in 2004 (Service de la pêche 2007).

Giant clams

The giant clam (*Tridacna maxima*) is a traditional dish for French Polynesians, and is eaten and marketed under the pressure of a steadily growing demand. Natural giant clam stocks are becoming depleted in certain lagoons (Gilbert *et al*. 2006). Stocks in the Society Islands have obviously been overexploited. With about 70 t of meat sold in 2006, this trade is a significant source of income for fishers on certain islands (Service de la pêche 2006b). Certain atolls in the eastern Tuamotu (mainly Tatakoto) and Austral (Raivavae and Tubuai) Islands do, however, have large stocks, with local densities in the eastern Tuamotu Islands of 44–88 clams/m^2 (Andréfouët *et al*. 2005) and are the main suppliers for the markets in Papeete. The amount produced is estimated at about 100 t/year (including produce for home consumption). In eastern Tuamotu, this species has been subjected to a management programme by the Service de la pêche since 2001, and a minimum size limit of 12 cm has been set since 1988 without impact on the Society Islands (Larrue 2006). The goal is to build knowledge, monitor the most heavily exploited sites and propose appropriate management measures. Several scientific studies have been launched to estimate stocks and propose management tools to be used in the lagoons of French Polynesia. Some MPAs have been (and will be) implemented in Tatakoto and Tubuai lagoons and co-management will begin in Tatakoto in 2009 (Georges Remoissenet pers. comm. September 2008).

The Service de la pêche also worked for four years, collecting, farming, transporting and reseeding giant clams in order to promote their preservation in the wild and their use in the aquarium trade and aquaculture (Yan 2005). The results from this work have been satisfactory; collection rates at both atolls in the eastern Tuamotu Islands (Tatakoto and Fangatau) are very high. Monitoring at the farms has confirmed promising growth rates for both islands, i.e. from 3 to 12 cm in four years, with survival rates of 79–95%. The goal is to use collecting techniques for farming, restocking, eco-tourism and the aquarium trade. Aquaculture regulations for giant clams were developed in 2008 and exportation should be restricted to spats collected using a traceable system from the farms in Tatakoto, the lagoon that was opened as a pilot model for spat collection (Georges Remoissenet pers. comm. September 2008).

Ciguatera fish poison

Ciguatera is a seafood poison that is common in many Pacific Island countries and territories. It is caused by a benthic unicellular microphytic algae, *Gambierdiscus* spp. (Laurent *et al*. 2005). Ciguatera is common in French Polynesia, with Bagnis *et al*. (1968) conducting a major survey from January to December 1966 covering 33,085 people, which was ~89% of the population of the districts and the two townships of Tahiti. The survey revealed that, during this period, 2798 cases of ciguatera were recorded, at a rate or incidence of 8.45%, which was very high. The study also identified over 40 species of toxic fish, most of which were carnivores (Bagnis *et al*. 1968).

Bagnis (1992) recorded 30,000 cases of ciguatera from 1960 to 1990 in French Polynesia, which equated to an incidence rate of 1:200. The most poisonous fish in French Polynesia are surgeonfish, grouper, cod, trevally, sea perch, emperorfish, parrotfish, wrasse and, to a lesser extent, mullet, triggerfish, moray eel and barracuda (Laurent *et al*. 2005). Research is ongoing through the Medical Oceanography Unit of the Louis Malardé Research Institute in Tahiti, French Polynesia, where they are working to isolate and culture the dinoflagellate that is the cause of this ciguatera (Legrand 1993).

1.3.3 Target research areas

Scientific research on marine resources in French Polynesia is carried out by a whole range of different agencies, e.g. IFREMER, the University, CRIOBE, the Berkley Gump Station, and IRD, to name only those most well known.

The Institut Français de Recherche et d'Exploitation de la MER (French Institute of Research for Oceanic Development – IFREMER) was created at Vairao on the Tahiti peninsula in 1972. Its core mission is applied research for the development of tropical aquaculture, technical support and scientific expertise for the various sectors of aquacultural production. It also carries out studies in a variety of areas, such as engineering (thermal energy from the ocean) and fisheries (tuna behaviour study by acoustics and fishing). Since the Institute's creation, teams of scientists have devoted themselves to studying the biology and rearing techniques for freshwater river prawns (*Macrobrachium* sp.), saltwater penaeid prawns (*Penaeus* sp.), tropical marine fish, and tropical molluscs (oysters, mussels). Support laboratories have also been set up, in particular, nutrition, pathology and ecophysiology–ecochemistry laboratories. Priority was given to penaeid-prawn farming and the Institute contributed in a large part to the development of shrimp farming throughout the world, particularly in New Caledonia. In French Polynesia, shrimp and fish farming are not very well developed. In contrast, pearl-oyster farming has expanded exponentially beginning in the 1990s. For that reason, IFREMER carried out a reorganisation in the Pacific in the early 2000s, with priority given to research on pearl-oyster farming in French Polynesia and research on shrimp farming at their other Pacific site in New Caledonia.

The University of French Polynesia, a public scientific, cultural and professional institution, was set up in Tahiti in 1987.

The Centre de Recherches Insulaires et Observatoire de l'Environnement (Island Research Centre and Environment Observatory - CRIOBE) a branch of the École Pratique des Hautes Etudes (EPHE, Practical School of Higher Studies) has been located on Moorea since 1971. The mission of EPHE is to contribute to the teaching and advancement of scientific knowledge through basic and applied research. The very essence of CRIOBE's work on coral reefs has been to integrate the concept of long-term ecosystem monitoring in terms of resilience to natural and manmade impacts. Currently, CRIOBE has produced the longest time series of monitoring data on Pacific coral ecosystems and a significant number (~1000) of publications. Recently, CRIOBE undertook a structural change with the recognition, in 2006, of the Centre National de la Recherche Scientifique (French National Scientific Research Centre – CNRS) becoming Unité Mixte de Service (combined service unit) 2978, with the co-sponsorship of EPHE-CNRS. In 2007, a framework collaboration agreement was signed by CNRS, EPHE and French Polynesia for cooperation on coral-reef research and development. The work of CRIOBE can be divided into three sectors: a South Pacific coral ecosystem observatory; a centre to host and promote research on island environments (land and marine) and societies in the South Pacific; and a unit to allow coral ecosystem communication and extension work. The main objective of the coral ecosystem observatory is to acquire long-term information about physical and biological systems so as to make it possible to better understand the ecological processes that regulate ecosystems over long periods of time.

The Gump Station Research Laboratory has also been operating on Moorea since 1981. The intended purpose of this satellite campus of the University of Berkley (in California) is to promote research and education within a sustainable development framework. For the past 25 years, the Gump Station has been carrying out a programme entitled 'The Moorea Coral Reef Long Term Ecological Research Network', whose overall objective is to monitor ecological phenomena over the long-term. The main research areas cover primary production dynamics and control, population dynamics of the main groups, and the outlines and consequences of disturbances brought about over the long-term.

Originally founded in 1944, the Institut de Recherche pour le Développement (IRD) carries out scientific research programmes in 35 countries and 5 French overseas territories. IRD's main areas of work are research, training and consultancy. Specific project areas include: natural hazards; continental and coastal water resources; food security; sustainable ecosystems management; health; and development and globalisation (IRD n.d.). Although French Polynesia benefits from participating in the work of IRD that is carried out in other countries, there have been IRD partnership projects carried out in French Polynesia itself. Recent projects include an agreement to establish a Polynesian centre for biodiversity research; the establishment of an online database of French Polynesia flora and other main herbaria around the world (Herbier de Tahiti 2008); the survey of *Tridacna maxima* clam stocks and provision of a proposed management regime; an international conference on aromatic and medicinal plants; an expert group review of natural substances of French Polynesian aromatic and medicinal plants; and archaeological work in the Marquesas Islands (IRD 2006, 2007).

1.3.4 Fisheries management

The pearl oyster and fisheries department was created some 50 years ago; over the years it has undergone many changes. In 2001, the Service de la pêche was given responsibility for reef and lagoon, coastal and oceanic fisheries and aquaculture-related activities, while the Service de la Perliculture handles those related to pearl oysters.

In April 2008, the minister in charge of pearl oyster farming presented a plan to the French Polynesian Assembly to revitalise the sector, using funding from the 9th European Development Fund, i.e. a total of XPF 435 million over a period of three years. This plan has three parts: training, research and marketing. At the heart of the project is the creation of a Maison de la perle (pearl house) that would bring together all those involved in pearl-oyster farming, thereby making it possible to simplify the administrative procedures for export, among other things. However, implementation of a medium-term policy on pearl oyster farming is hindered by government instability and a lack of coordination among professionals in the sector.

1.4 Selection of sites in French Polynesia

Four PROCFish/C sites were initially selected in French Polynesia, one in the Austral Islands (Raivavae), two in the Tuamotu Archipelago (Fakarava and Tikehau) and one village on the main island of Tahiti in the Society Islands, Windward Group (Mataiea). Following a further request from French Polynesia a fifth site was included, Maatea in Moorea, also in the Windward Group of the Society Islands (Figure 1.5). These sites were selected after several visits to French Polynesia by SPC staff.

Fakarava, Mataiea, Maatea, Raivavae and Tikehau were selected for two reasons. First, these sites shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country, were relatively closed systems[5], were appropriate in size, possessed diverse habitats, presented no major logistical limitations that would make fieldwork unfeasible, had been investigated by previous studies, and presented particular interest for French Polynesia's department of fisheries. Second, they represented a mix of marketing arrangements for the commercial catches: roadside sales at Maatea, Mataiea and Fakarava, air freighting to Papeete from Tikehau, and limited marketing availability at Raivavae.

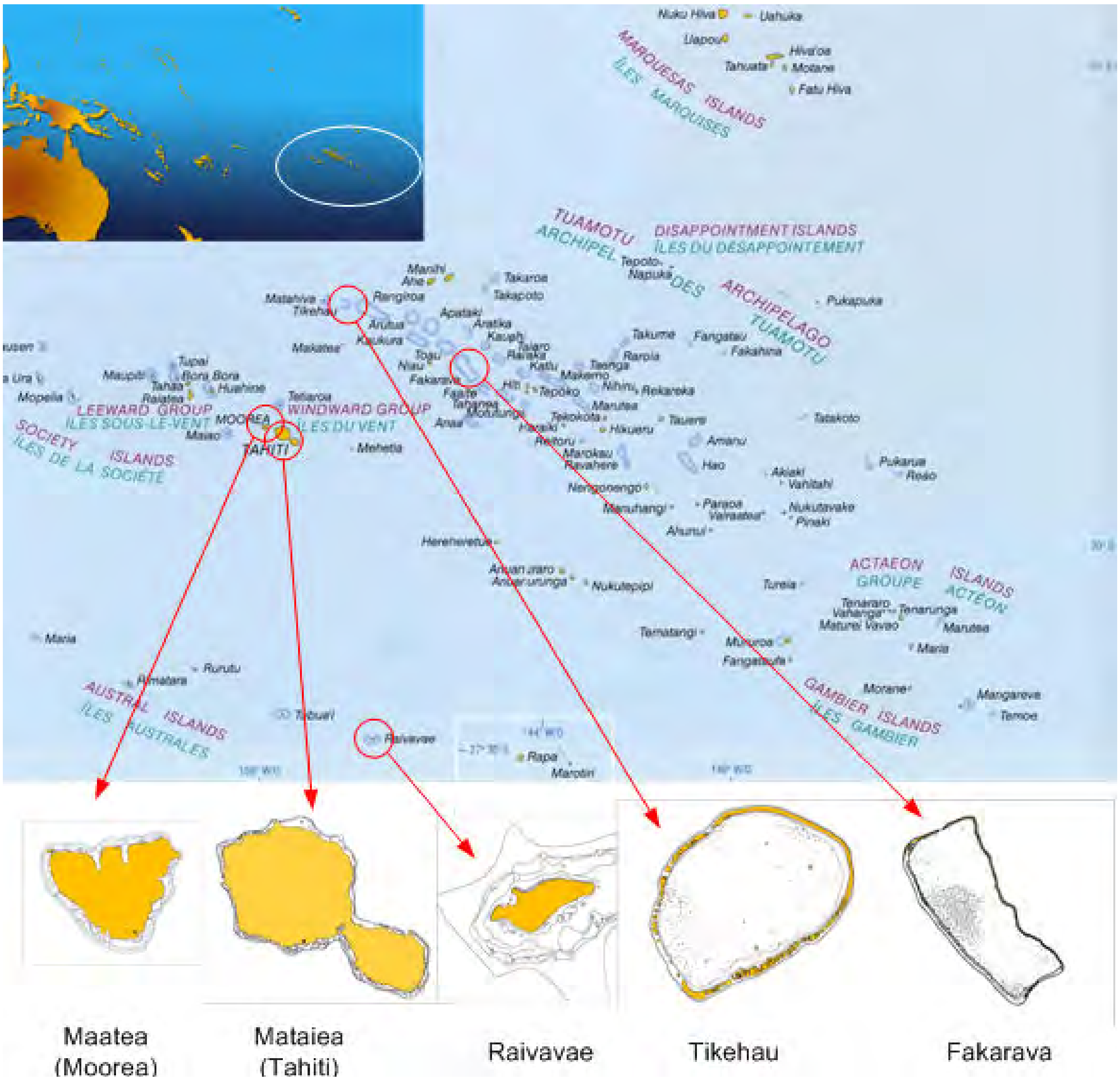

Figure 1.5: Map of the five sites selected in French Polynesia.

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

2. PROFILE AND RESULTS FOR FAKARAVA

2.1 Site characteristics

Fakarava is a coralline atoll with a rectangular shape, situated in the Tuamotu Archipelago at 16°19'24'S and 145°35'57'W (Figure 2.1). Its length is 54.8 km and its width is 25.8 km. The main village, Rotoava, is in the north of the atoll. Its population is 697 inhabitants, with a population density of 43.5 people/km². As often in the Tuamotu Archipelago, pearl culture is the second most developed sector after tourism.

The large lagoon, 1153 km², comprises only 16 km² of submerged area and its depth ranges between 30 and 50 m. Access to the lagoon is by the north via the Garuae passage, the largest passage in French Polynesia, and by the south via the Tumakohua passage. The area comprises only three habitats: outer reef, back-reef and intermediate reef, with a total reef area of ~77 km². This lagoon is the second largest in French Polynesia and is listed as a UNESCO biosphere reserve.

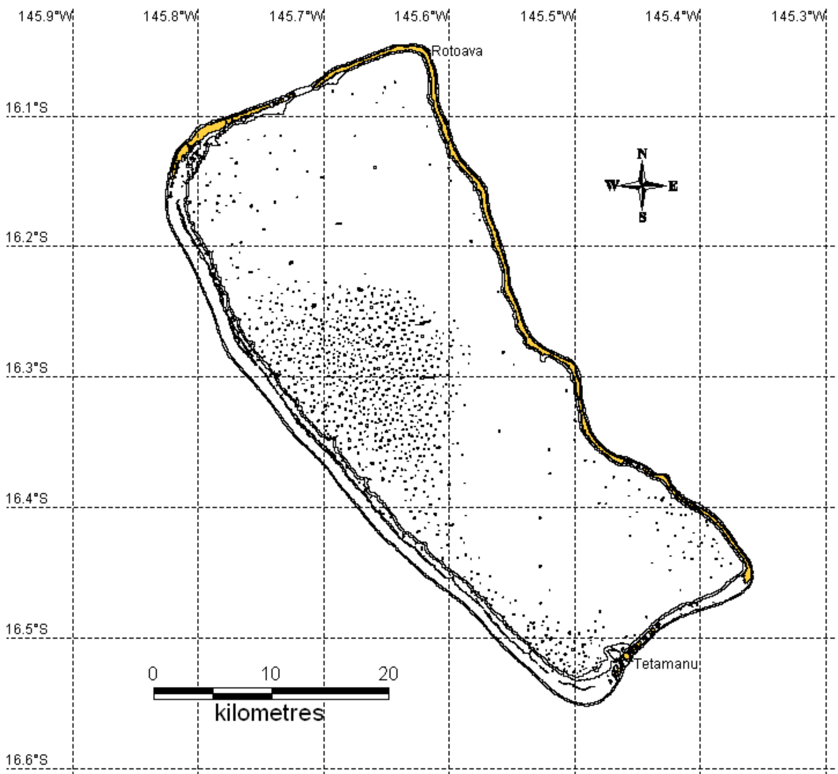

Figure 2.1: Map of Fakarava.

2.2 Socioeconomic surveys: Fakarava

Socioeconomic fieldwork was carried out in the community of Fakarava Island in January 2004. The survey covered a total of 25 households including 141 people. At the time of the survey, the atoll had an estimated total population of 821 people and 152 households. Thus, the survey sample represented about 17% of the community's total population and ~16% of all households.

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 18 individual interviews of finfish fishers (17 males, 1 female) and 10 invertebrate fishers (8 males, 2 females) were conducted. These fishers belonged to one of the 25 households surveyed. Sometimes, the same person may have been interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 2.1) suggest an average of almost two fishers per household. If we apply this average (<2) to the total number of households, we arrive at a total of 256 fishers in Fakarava. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 137 fishers who fish only for finfish (males and females), a total of 6 fishers who target only invertebrates (females) and 113 fishers who fish for both finfish and invertebrates (males and females).

About half (52%) of all households in Fakarava own a boat, and all of these are motorised.

Figure 2.2 suggests that fisheries are not an important source of income. Only 12% of the households surveyed rely on fisheries as their first source of income, and another 4% rely on fisheries as a secondary income source. Salaries provide almost half (48%) of all households with first income and another 24% gain their main cash income from other sources, including business, and social fees. These other sources are also an important income for 32% of the population surveyed. Only 8% reported salaries as providing a complementary income. Agriculture (copra production) is more important than fisheries as 16% of all households derive their first income from this sector, and another 24% complement their cash revenues from agricultural (copra) produce.

However, fisheries are important as a source of food: all households reported eating fresh fish, >90% invertebrates and 88% canned fish. The fish that is eaten is mostly caught by a member of the household (84%), but may also be frequently bought (56%) or received on a non-monetary basis (44%). The proportion of invertebrates caught by a member of the household is lower (44%), and invertebrates are rarely bought (8%) or received as a gift (8%). These results suggest that the people in Fakarava still maintain their traditional lifestyle, at the same time adopting some modern or urban practices. This conclusion is based on the proportion of households depending on fisheries for income generation as compared to salaries, and the amount of fish that is caught, bought and exchanged as a gift among community members. Figures also suggest that finfish is more important than invertebrates. These observations may be further highlighted by data collected from fisher interviews.

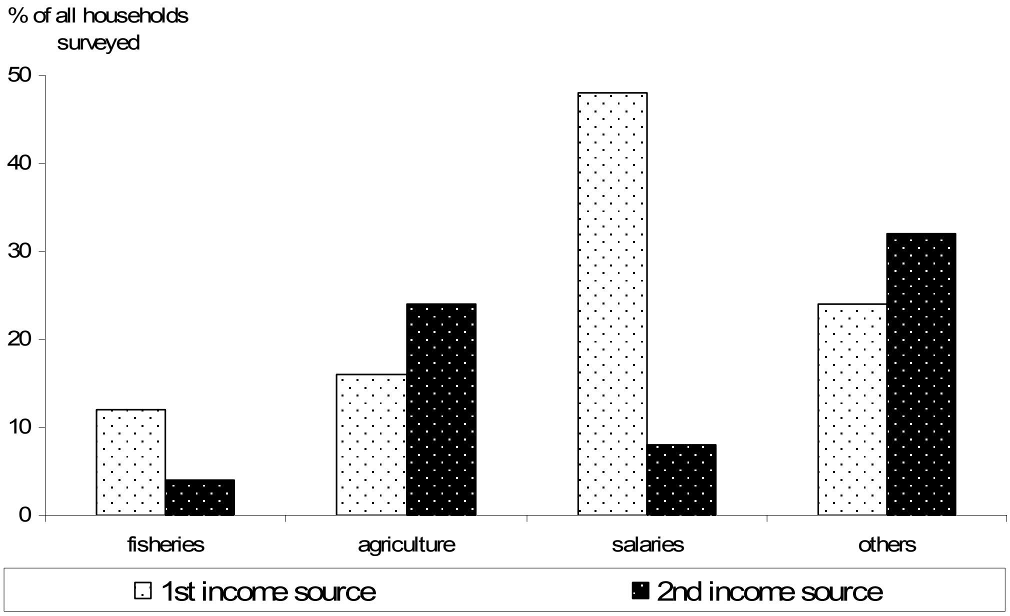

Figure 2.2: Ranked sources of income (%) in Fakarava.
Total number of households = 25 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

The per capita consumption of fresh fish (~64 kg/capita/year ±10.37) in Fakarava is above the regional average (FAO 2000) (Figure 2.3), and higher than the average for all PROCFish/C sites in French Polynesia. The average per capita consumption of invertebrates is low (2.13 kg/capita/year) (Figure 2.4) and only exceeds that of Mataiea and Maatea. The canned fish consumption is relatively low but slightly above canned fish consumption rates found elsewhere in the country (~4.1 kg/capita/year ±1.32) (Table 2.1).

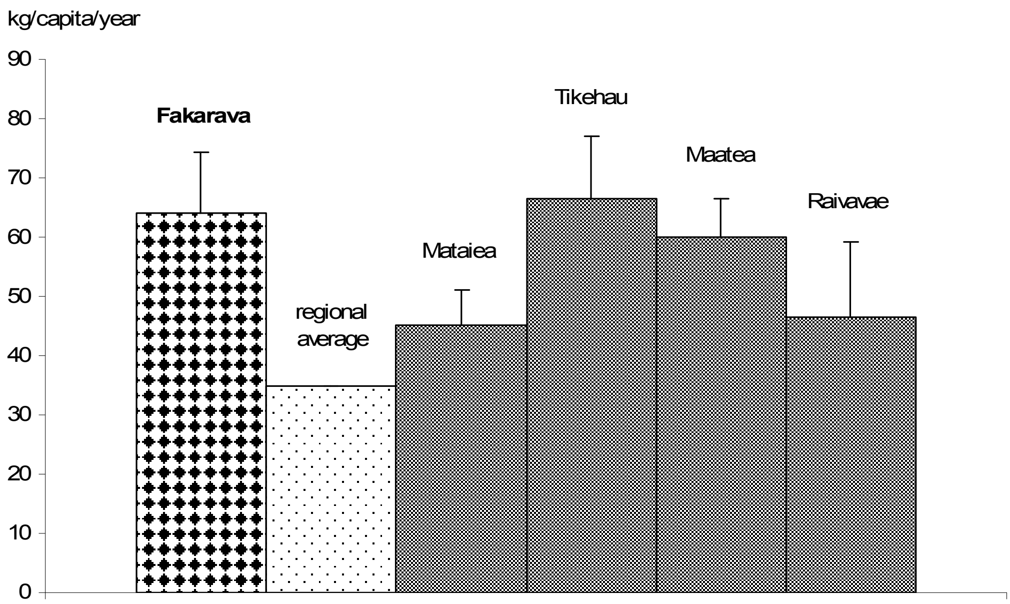

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Fakarava (n = 25) compared to the regional average (FAO 2008) and the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

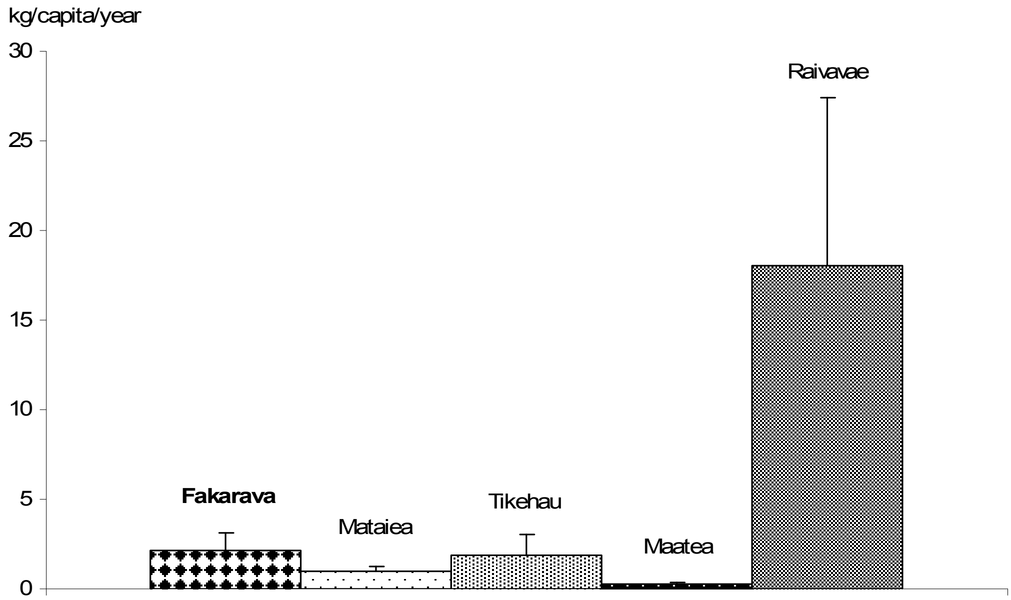

Figure 2.4: Per capita consumption (kg/year) of invertebrates (meat only) in Fakarava (n = 25) compared to the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

In comparison with the average from all five PROCFish/C sites in French Polynesia (Table 2.1), the people of Fakarava are less dependent on fisheries for income generation but they eat more fresh fish in a year. Invertebrate and canned fish consumption is generally low. Data show a much lower average household expenditure level, and remittances do not play any role at all.

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

Survey coverage	Site (n = 25 HH)	Average across sites (n = 138 HH)
Demography		
HH involved in reef fisheries (%)	88.0	85.5
Number of fishers per HH	1.72 (±0.31)	1.71 (±0.12)
Male finfish fishers per HH (%)	51.2	33.9
Female finfish fishers per HH (%)	2.3	9.7
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	2.3	14.0
Male finfish and invertebrate fishers per HH (%)	30.2	35.2
Female finfish and invertebrate fishers per HH (%)	14.0	6.8
Income		
HH with fisheries as 1st income (%)	12.0	14.5
HH with fisheries as 2nd income (%)	4.0	11.6
HH with agriculture as 1st income (%)	16.0	11.6
HH with agriculture as 2nd income (%)	24.0	13.8
HH with salary as 1st income (%)	48.0	46.4
HH with salary as 2nd income (%)	8.0	8.7
HH with other source as 1st income (%)	24.0	26.8
HH with other source as 2nd income (%)	32.0	34.1
Expenditure (USD/year/HH)	7937.40 (±1029.62)	9752.58 (±468.27)
Remittance (USD/year/HH) (1)		1055.66 (±393.52)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	63.94 (±10.37)	55.55 (±4.16)
Frequency fresh fish consumed (times/week)	3.72 (±0.40)	3.28 (±0.16)
Quantity fresh invertebrate consumed (kg/capita/year)	2.13 (±0.98)	4.91 (±4.16)
Frequency fresh invertebrate consumed (times/week)	0.17 (±0.06)	0.38 (±0.07)
Quantity canned fish consumed (kg/capita/year)	4.13 (±1.32)	3.95 (±0.59)
Frequency canned fish consumed (times/week)	0.57 (±0.16)	0.65 (±0.10)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	92.0	82.6
HH eat canned fish (%)	88.0	79.0
HH eat fresh fish they catch (%)	84.0	84.0
HH eat fresh fish they buy (%)	56.0	56.0
HH eat fresh fish they are given (%)	44.0	44.0
HH eat fresh invertebrates they catch (%)	44.0	44.0
HH eat fresh invertebrates they buy (%)	8.0	8.0
HH eat fresh invertebrates they are given (%)	8.0	8.0

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

2.2.2 Fishing strategies and gear: Fakarava

Degree of specialisation in fishing

Fishing in Fakarava is performed by both males and females (Figure 2.5). However, most fishers are males especially as applied to fishing exclusively for finfish (51%); very few females fish just for finfish (~2%). Very few respondents (~2%) specialised in collecting invertebrates only, and these were all females (~2%). For the fisher group which targets both finfish and invertebrates, more were males (~30%) and only 14% were females.

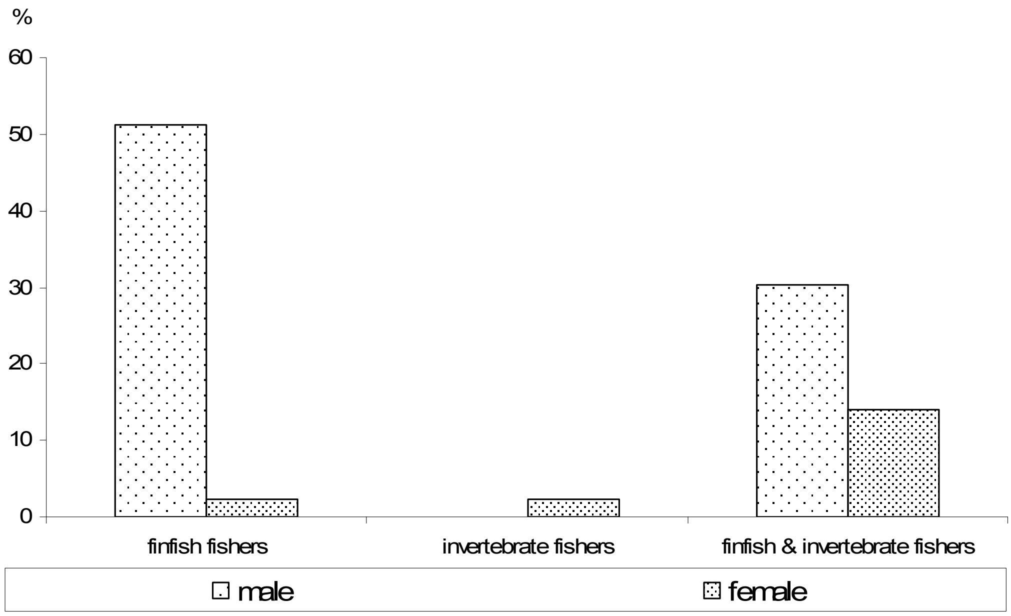

Figure 2.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Fakarava.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	23.5	0.0
	Lagoon	58.8	0.0
	Outer reef	11.8	0.0
	Passage	35.3	100.0
Invertebrates	Reeftop	87.5	0.0
	Intertidal	0.0	100.0
	Lobster	12.5	0.0
	Other	62.5	0.0

'Other' refers to the giant clam fishery.
Finfish fisher interviews, males: n = 17; females: n = 1. Invertebrate fisher interviews, males: n = 8; females, n = 2.

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip is used to estimate the fishing pressure imposed by people from Fakarava on their fishing grounds (Table 2.2).

Our survey sample suggests that fishers in Fakarava can choose among three habitats: sheltered coastal reef (including reef flats), a lagoon area and the outer reef. There are a few passages that are also fished, in particular with fish trap systems (*parcs*). Fishers seem to clearly distinguish between habitats targeted and only target one particular habitat on each fishing trip. Most fishers (~60% of the males) target the lagoon and only ~24% the sheltered coastal area including the accessible part of reef flats. Only 12% of all male fishers target the outer reef, but another 35% target the passages. Female fishers seem to be mostly engaged in fishing the passages using the *parcs*.

Invertebrate fisheries are not very diverse and data suggest that they are less important than the finfish fisheries. Most species collected are associated with reefs. Males mainly target the reeftops and accessible parts of reef flats (~88%) as well as diving for giant clams ('other' fishery ~63%). Lobster diving is less important and only ~13% of all male fishers are engaged in this fishery. Females mainly target the intertidal areas for shells that they use for handicraft and artisanal purposes (Table 2.2). As shown in Figure 2.6, regardless of gender, the same order of importance applies, i.e. reeftop gleaning is the most important, closely followed by giant clam diving, intertidal shell collection and lobster harvesting. Figure 2.7 confirms earlier observations that more males than females are engaged in invertebrate fisheries and that females mainly focus on collecting shells in intertidal habitats, while males collect species on the reef when they are diving for giant clams and lobsters.

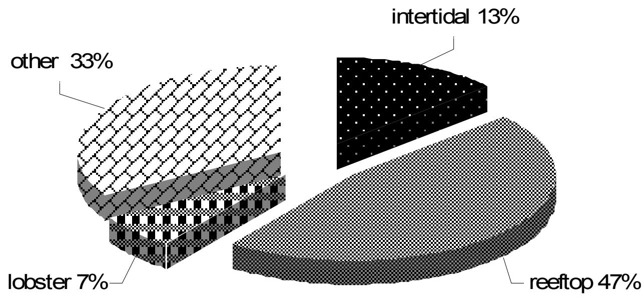

Figure 2.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Fakarava.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the giant clam fishery.

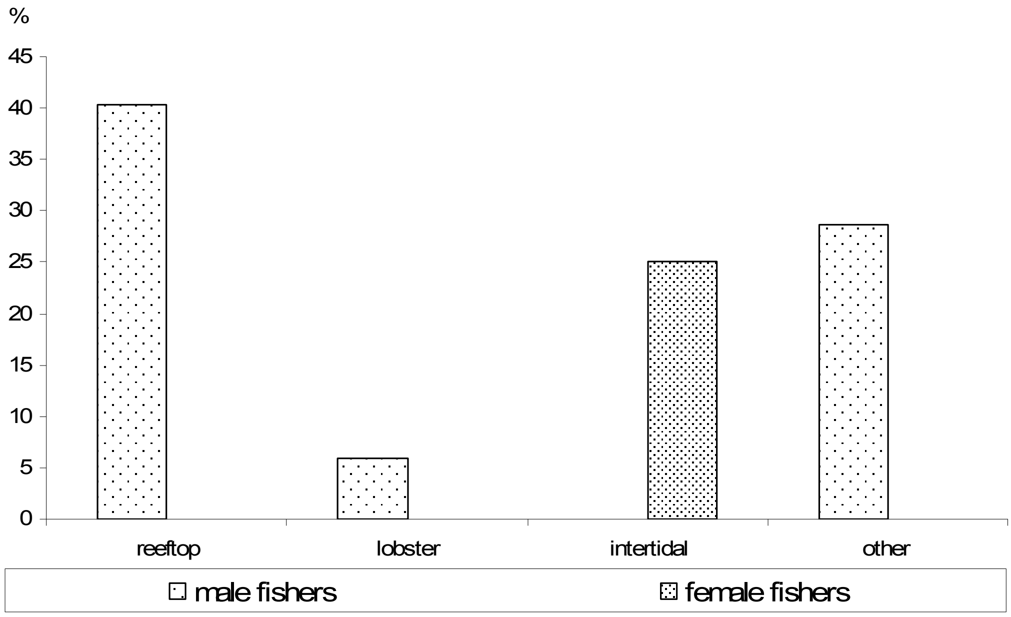

Figure 2.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Fakarava.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 8 for males, n = 2 for females; 'other' refers to the giant clam fishery.

Gear

Figure 2.8 shows that fishing on Fakarava is done using a variety of techniques. In general, handlining and spear diving are used at the sheltered coastal reef and in the lagoon. Spear diving is the main method used at the outer reef and may be complemented by the use of handheld spears. In the passages, permanent *parcs* (fish traps) are established and fishing is complemented by the use of handlines and spear diving. While most fishing involves a motorised boat, some lagoon fishing is done by reaching the fishing spot by car or bicycle and then spear diving in the lagoon area without using a boat.

Gleaning and free diving for invertebrates is done using very simple tools only. Lobsters and giant clams are either picked up by hand or by free diving using snorkel (not SCUBA). Diving for lobster is done exclusively by walking along the reeftop and diving from there. Boats are used on about half of all fishing trips for giant clams and reeftop fisheries. The same applies for female fishers, who sometimes walk to glean intertidal areas but at times also use a motorised boat to reach distant intertidal habitats.

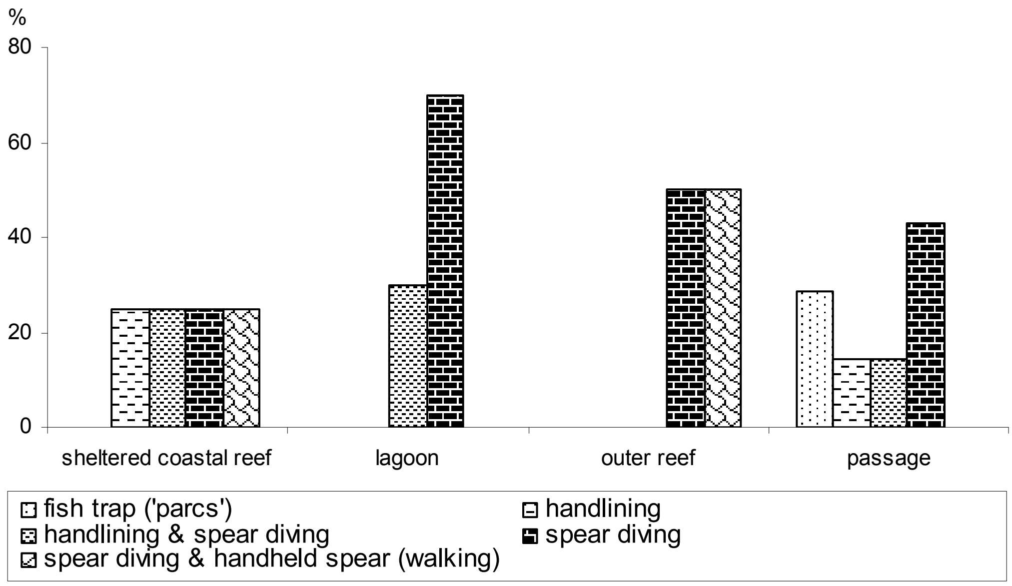

Figure 2.8: Fishing methods commonly used in different habitat types in Fakarava.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 2.3 the frequency of fishing trips varies among habitats targeted. Sheltered coastal reefs and the lagoon are fished once or twice a week, but the more distant outer reef and passage areas that require substantial time and cost for motorised boat transport are visited about once to three times per month only. These differences also show in the average fishing trip duration. The closer to the villages, the less the time spent, usually 3-4 hours. Passages and in particular fish trap operations (*parcs*) require more time, on average five hours. The remaining *parcs* in Fakarava’s lagoon system are installed in the south, near the *motu* of Tetamanu, some 50 km from the main village of Rotoava. The lesser importance of invertebrate fishing shows in the low frequency of fishing trips. Fishers usually go out less than once a month. However, invertebrate fishing trips take some time, on average 4–5 hours.

Fishing for finfish is usually performed at day time; however spear divers targeting the lagoon or passages may do so also at night. In general, finfish fishers fish for about half of the year or up to nine months. The engagement in copra production for commercial purposes may be one explanation, and seasonal and weather conditions may also be contributing factors. In the case of invertebrate collection, lobster fishing is only done at night, and reeftop gleaning may be done either at day or night. All other fisheries, including giant clam diving and intertidal gleaning are daytime activities. Invertebrate fishers, although they go out less frequently than finfish fishers, harvest throughout the year.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.77 (±0.58)		3.88 (±0.66)	
	Lagoon	1.27 (±0.22)	0	3.75 (±0.55)	0
	Outer reef	0.33 (±0.17)	0	2.75 (±0.25)	0
	Passage	0.89 (±0.40)	0.20 (n/a)	5.00 (±1.37)	6.00 (n/a)
Invertebrates	Reeftop	0.37 (±0.17)	0	5.00 (±0.53)	0
	Intertidal	0	0.13 (±0.10)	0	4.00 (±2.00)
	Lobster	0.23 (n/a)	0	5.00 (n/a)	0
	Other	0.34 (±0.19)	0	4.00 (±0.63)	0

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam fishery.
Finfish fisher interviews, males: n = 17; females: n = 1. Invertebrate fisher interviews, males: n = 8; females: n = 2.

2.2.3 Catch composition and volume – finfish: Fakarava

Catches from the sheltered coastal reef are basically determined by five fish groups; Scaridae are the most prominent (>31% of the reported annual catch), followed by Holocentridae (~20%), Acanthuridae (~17%), Carangidae (~15%), and Serranidae (~15%). Catches reported from the lagoon fishing are more diverse but, again, Scaridae (~26%) are the most important species group caught, followed by *Naso unicornis* (~18%), *Naso annulatus* (~8%), *Acanthurus xanthopterus* (~7%) and *Plectropomus laevis* (~5%). The reminder of the reported catch is determined by various Serranidae (>7%), Lethrinidae (>6%), Carangidae (~5%) and others. The outer-reef catches seem to be the least varied and apart from Scaridae comprising more than half (~54%), the determining fish groups are Carangidae (~34%) and Acanthuridae (*Naso annulatus*, *Naso hexacanthus*) (~8%). The dominance of Scaridae reported in all catches from the various habitats diminishes in catches from passage fishing. While the catch contribution of Scaridae (~25%) is still considerable, Acanthuridae (~26%), Carangidae (~22%) and Holocentridae (~16%) also determine an important proportion of the reported catch (Detailed data provided in Appendix 2.1.1).

Our survey sample of finfish fishers interviewed only represents about 7% of the projected total number of finfish fishers in Fakarava. However, we have included all commercial fishers in our survey which results in an overestimation of the average annual catch per fisher and the proportion of catch used for export and subsistence needs. In fact, there are only 3–4 *parcs* in the passage of Toau, and they are all owned by one family. The catches from these fish traps determine to a great extent the commercial catch rate for Fakarava. The family annual catch is estimated at 6 t. Although almost half of all households interviewed indicated that they may at times buy the fish they eat, the proportion that is sold locally is low. Some of the annual catch is transported, either by air cargo or by boat, to family members at Papeete, Tahiti. The annual air freight cargo at the time of the survey was estimated to amount to 3–4 t. The volume of fish transported by boat to Papeete, either for sale or as a gift to family members, is not known. Also, at the time of the survey, incidents of fish poisoning (ciguatera) had significantly increased and thus the sale of fish to the formerly regularly visiting commercial boat had ceased. In addition, disputes over ownership and rights to establish and operate *parcs* in any of the atoll's passages have reduced this fishing activity. Accordingly, some fish is imported from the nearby Faaite atoll to supplement decreased local catches. At the time of the survey, the volume of reef fish imported from Faaite to supply the local demand on Fakarava was estimated at 1–2 t/year. Based on our survey data, the total annual subsistence demand of the Fakarava atoll island population is estimated to be 65.6 t.

Despite the above explanations and the fact that our data represent the few commercial fishers rather than the predominantly subsistence fishers in general, we can still draw some conclusions regarding the current fishing pressure on the various habitats fished. Also, reported total annual catch volumes (Figure 2.9) confirm that the highest impact is imposed on the lagoon resources, which is mainly due to the commercial operation of the *parcs* (fish traps). The reported impact on the sheltered coastal reef (including accessible reef flats) is similar to that on passage resources. The data also confirm that finfish fishing is almost exclusively done by males, while females contribute little. While local fishers and respondents did not express any concern about the status of resources, they were, however, very much concerned about the effects of ciguatera fish poisoning that has prevented them from selling their catch elsewhere, and also about disputes over fish traps.

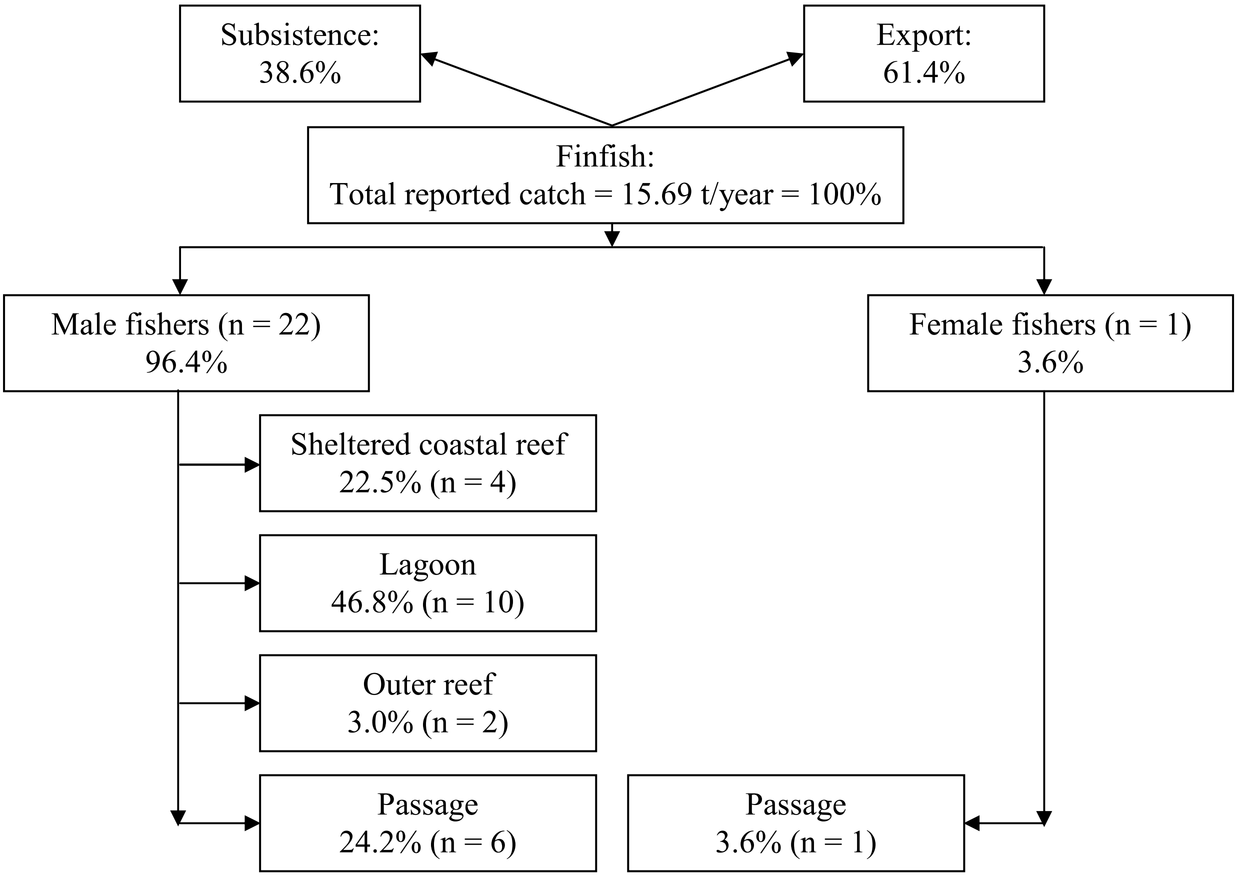

Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Fakarava.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

The high impact on the lagoon fishery is due to the large number of fishers targeting this habitat rather than the average annual catch per fisher. The latter, as shown in Figure 2.10, does not vary substantially if taking into account variability of data (SE) among fishers who target the sheltered coastal reef (~850 kg/fisher/year), the lagoon (~780 kg/fisher/year) or the passage (~650 kg/fisher/year). In fact, only fishers who fish the outer reef have much smaller average annual catch rates (~220 kg/fisher/year). The fact that the reported annual catch rates for male and female fishers targeting the passages are similar is explained by the fact that both belong to the same family that operates the fish traps.

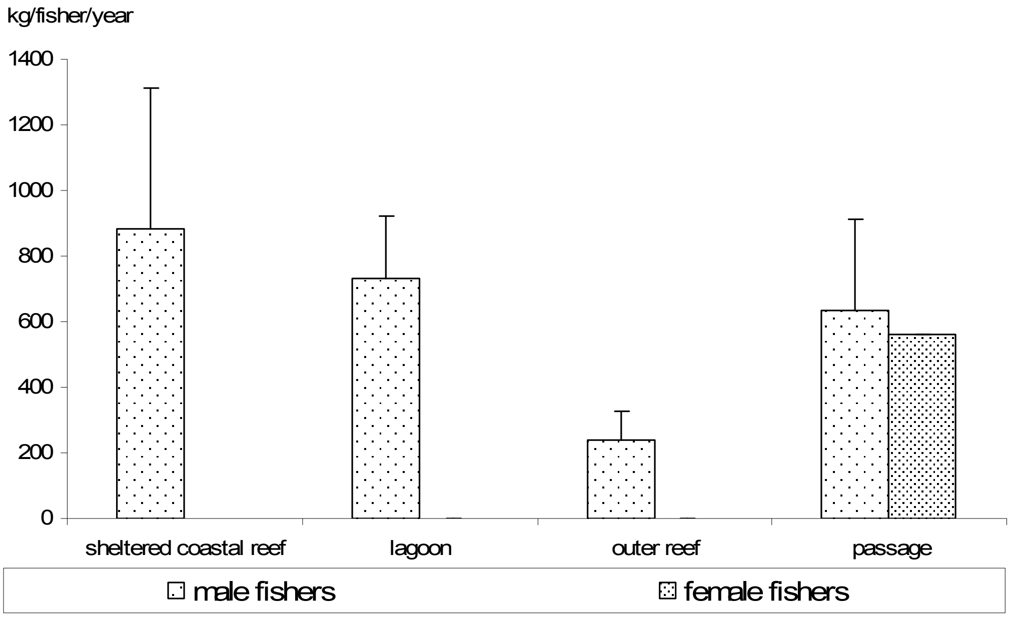

Figure 2.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Fakarava (based on reported catch only).

Comparing the CPUE calculated for the different habitats fished, one substantial difference emerges. Sheltered coastal reef and lagoon fishers are much less productive (~4 kg/hour fished) than those targeting the outer reef (~7 kg/hour fished). Because of the small sample size of female fishers, and the fact that they were in the same family as the males fishing the *parcs*, the average CPUE of both males and females combined may best represent passage fishing. As a result, the CPUE from passages is as low as those calculated for catches from sheltered coastal reef and lagoon habitats. This fact may be explained by the long distances involved in reaching those fish traps in the Toau passage, resulting in a considerably longer average fishing trip duration than elsewhere (Figure 2.11).

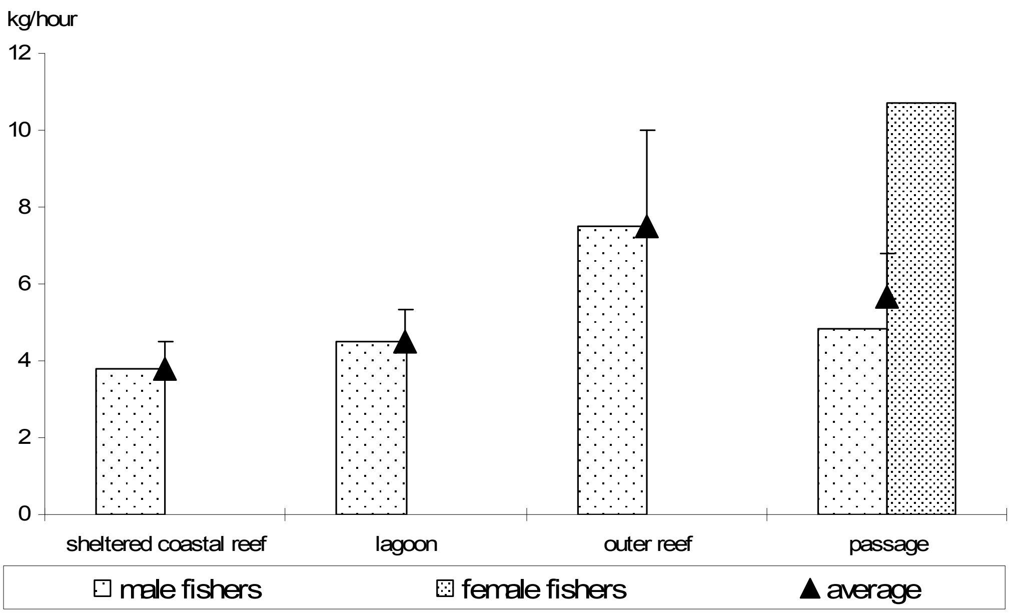

Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Fakarava.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data suggest that a proportion of catch from the passage fishery only is intended for commercial purposes, while catches from the sheltered coastal reef, the lagoon or the outer reef are to supply family needs, or to share with friends and family members. In fact, the proportion of fishing done intentionally to serve the traditional social network of non-monetary distribution of produce, food and goods is still very high among the Fakarava community (Figure 2.12).

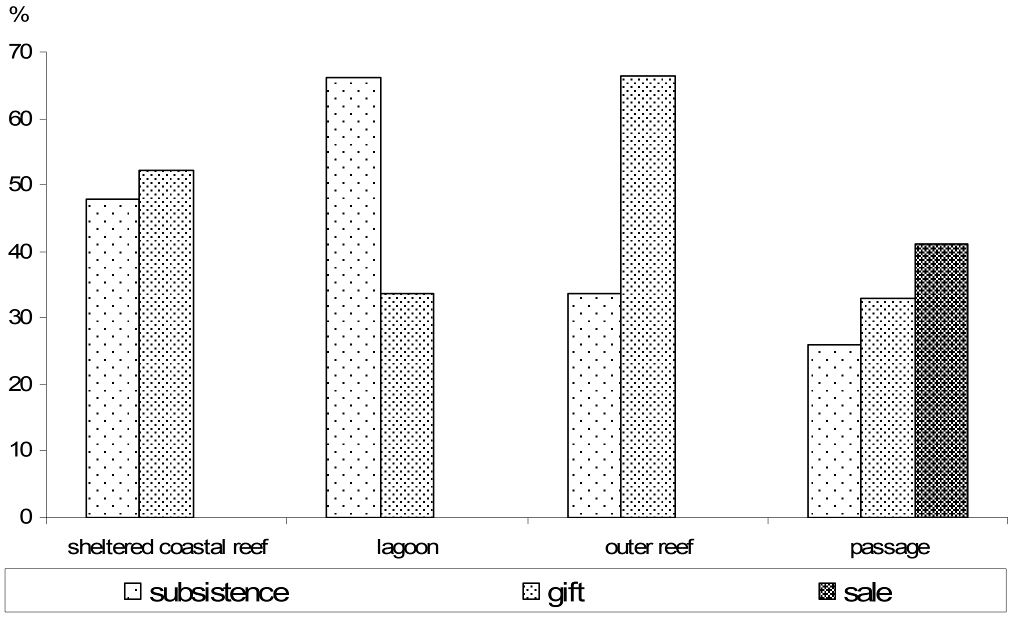

Figure 2.12: The use of finfish catches for subsistence, gift and sale, by habitat in Fakarava. Proportions are expressed in % of the total number of trips per habitat.

Data on the average (reported) finfish sizes by family and habitat as shown in Figure 2.13 do not show any general trend of increased or decreased size with distance from shore. In fact, this response only exists for Acanthuridae, where the average fish size significantly increases from the sheltered coastal reef and lagoon to the outer reef. For other families, if we use the standard errors to indicate variability of data, the fish sizes do not vary substantially among habitats targeted. This observation applies for Carangidae, Holocentridae and Scaridae. In general, however, fish sizes were reported to be large, on average ranging from 30 to >40 cm. This is particularly interesting in the case of Scaridae, a major target group for spearfishing and also reported as one of the most dominant species groups in the total annual catch from all habitats. The reported average size for catches of Scaridae does not vary among the four habitats, but is always large (~40 cm). It is therefore concluded that Scaridae show no detrimental impacts from fishing, especially not from spearfishing. This conclusion may also be supported by the fact that fishing on Fakarava, at least since the rise in ciguatera fish poisoning, is for subsistence rather than for export, and consequently limited.

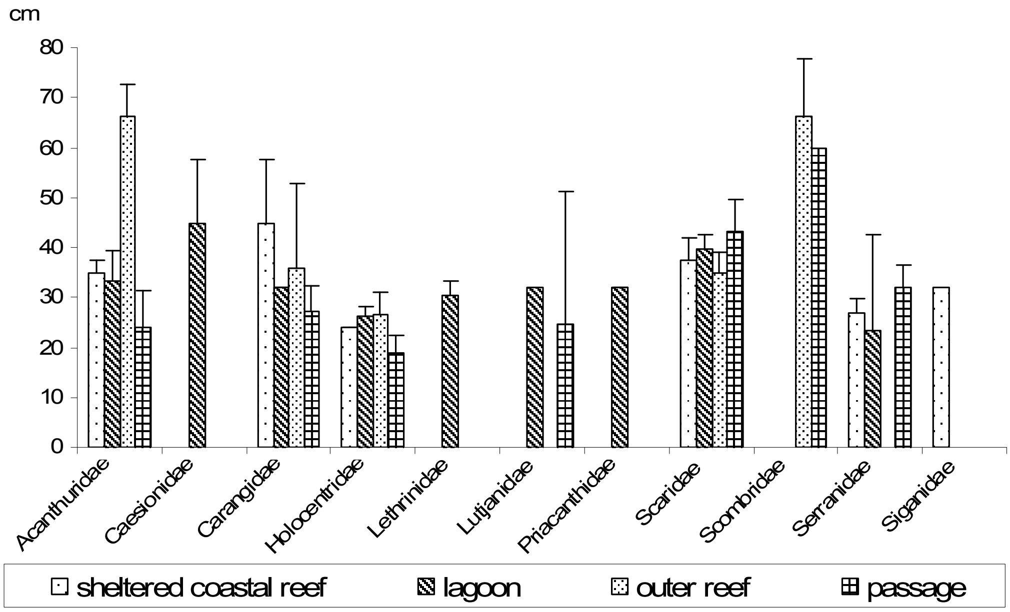

Figure 2.13: Average sizes (cm fork length) of fish caught by family and habitat in Fakarava. Bars represent standard error (+SE).

Some parameters selected to assess the current fishing pressure on Fakarava's living reef resources are shown in Table 2.4. The comparison of habitat surfaces shows that the lagoon comprises most of the available fishing ground area for Fakarava. However, all habitats fished are relatively large, and the fisher density is low. Average annual catch rates are limited to meet only subsistence and social needs. As a result, although total population density is moderate when calculated for the available and accessible reef area only, fisher density is low and fishing pressure, whether it be calculated on the available and accessible total reef area or the total fishing ground area, still remains low.

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

Parameters	Habitat					
	Sheltered coastal reef	Lagoon	Outer reef	Passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	10.96	631.79	10.93	1.98	76.71	653.68
Density of fishers (number of fishers/km^2 fishing ground) [(1)]	4	0	11		3	0
Population density (people/km^2) [(2)]					11	1
Average annual finfish catch (kg/fisher/year) [(3)]	880.86 (±432.32)	733.59 (±188.14)	239.20 (±86.51)	621.39 (±236.45)		
Total fishing pressure of subsistence catches (t/km^2)					0.63	0.07

Figures in brackets denote standard error; [(1)] total number of fishers is extrapolated from household surveys; [(2)] total population = 821; total number of fishers = 255; total subsistence demand = 48.49 t/year; [(3)] catch figures are based on recorded data from survey respondents only.

Although Stein (1988) suggests that the Fakarava lagoon system has never been exposed to extreme exploitation, figures presented show that past fishing efforts have been much higher than as estimated during the 2004 PROCFish/C survey, i.e. as high as 75–80 t in 1979, and then diminishing to 60–65 t in 1984, ~40 t in 1985 and 18–20 t in 1986.

Discussions with residents give reason to assume that fishing pressure was much higher in the past. For example, there were seven more *parcs* located in the passage of Tumakohua. These fish traps need licensing and they are limited in number to match the physical conditions of the passages or places where they are installed. These fish traps were abandoned in 2002/2003 due to economic reasons. Unfavourable weather and sea conditions, which caused high investment and operation costs, and increased transport costs to service these distant installations rendered *parcs* uneconomic. While the costs of operation, maintenance and fuel have increased, increases in fish prices, either on Fakarava or at Tahiti, did not keep pace. In addition, the increase in ciguatera fish poisoning was also unfavourable for the marketing and commercialisation of catches from Fakarava. For this reason, the commercial fish buying boat ('Hotu maru') that was previously visiting once a week is no longer landing at Fakarava. Part of this former commercial operation included the provision of the building material for the *parcs* by the fish trading company in return for a guaranteed purchase of 50% of all catches from these fish traps.

The local price of a fish string (~3–4 kg/string) was at the time of the survey about XPF 500 to 1000, with a price of XPF 700 /3 kg being the most commonly asked price (i.e. XPF 235 /kg fish). By comparison, the commercial sale prices to the fish export boat were:

1st grade	XPF 100 /kg (XPF 400 /5 kg) (*karong*, *kupa*, *iihi*);
2nd grade	XPF 95 /kg (XPF 380 /4 kg) (others); and
3rd grade	XPF 75 /kg (XPF 300 /4 kg) (*taia*, *toau*, *orare*)

The commercial potential of any reef fisheries is also restricted due to the limited air cargo volume. At the time of the survey Air Tahiti made available a maximum volume of 400 kg/flight/day for any fresh marine produce. Since December 2002 an ice machine has been installed and is operational on Fakarava. Before this, the lack of ice was the main factor restricting catch being sold to Tahiti.

In addition to the increased costs of investment, operation, maintenance and transport for *parcs*, disputes on ownership rights among Fakarava's families, licensing fees and prices to be paid for locations (an internal system imposed in addition to the fisheries service licensing process and fees) make any further development of *parcs* impossible. The passage of Garuae in the North is too exposed to wind to allow the installation of *parcs* there.

2.2.4 Catch composition and volume – invertebrates: Fakarava

Calculations of the recorded annual catch rates per species groups are shown in Figure 2.14. The graph shows that the only major impact by wet weight is on giant clams (*Tridacna maxima*) and lobsters (*Panulirus* spp.). By comparison, catches reported for *Turbo* spp. shells (*maoa*), *Cypraea annulus* (*kauri porcelaine*) and *Nerita plicata* are of minor if not insignificant importance (Detailed data are provided in Appendices 2.1.2 and 2.1.3.).

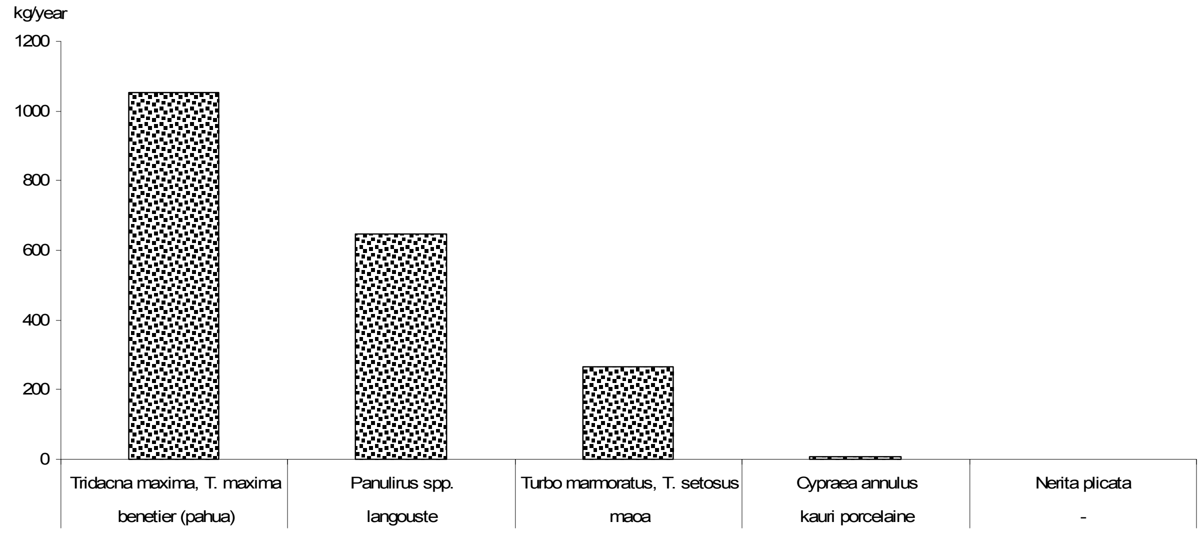

Figure 2.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Fakarava.

As already stated, invertebrate fisheries are limited and not of great importance on Fakarava. Accordingly, the limited biodiversity reported for catches is not surprising. Catches for reeftop gleaners include two species reported by vernacular names, i.e. representing *Turbo* spp. and lobsters, while the lobster fishery and 'other' dive fishery (giant clams) are each represented by one vernacular name only. Intertidal collectors target shells used for artisanal and handicraft purposes, and these are limited to two species groups only (Figure 2.15).

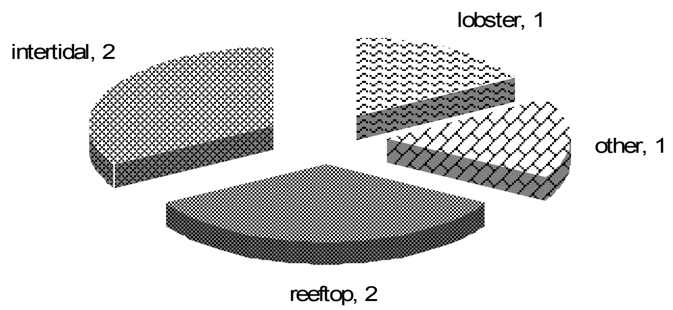

Figure 2.15: Number of vernacular names recorded for each invertebrate fishery in Fakarava.
'Other' refers to the giant clam fishery.

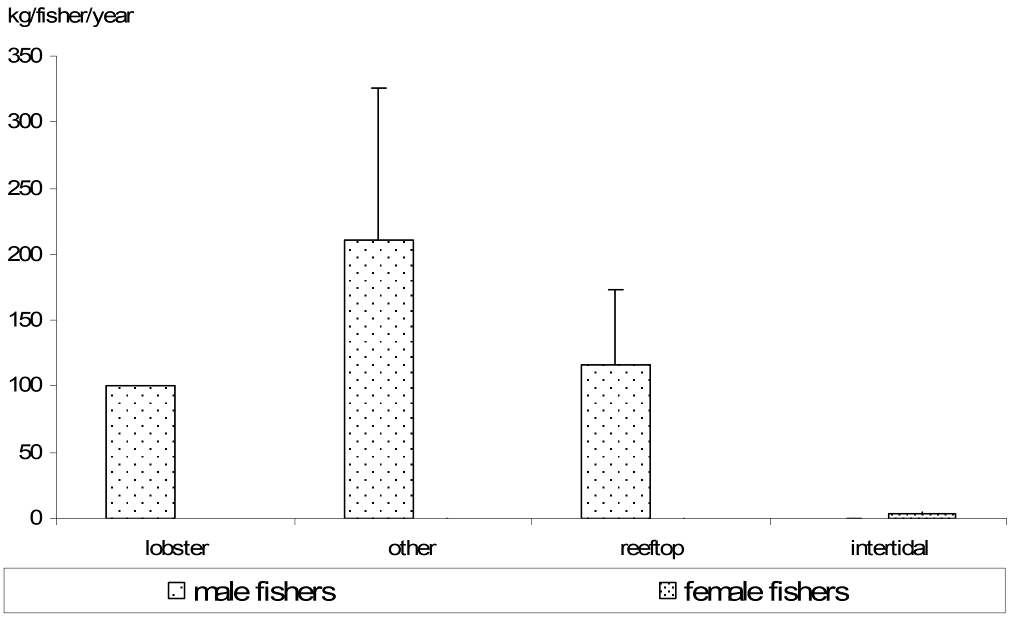

Figure 2.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Fakarava.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 13 for males, n = 2 for females).

Figure 2.16 shows that average annual catches of invertebrates are generally low. The highest catches by wet weight are obtained by giant clam divers, who may collect each as much as 200 kg/year of wet weight. Reeftop gleaners targeting *Turbo* shells and lobsters capture around 100 kg of catch/fisher/year which is similar to the catch rate of lobster fishers. The annual catch taken by intertidal gleaners is insignificant.

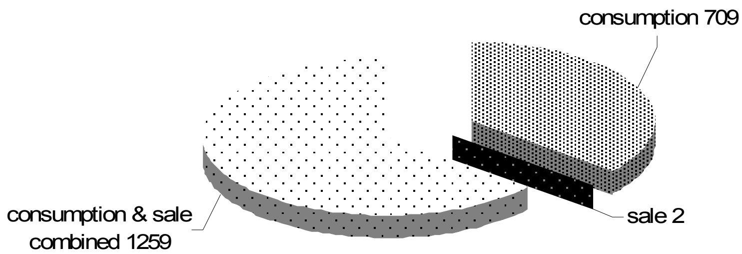

Figure 2.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Fakarava.

As compared to finfish fishers, invertebrate fishers do sell their produce, but mostly locally. A small proportion of lobsters and giant clams may be exported to Papeete, either as a gift or (sometimes) to be sold. However, in general, the share of invertebrate catch that is for sale alone is insignificant. If one assumes that about half of the reported catch that may be used for either sale or consumption may be indeed sold, the total percentage of catch that is sold may not exceed ~30% (Figure 2.17). Due to the geographical location of Fakarava, we can exclude any impact from fishers who are external to the community.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) is relatively small with ~2 t/year (1.95 t/year) (Figure 2.18). According to earlier information, giant clam catches account for the major share, followed by reeftop catches, which mainly consist of *Turbo* shells and lobster. The contributions of exclusive lobster fishing and artisanal shell collection (intertidal) are rather low (5% and 0.4% of the total reported annual catch respectively).

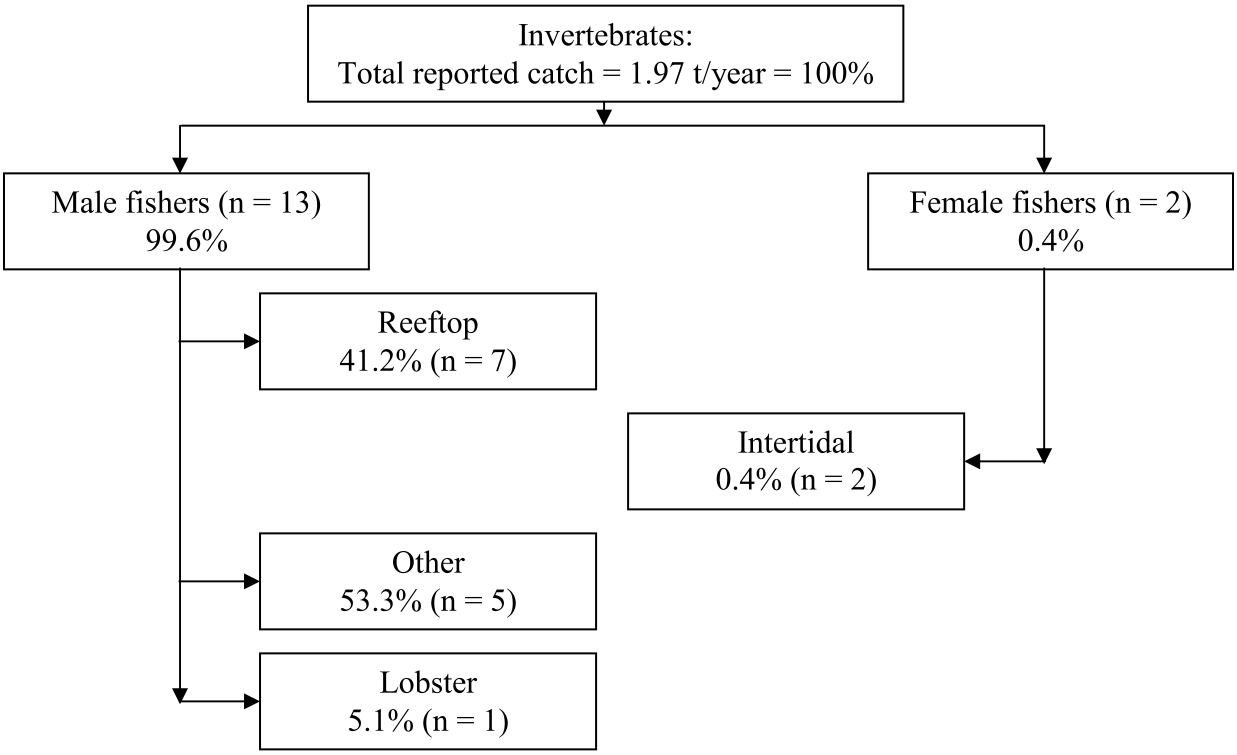

Figure 2.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Fakarava.
'Other' refers to the giant clam fishery; n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

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

Parameters	Fishery / Habitat			
	Reeftop	Intertidal	Other	Lobster [3]
Fishing ground area (km^2)	n/a	n/a	30.1	160.9
Number of fishers (per fishery) [1]	69	43	49	10
Density of fishers (number of fishers/km^2 fishing ground)			1.64	0.06
Average annual invertebrate catch (kg/fisher/year) [2]	115.95 (±57.13)	3.75 (±1.25)	210.44 (±115.81)	99.95 (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] linear measure km reef length; 'Other' refers to the giant clam fishery.

The parameters presented in Table 2.5 show that the total number of fishers per fishery and the reported average annual catch per fisher and fishery are low and suggest that the current fishing pressure on Fakarava's invertebrate resources does not pose a major problem. In this context, it may be noted that pearl farming is a very prominent activity in the Fakarava lagoon. At the time of the survey there were nine pearl farms, four under cooperative ownership and management, and five family operations from Fakarava. However, while some of the harvested meat is consumed locally, the pearl industry serves commercial and export interests (pearls and shells for artisanal purposes) and is therefore widely detached from the subsistence and small-scale artisanal invertebrate fishery of the Fakarava community. For these reasons, pearl farming has not been included in our socioeconomic survey.

There were two reported seasons for trochus harvesting: in 1992 and 1994. The only record of bêche-de-mer harvesting goes back to 1965 and the catch that was locally processed was sold to Papeete. However, local fishers voiced plans to establish a *rori* (bêche-de-mer) fishery. Buyers at Papeete, mainly restaurant owners, had already been identified and plans called for a first try in February 2004.

2.2.5 Fisheries management: Fakarava

At the time of the survey, the governmental authorities, including the Service de la pêche and others, and the community of Fakarava had developed and accepted a management model for the 'Réserve de biosphère des Tuamoto, commune de Fakarava'. This management plan includes various areas where regulations apply at different scales. In the central zone ('l'aire centrale'), a specially designated protected area, any exploitation of algae (*kopara*), turtle (*honu*) and coconut crabs (*kaveu*) is forbidden. Certain regulations apply for other zones, such as transitions between the central protected area and other-use zones.

Knowledge and awareness of the regulations concerning giant clam fisheries in Fakarava's fishing ground varied considerably among respondents.

2.2.6 Discussion and conclusions: socioeconomics in Fakarava

- The Fakarava community mainly relies on reef and lagoon fisheries for subsistence purposes. Due to increased ciguatera poisoning the island is no longer visited by a commercial fishery boat. Air cargo freight volume for fresh marine produce is very limited. Thus, there are few opportunities for commercial reef fisheries on Fakarava, either for fish or for invertebrates. This conclusion is supported by the fact that only 12% of all households reported that they depended on fisheries for their first income source. However, there are nine pearl farms on Fakarava, and all these serve commercial and export interests.

- The high dependence on fisheries produce for subsistence purposes is seen in the large amount of fish (64 kg/year) that is eaten per person, among the highest of all PROCFish/C sites in French Polynesia. However, only small amounts of invertebrates and canned fish are eaten.

- Because our survey sample included the main commercial male fishers, the data overestimate the proportion of the catch that is sold, and may also have overestimated the average catch rates, at least for passage fishers. In fact, most catch is taken for subsistence needs and social obligations; approximately 6 t of reef fish may be exported to friends and relatives elsewhere; and another 1–2 t/year of reef fish may be imported from the neighbouring Faaite atoll to complement local demand. The total annual subsistence demand of the Fakarava community is estimated at 65.6 t/year.

- Highest current fisher density for finfish fisheries exists on the outer reefs, followed by the sheltered coastal reef (including accessible reef flats) and lagoon habitats. At the time of the survey, one family was operating 3–4 *parcs* (permanent fish traps) in the southern passage of Toau. Seven other *parcs* located in the passage of Tamanau were closed in 2003. The average annual reported catches of fishers targeting the different habitats do not differ significantly, except for outer-reef fishers, who are much less productive. Conversely, the average CPUE reported from the outer reef is the highest of all habitats fished.

- Overall, catch data from finfish fishers suggest fishing pressure is currently low taking into account the total annual catch reported per available reef and total fishing ground area. Overall, population density per reef area or total fishing ground surface is low, and so is fisher density. Finfish fisheries are almost exclusively conducted for subsistence needs, which significantly limits the impact on these resources.

- Invertebrate fisheries are far less important and, apparently, were never very important, even in the past. Two trochus seasons were reported, both in the 1990s, and one bêche-de-mer harvesting activity in 1964, with catch sold to Papeete. Giant clam collection represented the highest impact by wet weight, followed by the collection of lobsters and shells of *Turbo* spp. At the time of the survey, there were plans to establish a bêche-de-mer fishery in early 2004.

- The total number of fishers, fisher density calculated for habitats known in size or length and the average annual reported catch per fisher, all suggest that current fishing pressure is low. The pearl industry does play a vital role, but was not included in this survey.

- Overall, average annual catch rates of invertebrates fishers are low and may not exceed 210 kg wet weight/fisher/year. Sales, either locally or as export to Tahiti may not exceed ~30% of the total annual reported catch.

- The very few females who take part in fisheries are all family members of the fish commercial *parc* fishery, and/or also collect shells for artisanal and handicraft purposes.

- At the time of the survey the management model 'Réserve de biosphère des Tuamotu, commune de Fakarava' was being developed and discussed between governmental and communal authorities.

- There is no reason to assume that fishing pressure may increase in the future because of the following factors.
  - Most of the very effective and commercial *parcs* have been closed because they were no longer economically viable.
  - Access to external marketing is lacking due to transport limitations and increased risk of ciguatera fish poisoning.
  - There is limited interest in invertebrate fisheries.
  - A management model that may limit fisheries in the future has been put in place.
  - The population on Fakarava is relatively stable and small.

- Current fishing pressure seems to pose no detrimental impact on any of the resources targeted. However, in the past, when commercial and export-oriented operations were still an option, fishing pressure may have been much higher.

2.3 Finfish resource surveys: Fakarava

Finfish resources and associated habitats were assessed between 19 and 25 March 2004, from a total of 24 transects (6 intermediate, 12 back- and 6 outer-reef transects, see Figure 2.19 and Appendix 3.1.1 for transect locations and coordinates respectively.).

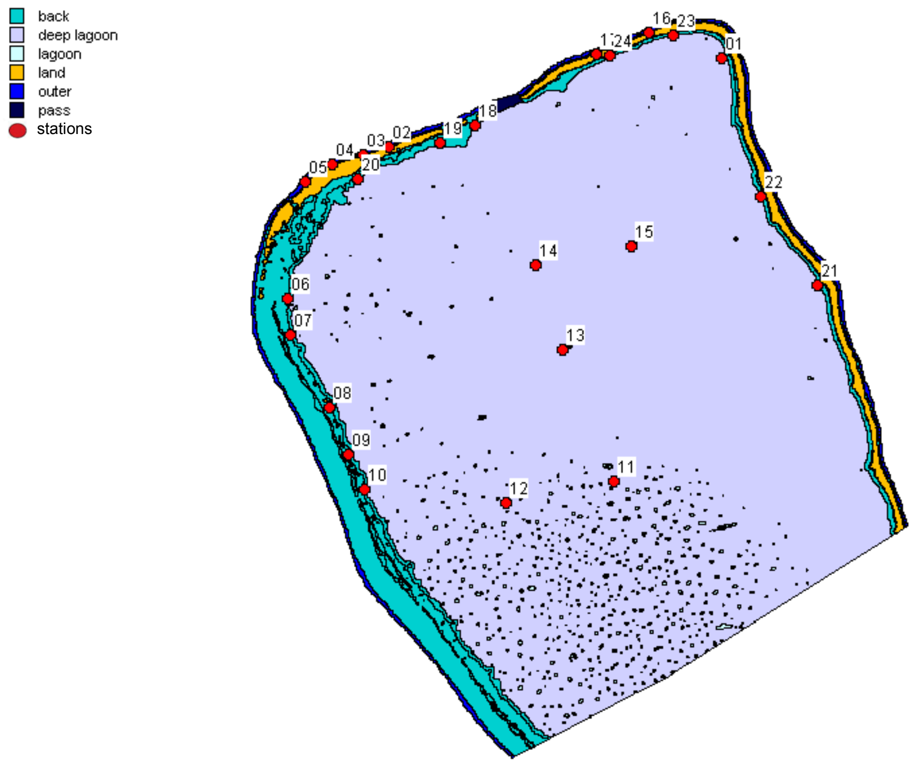

Figure 2.19: Habitat types and transect locations for finfish assessment in Fakarava.

2.3.1 Finfish assessment results: Fakarava

A total of 19 families, 49 genera, 133 species and 6885 fish were recorded in the 24 transects (See Appendix 3.1.2 for list of species.). Only data on the 13 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 40 genera, 119 species and 6745 individuals.

Finfish resources differed greatly among the three reef environments found in Fakarava (Table 2.6). The outer reef contained the greatest number of fish (0.6 fish/m^2), species (44 species/transect), and the largest biomass (120 g/m^2). In contrast, the back-reef displayed the lowest number of fish (0.3 fish/m^2) and species (27 species/transect), and the lowest size (15 cm) and biomass (50 g/m^2). Intermediate reefs showed intermediate values (density: 0.5 fish/m^2; biomass: 103 g/m^2).

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

Parameters	Habitat			
	Intermediate reef [(1)]	Back-reef [(1)]	Outer reef [(1)]	All reefs [(2)]
Number of transects	6	12	6	24
Total habitat area (km^2)	6.2	66.6	93.0	83.0
Depth (m)	5 (1–10) [(3)]	3 (1–6) [(3)]	7 (4–11) [(3)]	5 (1–11) [(3)]
Soft bottom (% cover)	11 ±5	16 ±4	1 ±0	14
Rubble & boulders (% cover)	19 ±5	23 ±3	8 ±3	17
Hard bottom (% cover)	48 ±7	46 ±6	37 ±3	43
Live coral (% cover)	21 ±4	14 ±4	50 ±6	27
Soft coral (% cover)	0 ±0	0 ±0	3 ±1	1
Biodiversity (species/transect)	35 ±3	27 ±2	44 ±2	33 ±2
Density (fish/m^2)	0.5 ±0.1	0.3 ±0.0	0.6 ±0.0	0.4
Size (cm FL) [(4)]	17 ±1	15 ±1	18 ±1	17
Size ratio (%)	51 ±2	41 ±2	59 ±2	48
Biomass (g/m^2)	103.5 ±23.6	50.2 ±16.2	120.3 ±19.8	78.2

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

Intermediate-reef environment: Fakarava

The intermediate-reef environment of Fakarava was dominated by two herbivorous families Acanthuridae and Scaridae, both in terms of density and biomass (Figure 2.20), represented by 33 species. Particularly high abundance and biomass were recorded for *Hipposcarus longiceps, Chlorurus microrhinos, Scarus altipinnis, S. schlegeli, Acanthurus lineatus, Chlorurus sordidus, Ctenochaetus striatus* and *A. albipectoralis* (Table 2.8). This reef environment presented a moderately diverse habitat with hard bottom predominating (48% cover) (Table 2.6 and Figure 2.20).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus albipectoralis*	Whitefin surgeonfish	0.04 ±0.03	28.0 ±18.5
	Acanthurus lineatus	Lined surgeonfish	0.02 ±0.01	6.2 ±4.4
	Ctenochaetus striatus	Striated surgeonfish	0.06 ±0.02	4.1 ±1.2
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.02 ±0.00	10.2 ±2.9
	Chlorurus microrhinos	Steephead parrotfish	0.01 ±0.00	8.8 ±4.3
	Chlorurus sordidus	Daisy parrotfish	0.05 ±0.01	7.0 ±1.4
	Scarus altipinnis	Filamentfinned parrotfish	0.01 ±0.00	4.6 ±2.2
	Scarus schlegeli	Schlegel's parrotfish	0.01 ±0.01	2.6 ±1.7

The density, biomass and biodiversity of fish on the back-reef of Fakarava are the highest among the five country sites. When compared to the other reef habitats of Fakarava, the intermediate reefs displayed the second-highest biomass, density and biodiversity, second only to the outer-reef values. Similar to the sheltered coastal and back-reef environments, there were more herbivorous than carnivorous fish (2.5 times higher density and four times higher biomass for herbivores) in Fakarava intermediate reefs (Figure 2.20). These differences were due to the near absence of carnivorous Labridae, Lutjanidae and Lethrinidae. Size ratios of Labridae, Lethrinidae, Mullidae and Scaridae were the lowest in the fish community and well below 50%, probably suggesting a response to exploitation.

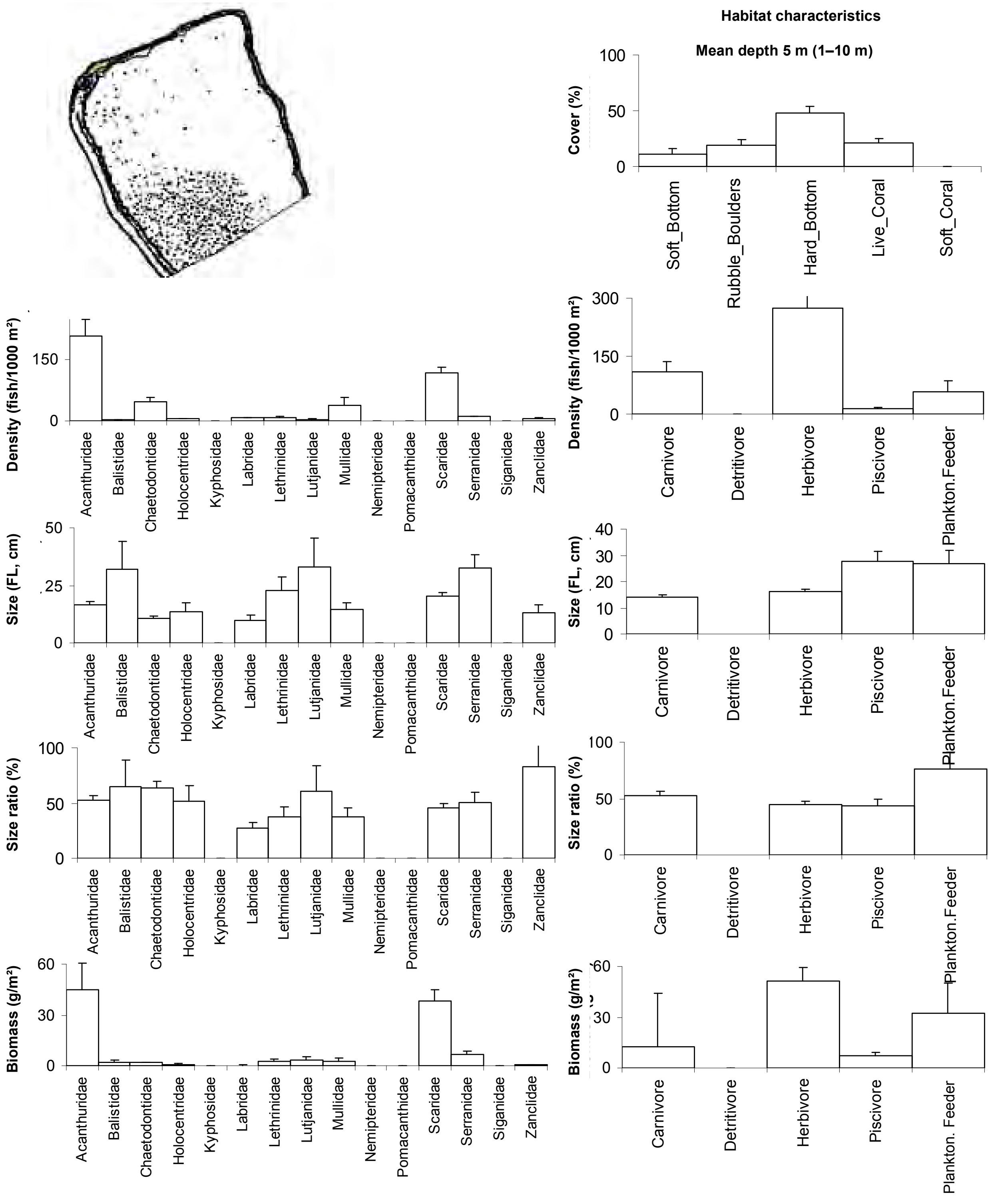

Figure 2.20: Profile of finfish resources in the intermediate-reef environment of Fakarava.
Bars represent standard error (+SE); FL = fork length.

However, the intermediate reef of Fakarava displayed very little soft bottom (11%), a substrate generally favourable to such carnivorous species, compared to similar reef habitats across the country. These natural differences in substrate may at least partially explain the particular nature of the trophic structure, which was highly dominated by herbivores. Similar to the coastal reefs, the most frequently fished families recorded were Scaridae and Acanthuridae.

Back-reef environment: Fakarava

The back-reef environment of Fakarava was dominated by two families of herbivorous fish: Acanthuridae and Scaridae and one family of carnivorous fish: Mullidae (Figure 2.21). These families were represented by 36 species; particularly high abundance and biomass were recorded for *Mulloidichthys flavolineatus*, *Chlorurus sordidus*, *Ctenochaetus striatus*, *Acanthurus triostegus, A. nigricauda*, *A. lineatus* and *Scarus altipinnis* (Table 2.9). This reef environment presented a moderately diverse habitat with hard bottom predominating (46% cover) (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 sheltered coastal reef environment of Fakarava

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05 ±0.01	2.8 ±0.9
	Acanthurus triostegus	Convict tang	0.04 ±0.01	1.5 ±0.5
	Acanthurus nigricauda	Epaulette surgeonfish	0.01 ±0.01	5.6 ±2.7
	Acanthurus lineatus	Lined surgeonfish	0.01 ±0.01	4.8 ±2.8
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.07 ±0.06	6.4 ±6.3
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05 ±0.01	3.4 ±1.2
	Scarus altipinnis	Filamentfinned parrotfish	0.01 ±0.01	7.5 ±4.1

The density, size, biomass and biodiversity of finfish of the back-reefs of Fakarava were the lowest among the three types of reef habitats. When comparing this site with the other four sites of French Polynesia, Fakarava back-reefs displayed the second-lowest value of biomass and the lowest values of density. The trophic structure in Fakarava back-reefs was strongly dominated by herbivorous species in terms of density (three times more herbivorous than carnivorous fish) and biomass. Herbivore size ratio, especially that of Scaridae and Acanthuridae, was well below 50%. The back-reef of Fakarava displayed a rather high percentage of hard bottom (46%) and a low percentage of soft bottom (16%). Such environmental differences in substrate may explain why herbivorous fish are particularly abundant since they are generally associated with hard-bottom substrates.

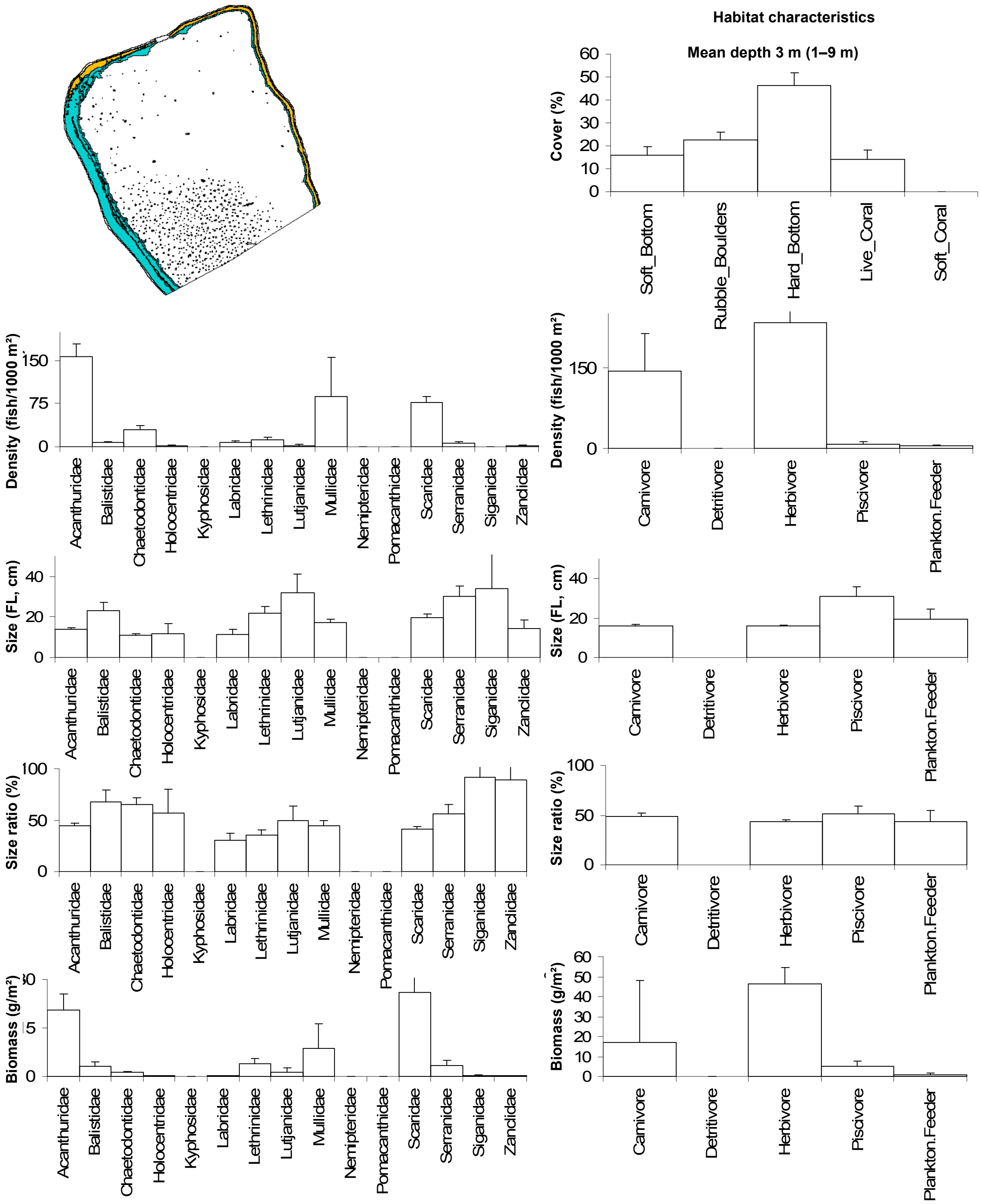

Figure 2.21: Profile of finfish resources in the back-reef environment of Fakarava.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Fakarava

The outer reef of Fakarava was dominated, both in terms of density and biomass, by herbivorous Acanthuridae and Scaridae and carnivorous Balistidae, Serranidae, Chaetodontidae, in terms of density only, and Lutjanidae for biomass only (Figure 2.22). These six families were represented by 55 species; particularly high abundance and biomass were recorded for *Melichthys niger*, *M. vidua, Acanthurus nigricans*, *Cephalopholis argus*, *Lutjanus gibbus*, *L. bohar*, *Chlorurus sordidus*, *Naso vlamingii*, *Acanthurus thompsoni*, *Balistapus undulatus* and *Ctenochaetus striatus* (Table 2.10). Hard bottom cover (37%) was high but the habitat was largely dominated by a high cover of live coral (50%, Table 2.6 and Figure 2.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus nigricans*	Whitecheek surgeonfish	0.07 ±0.02	8.2 ±2.3
	Naso vlamingii	Bignose unicornfish	0.01 ±0.01	5.3 ±3.0
	Acanthurus thompsoni	Thompson's surgeonfish	0.06 ±0.02	4.6 ±1.8
	Ctenochaetus striatus	Striated surgeonfish	0.05 ±0.02	3.5 ±1.4
Balistidae	*Melichthys niger*	Black triggerfish	0.05 ±0.02	11.7 ±5.1
	Melichthys vidua	Pinktail triggerfish	0.03 ±0.01	8.5 ±3.1
	Balistapus undulatus	Orangestriped triggerfish	0.02 ±0.00	3.9 ±0.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04 ±0.01	5.4 ±1.1
Serranidae	*Cephalopholis argus*	Peacock grouper	0.02 ±0.01	7.6 ±1.8
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.01 ±0.01	7.6 ±4.2
	Lutjanus bohar	Twinspot snapper	0.01 ±0.00	6.0 ±4.0

The size and size ratio of finfish in the outer reef of Fakarava were higher than those recorded in the other study sites of the region (Table 2.6). However, density, biomass and biodiversity were among the lowest values. The trophic composition was only slightly dominated by herbivores. The fish community composition was rather complex and defined by dominance of many families. Among these, Acanthuridae and Scaridae are the main families caught from this habitat. Size ratios of Scaridae as well as Labridae and Mullidae, were below 50% and this would suggest a strong impact on such selected families. Substrate composition showed a strong dominance of hard bottom and live coral (88%) explaining the high abundance of Acanthuridae, Scaridae and Balistidae. Chaetodontidae were in high abundance due to the very high percentage of live coral (50%).

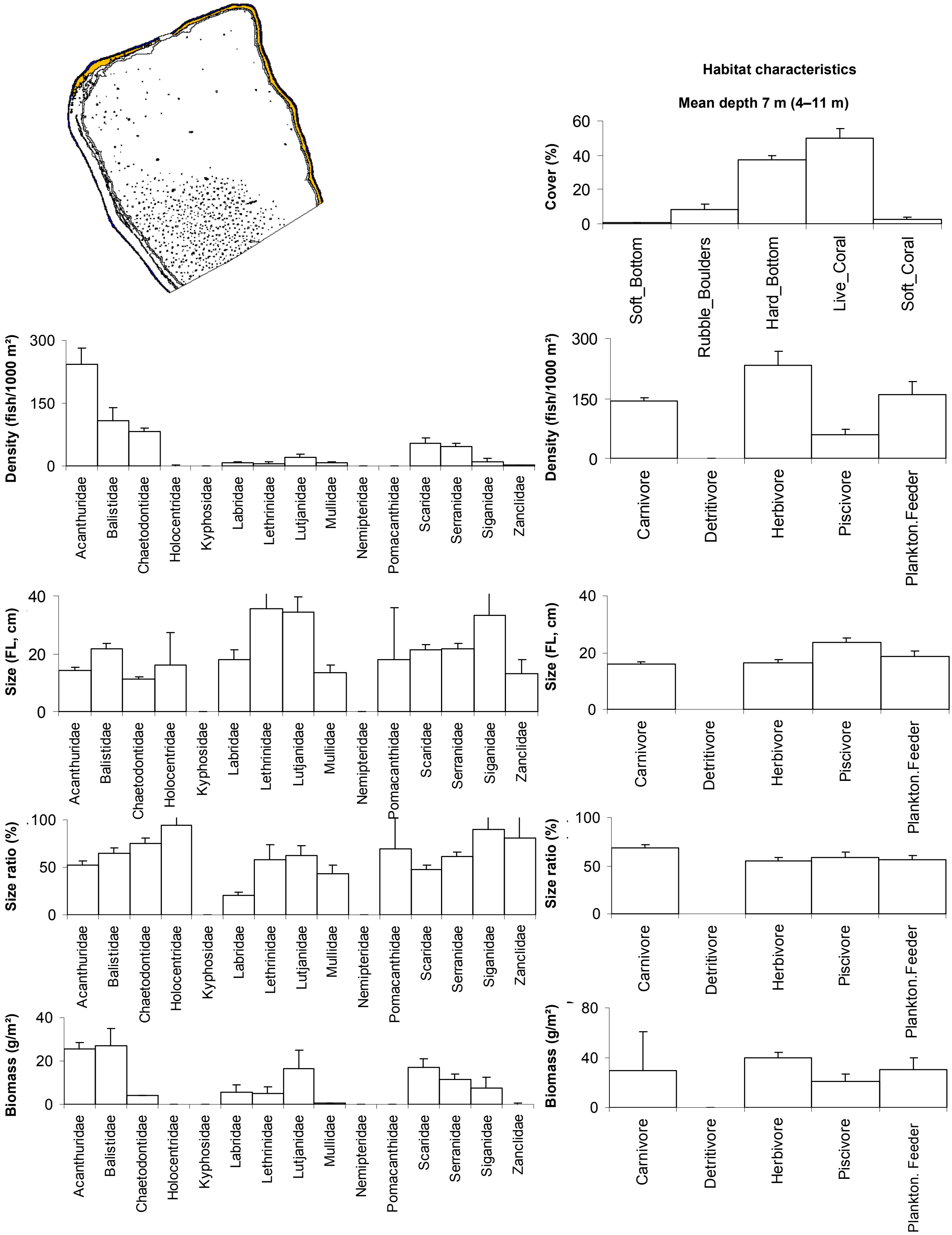

Figure 2.22: Profile of finfish resources in the outer-reef environment of Fakarava.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Fakarava

Over all the reef habitats combined, the fish assemblage of Fakarava was dominated, in terms of density and biomass, by the herbivore families Acanthuridae and Scaridae and the carnivores Mullidae (Figure 2.23). These three families were represented by a total of 46 species, dominated by *Mulloidichthys flavolineatus*, *Chlorurus sordidus*, *Ctenochaetus striatus*, *Chlorurus microrhinos*, *Scarus altipinnis*, *Acanthurus nigricauda* and *A. lineatus* (Table 2.11). Hard-bottom cover (43%) dominated the habitat and cover of live coral was fairly high (27%, Table 2.6 and Figure 2.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05	3.9
	Chlorurus microrhinos	Steephead parrotfish	0.01	7.3
	Scarus altipinnis	Filamentfinned parrotfish	0.01	6.7
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05	3.0
	Acanthurus nigricauda	Epaulette surgeonfish	0.01	4.5
	Acanthurus lineatus	Lined surgeonfish	0.01	4.3
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.05	5.3

Over all reef habitats, Fakarava showed the highest biodiversity and biomass among the five PROCFish/C sites. The trophic structure was dominated by herbivores, which displayed a biomass more than twice as high as carnivores. Hard bottom dominated substrate and live coral displayed the second highest value after Mataiea. Soft bottom represented about one fifth of the total substrate surface. Since carnivores are in general associated with soft-bottom substrates, their low presence could be explained by such substrate composition. Size ratio was below the 50% level for Acanthuridae, Labridae, Lethrinidae, Mullidae and Scaridae, suggesting a negative response of these families to a high level of exploitation.

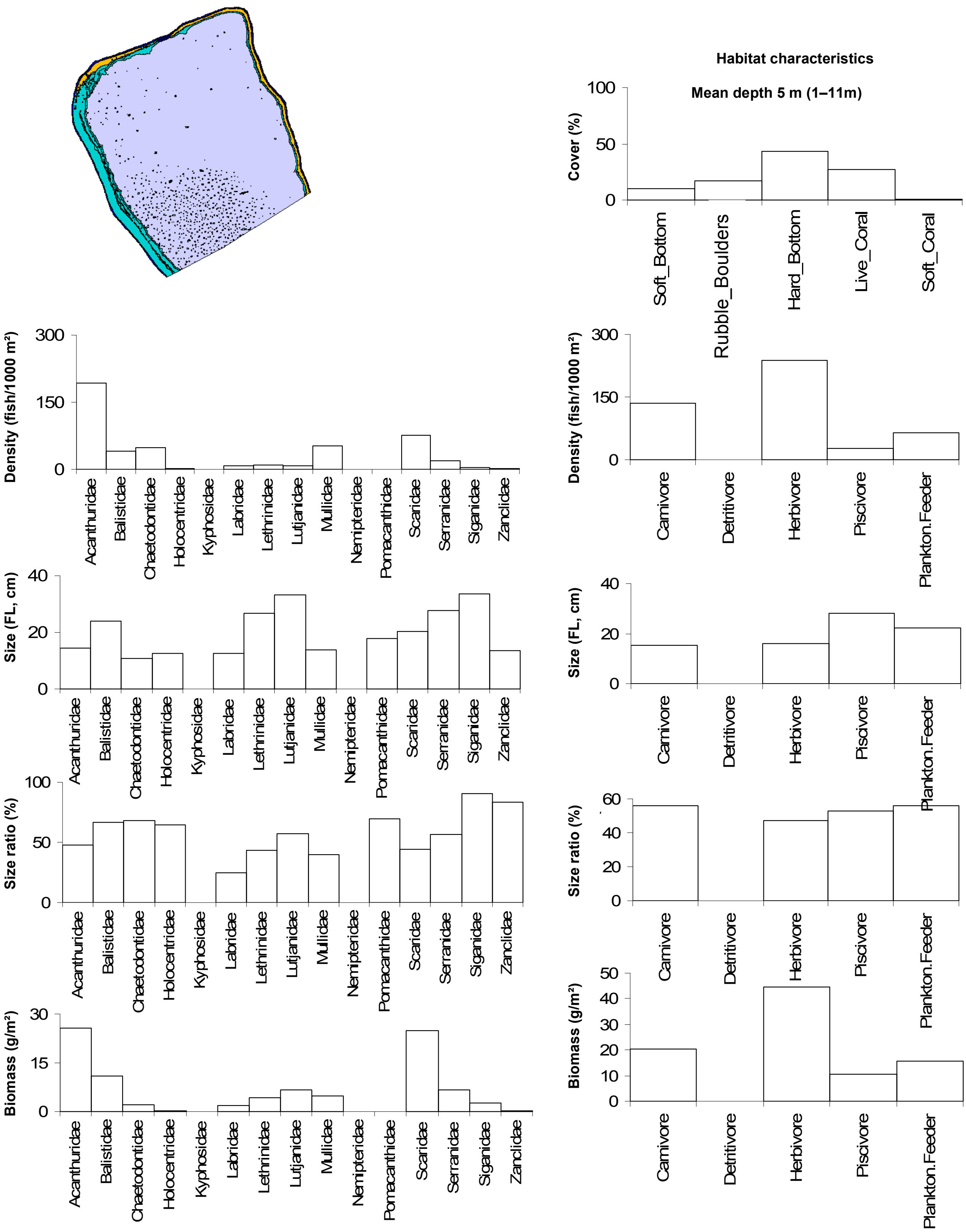

Figure 2.23: Profile of finfish resources in the combined reef habitats of Fakarava (weighted average).
FL = fork length.

2.3.2 Discussion and conclusions: finfish resources in Fakarava

The finfish resource assessment indicated that the status of finfish resources in this site is relatively poor, especially in the back-reefs. This is reflected in the low average fish size and size ratios for all habitats, especially back-reef. Fish traps were used in outer reefs in the past but have been abandoned in the last 4–5 years, further releasing pressure on this habitat. In fact in the outer reefs, density, biomass and fish sizes were the highest among all habitats and among the highest of the five sites, proving the resources here are in better condition compared to the more exploited habitats.

- Overall, Fakarava finfish resources appeared to be in relatively poor condition. Although, biomass was the second-highest among the five sites, both density and size ratio were the lowest. Size ratio was below 50% for Acanthuridae, Labridae, Lethrinidae, Mullidae and Scaridae indicating a strong impact on these target families.

- Early signs of impacts on carnivore species (especially Lethrinidae) were suggested by the low density and biomass, and small size of these fish in all reefs.

- Fish from the lagoon and back-reefs, where fishing pressure is higher, were much smaller in size, an early sign of over exploitation.

2.4 Invertebrate resource surveys: Fakarava

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

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

Table 2.12: Number of stations and replicate measures completed at Fakarava

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	11	66 transects
Reef-benthos transects (RBt)	16	96 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)	0	0 search period
Reef-front searches (RFs)	5 RFs 5 RFs_w	31 search periods 32 search periods
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	2	12 search periods

RFs_w = reef-front search by walking.

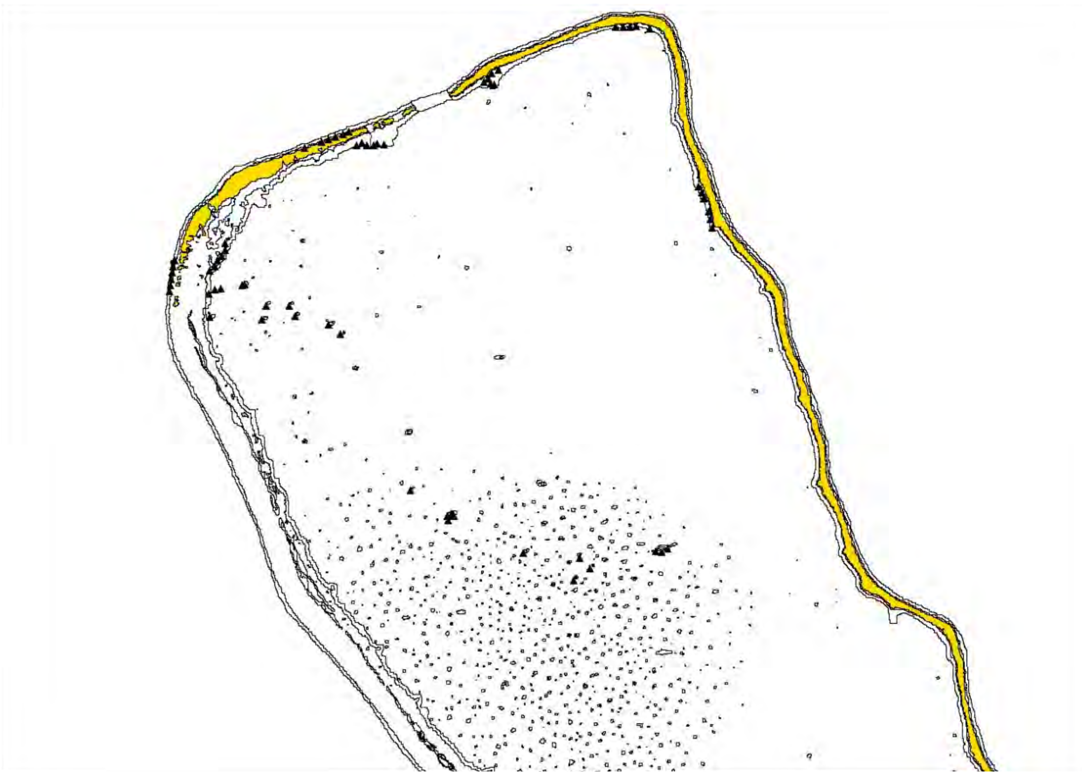

Figure 2.24: Broad-scale survey stations for invertebrates in Fakarava.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

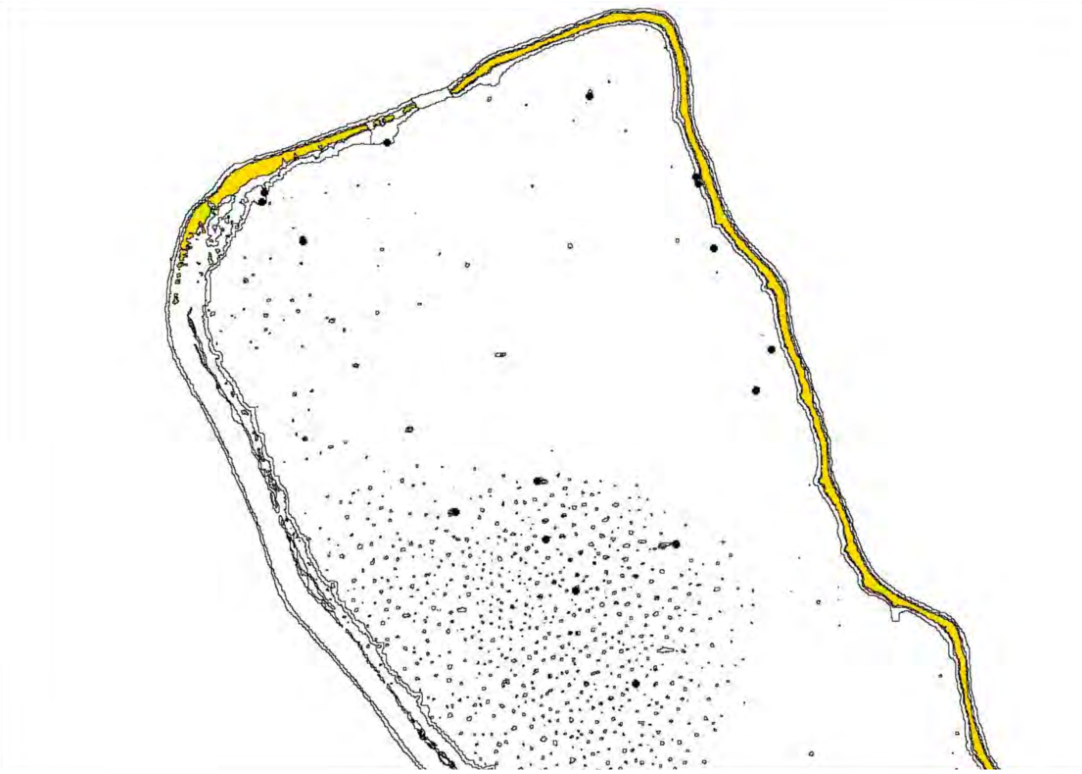

Figure 2.25: Fine-scale reef-benthos transect survey stations and soft-benthos transect stations for invertebrates in Fakarava.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

Figure 2.26: Fine-scale survey stations for invertebrates in Fakarava.
Grey triangles inverted: reef-front search stations (RFs);
grey triangles: reef-front search by walking stations (RFs_w);
black squares: mother-of-pearl transect stations (MOPt);
grey stars: sea cucumber day searches stations (Ds).

Twenty-six species or species groupings (groups of species within a genus) were recorded in the Fakarava invertebrate surveys: 4 bivalves, 8 gastropods, 8 sea cucumbers, 4 urchins, and 1 sea star (Appendix 4.1.1). Information on key families and species is detailed below.

2.4.1 Giant clams: Fakarava

Broad-scale sampling provided an overview of giant clam distribution at Fakarava. Shallow-reef habitat that is suitable for giant clams was very extensive in this, the second-largest atoll system in the world (60.6 km^2: approximately 45.5 km^2 within the lagoon and 15.1 km^2 on the reef front or slope of the barrier). Unlike in the PROCFish/C high-island sites of Mataiea and Raivavae, the lagoon at Fakarava was very large (1197 km^2, three times the size of that in Tikehau) and, as is characteristic of open atolls, greatly influenced by oceanic conditions. The low-lying atoll was relatively open to the elements and had dynamic water flow (one major passage at either end). Patch reef habitat (and *motu*) could be found mainly in the west and southwest of the survey area, which reached almost halfway down the lagoon to the south (Figure 2.24).

Reefs at Fakarava held one species of giant clam: the elongate clam *Tridacna maxima*. Records from broad-scale sampling revealed that *T. maxima* was widely distributed (found in 11 of 11 stations and 61 of 66 transects). The average station density of *T. maxima* in broad-scale assessments was 4503.3 /ha ±1934.6 (Figure 2.27).

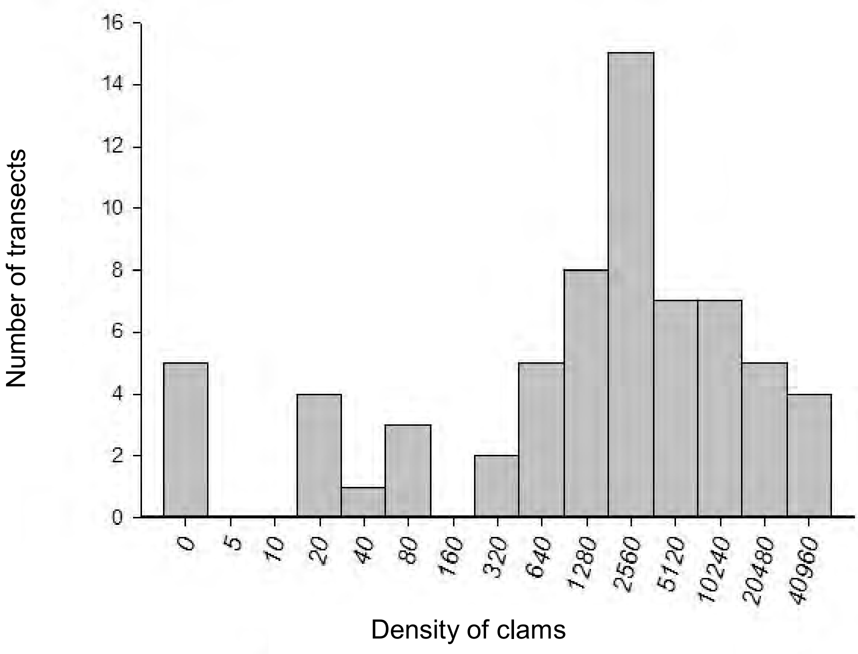

Figure 2.27: Frequency plot of density per 300 m transect measures (per ha) for *Tridacna maxima* clam at Fakarava, based on all broad-scale assessment stations.
Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of shallow reef and clam habitat (Figure 2.28). In these reef-benthos assessments (RBt), *Tridacna maxima* was present in 100% of stations at a mean density of 8507.8 /ha ±1575.3.

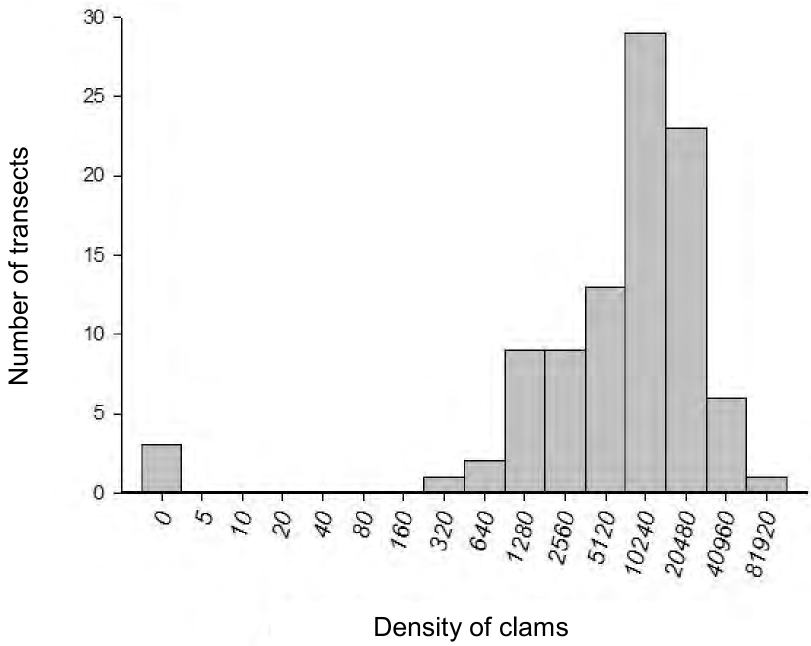

Figure 2.28: Frequency plot of density per 40 m transect measures (per ha) for *Tridacna maxima* clam at Fakarava, based on all fine-scale reef-benthos transect assessment stations. Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Shallow reefs with the greatest mean density of *T. maxima* (The top 10 RBt stations contained 7583–25,042 clams/ha) were not centred on the passage and were well distributed around the lagoon, including near main settlement areas. Clams were relatively abundant in Fakarava; the average density for the station with the highest density was >2.5 clams/m^2.

Of the 2296 records taken during all assessments, the average length of *T. maxima* was 9.8 cm ±0.1. The mean from shallow reef-benthos stations was similar at 9.9 cm ±0.1. A full range of lengths for *T. maxima* was recorded in survey (Figure 2.29), although, even on exposed reefs outside the barrier, clams were smaller than found in other parts of the Pacific and not generally larger than 19 cm in length (mean 13.8 cm ±0.4).

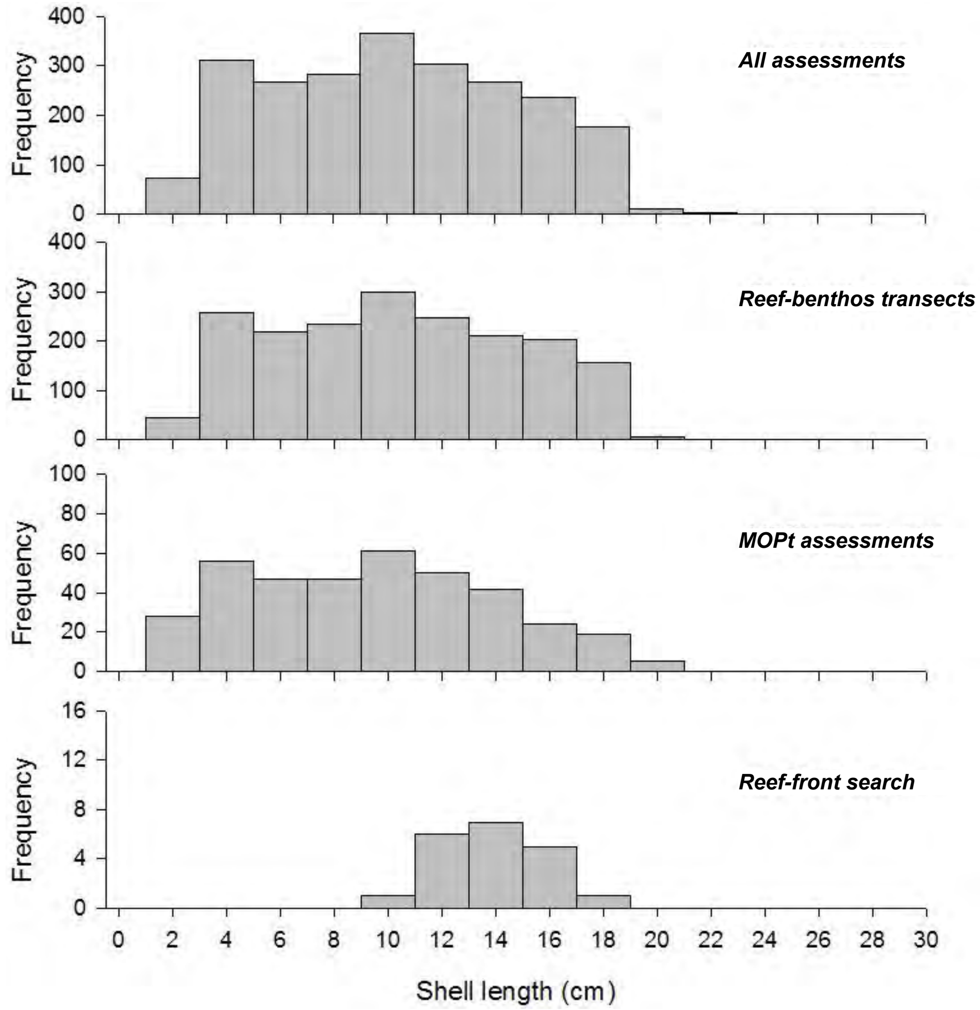

Figure 2.29: Size frequency histograms of giant clam (*Tridacna maxima*) shell length (cm) for Fakarava.

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

At approximately 16°S, Fakarava is well within the latitude where the commercial topshell, *Trochus niloticus*, is found in the Pacific. However, French Polynesia is positioned to the east of the natural distribution (limit Wallis) and their presence is a result of 170 shells that were introduced to Fakarava in 1969 (at the same time as translocations to Tikehau). The source of this stock was Port Vila (Vanuatu) from where, in 1957, 40 specimens were successfully delivered to Tahiti (Yen 1988). The original purpose of introducing trochus to French Polynesia was to counteract the gradual depletion of pearl shell stocks in the islands (Cheneson 1997).

The outer and lagoon reefs at Fakarava constitute extensive suitable benthos for *T. niloticus*, and this area could potentially support significant populations of this commercial species (74.6 km lineal distance of exposed reef perimeter). PROCFish/C survey work revealed that *T. niloticus* was mainly present on reefs inside the lagoon and passage of Fakarava; the outer-reef slope and barrier reeftops did not hold significant numbers of trochus. The suitability of reefs for grazing gastropods was highlighted by high trochus densities, but no great green turban (*Turbo marmoratus,* also called green snail) has been successfully introduced to Fakarava, nor is the green topshell (*Tectus pyramis*) found as far east as French Polynesia (Its range only extends to Samoa and Tonga.).

Table 2.13: Presence and mean density of mother-of-pearl species in Fakarava
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	55.9	18.6	7/11 = 64	27/66 = 41
RBt	1921.9	740.1	14/16 = 88	57/96 = 59
RFs	0.7	0.5	2/5 = 40	2/32 = 6
MOPt	192.7	172.5	2/4 = 50	8/24 = 33
Pinctada margaritifera				
B-S	9.0	2.3	6/11 = 55	17/66 = 26
RBt	10.4	4.7	4/16 = 25	4/96 = 4
RFs	0	0	0/5 = 0	0/32 = 0
MOPt	0	0	0/4 = 0	0/24 = 0

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

The distribution of trochus was not limited across the lagoon (total n = 2212 individuals recorded); however, the majority of the stock was found in very shallow reef areas (depth ~1.5 m). Trochus density on shallow reef-benthos stations ranged from 42 to 10,833 (highest density, as in Mataiea, ≥1 /m^2), with half the stations having densities over 600 /ha. This threshold of 600 /ha is the suggested minimum density that main aggregations should have reached before commercial fishing can be considered. As with other sites in French Polynesia, few trochus were seen on the reef slope and barrier reeftop at Fakarava. It is suggested that the very large oceanic swells (and related morphology of reef) and low levels of epiphytic growth on these substrates might have limited the presence of trochus in these locations. If fishing is considered in the near future, there may also be merit in transplanting some trochus from reefs holding high densities to other suitable areas of Fakarava to extend the distribution of stock as, in general, trochus eggs tend to recruit close to the parent stock.

Although small trochus are very cryptic, the shell size classes recorded during survey (Figure 2.30) indicate that recruitment is taking place and 'new' young trochus are entering the population (First maturity of trochus is at 7–8 cm, i.e. at ~3 years of age.). The mean basal width of trochus at Fakarava was 10.2 cm ±0.06 (n = 583). The fact that 24% of the measured stock were above the legal size of 11 cm highlights the significant number of older mature shells (valuable broodstock) that would be protected from fishing if there were any commercial harvests. This estimate of the protected portion of the population is slightly conservative, as shallow-reef assessments, where most of the length measurements were taken, are generally at the preferred depth for younger shell, with larger, mature trochus preferring to live slightly deeper.

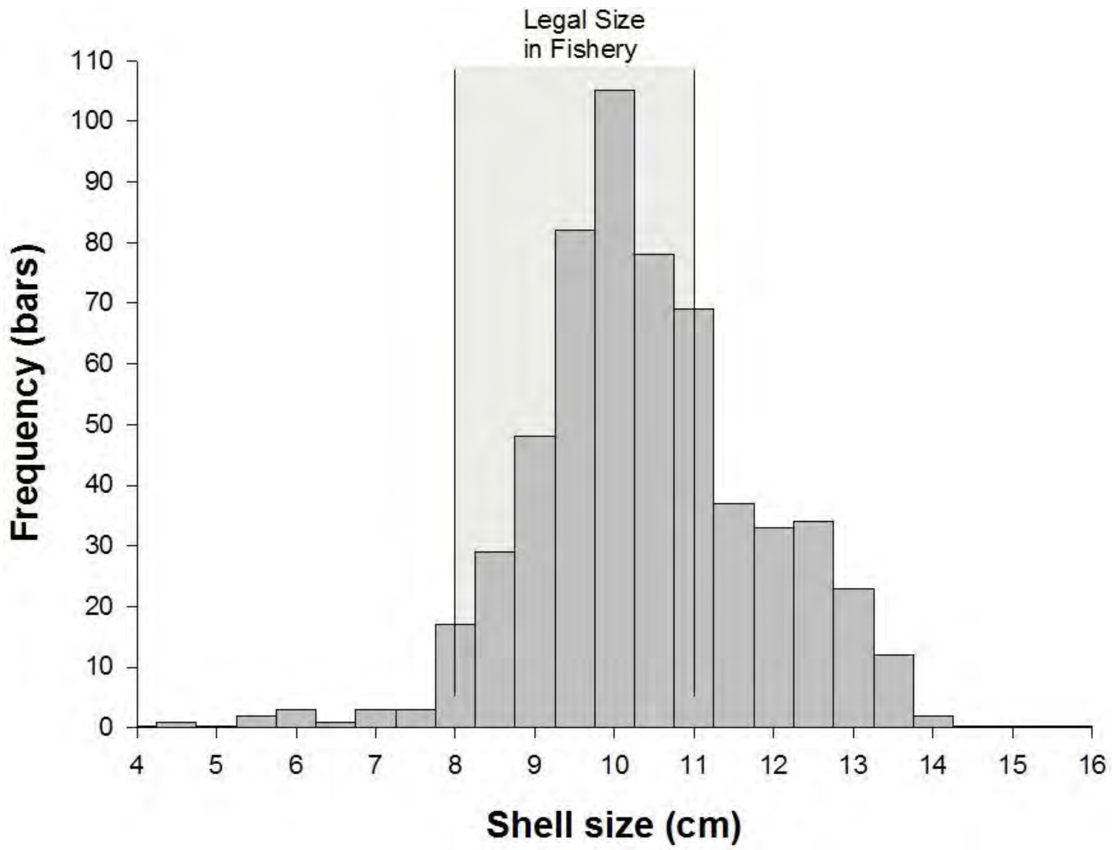

Figure 2.30: Size frequency histogram of giant clam shell base diameter (cm) for Fakarava.

Despite blacklip pearl oysters, *Pinctada margaritifera*, being cryptic, densities in more 'closed' lagoons can be relatively high when compared to more 'open' lagoon systems (such as those found at Mataiea). Survey records reveal blacklip oysters to be relatively common in the lagoon, with 44 shells recorded in survey (mean anterior–posterior measure 15.9 cm ±0.4). In Fakarava, the two passes may limit the concentration of pearl shell spawn to the lagoon and therefore spat are generally collected from more enclosed neighbouring atolls. However, blacklip are farmed commercially for the production of pearls at Fakarava, so elevated levels of spawning from the farmed stock would be expected.

2.4.3 Infaunal species and groups: Fakarava

The soft-benthos coastal margin of the shallow-water lagoon was sandy without seagrass or muddy areas, and did not hold concentrations of in-ground resources (shell 'beds'), such as arc shells (*Anadara* spp.) or venus shells (*Gafrarium* spp.). Therefore, no fine-scale assessments or infaunal stations (quadrat surveys) were made on soft benthos.

2.4.4 Other gastropods and bivalves: Fakarava

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), and *Lambis lambis* were recorded at low-to-medium density in broad-scale and finer-scale surveys (39 individuals recorded), but the strawberry or red lipped conch *Strombus luhuanus* was not present (Appendices 4.1.1 to 4.1.7). Out of the small turban shells, only *Turbo setosus* was relatively common (present in four of five reeftop search_walk stations, density 51.8 /ha ±12.6) and some *Turbo crassus* were also recorded at low density in reef-front searches within the breakers. Other resource species targeted by fishers (e.g. *Conus, Cypraea* and *Thais*) were also recorded during independent survey (Appendices 4.1.1 to 4.1.7). 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 4.1.7. No creel survey was conducted at Fakarava.

2.4.5 Lobsters: Fakarava

Fakarava had a very extensive area of exposed reef front (161 km lineal distance of barrier reef). This exposed reef front, with numerous *hoa*, and areas of submerged back-reef, represents a significant habitat for lobsters, which settle as transparent miniature versions of the adult (pueruli, 20–30 mm in length) after 6–12 months of floating in ocean currents. There was no dedicated night assessment work at Fakarava, and no lobsters (P*anulirus* spp. or *Parribacus* spp). were recorded in any of the daytime surveys (See Methods and Appendix 1.3.).

2.4.6 Sea cucumbers[6]: Fakarava

Fakarava is a large, low-lying atoll system, with a moderately deep, semi-enclosed lagoon. The scale of the system, and the extensive areas of reef margin, shallow reef and sand, provide abundant habitat for sea cucumbers. Outside the barrier the reef slope shelves steeply, is subject to large swell, and is considered less suitable. In general the atoll system is characterised by its oceanic influence, with two principal passes in the north and south, and many *hoa*, ensuring there is active circulation of water between the lagoon and the ocean (There is standing wave at the northern passage during ebb tides.). The small, low-lying land mass has no rivers and the large lagoon is exposed to the trade winds (56 km fetch within the lagoon). Although there were no rivers on the atoll, the reef on the inside edge of the northwest side and reef close to the main settlement was noticeably covered in epiphytes, which characterise higher nutrient loadings. In addition, visibility in the lagoon regularly became unclear as silts from the lagoon floor were stirred up by wind and currents, especially in the afternoons.

At Fakarava only five commercial species of sea cucumber were recorded (Table 2.14), which is similar to at other PROCFish sites in French Polynesia. The low number of sea cucumber species reflects the easterly position of French Polynesia compared to countries closer to the centre of biodiversity (situated further west in the Pacific), and also the lack of nutrient inputs into the system to feed sea cucumbers (Many species eat organic matter in the upper few mm of bottom substrates.). However, the varied environment of the lagoon, passages and barrier reef of Fakarava suited some species more tolerant of oceanic influences.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.14, Appendix 4.1; also see Methods.). In deep-water assessments (average depth 25.6 m) eight white teatfish (*Holothuria fuscogilva*) were recorded, along with two individuals of the low-value amberfish (*Thelenota anax*). These pass dives were over coral gardens (in strong current near the pass) on generally hard substrates that have been commercially fished in the recent past.

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[6] 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.

Of the other species associated with shallow-reef areas, leopardfish (*Bohadschia argus*) was moderately common but not found at high density (found in 30% broad-scale and 13% fine-scale assessments) and high-value black teatfish (*Holothuria nobilis*) was only recorded in one of the two deep-water assessment stations. Surf redfish (*Actinopyga mauritiana*) was recorded across the atoll, but generally at low density. On RFs_w assessments of the barrier, water originating from surf and spray kept the reeftop and pools near the reef front replenished. Surf redfish were recorded at three of five stations; however, no assessment of the southerly sections of the atoll (50 km away from base) were made. These areas are more exposed to swell and may have held greater densities. The fast growing and medium/high-value greenfish (*Stichopus chloronotus*) was not found at any sites in French Polynesia.

The lagoon became 'cloudy' due to the combination of tidal water movement, wind, and a fine, suspended silt load, but the system was generally nutrient poor. Epiphyte levels were low, and coverage by crustose coralline algae, even within the lagoon, was high. Areas of reef and soft benthos in the more protected, enclosed areas of the lagoon did not include blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), pinkfish (*Holothuria edulis*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*) although lower-value species, e.g. lollyfish (*H. atra*) and brown sandfish (*Bohadschia vitiensis*) were moderately common. The brown sandfish is well suited to the softer benthos in more depositional areas of the lagoon.

2.4.7 Other echinoderms: Fakarava

Edible urchins, such as the slate urchin *Heterocentrotus mammillatus*, were recorded at two of the five search stations on the barrier reeftop. No collector urchins (*Tripneustes gratilla*) were recorded in assessments. Other urchins that can be used within assessments as a food source or potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at very low levels (during broad-scale and reef-benthos stations, Appendices 4.1.1 to 4.1.7).

Starfish were very rare at Fakarava; the blue starfish (*Linckia laevigata*) was absent but the coralivore pincushion star (*Culcita novaeguineae*) was noted in higher density than was found at Tikehau (32% of broad-scale stations). No crown of thorns starfish (*Acanthaster planci*) were noted in our survey although records were made in a July 2005 survey of Fakarava (Amadis project 2005).

Table 2.14: Sea cucumber species records for Fakarava

Species	Common name	Commercial value [5]	B-S transects n = 66			Reef-benthos stations n = 16			Other stations RFs = 5; RFs_w = 5; MOPt = 4			Other stations Ds = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.8	16.7	5	7.8	125	6	2.4 2.6	11.8 4.3	20 RFs 60 RFs_w			
Bohadschia argus	Leopardfish	M	11.1	36.5	30	13.0	104.2	13	20.8	41.7	50 MOPt			
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L	23.6	103.6	23	15.6	83.3	19	10.4	41.7	25 MOPt			
Holothuria atra	Lollyfish	L	50.0	206.1	24	276.0	2208.3	13						
Holothuria fuscogilva [4]	White teatfish	H										14.3	14.3	100
Holothuria leucospilota	-	M												
Holothuria nobilis [4]	Black teatfish	H										3.6	7.1	50
Stichopus horrens	Peanutfish	M												
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H	0.3	16.7	2									
Thelenota anax	Amberfish	M										3.6	7.1	50

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

2.4.8 Discussion and conclusions: invertebrate resources in Fakarava

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 in the body of the invertebrate chapter.

- Fakarava had extensive reef suitable for the elongate clam *T. maxima.* Clams were common and at high density in most areas of the lagoon. *T. maxima* displayed a 'full' range of size classes, although the largest clams were somewhat smaller than those found in other parts of the Pacific. The number of small clams in the range of clam sizes indicates that spawning and recruitment are not generally impacted at the sites surveyed. Survey results support the assumption that clam stocks are not significantly impacted by fishing pressure.

- Trochus, *Trochus niloticus*, were common at Fakarava, but mainly limited to shallow-water reef in the lagoon. The protection of trochus broodstock (sizes ≥11 cm), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Fakarava are in the good condition found during survey.

- The blacklip pearl oyster, *P. margaritifera*, was relatively common at Fakarava compared to in other PROCFish sites in French Polynesia.

- There is a restricted range of sea cucumber species at Fakarava (due to biogeographical influence), and the oceanic conditions do not offer much potential for commercial harvesting of sea cucumbers.

2.5 Overall recommendations for Fakarava

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

- Spear diving, especially in the lagoon, should be regulated and spear diving at night be banned.

- Considering the high quality of habitat in Fakarava, marine protected areas should be considered as a primary management tool.

- The density and size range of trochus noted in survey suggests that limited fishing could be made at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing. If trochus harvests are considered, it is suggested that some stock be moved from areas of highest density to other suitable areas within Fakarava (possibly reeftop of barrier) in order to extend the range of trochus in Fakarava.

- Surf redfish (*Actinopyga mauritiana*) abundance should be monitored around the atoll, as there may be some potential for harvests of this species if aggregations are located. Further assessment is needed for the deeper-water white teatfish stock (*Holothuria fuscogilva*), especially in the southern pass of the atoll. The preliminary investigation and fishing history of this stock suggest there is potential for small-scale harvests in the future.

3. PROFILE AND RESULTS FOR MAATEA

3.1 Site characteristics

Moorea is part of the Windward Group in the Society Islands and is only 16 km northwest of Tahiti. Its surface area is 134 km² with a population of ~15,000 people (Figure 3.1). The village of Maatea is situated at 17°35'S and 149°48'W in the south of the island, a high-island (with the highest point reaching 1207 m). Its fishery area is delimited by the eastern and western reef passages. The lagoon (~7 km²) has large back-reefs and is composed of four habitats: outer reef, back-reef, intermediate reef and sheltered coastal reef, with a total reef area of ~11 km².

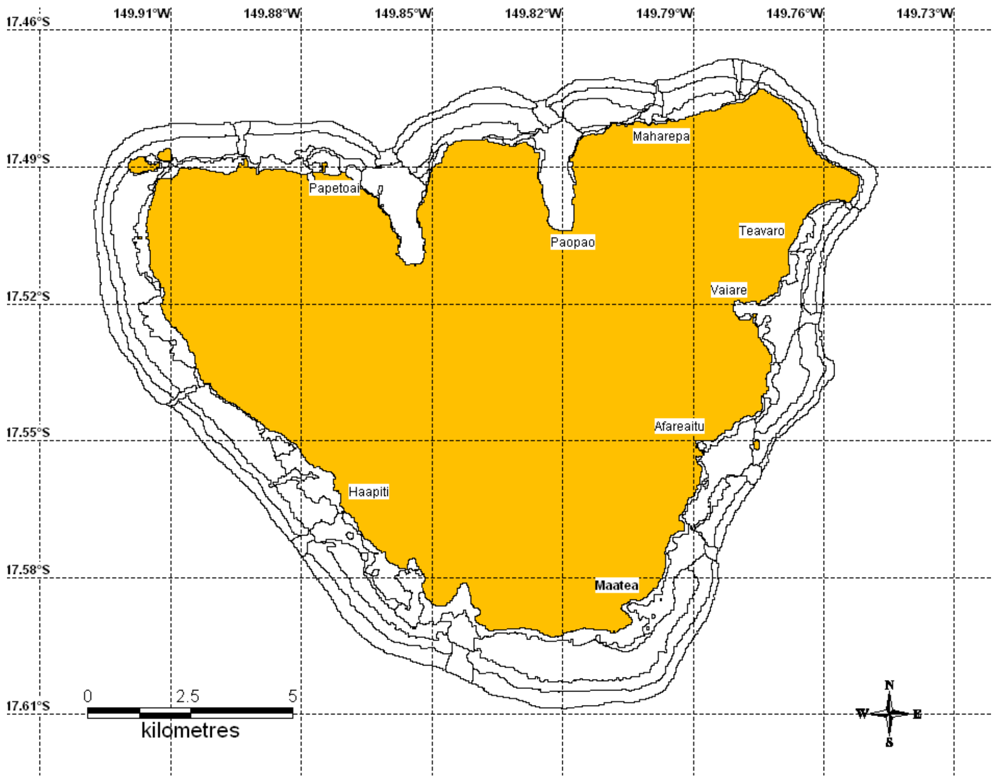

Figure 3.1: Map of Maatea.

3.2 Socioeconomic surveys: Maatea

Socioeconomic fieldwork was carried out in the community of Maatea, in the south of Moorea Island in May 2006. The survey covered a total of 28 households including 112 people, which represents only about 12% of the community's households (235) and total population (940).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 25 individual interviews of finfish fishers (17 males, 8 females) and 6 invertebrate fishers (4 males, 2 females) were conducted. These fishers belonged to one of the 28 households surveyed. Sometimes, the same person may have been interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 3.1) suggest an average of at least one fisher/household. If we apply this average (1.25) to the total number of households, we arrive at a total of 294 fishers in Maatea. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 235 fishers who fish exclusively for finfish (males, females), and a total of 59 fishers who fish for both finfish and invertebrates (males, females). There are no exclusive invertebrate fishers in Maatea.

Half (50%) of all households in Maatea own a boat; 44% of all boats are non-motorised canoes and 56% are motorised.

Ranked income sources (Figure 3.2) suggest that fisheries are of minor importance. About 18% of the households surveyed rely on fisheries as their first source of income, and another 11% quoted fisheries as a secondary income source. This situation relates to the role that agriculture plays as a source of income in Maatea. However, other sources of income, which are mainly social fees, retirement funds and perhaps to some extent small private business, are the most important income source for 43% of all households and a complementary source of revenue for another 43%. Salaries provide >21% of all households with first income, but play no role as a second income source.

However, fisheries are important as a food source; all households reported eating fresh fish, but only 46% eat invertebrates and 57% eat canned fish. The fish that is consumed is either caught by a member of the household (75%), bought (57%), or received as a gift (39%). The proportion of invertebrates caught by a member of the household is much lower (25%). Invertebrates are bought at about the same rate (25%) as fish and not often received as a gift (14%). These results show a certain dependency of Maatea's families on fisheries but they also suggest a degree of adoption of a western lifestyle. Moorea, an island in close proximity to Tahiti and Papeete, has changed substantially during the past 20 years. The island is a major attraction for tourism and also a preferred residential area for commuters who work in the greater Papeete area. There are 30 hotels and boarding houses on Moorea, with a capacity of >1100 guests (STT 2001). The cost of living has risen substantially as property values are driven up by outsiders purchasing land for new business and vacation or retirement homes, and because growth is limited by the small size of the island. As Moorea has increasingly become a suburb of Tahiti, accessible by ferry services, the population of Moorea has grown by over 58% since 1980, excluding tourists (Walker 2001). Maatea is one of the few remaining communities on Moorea where traditional values and lifestyle are still prominent. The community's relatively isolated geographical location may be a possible explanation for this. Against this background, the data show that, while welfare and other social fees determine to a great extent the lifestyle of Maatea's families, fisheries and agriculture continue to play some role in income generation. The data also show that the opportunities for earning local salaries are limited. In terms of fisheries, Maatea's people definitely show a strong preference for fresh fish rather than invertebrates. Today's situation may be explained by some of the information gathered from fisher interviews presented below, and from the resource survey reports.

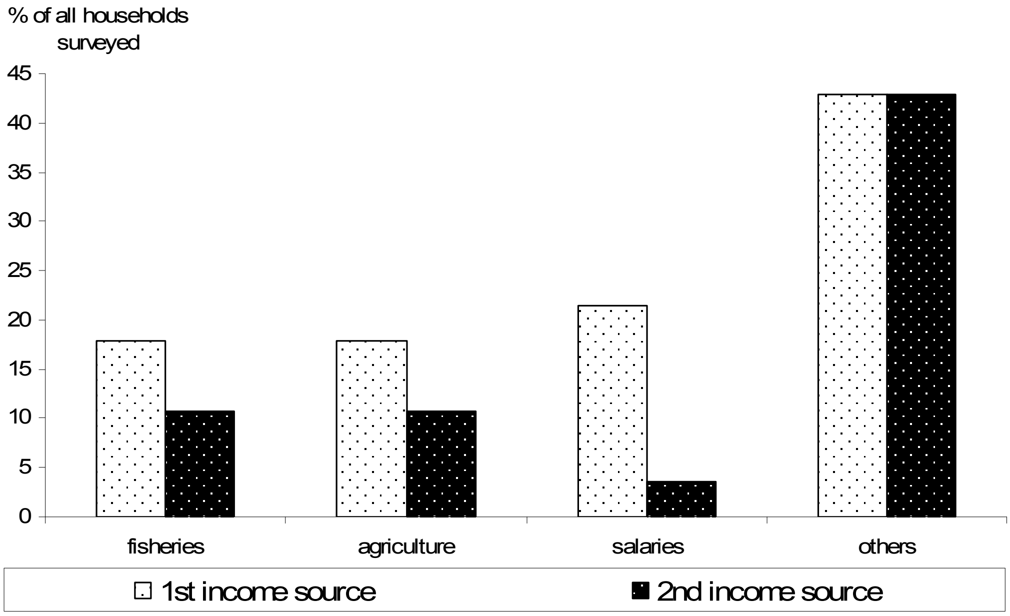

Figure 3.2: Ranked sources of income (%) in Maatea.
Total number of households = 28 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

The per capita consumption of fresh fish (~60 kg/capita/year ±6.45) in Maatea is above the regional average (FAO 2008) (Figure 3.3) and among the higher consumption levels across all PROCFish/C sites surveyed in French Polynesia. In contrast the per capita consumption of invertebrates (meat only) is the lowest (0.26 kg/capita/year) (Figure 3.4). While French Polynesian people in general do not prefer canned fish, the per capita consumption in Maatea is higher than found elsewhere in the country (~5 kg/capita/year) (Table 3.1).

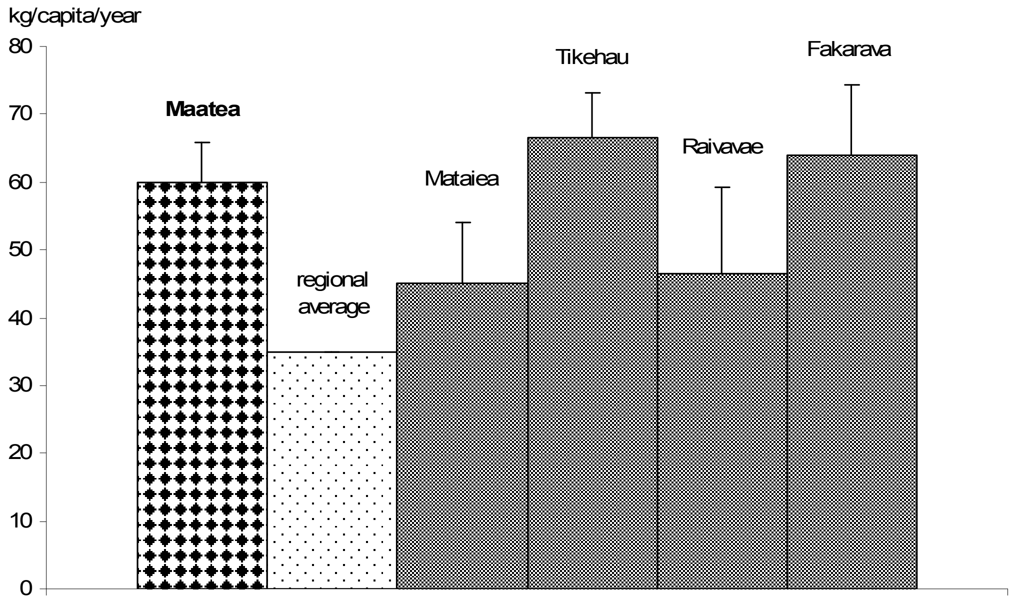

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Maatea (n = 28) compared to the regional average (FAO 2008) and the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

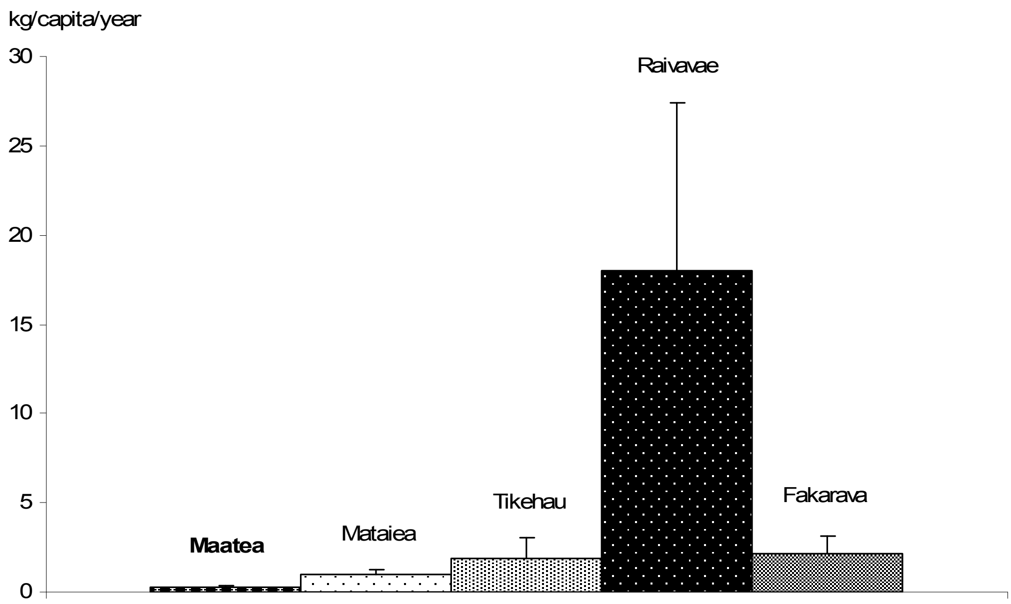

Figure 3.4: Per capita consumption (kg/year) of invertebrates (meat only) in Maatea (n = 28) compared to the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

If we compare results between Maatea and the average of all five PROCFish/C sites in French Polynesia (Table 3.1), the people of Maatea:

- are moderately dependent on fisheries for income generation;
- eat quite a high amount of fresh fish;
- rarely consume invertebrates;
- have a much higher average household expenditure; and
- receive slightly more remittances.

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

Survey coverage	Site (n = 28 HH)	Average across sites (n = 138 HH)
Demography		
HH involved in reef fisheries (%)	78.6	85.5
Number of fishers per HH	1.25 (±0.18)	1.71 (±0.12)
Male finfish fishers per HH (%)	60.0	33.9
Female finfish fishers per HH (%)	20.0	9.7
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	0.0	14.0
Male finfish and invertebrate fishers per HH (%)	14.3	35.2
Female finfish and invertebrate fishers per HH (%)	5.7	6.8
Income		
HH with fisheries as 1st income (%)	17.9	14.5
HH with fisheries as 2nd income (%)	10.7	11.6
HH with agriculture as 1st income (%)	17.9	11.6
HH with agriculture as 2nd income (%)	10.7	13.8
HH with salary as 1st income (%)	21.4	46.4
HH with salary as 2nd income (%)	3.6	8.7
HH with other source as 1st income (%)	42.9	26.8
HH with other source as 2nd income (%)	42.9	34.1
Expenditure (USD/year/HH)	12,135.84 (±897.38)	9752.58 (±468.27)
Remittance (USD/year/HH) (1)	1227.48 (±795.16)	1055.66 (±393.52)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	59.91 (±6.45)	55.55 (±4.16)
Frequency fresh fish consumed (times/week)	3.91 (±0.28)	3.28 (±0.16)
Quantity fresh invertebrate consumed (kg/capita/year)	0.26 (±0.10)	4.91 (±4.16)
Frequency fresh invertebrate consumed (times/week)	0.26 (±0.08)	0.38 (±0.07)
Quantity canned fish consumed (kg/capita/year)	5.09 (±1.39)	3.95 (±0.59)
Frequency canned fish consumed (times/week)	1.28 (±0.38)	0.65 (±0.10)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	46.4	82.6
HH eat canned fish (%)	57.1	79.0
HH eat fresh fish they catch (%)	75.0	84.0
HH eat fresh fish they buy (%)	57.1	56.0
HH eat fresh fish they are given (%)	39.3	44.0
HH eat fresh invertebrates they catch (%)	25.0	44.0
HH eat fresh invertebrates they buy (%)	25.0	8.0
HH eat fresh invertebrates they are given (%)	14.3	8.0

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

3.2.2 Fishing strategies and gear: Maatea

Degree of specialisation in fishing

Fishing in Maatea is performed by both males and females (Figure 3.5). However, most fishers who target finfish exclusively are males (60%); only ~20% of females were in this group. No respondent was found to specialise in collecting invertebrates only. Of the group who fish for both finfish and invertebrates, ~14% were males; only 6% were females. This picture confirms the household consumption data presented before, i.e. that the finfish fishery plays a major role, while invertebrate fishing is of minor importance. Usually, females fish for invertebrates rather than finfish, and this observation may explain the generally low participation of Maatea's females. During the survey one female fisher claimed to be the only remaining female in Maatea who still collects shells at the beach for artisanal purposes and local handicrafts. This information, although anecdotal, may underline recent and ongoing social changes affecting even the more traditional communities on Moorea, such as Maatea.

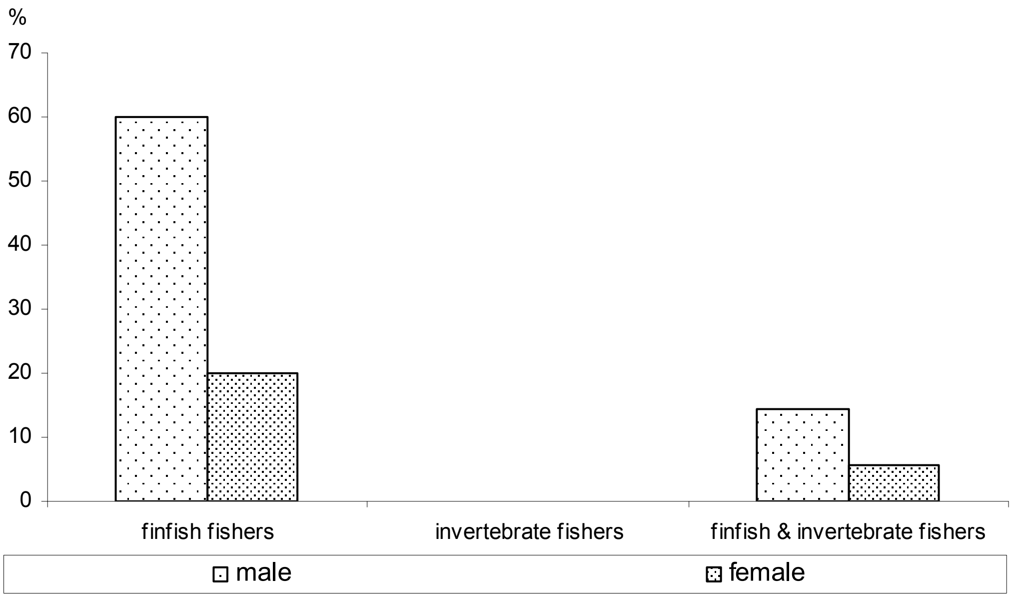

Figure 3.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Maatea.
All fishers = 100%.

Targeted stocks/habitat

Table 3.2: Proportion of interviewed finfish fishers and invertebrate fishers harvesting the various finfish and invertebrate stocks across a range of habitats in Maatea

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	47.1	87.5
	Lagoon	41.2	12.5
	Outer reef	29.4	0.0
Invertebrates	Mangrove	25.0	0.0
	Other	100.0	0.0
	Reeftop	25.0	0.0
	Intertidal	25.0	50.0
	Seagrass (sea urchins)	0.0	50.0

'Other' refers to the giant clam fishery.
Finfish fisher interviews, males: n = 17; females: n = 8. Invertebrate fisher interviews, males: n = 4; females, n = 2.

The combined information on the number of fishers, the frequency of fishing trips and the average catch/fishing trip are the basic factors used here to estimate the fishing pressure imposed by people from Maatea on their fishing grounds (Table 3.2).

Our survey sample suggests that fishers in Maatea can choose among three habitats: sheltered coastal reef, lagoon and outer reef. Fishers seem to clearly distinguish between habitats targeted; none reported combining any of the habitats in one fishing trip. Most fishers (47%

of the male fishers; 88% of the female fishers), however, target the sheltered coastal reef. Another 41% and 13% of male and female fishers respectively also target the lagoon area. Only 29% of fishers (males only) fish the outer reef.

Fishing patterns and strategies

Invertebrate fisheries are not very diverse and the data again support the observation that they are less important than finfish fisheries. Most species collected are associated with reefs. Males mainly target giant clams (70%), some crabs and *Turbo* shells on reeftops (25%), crabs from mangrove areas (25%) and sea urchins from soft benthos. Females collect some shells from the intertidal areas, mostly for handicraft purposes, and sea urchins from soft benthos. Overall, diving for giant clams is the most important invertebrate fishery in Maatea (Figure 3.6).

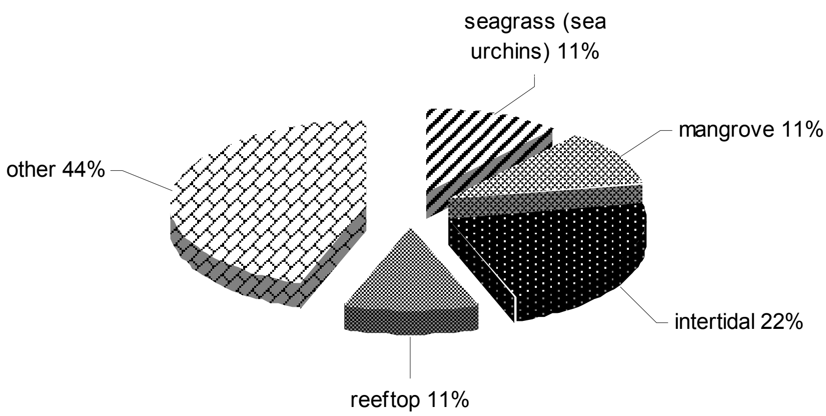

Figure 3.6: Proportion (%) of fishers targeting the five primary invertebrate habitats found in Maatea.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. ‘Other’ refers to the giant clam fishery.

Figure 3.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Maatea.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 4 for males, n = 2 for females; 'other' refers to the giant clam fishery.

Gear

Figure 3.8 shows that fishers use a range of different fishing techniques at the three major habitats targeted. In sheltered coastal reef areas and the lagoon, the main fishing methods are spear diving, handlining and rod-and-line fishing; some fishers may also use scoop nets. At the outer reef, techniques are more distinct and handlines dominate. Both rod-and-line fishing and spear diving are complementary techniques used by a few. Most fishing is done using a boat (75%). Fifty-three percent of male fishers and 63% of female fishers use non-motorised boats.

Gleaning and free diving for invertebrates are done using only very simple tools. Giant clams, sea urchins and shells are picked up by hand or, if done by free diving, on snorkel. Diving does not involve any SCUBA gear. Only reeftop gleaning is done with a non-motorised boat, while intertidal and mangrove fishing is mostly pursued by walking. For giant clam diving, boats are used in half of all trips, and the percentage of trips using motorised boats equals that of trips using non-motorised boats.

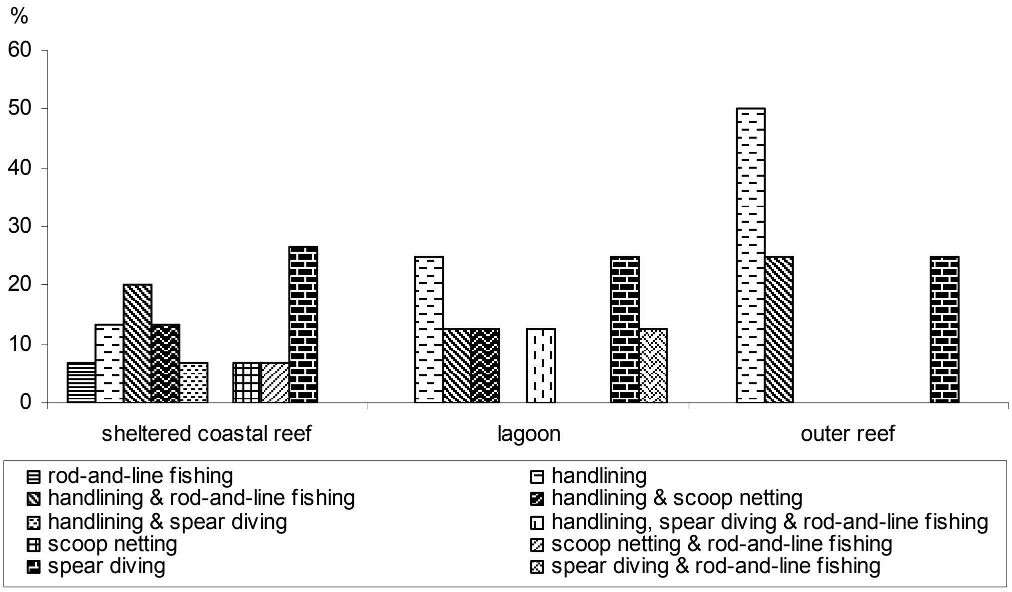

Figure 3.8: Fishing methods commonly used in different habitat types in Maatea.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 3.3 the frequency of fishing trips does not vary among habitats targeted. In general, finfish fishers go out 1.5 times/week. Taking into consideration that most households depend on income sources other than fisheries, finfish fishers may often use the weekend to catch fresh fish for the family. The average trip duration increases from sheltered coastal reef to lagoon and outer-reef fishing. The fact that the sheltered coastal reef may be fished by walking only, while lagoon fishing is often, and outer-reef fishing exclusively, dependent on a canoe or motorised boat, combined with increased distance from the coast to the outer reef may explain these differences.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.47 (±0.44)	1.13 (±0.39)	3.19 (±0.73)	4.14 (±0.67)
	Lagoon	1.96 (±0.33)	3.00 (n/a)	5.36 (±0.90)	5.00 (n/a)
	Outer reef	1.48 (±0.43)	0	6.88 (±0.77)	0
Invertebrates	Mangrove	1.00 (n/a)	0	5.00 (n/a)	0
	Other	0.73 (±0.18)	0	3.75 (±1.31)	0
	Reeftop	1.00 (n/a)	0	1.00 (n/a)	0
	Intertidal	0.23 (n/a)	5.00 (n/a)	4.00 (n/a)	4.00 (n/a)
	Seagrass (sea urchins)	0	0.69 (n/a)	0	2.50 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam fishery.
Finfish fisher interviews, males: n = 17; females: n = 8. Invertebrate fisher interviews, males: n = 4; females: n = 2.

As mentioned earlier, invertebrate fisheries are of much less importance. This also shows in the very low frequency of invertebrate fishing trips, often less than once a week. The duration of invertebrate fishing trips varies considerably and is longer for mangrove and intertidal collections (4–5 hours/trip), and shortest for reeftop gleaning (~1 hour/trip).

Finfish fishing is performed mostly during the day (~50%), with a few fishers fishing at night (spear divers mainly targeting the outer reef). A small group of fishers (12–20%) fish according to the tides, i.e. day and/or night. The fact that certain night fishing activities have been restricted may have altered the habitat of fishing predominantly at night as reported by Vieux (2002). In the case of invertebrate collection, reeftop gleaning and giant clam diving are mainly conducted during the day, while sea urchins and mangrove crabs are mostly collected at night.

Most finfish fishers reported fishing only during one-quarter or one-third of the year. Invertebrate fishers may also stop collecting during certain months, while some continue throughout the year. The fact that agricultural production also plays a role in Maatea may explain why at certain times people are engaged in gardening and farming rather than fishing.

3.2.3 Catch composition and volume – finfish: Maatea

Catches from the sheltered coastal reef include a variety of different fish species groups, dominated by *Naso unicornis* (Acanthuridae), Carangidae, and *Chorurus microrhinos* (Scaridae), comprising ~16%, ~14% and ~12% of the total reported catch respectively. *Cephalopholis argus* (Serranidae), *Lutjanus fulvus* (Lutjanidae) and *Siganus argentinus* (Siganidae) also contribute substantially, each comprising 5–9% of the total annual reported catch. The remainder is accounted for by another 20 species or species groups. For lagoon catches the composition changes, and *Naso lituratus* (11%), *Epinephelus merra* (10%) and *Mulloidichthys flavolineatus* (10%) are the predominant species. Species of the families of Siganidae, Scaridae, Acanthuridae, Lutjanidae and others also make up an important part of the total annual reported catch. Finally, the least diverse catches were reported for the outer reef. Here again, *Naso unicornis* (19%), but also *Lethrinus olivaceus* (14%), *Caranx melampygus* (11%) and *Myripristis* spp. (11%) are the main species. The remainder of the reported catch composition is distributed over 11 other species and species groups. The reported species composition (detailed in Appendix 2.2.1) shows that handlines, fishing rods and spear diving are the major fishing methods used.

Our survey sample of finfish fishers interviewed only represents about 8.5% of the projected total number of finfish fishers in Maatea. Discussions with local male fishers as well as the in-depth knowledge of the local fisheries staff member allowed us to include a number of active and important commercial fishers in our survey. Because of the low sample size in general, and the fact that we presumably have a higher representation of commercial and thus more active fishers in our sample than within the entire community, we only present the reported annual catches to assess the level of current impact.

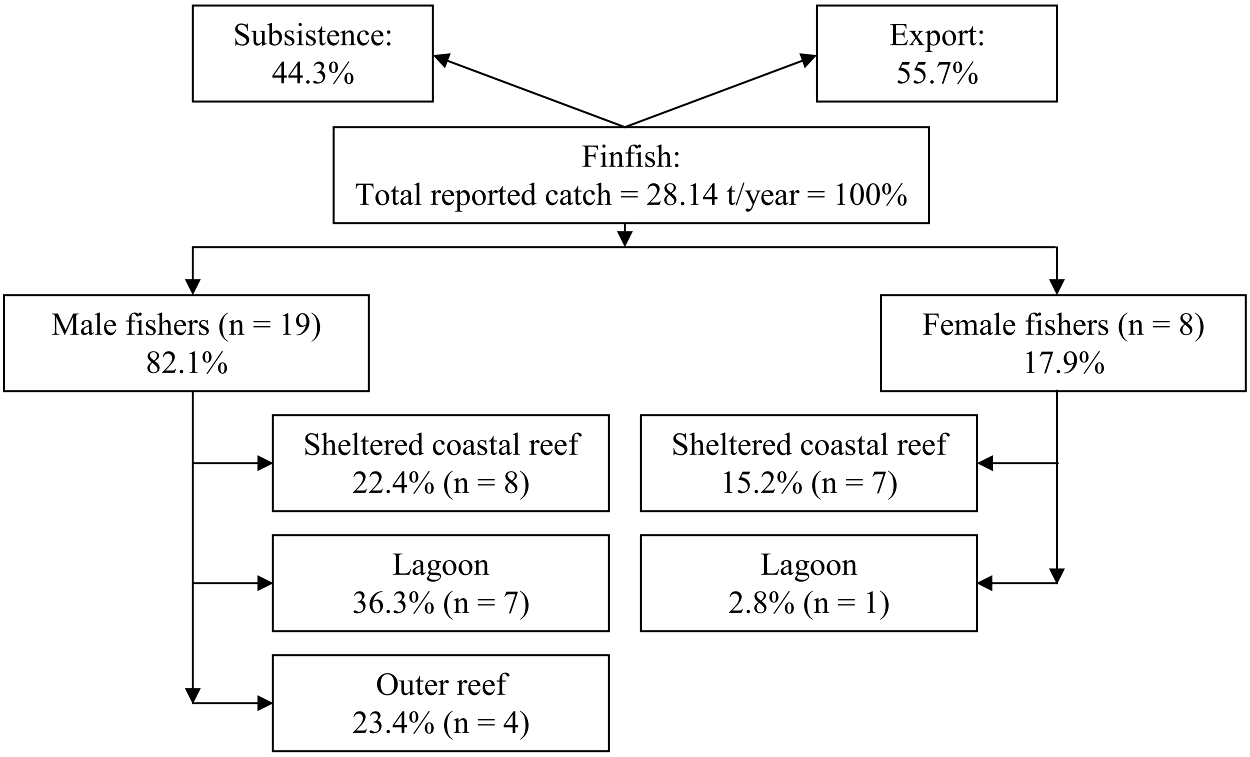

Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Maatea.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

As shown in Figure 3.9 about 56% of the reported catch is from commercial reef fishing, i.e. catches that are sold within the Maatea community either to community members or people living in neighbouring villages on Moorea. Subsistence needs of the households associated with the fishers interviewed determine about 44% of the reported catch. Taking into consideration that we have interviewed a large number of commercial fishers, and knowing the limited number of commercial and occasionally commercial male fishers, the proportion of catch reported here for sale is presumably over represented. Therefore, we can assume that the commercial proportion of the total catch would have been much smaller if we had sampled a higher percentage of the population. Nevertheless, these figures show that most of the catch is taken by male fishers, while females only play a minor role (<18%). Highest fishing pressure is shared equally between the sheltered coastal reef (~38%) and the lagoon (~39%), with far less impact on the outer reef (~23% of the total annual catch).

The high impact on the sheltered coastal reef and lagoon resources is a function of the number of fishers targeting these areas, rather than the average annual catch rate. This observation is particularly true for the sheltered coastal reef where average annual catches are almost half of those calculated for lagoon and outer-reef fishers. As shown in Figure 3.10, average annual catches for male fishers are ~800 kg/fisher/year for both lagoon and outer-reef catches but female fishers only take 400 kg/fisher/year from the lagoon. Female fishers catch even less, i.e. about 300 kg/fisher/year from the sheltered coastal reef. Figure 3.10 also shows a high data variability as indicated by the scale of the standard errors. The difference between gender groups and the high data variability for male fishers suggest that a) males are much more commercially oriented than females, and b) that there is a difference in the total annual productivity between commercial and non-commercial male fishers.

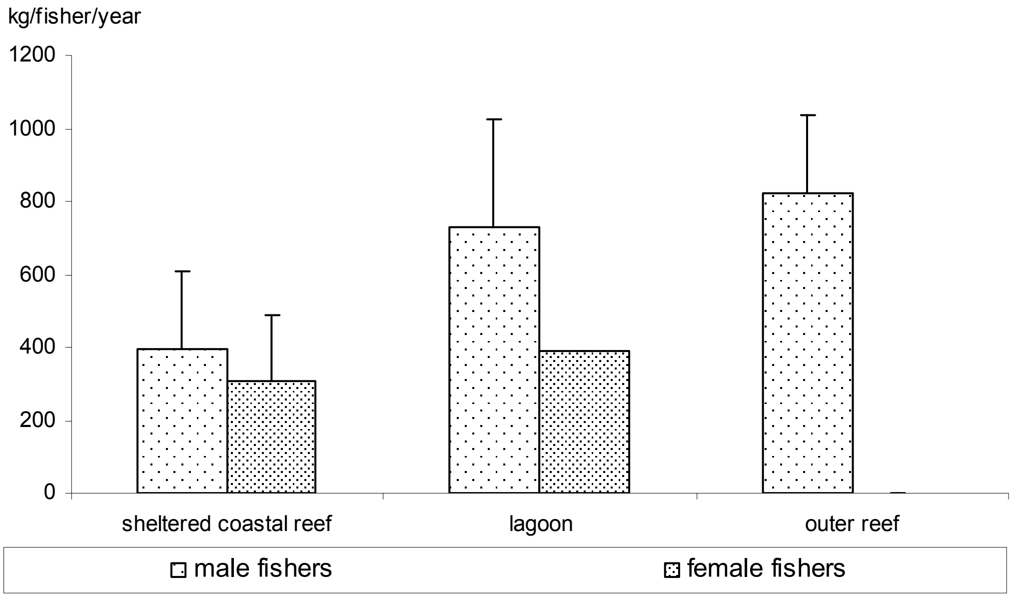

Figure 3.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Maatea (based on reported catch only).

Comparing the CPUE calculated for the different habitats fished, it is highest for the outer reef. However, CPUEs calculated for the sheltered coastal reef and lagoon differ only marginally. Again, the effectiveness of female fishers is far below that of males (Figure 3.11).

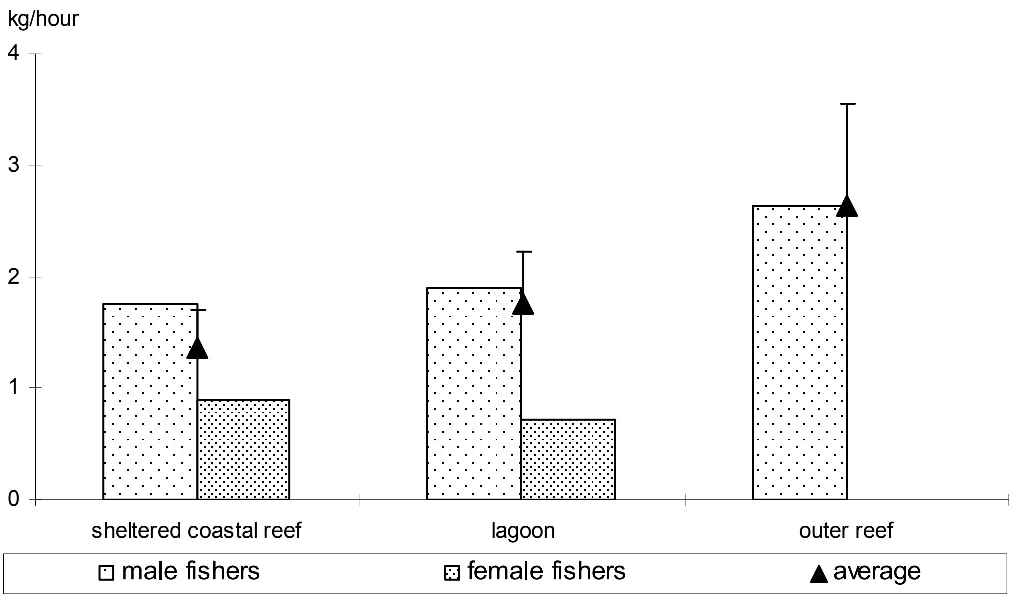

Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Maatea.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data suggest that there is not much difference among habitats in terms of the intention of fishers, i.e. the main purpose of fishers targeting any of the three habitats is commercial while subsistence needs are the second most important objective. The proportion of catch taken for non-monetary exchange also does not differ among the habitats, but is generally low (Figure 3.12).

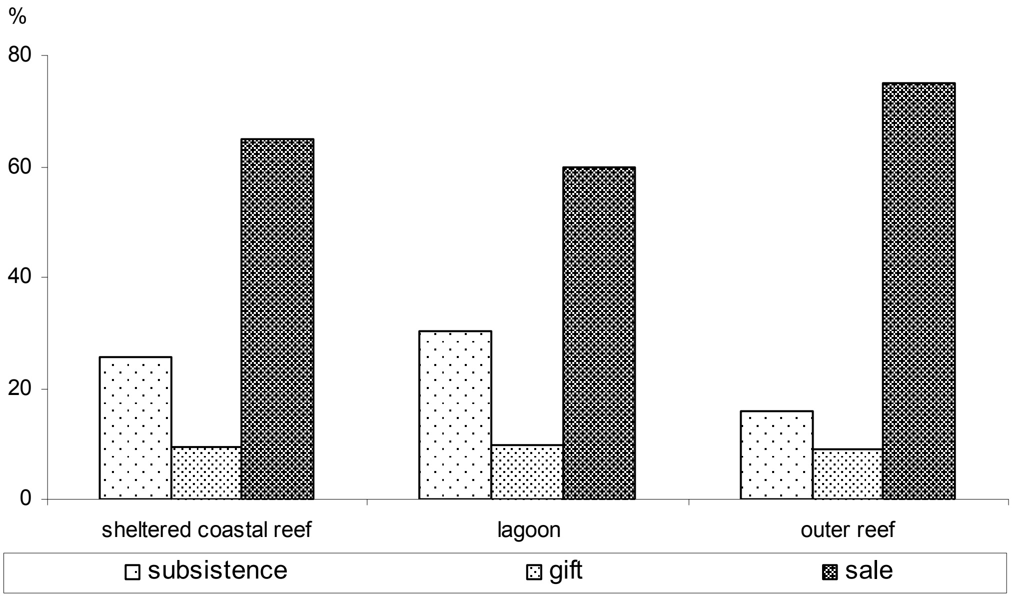

Figure 3.12: The use of finfish catches for subsistence, gift and sale, by habitat in Maatea.
Proportions are expressed in % of the total number of trips per habitat.

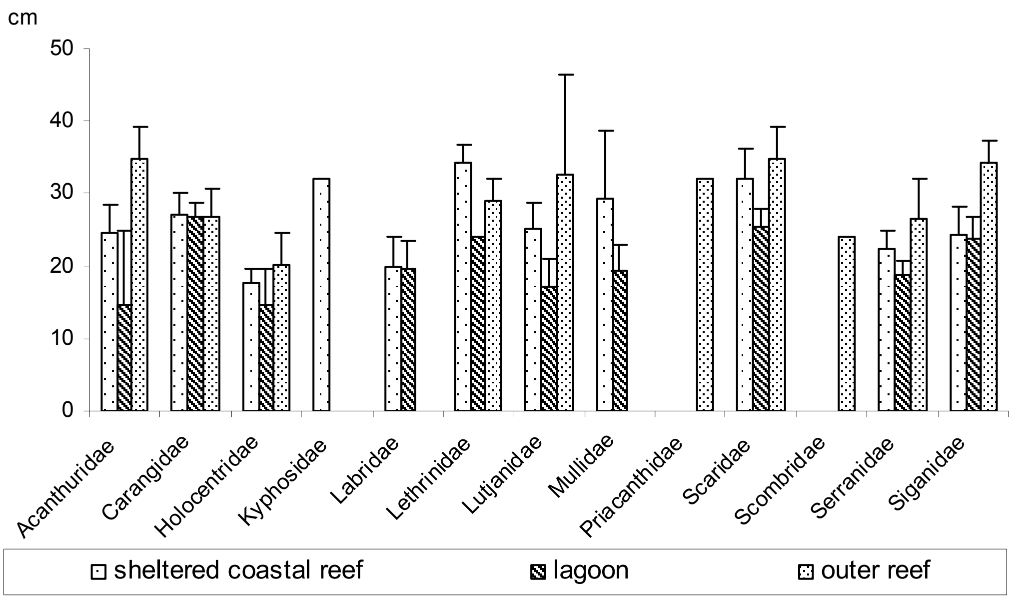

Figure 3.13: Average sizes (cm fork length) of fish caught by family and habitat in Maatea.
Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat as shown in Figure 3.13 show a trend: average fish size increases from the sheltered coastal reef towards the outer reef for Acanthuridae, Scaridae, Serranidae, Siganidae and Lutjanidae. However, in the case of Lethrinidae the opposite is true and for Holocentridae no changes are detectable. Overall, reported average fish sizes are over 15 cm and most range between 25 and 30 cm.

Some parameters selected to assess the current fishing pressure on Maatea's living reef resources are shown in Table 3.4. The comparison of habitat areas shows that the lagoon is the largest, while sheltered coastal reef and outer reef are very limited in size. The fact that the sheltered coastal reef area is very small but is one of the most fished habitats explains why fisher density there is extremely high. Fisher density is relatively low at the outer reef because it is targeted by fewer fishers, but is even lower in the lagoon, where numerous fishers disperse over a relatively large area. If we consider the total available reef and fishing ground areas, fisher density is moderate while population density figures are high. The total fishing pressure due to the subsistence needs of Maatea's community alone is substantial and reaches ~5 t/km^2 for the total reef area.

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

Parameters	Habitat				
	Sheltered coastal reef	Lagoon	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	1.41	8.46	2.49	10.85	12.36
Density of fishers (number of fishers/km^2 fishing ground) (1)	109	10	22	27	24
Population density (people/km^2) (2)				87	76
Average annual finfish catch (kg/fisher/year) (3)	352.14 (±138.43)	686.73 (±258.66)	823.15 (±215.16)		
Total fishing pressure of subsistence catches (t/km^2)				4.76	4.18

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 940; total number of fishers = 294; total subsistence demand = 51.63 t/year; (3) catch figures are based on recorded data from survey respondents only.

These high density and fishing pressure figures support the concern that is shared by fisheries authorities and local communities that the resources are overexploited. This concern has already triggered management planning and interventions by both groups.

3.2.4 Catch composition and volume – invertebrates: Maatea

Calculations of the reported annual catch rates/species groups are shown in Figure 3.14. The graph shows that the only major impact (by wet weight) is due to giant clam (*pahua*) catches, i.e. *Tridacna maxima*. Catches reported for *Carpilius maculatus* (crab) and *Diadema* spp. (sea urchin) are also substantial, while all others, including *poupou* (used for artisanal purposes), *Turbo* spp., *opareo*, *tarona* and *tipauti* are insignificant (Detailed data are provided in Appendices 2.2.2 and 2.2.3.).

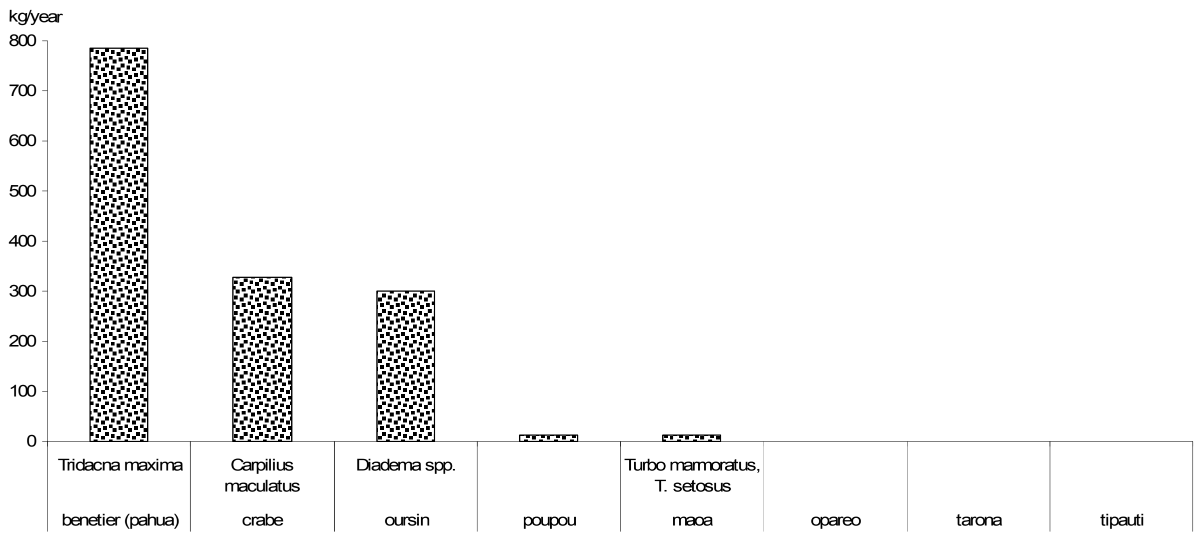

Figure 3.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Maatea.

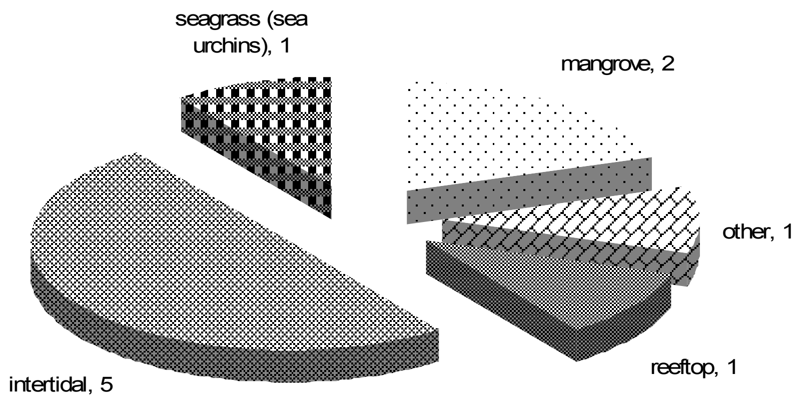

Figure 3.15: Number of vernacular names recorded for each invertebrate fishery in Maatea.

As already stated, invertebrate fisheries are limited and today of no great importance in Maatea. Accordingly, the limited biodiversity reported for catches is not surprising. Catches for reeftop gleaners reported by vernacular names included one species group only (*Turbo* spp.); 'other' diving targets giant clams only; seagrass is fished for sea urchins only, mangroves provide mainly a certain crab species; and a number of smaller shells may be collected for subsistence and artisanal purposes in the intertidal zones (Figure 3.15).

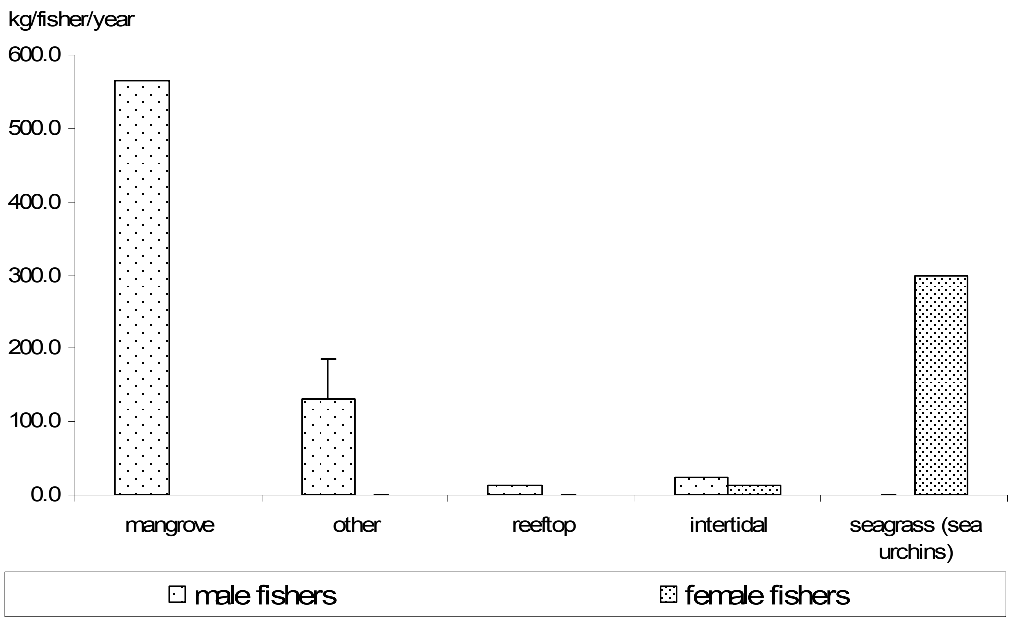

Figure 3.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Maatea.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 16 for males, n = 4 for females).

Figure 3.16 shows that average annual catches of invertebrate fishers are generally low. The highest average annual catches by wet weight are obtained from the mangroves by male fishers collecting crabs. Due to the limited sample size, this figure may, however, be misleading. Other male fishers who target mainly giant clams collect around 110 kg/fisher/year wet weight and female fishers may collect sea urchins at a rate of 300 kg/fisher/year.

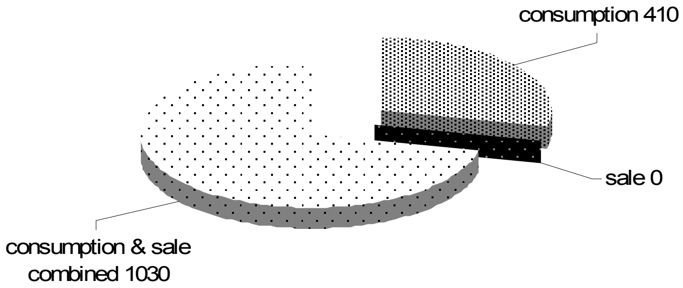

Figure 3.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Maatea.

Unlike the finfish fisheries, invertebrate fisheries are mainly pursued for subsistence purposes, and the share sold within the Maatea community may not exceed 36% of the total reported catch (Figure 3.17) if we assume that about half of the catch reported for both commercial and subsistence purposes combined is sold. Although fishers from Maatea may sell only rarely to clients outside the community, we cannot exclude the fact that further impact on Maatea's invertebrate resources is added by external fishers who are reported to visit and fish in Maatea's fishing ground without permission.

In line with the overall finding that invertebrate fisheries are not of great importance for Maatea's community, the total annual catch volume (expressed in wet weight and based on data reported by all respondents interviewed) is very small. It only reaches 1.4 t/year (Figure 3.18). Mangrove and giant clam catches account for the major shares of these reported catches (39% and 36% respectively). In addition, sea urchin collection from seagrass habitats contributes significantly (21%). Overall, female fishers' contribution to the reported invertebrate impact in Maatea is small (22%) compared to that of males (78%).

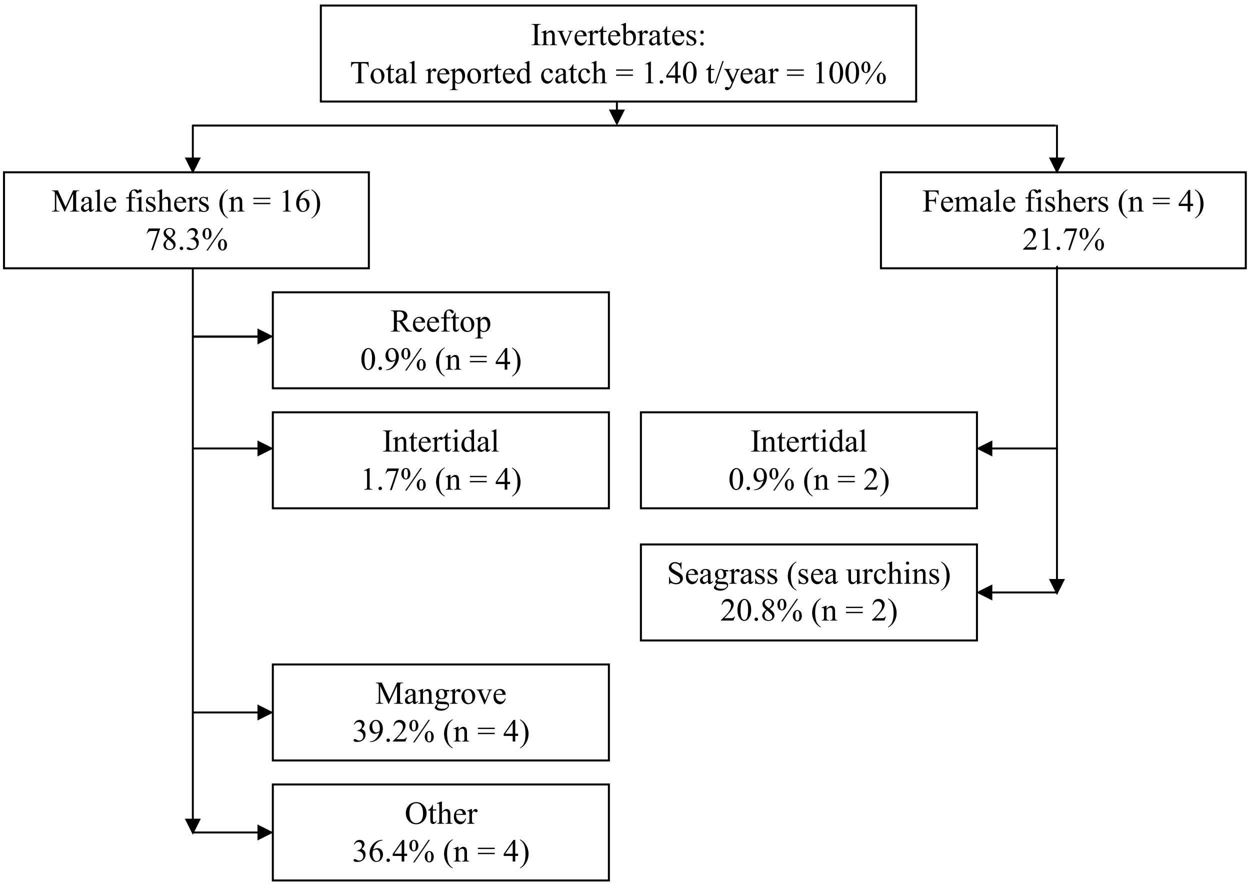

Figure 3.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Maatea.
n is the total number of interviews conducted per each fishery; 'other' refers to the giant clam fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

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

Parameters	Fishery / Habitat				
	Reeftop (3)	Intertidal	Soft benthos	Mangrove	Other
Fishing ground area (km^2)	0.35				2.7
Number of fishers (per fishery) (1)	10	19	8	10	42
Density of fishers (number of fishers/km^2 fishing ground)	30				16
Average annual invertebrate catch (kg/fisher/year) (2)	13.03 (n/a)	19.03 (±5.46)	299.84 (n/a)	564.57 (n/a)	130.98 (±54.93)

Figures in brackets denote standard error; n/a = no standard error calculated; (1) total number of fishers is extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only; (3) reef area determined for finfish resources survey as sheltered coastal reef; 'Other' refers to the giant clam fishery.

In order to assess the level of the current fishing pressure on invertebrate resources at Maatea, we may need to take into account some factors that are not reported and thus not quantifiable. For instance, some of the community members are known to continue to harvest certain species under *rahui* (ban), such as *Lambis lambis*, trochus, etc. Also, the extent of any impact from fishers external to the Maatea community is not known. In Table 3.5 some parameters are presented that are based on reported information by fishers interviewed, including the size of some habitats. Results suggest that neither the numbers of fishers per fishery, nor the reported average annual catch per fisher are high. Also, the calculated fisher density for the two fisheries where areas are known: 'other' (diving at the outer reef) and reeftop gleaning, does not indicate that there is currently a major problem. However, the scale of impact also imposed on the same resources by residents fishing illegally or external fishers, is not known.

The reasons why so few members of the Maatea community collect invertebrates and the exploitation level reported is so low, are, however unclear. Several explanations may be considered, including:

- social change, in turn causing changes in nutritional or fishing practices,
- scarce resources – whether a naturally low occurrence or due to previous fishing impact,
- a low general (and traditional) interest.

3.2.5 Fisheries management: Maatea

There are a number of fisheries management regulations and rules that are governed under Service de la Pêche. Also, concerted efforts have been made by Commune de Moorea (Maiao), Comité du PGEM de Moorea (Te Tairoro No Te Ui Tau), Service de la Pêche, Service de l'Urbanisme and Direction de l'Environnement to agree on the 2005 Plan de Gestion de l'Espace Maritime (PGEM) for Moorea. This plan includes the establishment of several marine protected areas (MPAs) in the Moorea lagoon system. However, it is worth mentioning that fishing was the only impact under consideration for regulation in the MPA decision-making process, excluding any impacts that may be also significant but imposed by land-based pollution from urban, suburban, and agricultural development on Moorea (Porcher and Gabrié 1987, Gabrié *et al.* 1988, Aubanel 1993). The idea of designating MPAs in the Moorea lagoon was conceived by the members of the territorial government and Moorea's local government, in response to a recommendation by a Pacific Asia Travel Association Task Force (PATA 1991), as well as their perception of overfishing (Walker 2001). The increased population pressure is largely held responsible for the latter. Among other things, the PGEM established some fisheries regulations, including:

- the minimum mesh size of gillnets must be ≥45 mm;
- for 'haapua' fishing, fish cage mesh size must be ≥55 mm;
- zones for spear diving must be further than 100 m off beaches and 50 m minimum distance to any swimmer;
- gillnetting at night is forbidden;
- selling fish without a licence is forbidden.

One of the eight MPAs is located within the Maatea fishing grounds. All fishing is forbidden in the MPA with the exception of handlining and beach netting between coast and channel, and with the exception of spear diving by day and gillnetting (maximum length of 50 m and mesh size ≥50 mm) between the channel and the outer reef.

Although many efforts have been made by the Moorea community and the members of the Maatea community in particular, compliance with the regulations and restrictions that have been established and jointly agreed by all partners, is not necessarily as desired. This applies to night fishing activities; harvesting of protected species, in particular invertebrates; and selling of fish by people who are not licence holders. This lack of compliance may be partly explained by three types of conflicts: 1) conflicts over modern versus traditional forms of lagoon conservation, 2) conflicts over policy-makers'/scientists' knowledge versus fishers'/locals' knowledge about the lagoon environment and ecology, and 3) conflicts over access to lagoon space and resources, which have provoked resistance to state conservation interventions (Walker 2001).

3.2.6 Discussion and conclusions: socioeconomics in Maatea

- Maatea, although considered as one of the few remaining more traditional communities on Moorea, represents a community that has adopted, to quite a large extent, the urbanised lifestyle of nearby Papeete and Tahiti.

- The high consumption of fresh fish illustrates the continued traditional nutritional preferences of the community; however, this does not apply for invertebrates. However, the per capita consumption estimated in this survey is almost half as low as that suggested by Yonger (2002). Also, if we apply our per capita consumption estimate, Maatea's subsistence demand for fresh fish alone amounts to ~70 t/year. However, estimates of the total annual production from the entire Moorea lagoon system are only 57 to 60 t according to Aubanel (1993) and 92 t/year according to Vieux (2002). Although the PROCFish/C consumption figures include some pelagic fish, previous total lagoon fishery estimates may underestimate current fishing pressure.

- The financial dependence of the community on fisheries is similar to its dependence on agriculture and, generally speaking, both sectors are less important than salaries and social fees.

- The high household expenditure level is explained by the high influence of international tourism, which has caused living costs on this small island to soar.

- Overall, more males than females are engaged in fishing. Most fishers target the easy-to-reach sheltered coastal reef, fewer target the lagoon, and very few the outer reef. However the impact imposed by annual catch is comparatively high on sheltered coastal reef and lagoon resources. Invertebrate fisheries are limited to a few species and are far less important than finfish fisheries.

- The choice of gears and boat transport used also suggests that participation by commercial fishers is relatively low and that, overall, low-investment-cost options are preferred when fishing for subsistence and leisure purposes. Fishing is still done using non-motorised boats, or by walking; handlines and fishing rods are preferred.

- The reported average catch sizes of reef fish follow the expected trend, i.e. sizes increase from the sheltered coastal reef to the outer reef. In parallel, data also suggest a slight increase in CPUE from the sheltered coastal reef to the outer reef.

- Due to the limited reef and total fishing ground area available and the size of the Maatea community, the densities of fishers and of the population are moderate to high. Also, the exploitation level only due to the subsistence needs of the community/km^2 of reef and total fishing ground area suggests a moderate fishing pressure (~5 t/km^2).

- For the invertebrate fisheries, survey results found low values: for the number of reported target species; the proportion of people in the community who are engaged in invertebrate fisheries; and the reported annual catch of these fishers. However, the question remains whether these values are low due to a general lack of interest in invertebrates, due to a resource that is poor naturally or because of human impacts; or due to social changes and thus reduced participation in invertebrate fisheries. It is also unclear to what extent illegal fishing by local residents and fishing by outside fishers currently impact resources.

- The survey data suggest that fishing pressure imposed by the subsistence needs of the Maatea community alone is high. Invertebrate data also suggest that reef resources are poor. However, before concluding how far the resources of Maatea already show signs of stress due to fishing pressure, or to what extent they may be under risk in future, results from the resource surveys need to be examined.

3.3 Finfish resource surveys: Maatea

Finfish resources and associated habitats were assessed in Maatea between 25 May and 03 June 2006 from a total of 24 transects (6 sheltered coastal, 6 intermediate, 6 back- and 6 outer-reef transects. See Figure 3.19 and Appendix 3.2.1 for transect locations and coordinates respectively.).

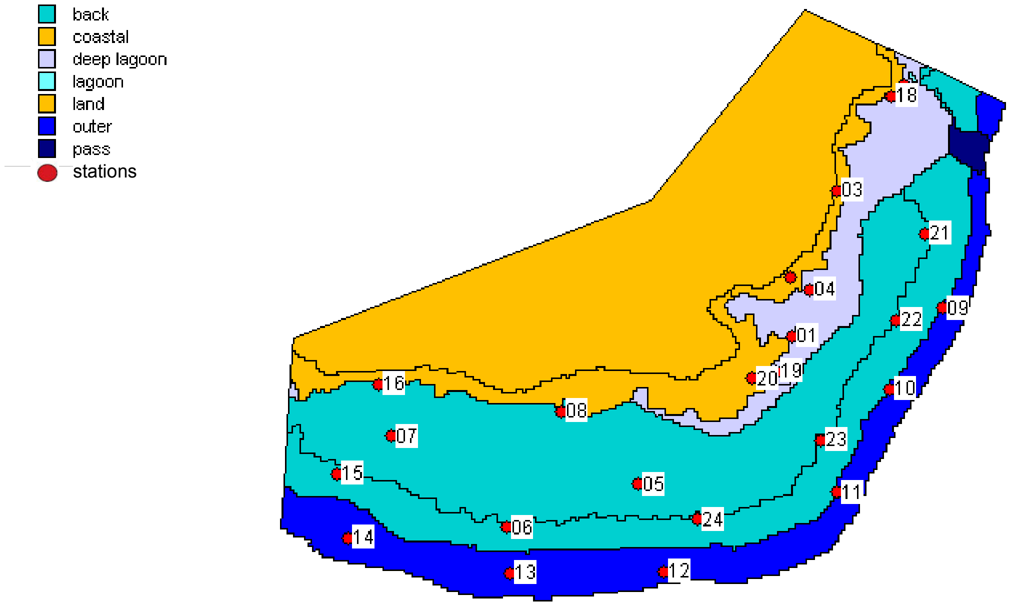

Figure 3.19: Habitat types and transect locations for finfish assessment in Maatea.

3.3.1 Finfish assessment results: Maatea

A total of 23 families, 53 genera, 123 species and 14,002 fish were recorded in the 24 transects (See Appendix 3.2.2 for list of species.). Only data on the 13 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 41 genera, 111 species and 13,720 individuals.

Finfish resources varied greatly among the four reef environments found in Maatea (Table 3.6).

- The outer reef contained the greatest number of fish (1 fish/m^2), the highest of all the five outer reefs studied in the country; highest biomass (99 g/m^2) and highest biodiversity (34 species/transect).

- The sheltered coastal reefs displayed the lowest density (0.5 fish/m^2, equal to intermediate reefs); biomass (34 g/m^2) and size (13 cm, size ratio 48%).

- The intermediate reefs showed the highest size (16 cm) and size ratios (60%); the second-highest biomass (73 g/m^2) and biodiversity (32 species/transect); but third-ranked density (0.5 fish/m^2).

- The back-reefs had intermediate values between the outer and intermediate reefs, with second-highest density (0.6 fish/m^2) and third-ranked biomass (59 g/m^2), but lowest biodiversity (30, equal to coastal-reef values).

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

Parameters	Habitat				
	Sheltered coastal reef (1)	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	6	6	6	24
Total habitat area (km^2)	1.4	0.1	6.9	2.4	10.8
Depth (m)	3 (1–8) (3)	5 (1–10) (3)	2 (2–2) (3)	9 (7–12) (3)	4 (1–12) (3)
Soft bottom (% cover)	22 ±5	24 ±7	15 ±3	1 ±1	13
Rubble & boulders (% cover)	27 ±8	10 ±3	21 ±6	3 ±1	18
Hard bottom (% cover)	35 ±4	41 ±5	45 ±5	67 ±3	48
Live coral (% cover)	15 ±2	26 ±7	19 ±2	30 ±3	21
Soft coral (% cover)	0 ±0	0 ±0	0 ±0	0 ±0	0
Biodiversity (species/transect)	30 ±4	32 ±6	30 ±3	34 ±3	31 ±2
Density (fish/m^2)	0.5 ±0.1	0.5 ±0.2	0.6 ±0.1	1.0 ±0.1	0.7
Size (cm FL) (4)	13 ±1	16 ±1	15 ±1	15 ±1	15
Size ratio (%)	48 ±2	60 ±3	56 ±3	49 ±2	53
Biomass (g/m^2)	34.1 ±4.6	73.4 ±25.1	59.2 ±12.5	99.1 ±15.4	64.6

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

Sheltered coastal reef environment: Maatea

The sheltered coastal reef environment of Maatea was dominated by two families of herbivorous fish: Acanthuridae and Scaridae and, to a much lower extent, by carnivorous Chaetodontidae (only in terms of density), Lethrinidae and Mullidae (Figure 3.20). These five families were represented by 38 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Mulloidichthys flavolineatus*, *Scarus psittacus*, *Zebrasoma scopas*, *Gnathodentex aureolineatus* and *Parupeneus multifasciatus* (Table 3.7). This reef environment presented a moderately diverse habitat with hard bottom, rubble, and soft bottom in similar proportions (Table 3.6 and Figure 3.20).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.19 ±0.07	8.4 ±2.4
	Zebrasoma scopas	Twotone tang	0.03 ±0.01	1.9 ±0.5
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.03 ±0.01	4.8 ±2.3
	Scarus psittacus	Common parrotfish	0.02 ±0.01	3.1 ±2.3
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.03 ±0.03	1.6 ±1.5
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.01 ±0.01	3.3 ±2.6
	Parupeneus multifasciatus	Many bar goatfish	0.01 ±0.00	1.0 ±0.4

The density of finfish in the sheltered coastal reefs of Maatea was higher than at the other four coastal reefs, while size, size ratio and consequently biomass were the lowest.

Biodiversity was the second-highest among the sites, lower only to in Fakarava (Table 2.6). The trophic structure in Maatea coastal reef was dominated by herbivorous species in terms of both density and biomass, especially due to high abundance of Acanthuridae.

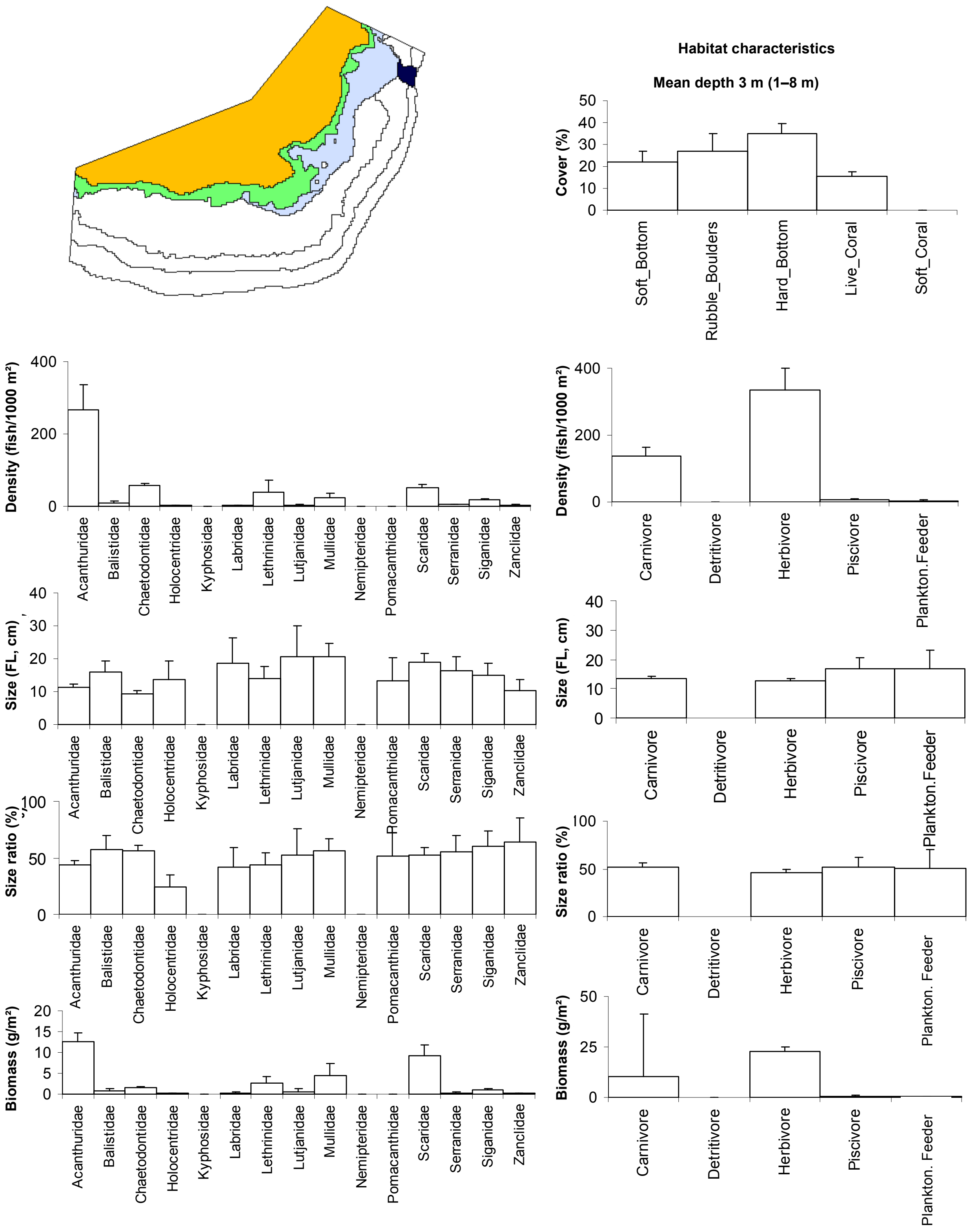

Figure 3.20: Profile of finfish resources in the sheltered coastal reef environment of Maatea.
Bars represent standard error (+SE); FL = fork length.

Surgeonfish and parrotfish are the families most targeted by fishers in this habitat, and parrotfish showed a very low level of abundance. Carnivorous species Lethrinidae and Mullidae displayed very low values of abundance and biomass, while Lutjanidae were almost absent.

Size ratio, used as an indication of fishing stress on the fish population, was below the 50% limit for Acanthuridae, Labridae, Lethrinidae and Lutjanidae. Substrate composition was almost equally distributed between hard bottom, soft bottom and rubble, while live coral cover was particularly low. The complexity of the substrate composition partially explains the rather diverse fish community composition. Although the good cover of soft bottom (higher than 20%), normally ensures a good density of carnivores, especially Lethrinidae, these were less common than expected, more evidence of impact from heavy fishing.

Intermediate-reef environment: Maatea

The intermediate-reef environment of Maatea was dominated by four families: the herbivorous Acanthuridae and Scaridae and carnivorous Mullidae and Chaetodontidae (density only) (Figure 3.21). These four families were represented by 39 species; particularly high abundance and biomass were recorded for *Mulloidichthys vanicolensis*, *Ctenochaetus striatus*, *Zebrasoma scopas*, *Chlorurus sordidus*, *Mulloidichthys flavolineatus* and *Scarus psittacus* (Table 3.8). This reef environment presented a diverse habitat dominated by hard bottom (41%), with a relatively important cover of soft bottom (20%) and high live-coral cover (26%, Table 3.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.10 ±0.02	13.1 ±3.3
	Zebrasoma scopas	Twotone tang	0.09 ±0.03	7.3 ±2.6
Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	0.06 ±0.05	19.2 ±16.4
	Mulloidichthys flavolineatus	Yellowstripe goatfish	0.01 ±0.01	3.9 ±2.5
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.02 ±0.01	5.6 ±1.9
	Scarus psittacus	Common parrotfish	0.01 ±0.01	2.7 ±1.3

The density of finfish in the intermediate reefs of Maatea was comparable to in the other survey sites. However, size, biomass and biodiversity were in the lower range of all values from intermediate reefs (Table 2.6). Herbivores and carnivores were equally important in the biomass and density composition of the trophic structure. Acanthuridae for one trophic group and Mullidae for the other were the two most important families in this habitat. Similar to the situation in coastal reefs, Lethrinidae and Lutjanidae were present in very small numbers. Average size ratio was quite high (60%) and most families had values above 50%, except Balistidae and Lutjanidae.

The intermediate reefs of Maatea displayed a high cover of hard bottom (41%) and the highest coral cover (23%) among the intermediate reefs of all sites, explaining the high abundance and diversity (16 species) of Chaetodontidae. Soft bottom, here present as 25% of the substrate composition, is generally favourable to carnivorous species, but these were particularly rare at this site. Lethrinidae and Lutjanidae also displayed the lowest size ratio, an index of impact from fishing pressure. Results showed, in fact, that Lutjanidae along with Serranidae, were among the most targeted finfish families in this habitat.

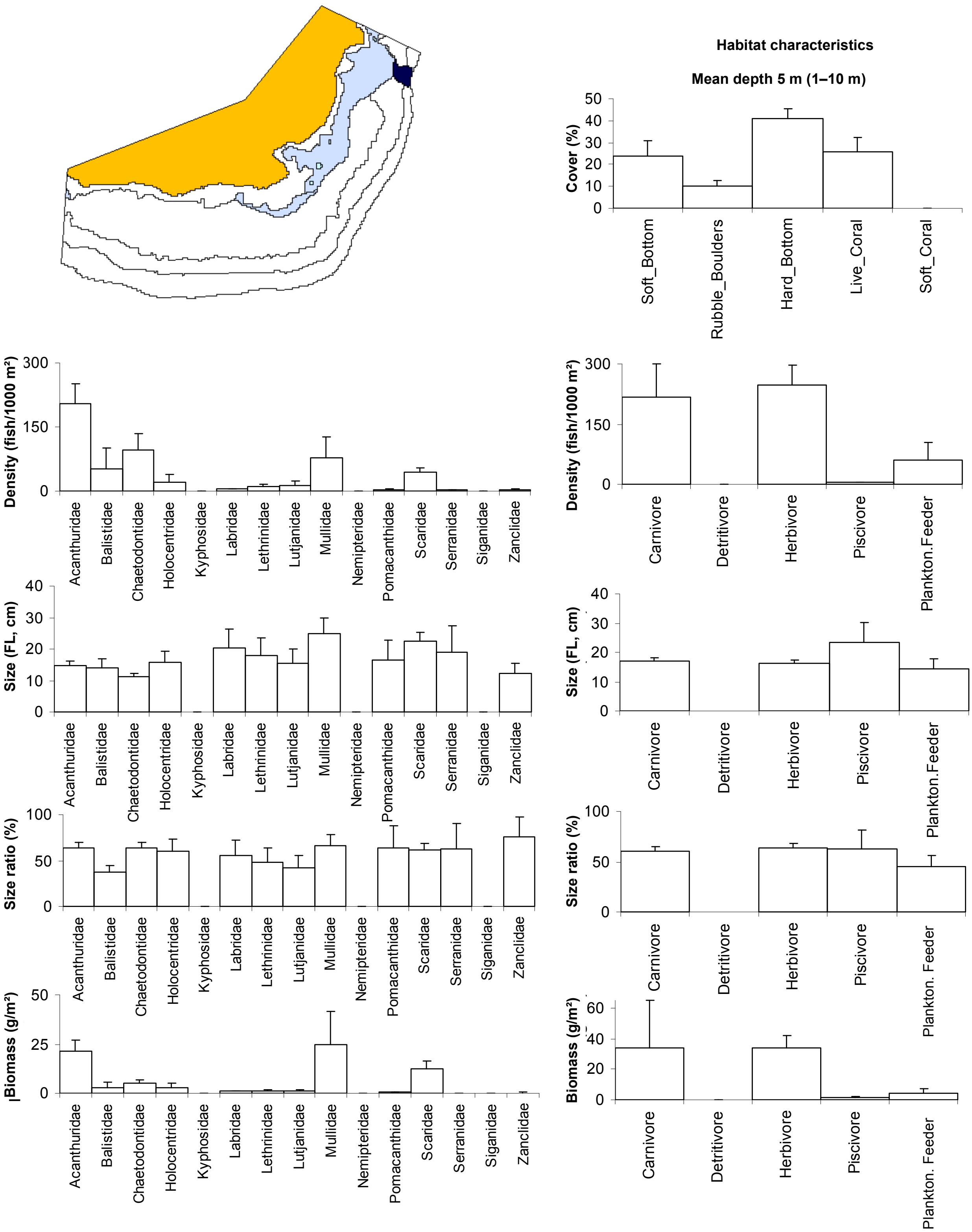

Figure 3.21: Profile of finfish resources in the intermediate-reef environment of Maatea.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Maatea

The back-reef environment of Maatea was dominated by three families: herbivorous Acanthuridae and Scaridae and, to a much lesser extent, carnivorous Mullidae (only in terms of biomass, Figure 3.22). These three families were represented by 17 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Acanthurus triostegus*, *Scarus psittacus*, *Mulloidichthys flavolineatus*, *Chlorurus sordidus*, *Zebrasoma scopas* and *Parupeneus multifasciatus* (Table 3.9). This reef environment presented a diverse substrate composition with strong dominance of hard bottom (45% cover) (Table 3.6 and Figure 3.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.20 ±0.03	19.0 ±5.2
	Acanthurus triostegus	Convict tang	0.21 ±0.13	17.0 ±10.7
	Zebrasoma scopas	Twotone tang	0.01 ±0.01	0.9 ±0.7
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.01 ±0.01	4.0 ±1.4
	Parupeneus multifasciatus	Many bar goatfish	0.00 ±0.00	0.8 ±0.3
Scaridae	*Scarus psittacus*	Common parrotfish	0.04 ±0.02	7.2 ±3.2
	Chlorurus sordidus	Daisy parrotfish	0.02 ±0.01	3.1 ±1.3

The density of finfish in the back-reef of Maatea was the highest among the back-reefs studied in the country and biomass was comparable to in the other sites, second only to Tikehau (Table 3.7). Biomass of Mullidae was very high, and due mostly to large presence of *Mulloidichthys flavolineatus*. Other carnivores were particularly rare or absent. As a consequence, trophic structure in terms of both density and biomass was dominated by herbivores. The back-reef of Maatea displayed low values of soft-bottom cover (15%) and very high cover of hard bottom (45%), a substrate combination that typically favours herbivores.

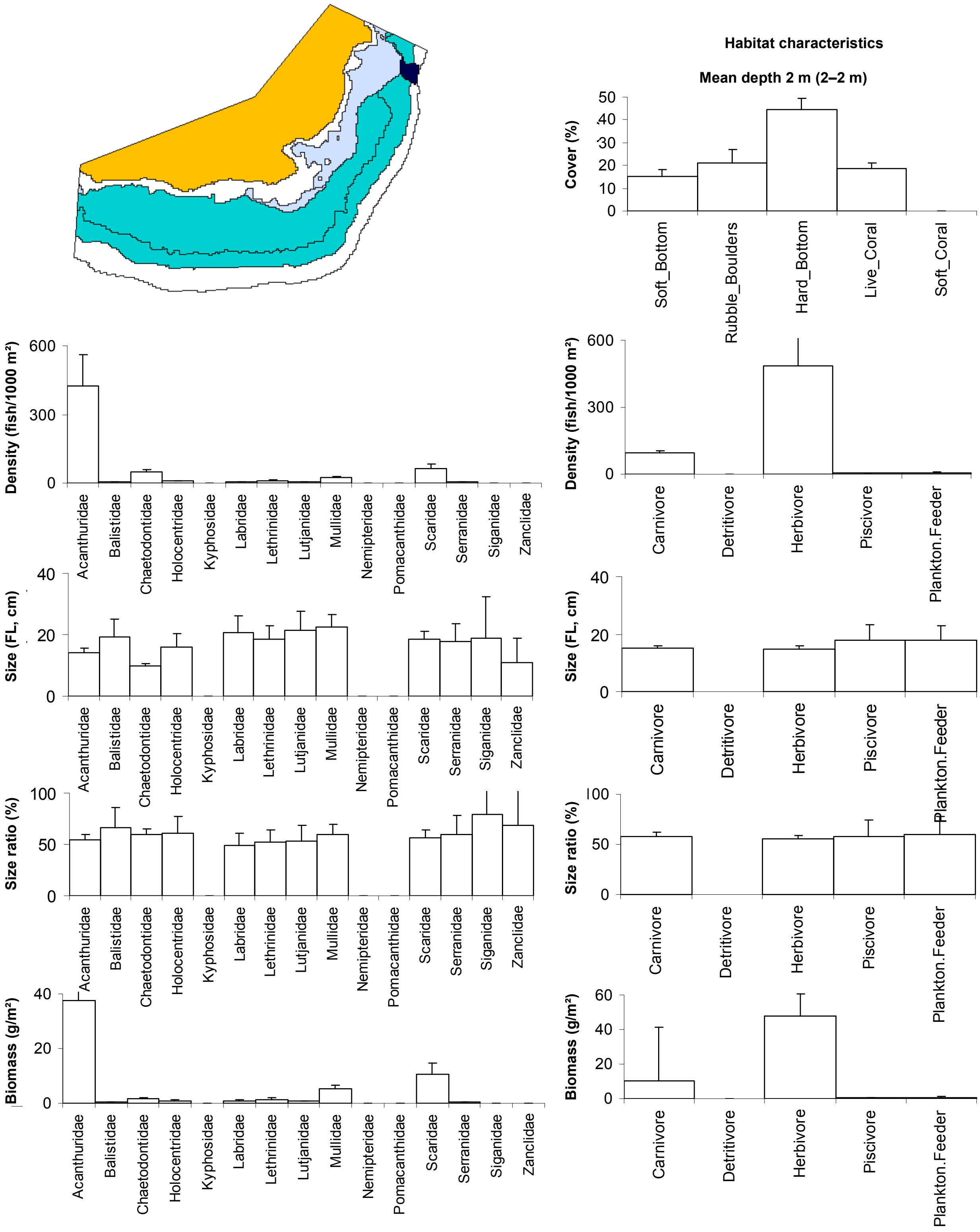

Figure 3.22: Profile of finfish resources in the back-reef environment of Maatea.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Maatea

The outer reef of Maatea was dominated by two herbivorous families: Acanthuridae and Scaridae, and by one carnivorous family, Balistidae (Figure 3.23). These three families were represented by 27 species; particularly high abundance and biomass were recorded for *Chlorurus sordidus*, *Acanthurus olivaceus*, *Ctenochaetus striatus*, *Scarus psittacus*, *A. nigroris*, *Melichthys niger*, *M. vidua* and *Zebrasoma scopas* (Table 3.10). Hard bottom (67% cover) largely dominated the substrate of this reef environment (Table 3.6 and Figure 3.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus olivaceus*	Orangeband surgeonfish	0.06 ±0.02	10.3 ±3.4
	Ctenochaetus striatus	Striated surgeonfish	0.21 ±0.04	9.9 ±1.9
	Acanthurus nigroris	Bluelined surgeonfish	0.08 ±0.02	5.7 ±2.1
	Zebrasoma scopas	Twotone tang	0.03 ±0.02	1.8 ±1.2
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.22 ±0.05	26.9 ±5.8
	Scarus psittacus	Common parrotfish	0.07 ±0.03	9.7 ±3.4
Balistidae	*Melichthys niger*	Black triggerfish	0.04 ±0.02	5.3 ±2.0
	Melichthys vidua	Pinktail triggerfish	0.04 ±0.01	4.8 ±0.8

The density of finfish in the outer reef of Maatea was the highest (1.0 fish/m^2) among the five outer reefs surveyed in the country, but size and size ratios were the lowest, and biomass ranked third (99 g/m^2). Biodiversity was comparable to at the other sites (Table 3.7). Carnivores were very low in abundance and biomass and the trophic structure was highly dominated by herbivores. Size ratios were below 50% for Acanthuridae, Labridae, Lutjanidae and Scaridae. Substrate composition was strongly dominated by hard bottom (the highest cover of all outer reefs, 67%) with a relatively low coral cover (30%). Results found that Acanthuridae and Lethrinidae were among the most frequently targeted families in this habitat. Although outer reefs were targeted by the lowest fisher density compared to the other habitats, the small numbers of carnivores suggest impact from fishing; emperor fish, for example, were practically absent.

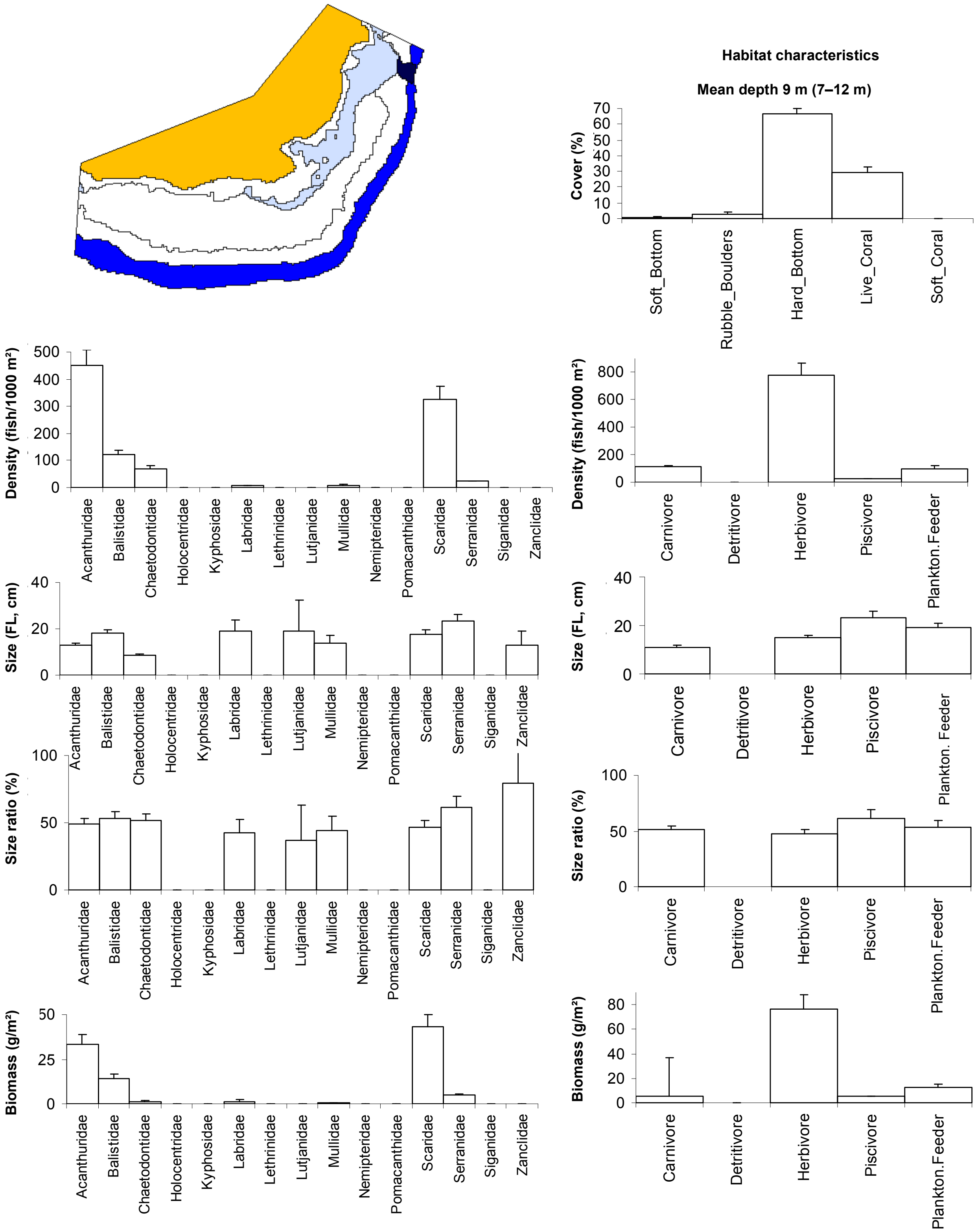

Figure 3.23: Profile of finfish resources in the outer-reef environment of Maatea.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Maatea

Over all the reef habitats combined, the fish assemblage of Maatea was dominated by Acanthuridae and Scaridae (in terms of both density and biomass, Figure 3.24). These two families were represented by a total of 28 species, dominated (in terms of both density and biomass) by *Ctenochaetus striatus*, *Acanthurus triostegus*, *Chlorurus sordidus*, *Scarus psittacus*, *Zebrasoma scopas*, *A. olivaceus* and *A. nigroris* (Table 3.11). As expected, the overall fish assemblage in Maatea shared characteristics of back-reefs (63% of total habitat), outer reef (22% of total habitat) and, to a lesser extent, coastal reefs (13% of total habitat) and intermediate reefs (2%).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.20	15.6
	Acanthurus triostegus	Convict tang	0.14	11.1
	Zebrasoma scopas	Twotone tang	0.02	1.2
	Acanthurus olivaceus	Orangeband surgeonfish	0.01	2.4
	Acanthurus nigroris	Bluelined surgeonfish	0.02	1.3
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.07	8.5
	Scarus psittacus	Common parrotfish	0.04	7.2

Overall, Maatea appeared to support a similar finfish resource to the average for PROCFish/C study sites in the country, with the highest density (0.7 fish/m^2), the second highest biodiversity (31 species/transect), but third-lowest biomass (65 g/m^2 i.e. below Fakarava and Raivavae values), and intermediate-to-low average fish-size values (average size 15 cm FL and size ratio 53%) (Table 3.6). While these results suggest that finfish resources in Maatea are in average-to-low condition, detailed assessment at the family level also revealed a systematic low abundance of carnivores Labridae, Lethrinidae (except for *Gnathodentex aureolineatus*, present in high numbers in sheltered coastal reefs) and Lutjanidae, with a relatively high presence of Mullidae, especially in the back- and intermediate reefs. Unfavourable environmental conditions (either from natural or human causes) for the development of these carnivore species may explain this trend in Maatea. However, higher impact from fishing on specific carnivorous species (especially Lethrinidae in the outer reefs, and Lutjanidae in the coastal reefs) at this site, compared to the average from all sites, could be the cause. Indeed, the density of fishers per reef area is much higher than at other sites.

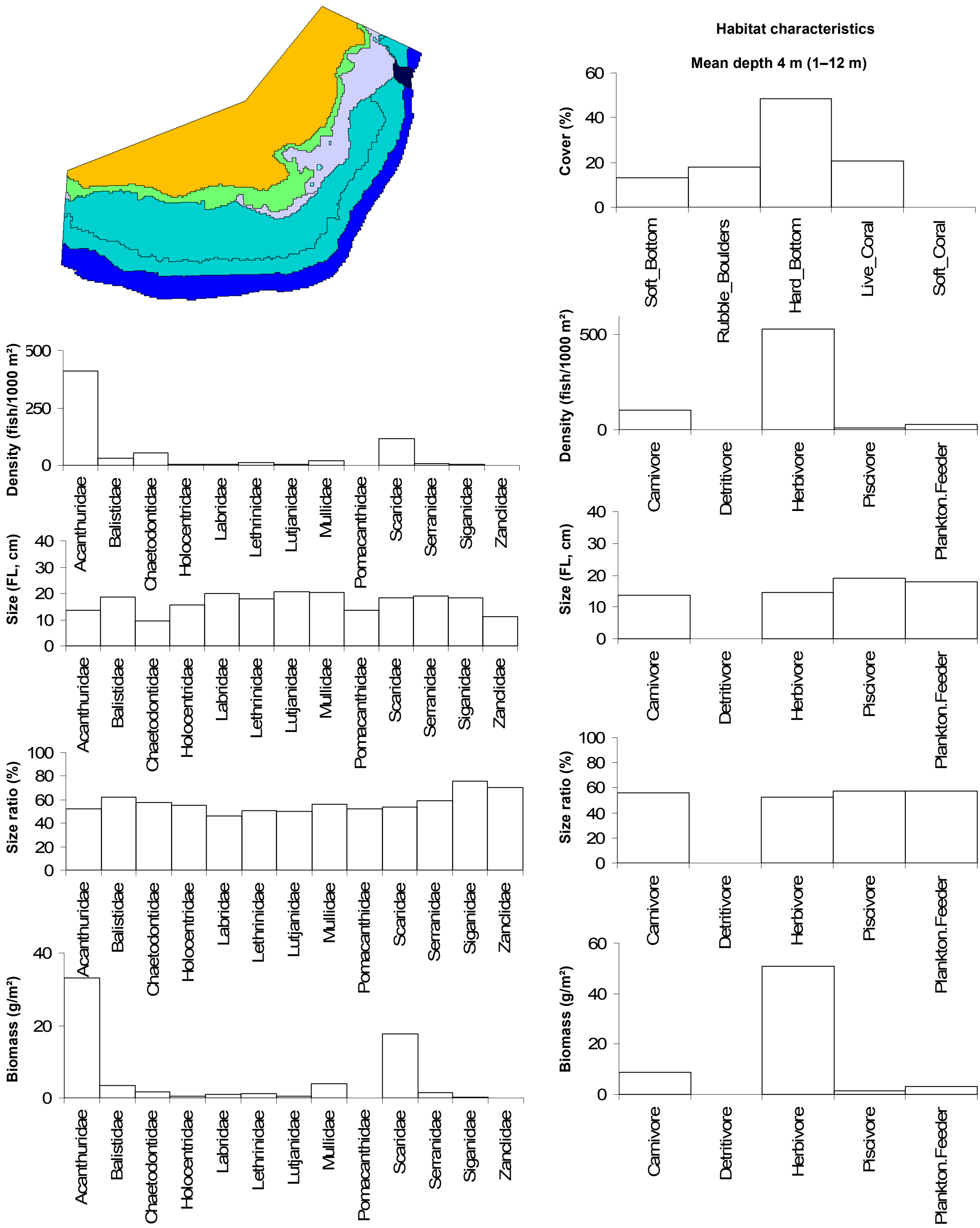

Figure 3.24: Profile of finfish resources in the combined reef habitats of Maatea (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Maatea

Survey results show that the status of finfish resources in Maatea is slightly lower than the average across PROCFish/C study sites in the country. Detailed assessment at reef level also revealed a systematic, lower-than-average abundance for snappers (Lutjanidae), goatfish (Mullidae) and especially emperors (Lethrinidae). These results suggest that this trend could be due to greater-than-average fishing impact on carnivorous species. Fishing in Maatea is mostly carried out for sustenance purposes. However, the impact on fish resources is already visible: in the low average fish size of some families; the particular trophic structure, which is highly dominated by herbivores; and in the very low number or lack of carnivores, especially of targeted species groups, such as Lethrinidae.

- Overall, Maatea finfish resources appeared to be relatively poor, despite the relatively rich reef habitat.

- Populations of emperors (Lethrinidae), snappers (Lutjanidae) and goatfish (Mullidae) were systematically lower than the country average.

- The total fishing pressure on Maatea was found to be high and obvious impacts were revealed by the lower-than-average fish size and in the herbivore-dominated trophic composition of the finfish population.

3.4 Invertebrate resource surveys: Maatea

The diversity and abundance of invertebrate species at Maatea were independently determined using a range of survey techniques (Table 3.12): broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 3.25) and finer-scale assessment of specific reef and benthic habitats (Figures 3.26 and 3.27).

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

Table 3.12: Number of stations and replicate measures completed at Maatea

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	73 transects
Reef-benthos transects (RBt)	19	114 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	6	36 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches	7 RFs 0 RFs_w	42 search periods 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	5	30 search periods

RFs = reef-front search; RFs_w = reef-front search by walking.

Figure 3.25: Broad-scale survey stations for invertebrates in Maatea.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 3.26: Fine-scale reef-benthos transect survey stations for invertebrates in Maatea.
Black squares: reef-benthos transect stations (RBt).

Figure 3.27: Fine-scale survey stations for invertebrates in Maatea.
Grey stars: sea cucumber day search stations (Ds);
black inverted triangles: reef-front search stations (RFs);
black squares: mother-of-pearl transect stations (MOPt).

Thirty-one species or species groupings (groups of species within a genus) were recorded in the Maatea invertebrate surveys. These included, among others, 4 bivalves, 10 gastropods, 7 sea cucumbers, 5 urchins, 3 sea stars, and 1 cnidarian (Appendix 4.2.1). Information on key families and species is detailed below.

3.4.1 Giant clams: Maatea

Shallow reef habitat that is suitable for giant clams was moderate in scale at Maatea (7.04 km^2: approximately 4.3 km^2 within the lagoon and 2.7 km^2 on the reef front or slope of the barrier). Unlike at the PROCFish/C atoll sites of Tikehau and Fakarava, inshore areas at this high-island site had noticeably greater land influence. Nutrient inputs, in the form of allochthonous matter was less obvious as one moved through the back-reef towards the barrier-reef slope, but during the time of our survey (during heavy rain), shallows along the coastal edge were often too dirty to allow visual census. In general, the lagoon at Maatea had a moderately deep and wide mid-section, which became narrower as one travelled south round Moorea, as the shallow-water back-reef became more extensive. Maatea faces the prevailing swells, and there is dynamic water movement across the barrier and through the numerous passes of the lagoon, which allows oceanic water to flush the outer areas of the lagoon.

Broad-scale sampling provided an overview of giant clam distribution at Maatea. Reef at this site held only one species of giant clam: the elongate clam *Tridacna maxima*; records from broad-scale sampling revealed a wide distribution (found in 11 of 12 stations and 61 of 73 transects). The average station density of *T. maxima* in broad-scale assessments was 269.4 /ha ±64.6, Figure 3.28).

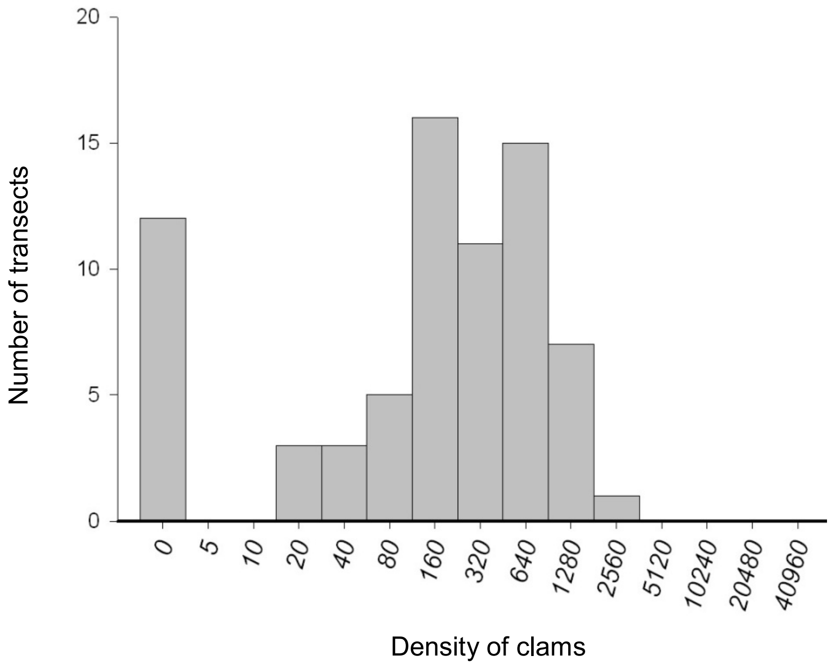

Figure 3.28: Frequency plot of density per 300 m transect measures (per ha) for *Tridacna maxima* clams at Maatea, based on all broad-scale assessment stations.
Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 3.29). In these reef-benthos assessments (RBt) *T. maxima* was present in 89% of stations at a mean density of 1491.2 /ha ±303.5.

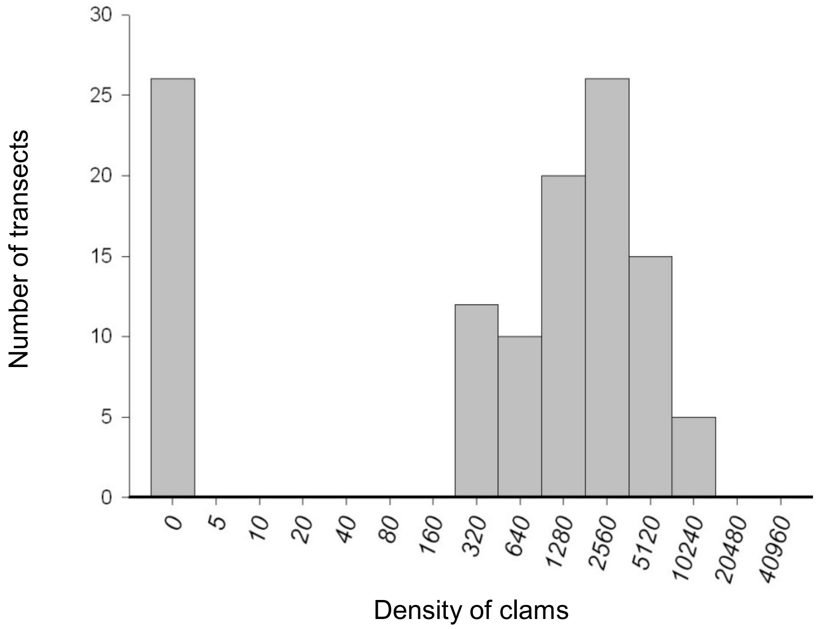

Figure 3.29: Frequency plot of density per 40 m transect measures (per ha) for *Tridacna maxima* clams at Maatea, based on all fine-scale reef-benthos transect assessment stations. Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Two of the five RBt stations situated close to shore held no clams. *T. maxima* were found at the highest density at RBt stations at shallow reef stretching behind the barrier reef crest, with 63% of stations having an average density >1000 clams/ha. At their highest density, clams in one transect were recorded at 8750 /ha, or just <1 /m^2.

Of the 711 records taken during all assessment techniques, the average length of *T. maxima* was 8.9 cm ±0.1. The mean from shallow reef-benthos stations was similar at 9.2 cm ±0.2. A full range of lengths for *T. maxima* were recorded in survey, although clams were generally smaller than found in other parts of the Pacific. Larger clams (≥16 cm) were rare in shallow water and were mainly restricted to reefs in more exposed locations (The mean clam size from mother-of-pearl SCUBA surveys was 12.4 cm, Figure 3.30.).

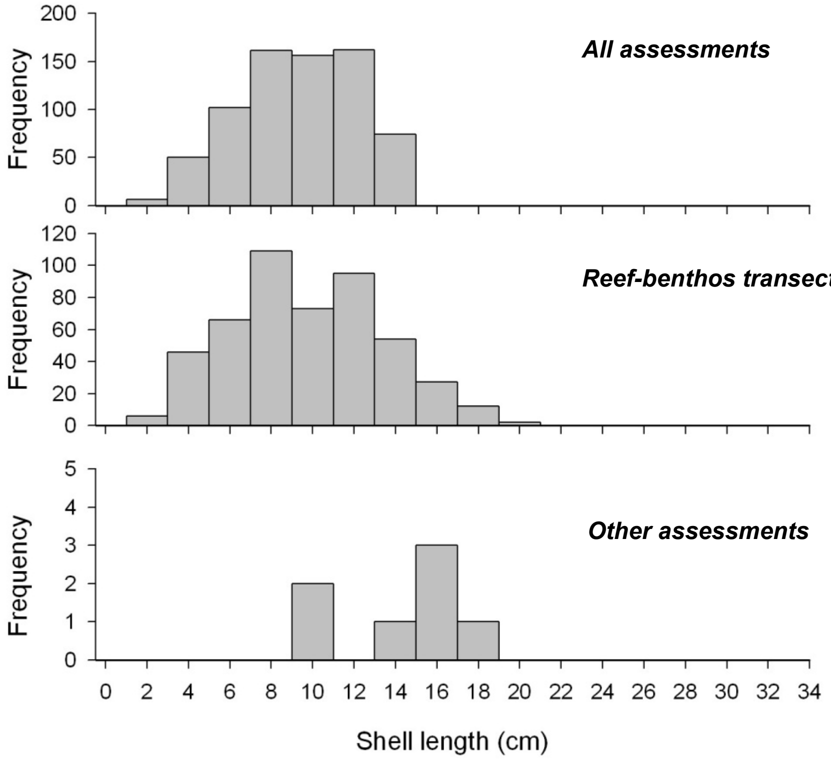

Figure 3.30: Size frequency histograms of giant clam shell length (cm) for Maatea.

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

Maatea lies at approximately 17°32'S, which is well within the latitude for the commercial topshell, *Trochus niloticus*, in the Pacific. However, trochus do not naturally occur in French Polynesia; their natural distribution stops at Wallis Island (Wallis and Futuna), over 2000 km to the west of Moorea. However, 40 commercial topshells were introduced to French Polynesia (to the Tautira district of Tahiti) from Vanuatu (Port Vila) in November 1957. Although shells may have been moved to Moorea on a number of occasions, there is a translocation from Tahiti to Moorea recorded six years after the introduction of shell to Tahiti (In 1963, 800 individuals were transferred.). It was not until 14 years after its introduction to French Polynesia (November 1971) that commercial harvesting of trochus began. Commercial harvesting in Moorea occurred twice, once in 1973 (46,643 kg shell only) and again in 1978 (72,396 kg) followed by a long period of closure until the present survey. Non-commercial fishing has continued at a low level, with trochus meat removed from the shell on the trochus grounds (Dead shells with harvest holes were noted during the survey.).

The outer reef at Maatea (16.8 km lineal distance of exposed reef perimeter) constitutes extensive benthos for *T. niloticus*. However, it is subject to very large trade wind swells, which flatten the relief and complexity of the benthos, making it less suitable for high-density populations of trochus. On the other hand, back-reef and coastal reef that faces passages do provide suitable habitat, and these areas could potentially support significant populations of this commercial species.

PROCFish/C survey work revealed that *T. niloticus* was relatively widespread across reefs in Maatea, being present on the barrier reef (back-reef, reeftop and outer-reef slope), on reef within passages, and along the coast of the lagoon (Table 3.13). The suitability of reefs for grazing gastropods was highlighted by the presence of trochus and green snail (*Turbo* *marmoratus*), but there were no results for the related green topshell (*Tectus pyramis*), as this species only extends east as far as Tuvalu, Samoa and Tonga (Table 3.13).

Table 3.13: Presence and mean density of *Trochus niloticus* and *Turbo marmoratus* in Maatea
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	75.8	26.0	12/12 = 100	37/73 = 51
RBt	2210.5	1161.2	16/19 = 84	67/114 = 59
RFs	210.1	191.3	5/7 = 71	20/42 = 48
MOPt	1371.5	811.7	6/6 = 100	22/36 = 61
Turbo marmoratus				
B-S	4.1	1.7	4/12 = 33	8/73 = 11
RBt	78.9	37.4	6/19 = 32	18/114 = 16
RFs	29.1	8.0	7/7 =,100	21/42 = 50
MOPt	104.2	29.9	6/6 = 100	15/36 = 42

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

Trochus were numerous and found at most reef locations around Maatea (total n = 2144 individuals recorded). Aggregations of trochus were predominantly concentrated on shoreline reef opposite passages, or on the lagoon side of the barrier (less exposed back-reef). The greatest density (averaging >2 individuals/m^2 for a single reef-benthos station) was recorded on coastal fringing reef just south of Afareaitu, opposite a passage in the barrier reef where both land and oceanic influences were present. Few trochus were seen in front of the barrier, where the shallow water is subject to very large swells and the epiphytic growth on the substrate is more limited.

The mean basal width of trochus at Maatea was 9.6 cm ±0.1 (n = 620). At present there are no commercial harvests of trochus, and only some subsistence fishing for trochus meat. The presence of 21.8% of the measured stock above the legal size of 11 cm highlights the older mature portion of the stock that would be protected from fishing if there were commercial harvests (and serve as broodstock). This estimate of the protected portion of the population is conservative, as shallow-reef assessments would not necessarily yield as many measures of older shell, which predominantly live deeper than smaller, younger trochus.

Although small trochus are very cryptic, shells smaller than 8 cm were also common (making up 23.4% of the stock). There was a noticeable peak in the abundance of shell sizes around 7.5 cm (Figure 3.31) indicating a successful spawning and settlement that took place in the late summer of 2003. These ‘new’ young trochus are entering the fishery proportion of the stock as ~3 year-old shells.

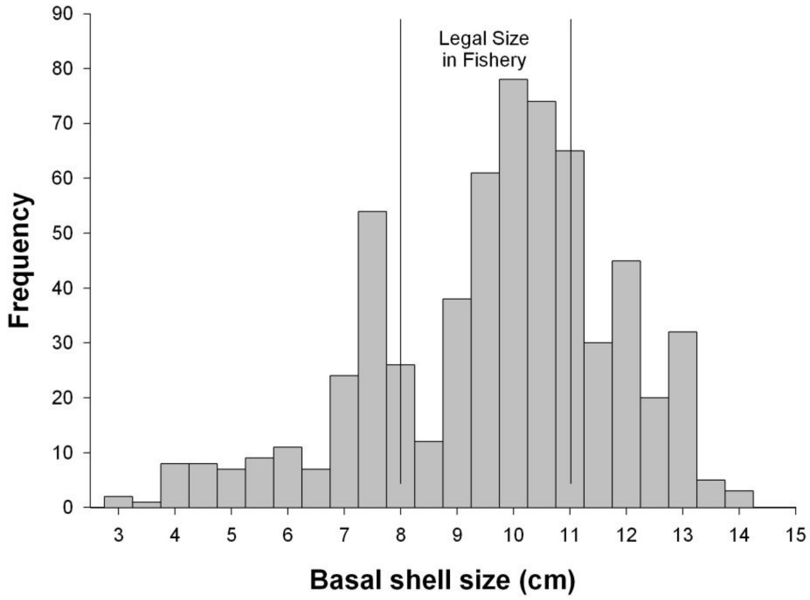

Figure 3.31: Size frequency histogram of giant clams shell base diameter (cm) for Maatea.

The great green turban shell (more usually called 'green snail'), *Turbo marmoratus*, was also recorded in Maatea (n = 139). The bulk of this stock was recorded on shallow outer reef, and near the surf zone on the barrier. This species was also recorded at high density on reef affected by swell that was close to the mainland. In fact the greatest density (1–4 individuals for five of the six 40 m transects) was recorded at a single reef-benthos station in the south of Moorea, among trochus and the surf red sea cucumber, *Actinopyga mauritiana*.

The size of great green turbans can be a little tricky to measure. Although the regulations in French Polynesia stipulate that the *T. marmoratus* shell length should be between 160 mm min and 180 mm max for legal fishing (across the longest diameter), on occasion the largest gape measure on the whorl opening (shell mouth) is measured. This allows a measurement to be made without needing to overcome the curvature of the shell, which can interfere with normal shell length measurements. *T. marmoratus* in Maatea were seen at a full range of sizes (4.5–22 cm) and had a mean size (longest diameter) of 14.5 cm ±0.4.

Although blacklip pearl oysters, *Pinctada margaritifera,* are cryptic and normally sparsely distributed in open lagoon systems, they are still normally recorded in shallow-water assessments. In Maatea, blacklip pearl oysters were surprisingly rare, with only a single shell recorded in survey (at a sea cucumber day search station in deep water).

3.4.3 Infaunal species and groups: Maatea

No fine-scale assessments or infaunal stations (quadrat surveys) were made at Maatea. The soft-benthos coastal margin of the shallow-water lagoon was sandy without extensive areas of seagrass or mud, and no concentrations of in-ground resources (shell 'beds'), such as arc shells (*Anadara*) or venus shells (*Gafrarium* spp.), were identified.

3.4.4 Other gastropods and bivalves: Maatea

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded at medium-to-high density in broad-scale and finer-scale surveys (n = 21 individuals recorded), but *Lambis lambis* and the strawberry or red-lipped conch *Strombus luhuanus* were not present (Appendices 4.2.1 to 4.2.7). Out of the range of small turbans (e.g. *Turbo argyrostomus*, *T. chrysostomus* and *Turbo setosus*), only *Turbo setosus* was recorded, and this was at low density in shallow-reef stations (mean density 17.5 /ha ±9.7). It was not possible to closely inspect the surf zone at Maatea as the large swells during the time of the survey made this work too dangerous; however, the species was absent from MOP surveys. Other resource species targeted by fishers (e.g. *Astralium*, *Cassis*, *Conus*, *Cypraea* and *Thais*), were also recorded during independent surveys (Appendices 4.2.1 to 4.2.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus*, are also in Appendices 4.2.1 to 4.2.7. No creel survey was conducted at Maatea.

3.4.5 Lobsters: Maatea

Maatea had 16.8 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef, represents a moderately large amount of habitat for lobsters. Lobsters are an unusual invertebrate species that can recruit from near and distant reefs as their larvae drift in the ocean for 6–12 months (up to 22 months) before settling as transparent miniature versions of the adult (pueruli, 20–30 mm in length).

There was no dedicated night search conducted for lobsters (See Methods and Appendix 1.3.), and no lobsters (neither *Panulirus* spp. nor *Parribacus* spp.) were recorded in the survey. Night searches (Ns) for nocturnal sea cucumber species were not conducted due to the unusually heavy rain and flooding that occurred during the survey period, so no further opportunities to record lobster species arose.

3.4.6 Sea cucumbers[7]: Maatea

Maatea has a moderately extensive, shallow lagoon system bordering a large high-island land mass. Reef margins and areas of shallow, mixed hard- and soft-benthos habitat suitable for sea cucumbers were present, however much of the benthos was clean sand and limestone pavement. There was significant land influence close to shore, and riverine input was obvious, but generally surfaces were without heavy algal and epiphytic growth. In general the system could be considered to be largely oceanic-influenced. Outside the barrier reef the reef slope is impacted by the large swell, and shelves off relatively steeply into deeper water.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.14, Appendices 4.2.2 to 4.2.6; also see Methods.). At Maatea, seven commercial species of sea cucumber were recorded during in-water assessments (Table 3.14), a similar amount to other high islands or atoll PROCFish/C sites in French Polynesia. The range of sea cucumber species recorded in Maatea reflected the easterly position of French Polynesia, which is distant from the centre of biodiversity, and the largely exposed, oceanic-

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

influenced nature of the habitats present. However, the lagoon, passages and outer reef of Maatea suited some of these deposit-feeding sea cucumber species (which eat organic matter in the upper few mm of bottom substrates).

Sea cucumber species associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were very common (found in 73% and 47% of broad-scale and targeted assessments, respectively) and often at high density, indicating a stock that is under low fishing pressure. However, the high-value black teatfish (*Holothuria nobilis*[8]) was not recorded, despite there being significant suitable areas within the back-reef for this species. Black teatfish stocks can usually be found in shallow water and are therefore highly susceptible to fishing pressure. There is also evidence that this stock can be depleted to levels that make recovery difficult, so that heavy fishing occurring even decades previously could still be impacting the viability of this species on Moorea. The fast-growing and medium/high-value greenfish, (*Stichopus chloronotus*) was also not found at any stations of Moorea and may be absent from French Polynesia.

Surf redfish, *Actinopyga mauritiana*, were recorded across the site, but generally at low density. The highest densities never exceeded 200 /ha (167 at a shallow reef RBt station among the trochus and green snail in the south of Moorea). This species can be found at commercial densities of 500–600 /ha in other islands of French Polynesia, and in Cook Islands, Tonga and Solomon Islands.

In more protected areas of reef and soft benthos at embayments in the lagoon we did not record blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), pinkfish (*Holothuria edulis*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*), although lower-value species, e.g. lollyfish (*H. atra*) were moderately common and brown sandfish (*Bohadschia vitiensis*) was noted.

Deep-water assessments (30 searches of 5 mins, average depth 25.6 m, maximum 33 m) were completed to obtain a preliminary abundance estimate for white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the narrow and wide passages had suitably dynamic water movement for these species, but *H. fuscogilva* was only recorded in one of the five stations surveyed. Interestingly, white teatfish records were also made in shallow water, during both broad-scale and reef-benthos transect surveys. In all these recordings, white teatfish were at low-to-moderate density (<13 individuals/ha). Deep-water assessments did not detect amberfish (*T. anax*) or prickly redfish (*T. ananas*).

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

3.4.7 Other echinoderms: Maatea

The edible collector urchin, *Tripneustes gratilla*, was present at low density (n = 13) but no slate urchins, *Heterocentrotus mammillatus*, were noted (possibly due to large swells keeping surveyors away from the reef crest). Other urchins that can be used within assessments as a food source or potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at high levels. The large, black *Echinothrix* spp. (*E. diadema* and *E. calamaris*) were unusually common, being recorded at every broad-scale station (mean transect density 70.1 /ha ±11.5) and all RBt stations (65% of RBt transects, mean station density of 936.4 /ha ±254.2, Appendices 4.2.1 to 4.2.7).

Starfish were sparsely distributed at Maatea; the blue starfish, *Linckia laevigata*, was only present in small numbers (n = 4 recorded) and, although pincushion stars, *Culcita novaeguineae*, were noted at 50% of broad-scale stations, they were not in high density (2.5 /ha). Six records of another coralivore (coral eating) starfish, the crown of thorns star (*Acanthaster planci*), was noted. Its presence was not concentrated in one area, although shallow-water reef in the lagoon east of Maatea and on either side of Avarapa passage in the south were colonised (See presence and density estimates in Appendices 4.2.1 to 4.2.7.).

Table 3.14: Sea cucumber species records for Maatea

Species	Common name	Commercial value [5]	B-S transects n = 73			Reef-benthos stations n = 19			Other stations RFs = 7; MOPt = 6			Other stations Ds = 5		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	3	43.3	7	37.3	141.7	26	7.3 13.9	17.0 41.7	43 RFs 33 MOPt			
Bohadschia argus	Leopardfish	M	79.7	109.7	73	61.4	129.6	47				5.7	14.3	40
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L	0.5	16.7	3	2.2	41.7	5						
Holothuria atra	Lollyfish	L	345.0	2098.5	16	366.2	1740	21						
Holothuria fuscogilva [4]	White teatfish	H	0.7	16.7	4	2.2	41.7	5				12.8	64.2	20
Holothuria leucospilota	-		0.2	17.9	1									
Holothuria nobilis [4]	Black teatfish	H												
Stichopus horrens	Peanutfish	M												
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H	1.6	19.4	8	4.4	41.7	11						
Thelenota anax	Amberfish	M												

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

3.4.8 Discussion and conclusions: invertebrate resources in Maatea

- The reefs at Maatea, especially the shallow-water back-reef habitat, were very suitable for the elongate clam, *Tridacna maxima*. The fringing reef was less suitable for giant clams, due to significant river inflows. Giant clam density was high compared to other open-lagoon, high-island sites in the Pacific, although the coverage and density were not remarkable compared to results from more enclosed atoll sites in French Polynesia. 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 shore and of large-sized clams was relatively low, supporting the assumption that clam stocks are moderately impacted by fishing.

- Trochus, *Trochus niloticus,* stocks are common at Maatea, with the greatest concentrations on fringing reef opposite the main passes. Strict protection of trochus broodstock (sizes 11 cm and up), and the long 'resting' of stock since the last commercial fishing is considered the main reasons why trochus stocks at Maatea are in the healthy condition found during the survey. Periodic harvests along with strict size controls have proved a successful strategy for stock management in French Polynesia. The blacklip pearl oyster, *Pinctada margaritifera* was uncommon at Maatea.

The potential for developing a commercial sea cucumber fishery based on stocks around Maatea is limited. A restricted range of sea cucumber species was present, mainly due to biogeographical influences, the easterly position of Moorea in the Pacific, and the limited number of protected habitats available in this largely oceanic-influenced lagoon system. A high density of the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish were recorded, but few medium-value prickly redfish (*Thelenota ananas*) were recorded.

3.5 Overall recommendations for Maatea

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

- The development and implementation of Moorea's marine management plan (Plan de Gestion de l'Espace Maritime (PGEM)) agrees with the perception that the lagoon resources of Maatea and Moorea are generally declining, due to increases in population and tourism. However, the effectiveness of this PGEM may need further improvement as there are a number of conflicts arising between governmental and local authorities concerning modern and traditional conservation approaches and methods.

- Spear diving is a common practice in the coastal, lagoon and outer reefs; this very selective fishing practice should be regulated and night diving banned.

- Marine protected areas could be considered as a primary management tool to enable overexploited fishing areas to recover.

- There is scope for trochus fishing at Maatea at areas where stocks are at their highest densities (500–600 /ha are required); especially if the gauntlet fishery regulation is adhered to (i.e. only shells with a basal width between 8 and 11 cm are taken).

- The green snail (*Turbo marmoratus*), is common in some places in Maatea, but the density of this species is not high across its range. No commercial fishing of *T. marmoratus* is recommended at this stage due to the limited area and distribution of this species across its potential range at Maatea.

- Interviewing older fishers to identify areas that traditionally held trochus and green snail stocks, but which are now overfished, might allow range extension of both these resources. Transplantation of adults from dense aggregations into new areas that have become depleted is advised if commercial harvests are not to go ahead in the short term.

- The high-value black teatfish (*Holothuria nobilis*) was absent around Maatea. In addition, further assessment of deeper-water white teatfish stocks (*H. fuscogilva*) is required to understand its fishery potential. Extra survey effort is recommended to ascertain the status of these stocks on Moorea, and to see if extra protection is needed to rebuild populations of this species locally.

4. PROFILE AND RESULTS FOR MATAIEA

4.1 Site characteristics

The village of Mataiea is located in the south of Tahiti Nui high-island, at the position 17°46'S and 149°24'W (Figure 4.1). This island, which is part of the Windward Group in the Society Archipelago, is the biggest island in French Polynesia (1045 km²). It comprises two dormant volcanoes linked by a natural isthmus: Tahiti Nui (big) and Tahiti Iti (small). It is also the most inhabited island, with 70% of the total population. Only the coastal band is inhabited and there are 22 districts in total. The fishery ground area is open access and extends 11.3 km x 2.2 km. The lagoon comprises four habitats: outer reef, back-reef, intermediate reef and sheltered coastal reef, with a total reef area of ~14 km². As most of the people work in the capital city, fishing is performed for food-rather than income.

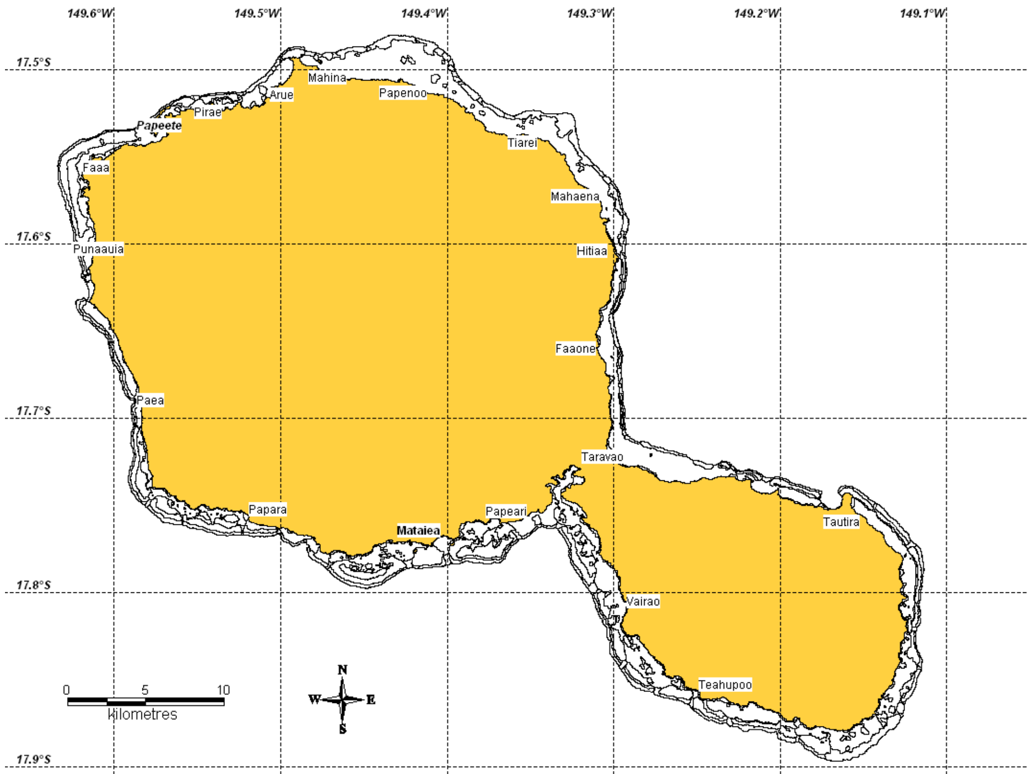

Figure 4.1: Map of Mataiea.

4.2 Socioeconomic surveys: Mataiea

Socioeconomic fieldwork was carried out in the community of Teva I Uta, which combines the settlements of Mataiea and Papeari (in the following referred to as 'Mataiea'). Mataiea is located about 80 km north of Papeete, the capital of French Polynesia. The survey was conducted in February 2004, and covered a total of 33 households, including 160 people. Due to the extensive size of the community, the survey only represents about 2% of the community's households (1537) and total population (7933).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 22 individual interviews of finfish fishers (18 males, 4 females) and 12 invertebrate fishers (10 males, 2 females) were conducted. These fishers belonged to one of the 33 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 4.1) suggest an average of at least one fisher per household. If we apply this average (1.39) to the total number of households, we arrive at a total of 2136 fishers in Mataiea. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 1143 fishers who fish only for finfish (males, females), a total of 49 fishers who harvest only invertebrates (females) and 944 (males, females) fishers who fish for both finfish and invertebrates.

Over 60% of all households in Mataiea own a boat, 52% of all boats are non-motorised canoes and 48% are motorised.

Ranked income sources (Figure 4.2) suggest that fisheries are not an important sector. Only 3% of the households investigated rely on fisheries as first source of income, and still less than a quarter (23%) quoted fisheries as a second source of income. Salaries provide 90% of all households with first income, and another 6% gain their main cash income from other sources, including businesses and social fees. These other sources are also an important complementary income source for almost half of the population surveyed (45%). Agriculture is insignificant as far as income generation is concerned.

The importance of fisheries, however, shows in the fact that all households reported eating seafood, including fresh fish, invertebrates and canned fish. The fish that is consumed is either caught by a member of the household (77%) or bought (65%), but much less often received as a gift (32%). The proportion of invertebrates caught by a member of the household where consumed is lower (42%); about 13% of all households buy invertebrates for consumption. Some are still distributed on a non-monetary basis (19%). These results suggest that the people in Mataiea enjoy a rather modern or urbanised lifestyle. The engagement of most people in salary-based employment explains why fishing is mainly performed for subsistence purposes, and may also explain the high percentage of seafood that is commercially acquired.

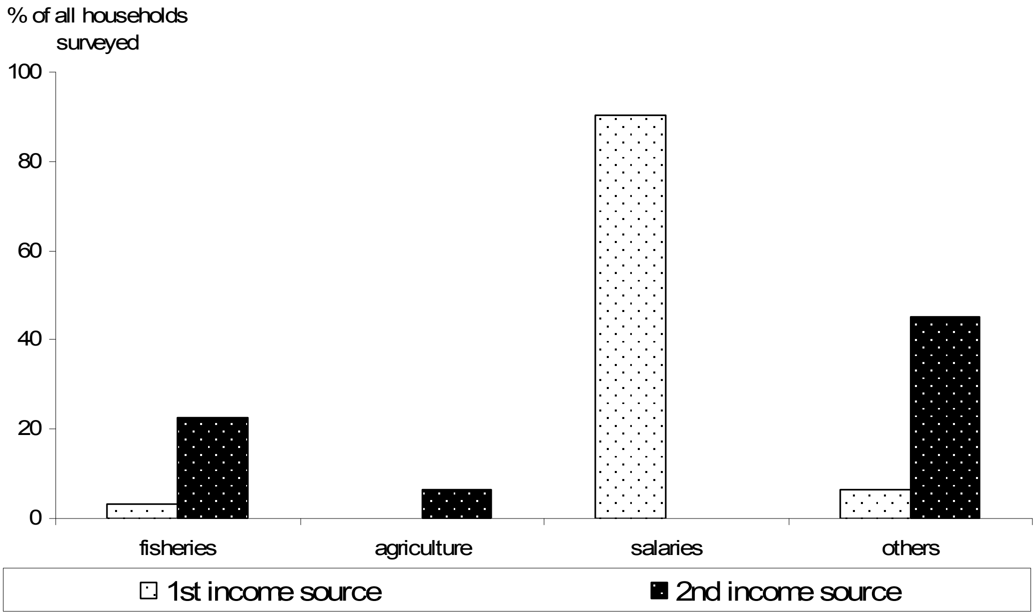

Figure 4.2: Ranked sources of income (%) in Mataiea.
Total number of households = 33 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small businesses.

The per capita consumption of fresh fish (~45 kg/capita/year ±5.9) in Mataiea is above the regional average (FAO 2008) (Figure 4.3), but the lowest as compared to the other four PROCFish/C sites in French Polynesia. The consumption of invertebrates (meat only) is very low (0.96 kg/capita/year) (Figure 4.4) and also among the lowest figures compared to the other four PROCFish/C sites. Canned fish consumption is relatively low but similar to the rates found elsewhere in French Polynesia (~2.4 kg/capita/year ±1.24) (Table 4.1).

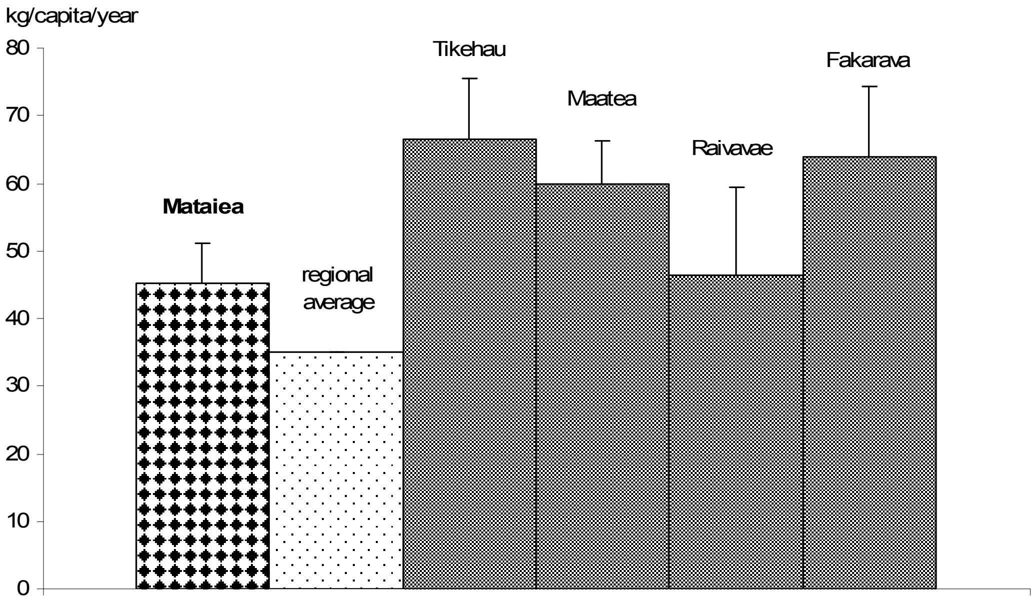

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Mataiea (n = 33) compared to the regional average (FAO 2008) and the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

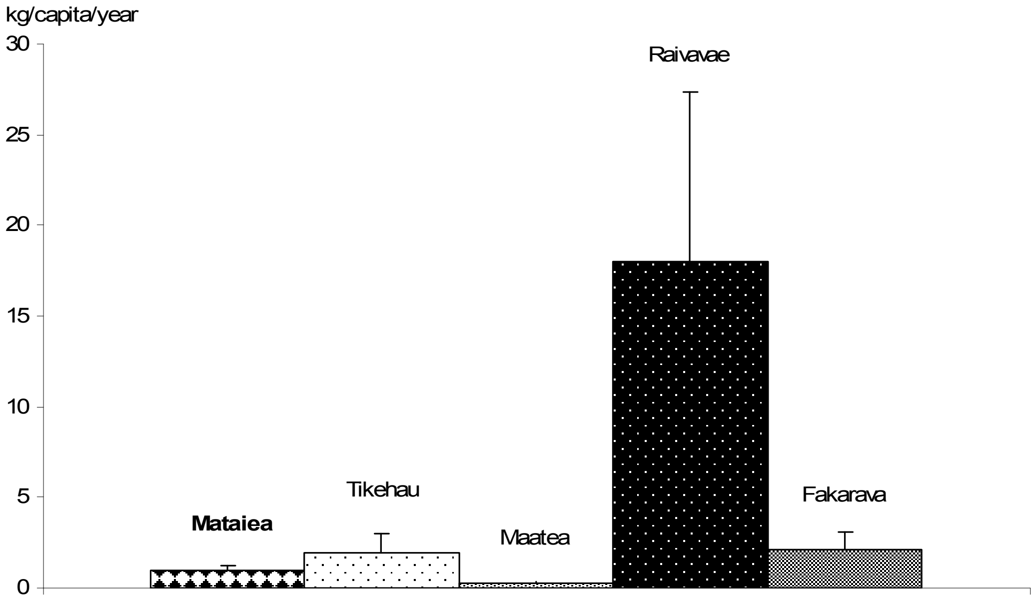

Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Mataiea (n = 33) compared to the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Comparing results between Mataiea and the average of all five PROCFish/C sites in French Polynesia (Table 4.1), the people of Mataiea are less dependent on fisheries for income generation, and eat less fresh fish and invertebrates in a year. Data show a much higher average household expenditure level while remittances do not play any role at all.

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

Survey coverage	Site (n = 33 HH)	Average across sites (n = 138 HH)
Demography		
HH involved in reef fisheries (%)	77.4	85.5
Number of fishers per HH	1.39 (±0.19)	1.71 (±0.12)
Male finfish fishers per HH (%)	41.9	33.9
Female finfish fishers per HH (%)	11.6	9.7
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	2.3	14.0
Male finfish and invertebrate fishers per HH (%)	41.9	35.2
Female finfish and invertebrate fishers per HH (%)	2.3	6.8
Income		
HH with fisheries as 1st income (%)	3.2	14.5
HH with fisheries as 2nd income (%)	22.6	11.6
HH with agriculture as 1st income (%)	0.0	11.6
HH with agriculture as 2nd income (%)	6.5	13.8
HH with salary as 1st income (%)	90.3	46.4
HH with salary as 2nd income (%)	0.0	8.7
HH with other source as 1st income (%)	6.5	26.8
HH with other source as 2nd income (%)	45.2	34.1
Expenditure (USD/year/HH)	12,718.58 (±913.47)	9752.58 (±468.27)
Remittance (USD/year/HH) (1)	86.46 (n/a)	1055.66 (±393.52)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	45.13 (±5.93)	55.55 (±4.16)
Frequency fresh fish consumed (times/week)	2.72 (±0.36)	3.28 (±0.16)
Quantity fresh invertebrate consumed (kg/capita/year)	0.96 (±0.29)	4.91 (±4.16)
Frequency fresh invertebrate consumed (times/week)	0.13 (±0.04)	0.38 (±0.07)
Quantity canned fish consumed (kg/capita/year)	2.37 (±1.24)	3.95 (±0.59)
Frequency canned fish consumed (times/week)	0.30 (±0.11)	0.65 (±0.10)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	100.0	82.6
HH eat canned fish (%)	100.0	79.0
HH eat fresh fish they catch (%)	77.4	84.0
HH eat fresh fish they buy (%)	64.5	56.0
HH eat fresh fish they are given (%)	32.3	44.0
HH eat fresh invertebrates they catch (%)	41.9	44.0
HH eat fresh invertebrates they buy (%)	12.9	8.0
HH eat fresh invertebrates they are given (%)	19.4	8.0

HH = household; n/a = standard error not calculated; (1) average sum for households that receive remittances; numbers in brackets are standard error.

4.2.2 Fishing strategies and gear: Mataiea

Degree of specialisation in fishing

Fishing in Mataiea is performed by both males and females (Figure 4.5). However, most of all fishers who target exclusively finfish are males (42%), fewer are females (~12%). Very few respondents specialised in the collection of invertebrates only, and these were all females (~2%). More males (~42%) than females (2%) target both finfish and invertebrates.

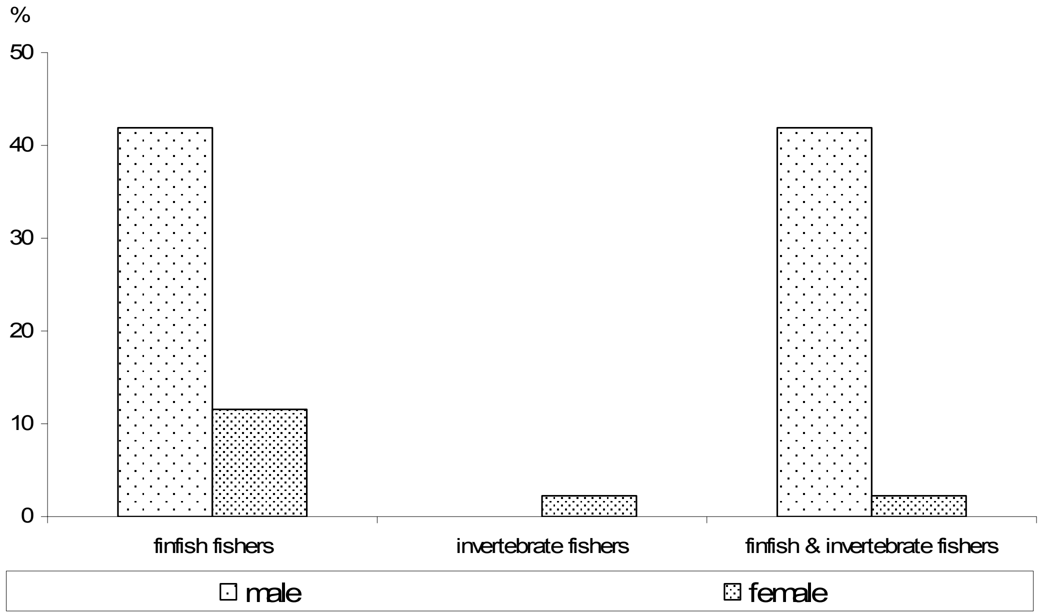

Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Mataiea.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	22.2	25.0
	Lagoon	66.7	75.0
	Outer reef	11.1	0.0
Invertebrates	Lobster	70.0	0.0
	Other	30.0	100.0
	Reeftop	10.0	50.0

'Other' refers to the giant clam and sea urchin fisheries.
Finfish fisher interviews, males: n = 18; females: n = 4. Invertebrate fisher interviews, males: n = 10; females, n = 2.

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Mataiea on their fishing grounds (Table 4.2).

Our survey sample suggests that fishers in Mataiea can choose among sheltered coastal reef, lagoon and outer reef. Fishers seem to clearly distinguish between habitats targeted and visit only one at any time. None of the respondents reported combining any of the habitats in one fishing trip. Most fishers, i.e. 67% of male fishers and 75% of female fishers, however, target the lagoon. Only 11% of all male fishers target the outer reef; a quarter of both male and female fishers target the sheltered coastal reef.

Fishing patterns and strategies

Invertebrate fisheries are not diverse, and data suggest they are less important than finfish fisheries. Most species collected are associated with reefs. Males mainly target lobsters (70%) and females collect giant clams and sea urchins either by walking or free diving (Figure 4.6). About half of all female fishers also glean the reeftop targeting the same invertebrate groups, which are very limited in number, including shells of *Turbo* spp. As shown in Figure 4.7, more males than females are engaged in invertebrate fisheries overall, and lobster diving is performed exclusively by male fishers.

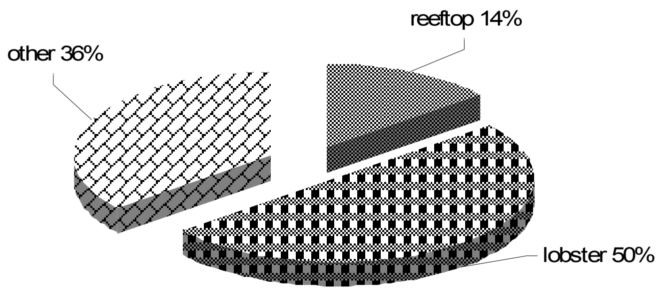

Figure 4.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Mataiea.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the giant clam and sea urchin fisheries.

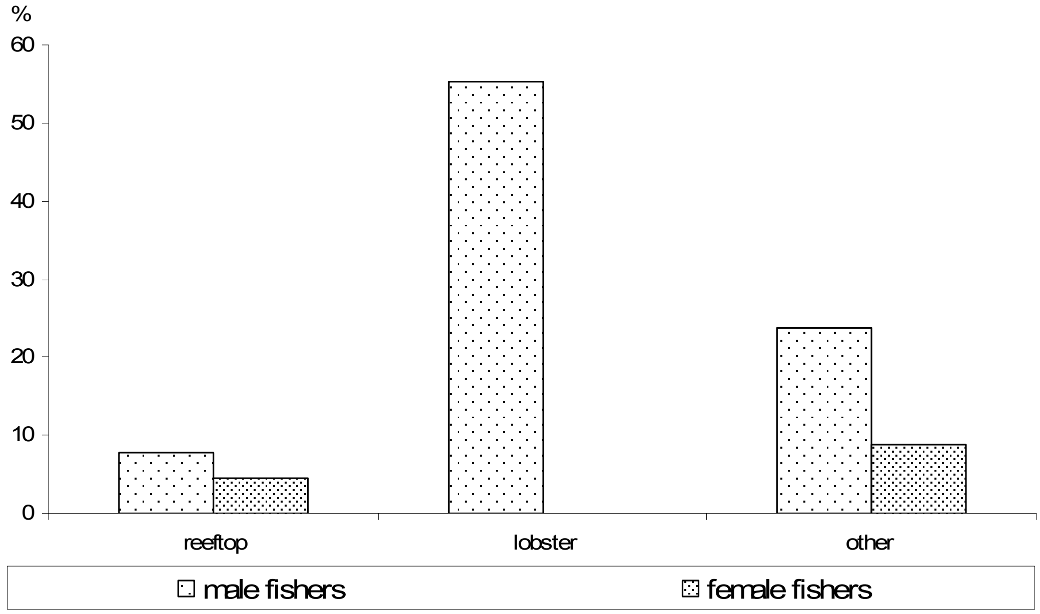

Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Mataiea.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 10 for males, n = 2 for females; 'other' refers to the giant clam and sea urchin fisheries.

Gear

Figure 4.8 shows that strategies vary considerably among habitats targeted. Fishers targeting the sheltered coastal reef usually use a variety of methods, often including a combination of gillnetting, spear diving and handlining. Sometimes handlining, spears or gillnets are exclusively used. Handlining is the main method used in the lagoon; spear diving is also used in the lagoon and is the only method used in the outer reef. All fishing is done from boats. Male fishers used motorised boats for ~44% of fishing trips and paddling canoes for ~56% of trips. Female fishers always use non-motorised canoes.

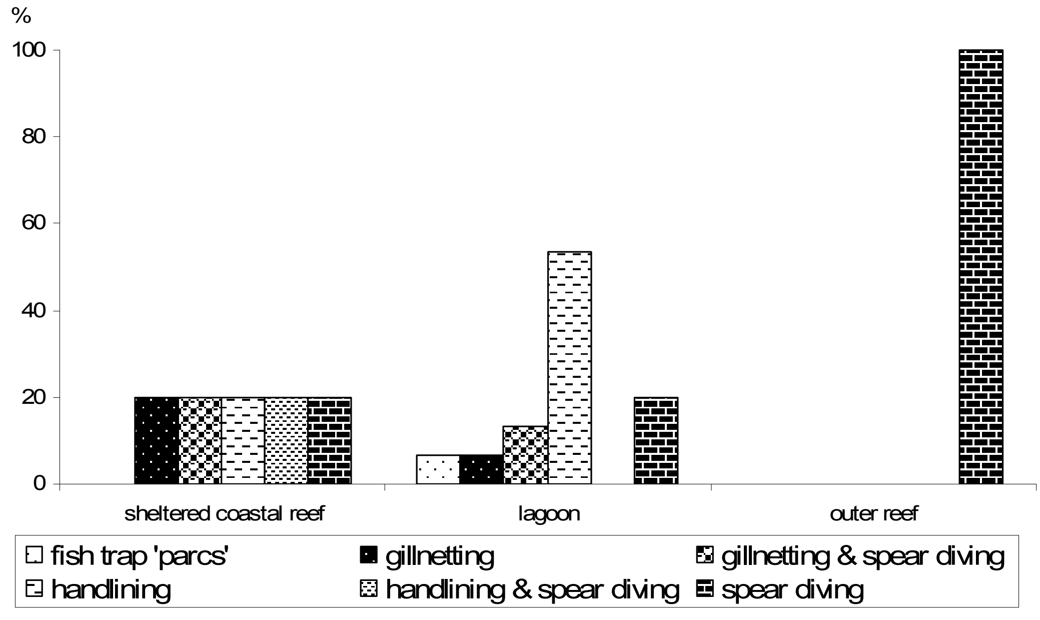

Figure 4.8: Fishing methods commonly used in different habitat types in Mataiea.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Gleaning and free diving for invertebrates are done using very simple tools only. Lobsters and giant clams are picked up by hand and, if done by free diving, use dive mask, fins, snorkel and possibly dive suit. Diving does not involve any SCUBA gear. Only diving for lobsters and giant clams is always done using boat transport, in most cases motorised boats. Reeftop gleaning and free diving for giant clams and sea urchins use boats in about half of all cases, but these are mostly non-motorised canoes. Reeftop gleaning is also sometimes done by walking.

Frequency and duration of fishing trips

As shown in Table 4.3 the frequency of fishing trips does not vary among habitats targeted. In general finfish fishers go out once a week. Taking into consideration that most households depend on salary-based income, finfish fishers often use the weekend to provide their household with fresh fish. Considering the average trip duration, again there is no obvious variation among the habitats targeted. In general, male fishers go out for 4–5 hours, while female fishers spend 2–4 hours at sea.

As mentioned earlier, invertebrate fisheries are of much less importance. This also shows in the very low frequency of invertebrate fishing trips, often less than once in three months for male fishers and perhaps 2–4 times a month for female fishers. The trip duration of invertebrate fishing is comparable to finfish fishing, i.e. 3–5 hours for male fishers and 2–4 hours for female fishers.

Finfish fishing is performed either according to tidal conditions, i.e. at night or during the day or, in about half of all cases, fishers prefer fishing in the day, except for spear divers, who dive at night only. In the case of invertebrate collection, lobster fishing is exclusively done at night, while all other collection targeting the reeftop, and free diving for giant clams, urchins and perhaps lobsters, are exclusively performed during the day. While most finfish fishers fish only during half of the year or less, invertebrate fishing continues throughout the year.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.18 (±0.48)	1.00 (n/a)	5.25 (±0.43)	2.00 (n/a)
	Lagoon	1.29 (±0.43)	1.50 (±0.76)	4.92 (±0.57)	4.00 (±1.53)
	Outer reef	1.06 (±0.94)	0	4.50 (±1.50)	0
Invertebrates	Lobster	0.08 (±0.03)	0	4.71 (±0.47)	0
	Other	0.13 (±0.06)	0.85 (±0.15)	4.33 (±0.67)	3.50 (±1.50)
	Reeftop	0.09 (n/a)	0.23 (n/a)	3.00 (n/a)	2.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam and sea urchin fisheries.
Finfish fisher interviews, males: n = 18; females: n = 6. Invertebrate fisher interviews, males: n = 10; females: n = 2.

4.2.3 Catch composition and volume – finfish: Mataiea

Catches from the sheltered coastal reef include a variety of different fish species; Acanthuridae, Scaridae and *Naso unicornis* dominate, with ~36%, ~24% and ~16% of the total reported catch respectively. Another 12 species or species groups constitute the remaining catch composition that was reported by the respondents from Mataiea. For lagoon catches the composition changes; *Caranx* spp., *Myripristis* spp. and *Epinephelus merra* dominate, with a contribution of 10–13% each to the total catch, while Acanthuridae, *Lutjanus fulvus*, Scaridae and *Cheilinus trilobatus* play minor roles. Over 15 other species or species groups were also frequently recorded. The catch composition reported by outer-reef spear divers is much less diverse. There were five main species reported, including *Chlorurus microrhinos* (~23%), *Naso unicornis* (~20%), *Caranx* spp. (~17%), *Acanthurus xanthopterus* (~17%) and *Kyphosus* spp. (~17%). Another three species or species group were listed, including (to an insignificant extent) Scaridae and Siganidae (Detailed data are provided in Appendix 2.3.1.).

Our survey sample of finfish fishers interviewed only represents about 2% of the projected total number of finfish fishers in Mataiea. However, discussions with the local fishing association showed that there are basically three different fisher groups: (a) commercial fishers, (b) fishers who may occasionally sell fish, and (c) subsistence and leisure fishers. Local informants indicated that the group of commercial fishers consisted of a total of 10 male fishers (five each in Mataiea and Papeari), while the group of fishers who occasionally sell fish may include about 30 male fishers (half in either community). Fish is mainly sold along the roadside within the community and, in the early mornings of Saturday or Sunday, next to well-known shops, door-to-door, at the male fisher's house, or upon command. Clients pay between XPF 1000 and 2000 for one string and, for lobsters, prices may range between XPF 1800 and 2600 /kg.

Based on the information of the various fishers' groups, we decided to include many of the commercially oriented fishers, at least those who are known to regularly sell their catch along the local roadsides. However, due to the size of the community and the low representation of our sample size we did not extrapolate our results to estimate the total annual fishing pressure. We therefore only present and discuss here the reported data from the 22 respondents. It should also be noted that Mataiea fishing grounds are subject to heavy impact from external fishers, in particular, fishers with motorised boat transport who come from as far as the urban area of Papeete, and who are frequent and numerous, particularly at weekends and holidays. Respondents expressed major concern about external fishing pressure and impact and many fishers hold these 'intruders' responsible for a perceived decline of local reef resources.

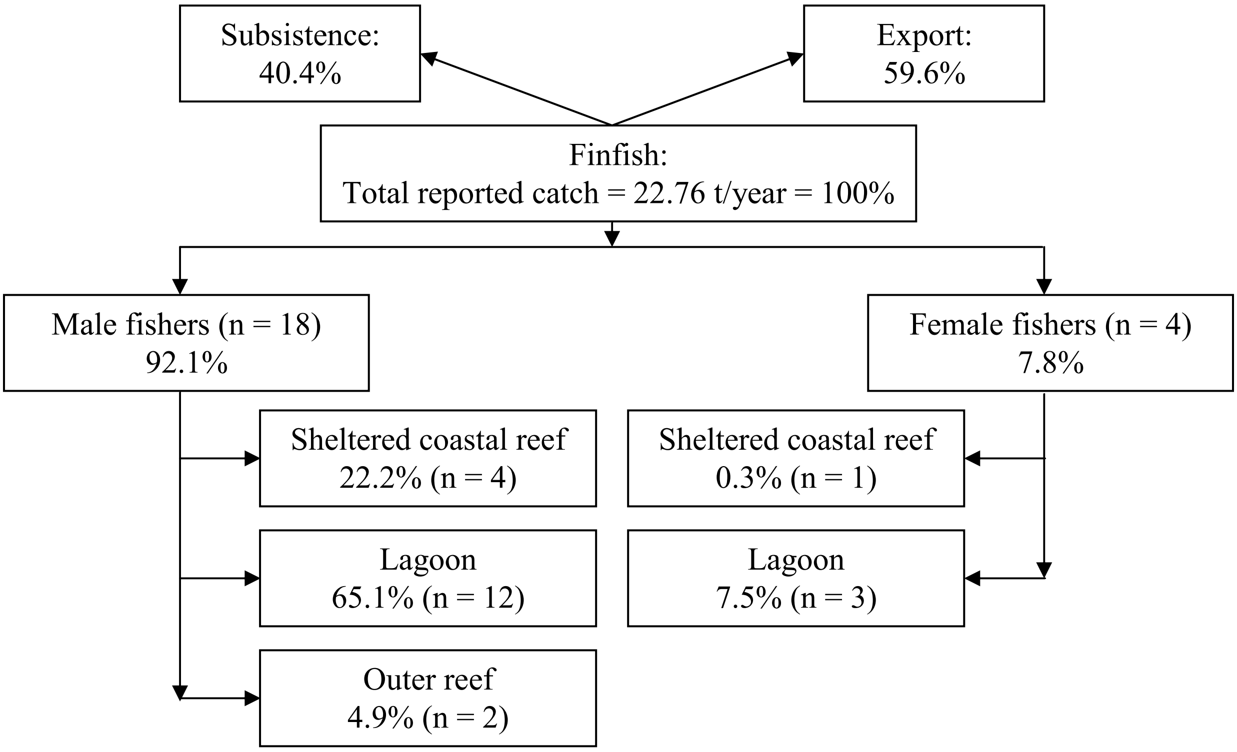

Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mataiea.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

As shown in Figure 4.9, about 60% of the reported catch is due to commercial reef fishing, i.e. catches that are sold within the Mataiea community. Subsistence needs of the households associated with the fishers interviewed determine about 40% of the reported catch. Taking into consideration that we interviewed a large number of commercial fishers, and by knowing the limited number of commercial and occasionally commercial male fishers (10 and 30 respectively), the proportion of catch reported here for sale is presumably over-represented. Therefore, we can assume a much smaller commercial proportion of total catch if we had sampled wider across a higher percentage of the population. Nevertheless, these figures show that most of the catch is taken by male fishers, while females only play a minor role (<8%). Highest pressure is imposed on the lagoon, with much less impact on the sheltered coastal reef (~22%), and outer reef (~5% of the total annual catch).

The high impact on the combined sheltered coastal reef and lagoon habitats is a function of the number of fishers targeting these areas, as well as the average annual catch rate. As shown in Figure 4.10, average annual catches for male fishers are about 600 kg/fisher/year for both sheltered coastal reef and lagoon catches, but only about half (<300 kg/fisher/year) for outer-reef catches. Female fishers catch much less, i.e. about 50 kg/fisher/year if targeting the sheltered coastal reef and less than 300 kg/fisher/year in the lagoon. This difference between gender groups suggest that male fishers are much more commercially oriented than females, who mainly fish for subsistence needs only.

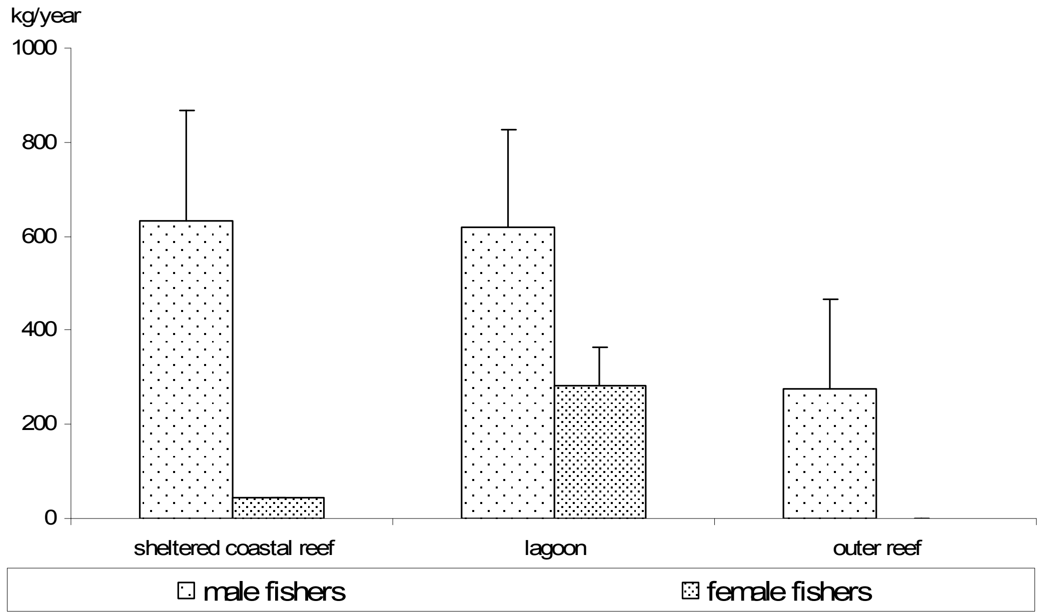

Figure 4.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Mataiea (based on reported catch only).

Comparing the CPUE calculated for the different habitats fished, not much difference was found between lagoon and outer-reef areas; however, CPUEs reported by male fishers targeting the sheltered coastal reef appear slightly higher (Figure 4.11).

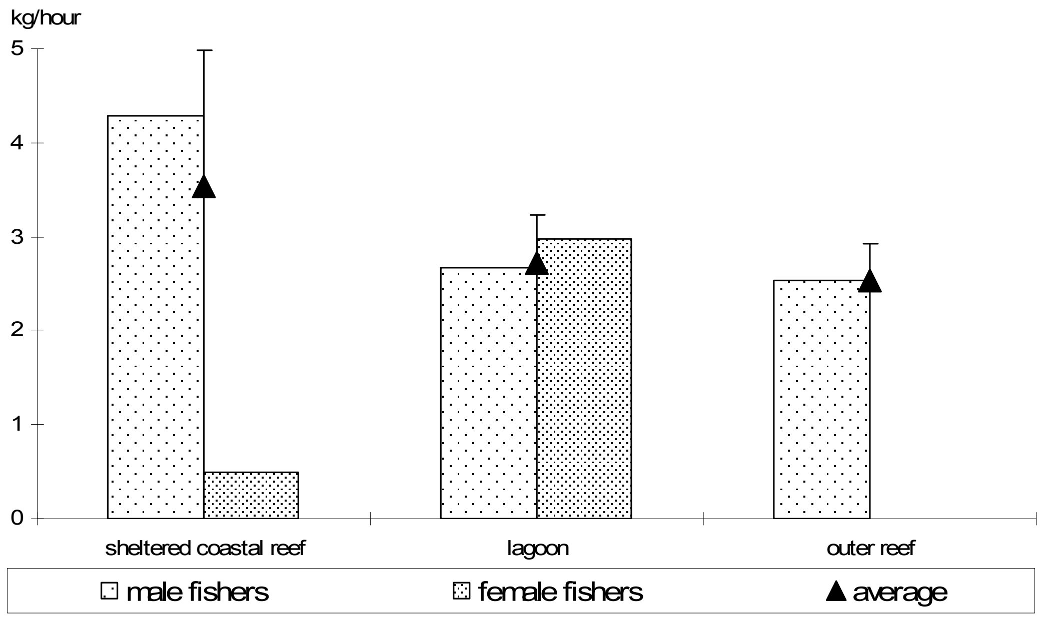

Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Mataiea.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data suggest that most catch from the sheltered coastal reef and the outer reef is intended for sale, although most sales occur within the Mataiea community. Lagoon catches are used almost equally for subsistence and commercial purposes. The proportion of any catch that is distributed among community members on a non-monetary basis is always very low (Figure 4.12).

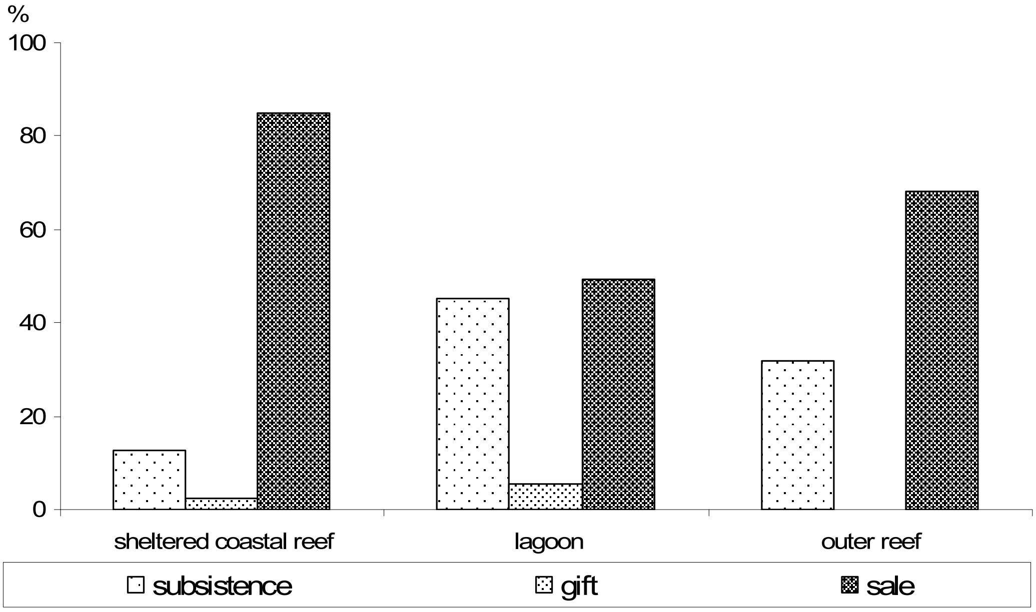

Figure 4.12: The use of finfish catches for subsistence, gift and sale, by habitat in Mataiea. Proportions are expressed in % of the total number of trips per habitat.

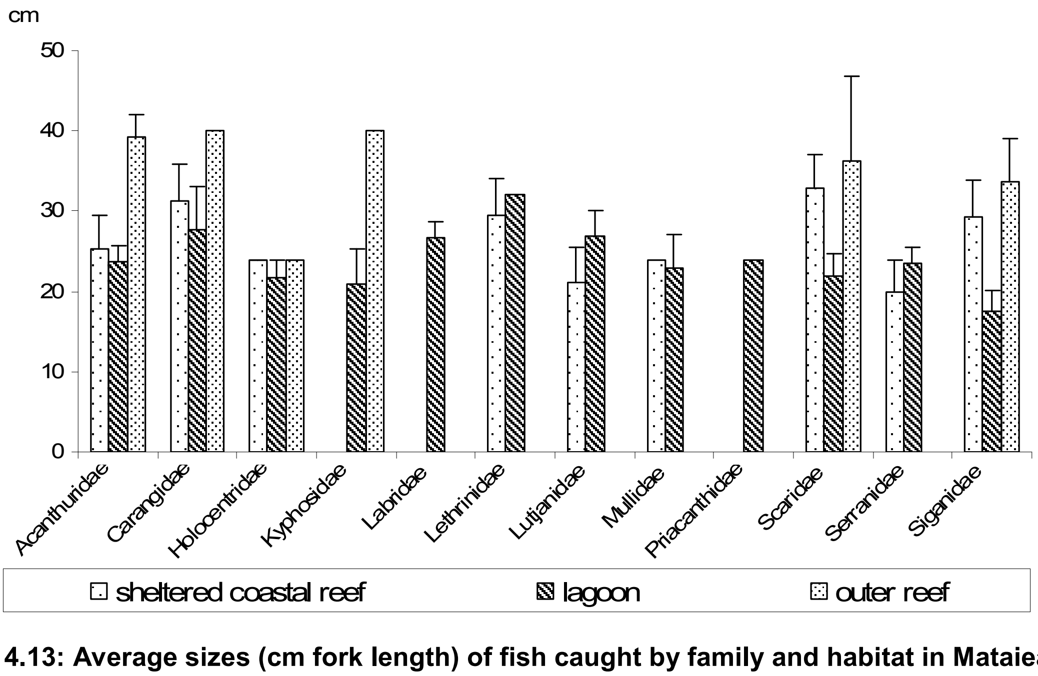

Figure 4.13: Average sizes (cm fork length) of fish caught by family and habitat in Mataiea. Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat as shown in Figure 4.13 show a trend: the average fish size increases from the sheltered coastal reef towards the outer reef, for Acanthuridae, Carangidae, Kyphosidae, Scaridae and Siganidae. When comparing the average fish sizes reported for sheltered coastal reef and lagoon habitats, there are a number of size increases towards the lagoon, particularly for Lutjanidae and Serranidae, but mainly average fish size is larger for catches reported from the sheltered coastal reef, including Acanthuridae, Carangidae, Scaridae and Siganidae. Overall, reported average fish sizes are over 20 cm and most fall in the size range of 25–30 cm.

Some parameters selected to assess the current fishing pressure on Mataiea's living reef resources are shown in Table 4.4. The comparison of habitat surfaces shows that the lagoon area determines most of the available fishing ground area for Mataiea. The fact that the sheltered coastal reef area is very limited in size explains why fisher density is highest. The outer reef is larger than the sheltered coastal reef and is the least targeted, thus a very low fisher density results. It is nevertheless surprising that the average annual catches per fisher reported for the sheltered coastal reef and the lagoon areas are not much different. Overall, population density and fisher density are high and the fishing pressure imposed by the calculated subsistence needs of the Mataiea community alone is alarming, with a calculated 27 t/km^2 for the reef surface and a 17 t/km^2 for the entire fishing ground. This estimate supports the concerns often voiced by respondents, on the perceived significant decrease of the community's reef and marine resources.

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

Parameters	**Habitat**				
	Sheltered coastal reef	**Lagoon**	**Outer reef**	**Total reef area**	**Total fishing ground**
Fishing ground area (km^2)	0.86	19.38	2.72	14.38	22.96
Density of fishers (number of fishers/km^2 fishing ground) (1)	547	73	73	145	91
Population density (people/km^2) (2)				552	346
Average annual finfish catch (kg/fisher/year) (3)	513.84 (±217.96)	550.56 (±170.86)	276.37 (±188.68)		
Total fishing pressure of subsistence catches (t/km^2)				27.31	17.11

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 7933; total number of fishers = 2082; total subsistence demand = 392.67 t/year; (3) catch figures are based on recorded data from survey respondents only.

4.2.4 Catch composition and volume – invertebrates: Mataiea

Calculations of the recorded annual catch rates per species groups are shown in Figure 4.14. The graph shows that the only major impact by wet weight is due to lobster catches, i.e. *Panulirus* spp. By comparison, catches reported for giant clams, *Turbo* spp. and *Diadema* spp. are of minor, if not insignificant, importance (Detailed data are provided in Appendices 2.3.2 and 2.3.3.).

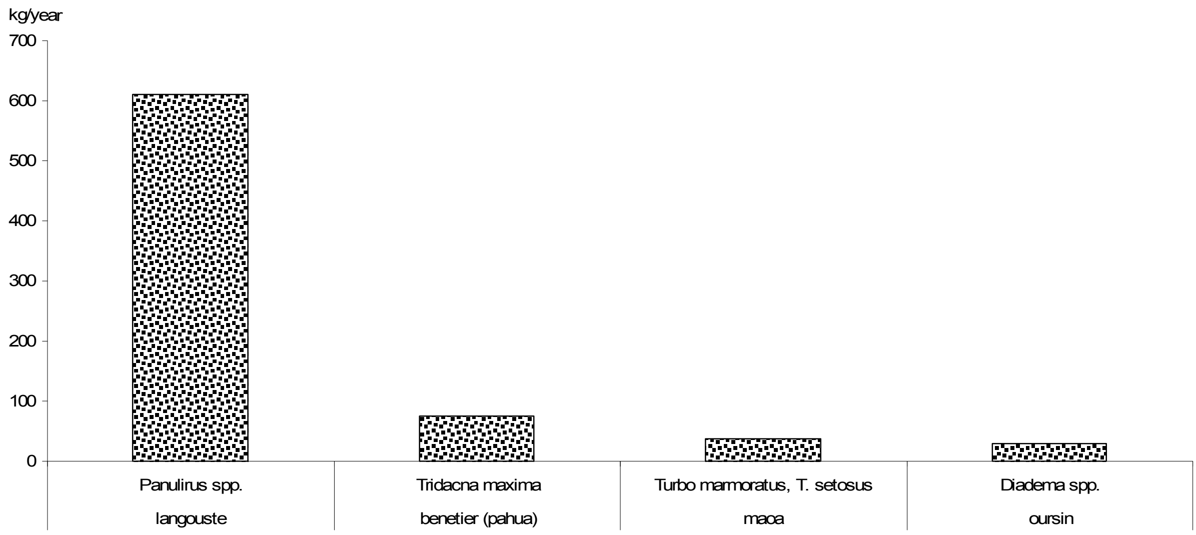

Figure 4.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Mataiea.

As stated above, invertebrate fisheries are limited and not of great importance in Mataiea. Accordingly, the limited biodiversity reported for catches is not surprising. Catches for reeftop gleaners include two species reported by vernacular names, i.e. representing *Turbo* spp. and *Tridacna* spp., while the lobster fishery is represented by one vernacular name only. 'Other', i.e. the dive fishery, includes *Tridacna* spp., *Diadema* spp., and sometimes lobsters (Figure 4.15).

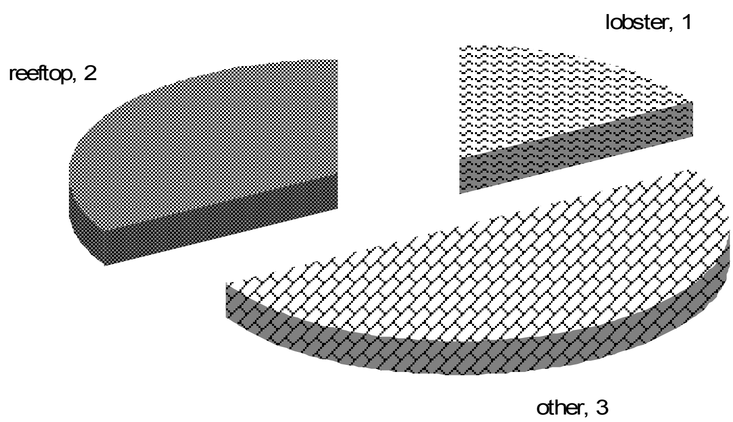

Figure 4.15: Number of vernacular names recorded for each invertebrate fishery in Mataiea.
'Other' refers to the giant clam and sea urchin fisheries.

Figure 4.16 shows that the average annual catches of invertebrate fishers are generally low. The highest catches by wet weight are obtained by lobster divers, who may collect over 80 kg/fisher/year, while reeftop gleaners collect around 10 kg/fisher/year of invertebrates by wet weight, and females who free dive mainly for giant clams and *Diadema* spp. may take a catch of up to 60 kg/fisher/year.

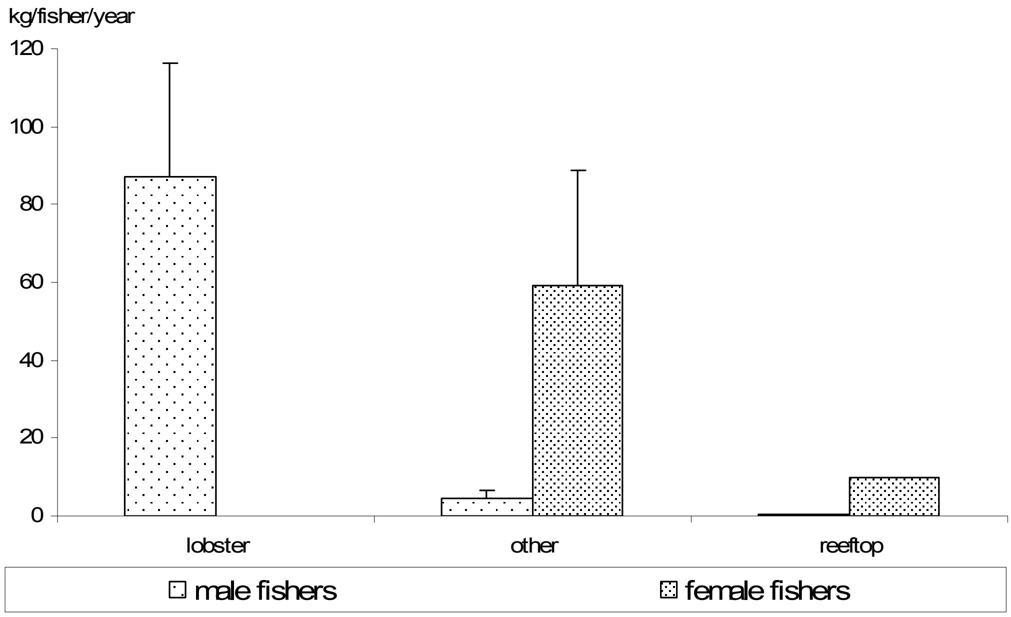

Figure 4.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Mataiea.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 11 for males, n = 3 for females). 'Other' refers to the giant clam and sea urchin fisheries.

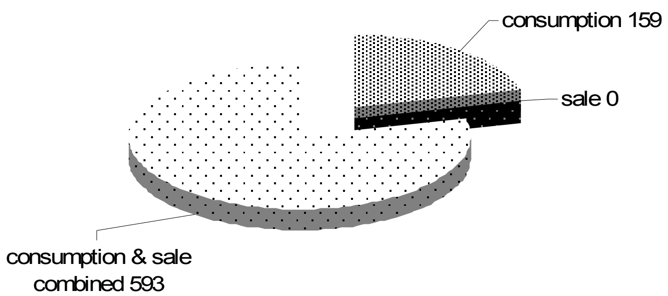

Figure 4.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Mataiea.

Even more so than for finfish fishing, invertebrate fishing is mainly pursued for subsistence purposes; the share sold within the Mataiea community (or, rarely outside to Papeete clients) may not exceed 39% of the total reported catch (Figure 4.17). Although fishers from Mataiea may only sell rarely to clients outside the community, we cannot exclude the fact that further impact on Mataiea's invertebrate resources is added by external fishers, who are reported to visit frequently, particularly during weekends and holidays.

The total annual catch volume, expressed in wet weight and based on recorded data from all respondents interviewed, is very small and does not even reach 1 t/year (0.75 t/year) (Figure 4.18). Lobster catches, exclusively taken by male fishers, determine over 80% of the total annual reported catch, while the remaining proportion is mainly made up of giant clams and sea urchins (= 'other' fishery). Overall, female fishers' contribution to the reported invertebrate catch in Mataiea is small.

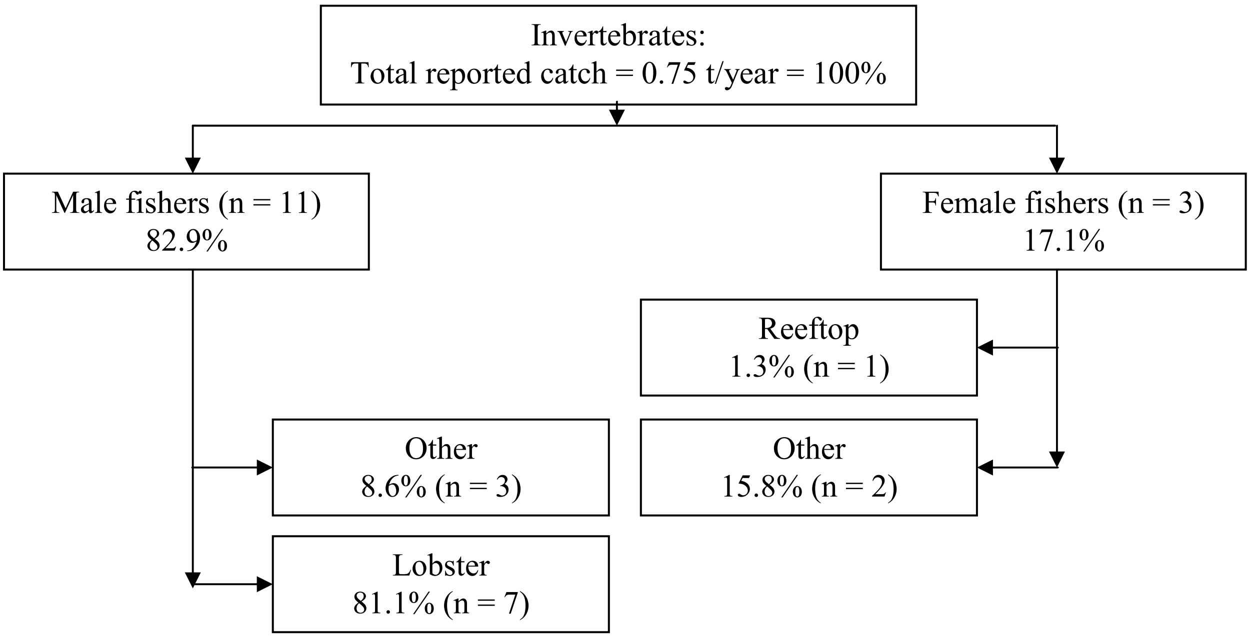

Figure 4.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mataiea.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to the giant clam and sea urchin fisheries.

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

Parameters	Fishery / Habitat		
	Reeftop	Other	Lobster
Fishing ground area (km^2)	0.88	3.30	15.30 [3]
Number of fishers (per fishery) [1]	139	367	625
Density of fishers (number of fishers/km^2 fishing ground)	159	111	41
Average annual invertebrate catch (kg/fisher/year) [2]	5.18 (±4.81)	26.40 (±16.35)	87.15 (±29.19)

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 measure km reef length; 'Other' refers to the giant clam and sea urchin fisheries.

The parameters presented in Table 4.5 show a high variability in the size of the available fishing grounds for the various fisheries. However, generally speaking, the available fishing ground areas are small with the exception of a considerable outer-reef length that may provide a suitable habitat for lobsters. Taking into consideration the average recorded annual catch/fisher (wet weight) and the density of fishers, the current fishing pressure on reef surfaces is reasonable if taking into account the high population density of the Mataiea community. However, it is necessary to remember that external fishers may add considerably to the current fishing pressure. Despite the favourable length of the outer reef, the lobster fisher density is high and, at the same time, the lobster fishery is the most intense invertebrate fishery by wet weight. The very limited number of invertebrate species that are targeted at present by respondents and the low frequency of fishing trips in combination with the low average annual catches point to the conclusion that invertebrate resources – and not only lobsters – are in a rather limited, if not degraded, state.

4.2.5 Discussion and conclusions: socioeconomics in Mataiea

- The community of Teva I Uta, Mataiea, displays a peri-urban character. This is not only determined by the size of the community (>7900 people) but also by its proximity to the country's capital city Papeete (~80 km). Its peri-urban character is highlighted by the high dependency on salaries, and fisheries that are mainly conducted for subsistence and leisure rather than for income generation.

- Mataiea people, like all Tahitians, enjoy all kinds of fresh seafood. All respondents consume fresh fish, invertebrates and, to some extent, canned fish. However, fresh fish is the main protein source, and the average per capita consumption of ~45 kg/year is above the regional average, but the lowest compared to the other PROCFish/C sites in French Polynesia. In contrast, invertebrate consumption (meat only) is very low (1.5 kg/year); canned fish consumption is also low.

- The peri-urban character of the Mataiea community also shows in the small proportion of seafood that is exchanged on a non-monetary basis among community members. In contrast, a considerable share of households interviewed reported that they sometimes purchase fresh fish, and also invertebrates, but to a much lesser extent.

- The difference between finfish and invertebrate fisheries shows in the data from fisher interviews. Finfish fishing mainly targets the lagoon between the passages of Teavaraa and Temaraui, the sheltered coastal reef and, to a much lesser extent, the outer reef. The reason why less fishing is done at the outer reef is the lack of suitable transport. Most fishers use paddling canoes, sometimes equipped with small outboard engines (9–15 hp), which do not allow them to venture out to the outer reef in all conditions. Invertebrate fisheries are very limited in terms of the target species as well as in terms of the average catch/fisher/year.

- Most fishing is done by males; overall, females fish less, but may participate in weekend and leisure fishing. Lobster diving is exclusively done by males. Also, no females were involved in local marketing of finfish at roadsides or in front of prominent shops during the early mornings at the weekends.

- Various methods are used for finfish fishing; gillnetting, spear diving and handlining are the main methods used at the sheltered coastal reef; handlining in the lagoon, and spear diving at the outer reef.

- Highest fishing pressure is on the lagoon and, to some extent, on the sheltered coastal reef. This impact is the combined effect of high numbers of fishers targeting each of these habitats and the average annual catch. CPUEs for the sheltered coastal reef were slightly higher than those for the lagoon and outer reef. The reported average sizes of fish caught in the different habitats suggest a trend of increased fish size with distance from the sheltered coastal reef to the outer reef. However, this trend is not always consistent if comparing catches from the sheltered coastal reef and lagoon only, i.e. average reported fish sizes of Acanthuridae, Carangidae, Scaridae and Siganidae were larger in catches from the sheltered coastal reef.

- In addition, the frequent and numerous external fishers who target Mataiea fishing grounds, in particular at the weekends and during holidays, need to be taken into consideration.

- Invertebrate fisheries mainly serve the subsistence needs of the Mataiea community, and less than 40% may be sold among the community's members. Due to the fact that over 80% of all reported catches by wet weight are accounted for by lobsters, it can be assumed that mainly lobsters are locally sold. Lobsters are a favourite food item for festivities and special occasions.

- Highest current fishing pressure was found for lobster diving. However, the limited number of invertebrate species usually targeted and the very low average annual reported catches give reason to assume that the overall status of Mataiea invertebrate resource has already declined or may still be in the process of deteriorating further.

- Data from the socioeconomic survey suggest that fishing pressure on Mataiea reef resources is high given the high population density, the relative high demand for fresh fish and the size of the available fishing ground. This situation is likely to be aggravated by the fact that the fishing ground is also subject to impact by frequent and numerous external fishers. Reported data on average fish sizes, CPUEs, average catches and diversity of target species, especially invertebrates, suggest that the resources are declining and/or have already suffered severely from past impact. This conclusion coincides with the general perception of respondents, most of whom expressed serious concern regarding the status of their reef resources.

4.3 Finfish resource surveys: Mataiea

Finfish resources and associated habitats were assessed between 29 September and 04 October 2003 from a total of 24 transects (6 sheltered coastal, 6 intermediate-, 6 back- and 6 outer-reef transects, see Figure 14 and Appendix 3.3.1 for transect locations and coordinates respectively.).

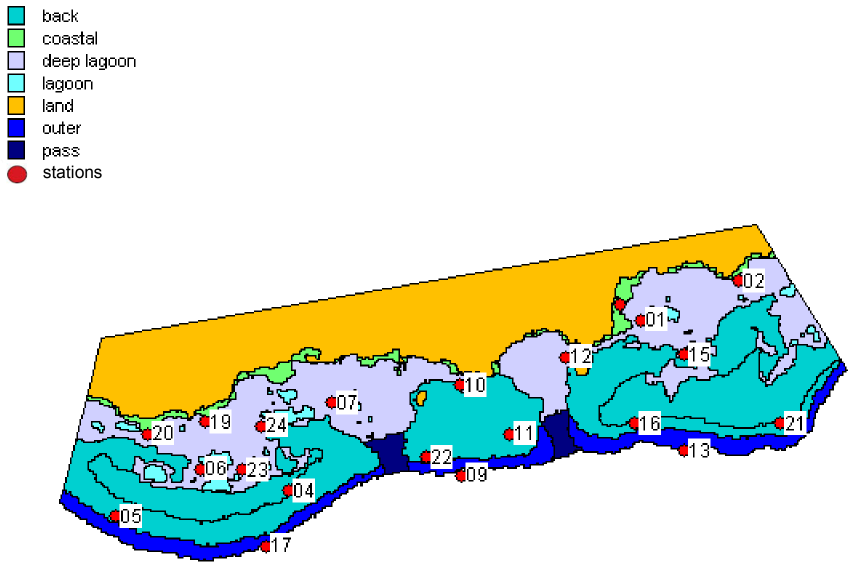

Figure 4.19: Habitat types and transect locations for finfish assessment in Mataiea.

4.3.1 Finfish assessment results: Mataiea

A total of 21 families, 47 genera, 113 species and 5419 fish were recorded in the 24 transects (See Appendix 3.3.2 for list of species.). Only data on the 13 most dominant families (See Methods.) are presented below, representing 36 genera, 101 species and 5371 individuals.

Finfish resources differed greatly between the four reef environments found in Mataiea (Table 4.6). The intermediate reef contained the lowest number of fish (0.2 fish/m^2), biomass (24 g/m^2) and number of species, while the outer reef displayed the highest biomass (78 g/m^2), size (19 cm FL), size ratio (61 %) and biodiversity (26 species/transect) at the site. Coastal and back-reefs shared the same values of density as the outer reef and displayed similar values of biomass (42 and 43 g/m^2 respectively).

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

Parameters	Habitat				
	Sheltered coastal reef (1)	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	6	6	6	24
Total habitat area (km^2)	0.9	0.7	10.8	2.3	14.7
Depth (m)	3 (1–6) (3)	4 (1–11) (3)	2 (1–2) (3)	7 (5–11) (3)	3 (1–11) (3)
Soft bottom (% cover)	19 ±4	26 ±4	15 ±4	0 ±0	14
Rubble & boulders (% cover)	27 ±4	20 ±4	25 ±7	0 ±0	21
Hard bottom (% cover)	31 ±7	38 ±6	32 ±9	61 ±5	37
Live coral (% cover)	23 ±6	15 ±2	28 ±9	38 ±5	29
Soft coral (% cover)	0 ±0	0 ±0	0 ±0	0 ±0	0
Biodiversity (species/transect)	22 ±3	22 ±4	25 ±2	26 ±2	23 ±1
Density (fish/m^2)	0.4 ±0.1	0.2 ±0.0	0.4 ±0.1	0.4 ±0.1	0.4
Size (cm FL) (4)	15 ±1	16 ±1	16 ±1	19 ±1	16
Size ratio (%)	59 ±3	63 ±4	58 ±3	61 ±3	59
Biomass (g/m^2)	42.0 ±10.5	24.0 ±6.9	43.2 ±8.5	78.3 ±19.4	47.4

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

Sheltered coastal reef environment: Mataiea

The sheltered coastal reef environment of Mataiea was dominated by four families: herbivores Acanthuridae and Scaridae and, in much lower measure, carnivores Mullidae and (only in terms of density) Chaetodontidae (Figure 4.20). These four families were represented by 31 species; particularly high abundance and biomass were recorded for: *Ctenochaetus striatus*, *Parupeneus multifasciatus*, *Scarus psittacus*, *Zebrasoma scopas*, *Chlorurus sordidus* and *Acanthurus triostegus* (Table 4.7). This reef environment presented an equal proportion of hard bottom (31%) and rubbles/boulders (27%), and relatively high cover of soft bottom (19%) and live corals (23%). Such diverse habitat was reflected in the diversity of fish community composition (Table 4.7 and Figure 4.20).

Table 4.7: Finfish species contributing most to main families in terms of densities and biomass in the sheltered coastal reef environment of Mataiea

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.15 ±0.07	17.6 ±8.5
	Zebrasoma scopas	Twotone tang	0.04 ±0.02	2.4 ±1.1
	Acanthurus triostegus	Convict tang	0.02 ±0.01	0.8 ±0.6
Scaridae	*Scarus psittacus*	Common parrotfish	0.03 ±0.01	2.5 ±1.2
	Chlorurus sordidus	Daisy parrotfish	0.02 ±0.01	1.8 ±0.5
Mullidae	*Parupeneus multifasciatus*	Many bar goatfish	0.03 ±0.01	3.0 ±1.2

The density of fish in the coastal reefs of Mataiea was second-lowest among coastal reef values in all survey sites and equal to the value in Raivavae. Biomass was one of the lowest values, higher only to Maatea coastal reef. Biodiversity was the lowest, with 22 species per transect (Table 4.6). Size ratio was very low for Lethrinidae, Lutjanidae and Scaridae. Trophic structure was dominated by herbivorous fish, mainly Acanthuridae. The substrate was almost equally composed of hard bottom, soft bottom and rubbles, with a fairly good cover of live corals, hosting a high density of Chaetodontidae. Only Mullidae represented carnivores in fairly good numbers, while Lethrinidae and Lutjanidae were practically absent.

Acanthuridae and Scaridae are targeted for consumption and the low presence of parrotfish could be the result of heavy fishing. This environment, similarly to intermediate reefs, is in fact subject to the highest fishing pressure and highest fisher density of the whole site.

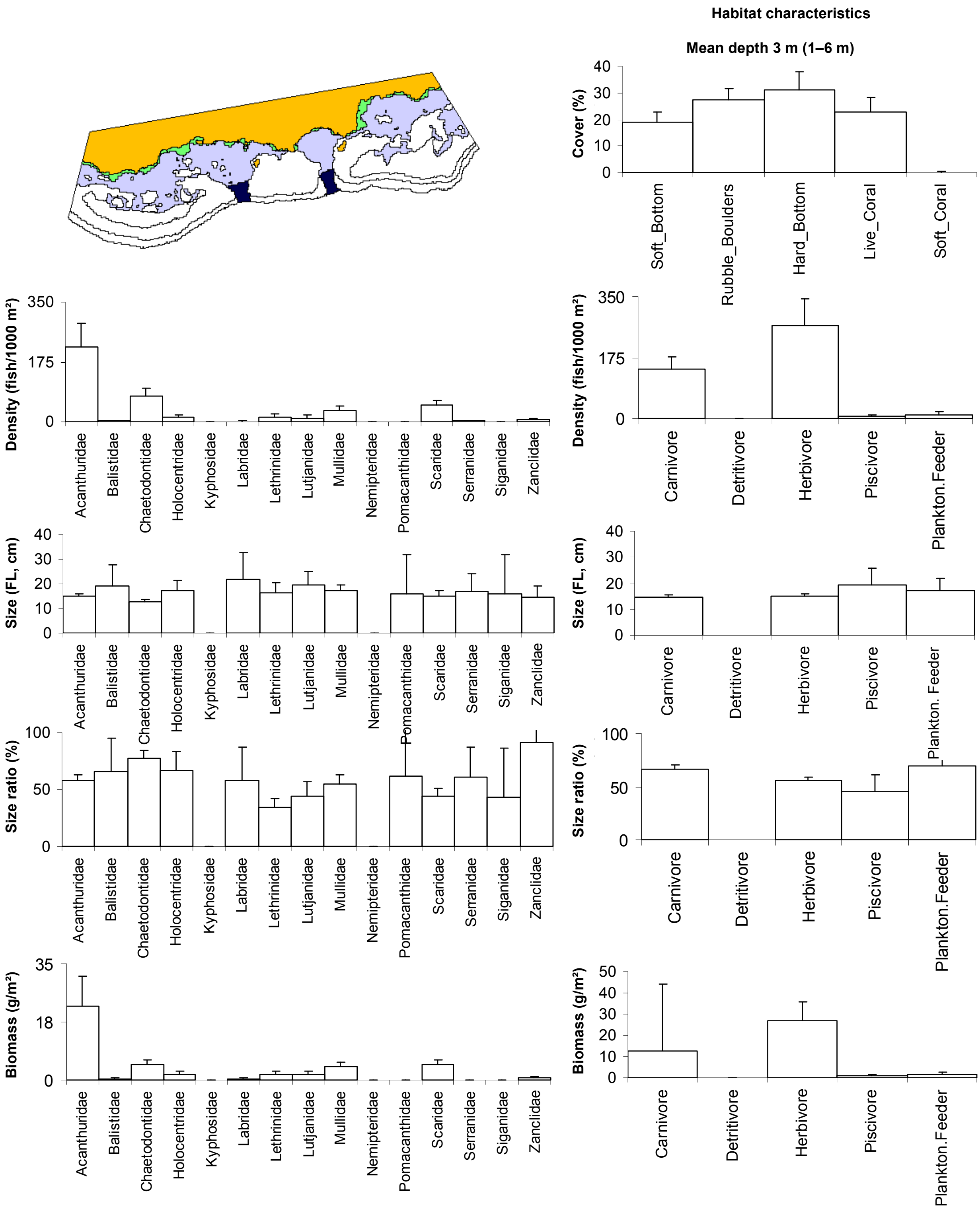

Figure 4.20: Profile of finfish resources in the sheltered coastal reef environment of Mataiea.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Mataiea

The intermediate-reef environment of Mataiea was dominated by three families: herbivorous Acanthuridae and Scaridae and (in terms of density only) Chaetodontidae (Figure 4.21). These three families were represented by 29 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Scarus psittacus*, *Chlorurus sordidus* and *Zebrasoma scopas* (Table 4.8). This reef environment presented a moderately diverse habitat with dominance of hard bottom (38%), and soft bottom and rubbles in similar proportions (Table 4.6 and Figure 4.21). Cover of live corals was not high (15%). The dominance of hard bottom usually favours the presence of herbivores, as observed.

Table 4.8: Finfish species contributing most to main families in terms of densities and biomass in the intermediate-reef environment of Mataiea

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.06 ±0.02	7.2 ±2.2
	Zebrasoma scopas	Twotone tang	0.03 ±0.01	2.0 ±0.7
Scaridae	*Scarus psittacus*	Common parrotfish	0.01 ±0.01	2.7 ±1.9
	Chlorurus sordidus	Daisy parrotfish	0.01 ±0.01	2.5 ±1.0

The density and biomass of fish in the intermediate reefs of Mataiea were the lowest recorded among similar habitats in all the survey sites. Biodiversity was also the lowest, as low as 22 species per transect (Table 4.6). Size ratio was low only for Lethrinidae. Herbivorous fish dominated the trophic structure of the fish community in this habitat, in terms of both density and biomass. Carnivorous species were almost absent from this habitat, showing only a high presence of Mullidae (*Parupeneus multifasciatus*). The substrate was dominated by hard bottom, favouring the presence of herbivores. However, the high dominance of herbivores and the almost total absence of carnivores could also be the result of fishing impact. This is in fact a highly fished habitat, with second-highest fisher density and annual catches as high as those from the coastal reef habitat.

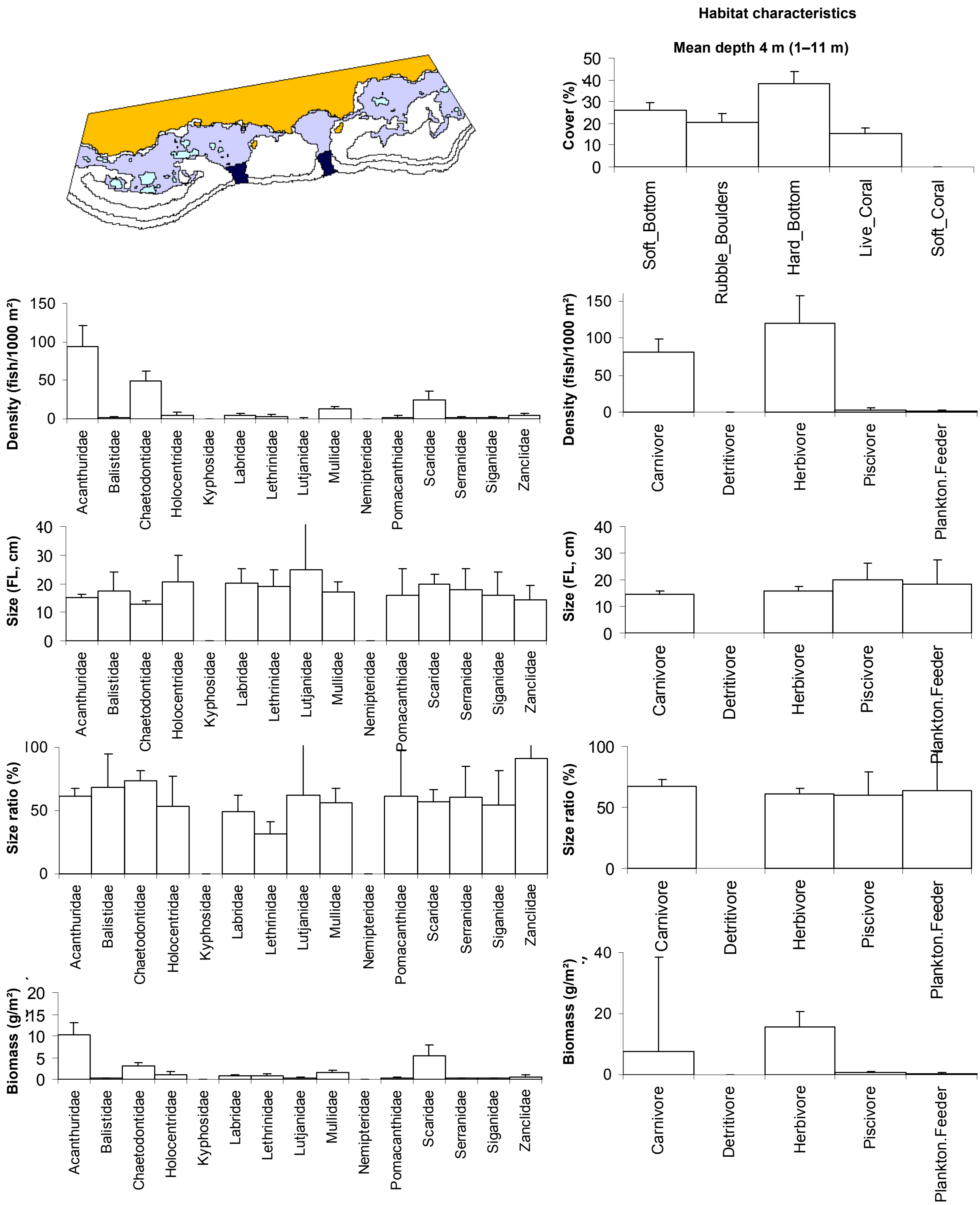

Figure 4.21: Profile of finfish resources in the intermediate-reef environment of Mataiea.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Mataiea

The back-reef environment of Mataiea was dominated by three families: two herbivorous fish: Acanthuridae and Scaridae, in terms of both density and biomass, and, to a lesser extent, Chaetodontidae, for density only (Figure 4.22). These five families were represented by 24 species; particularly high abundance and biomass were recorded for *Scarus psittacus*, *Ctenochaetus striatus*, *Chlorurus sordidus* and *Zebrasoma scopas* (Table 4.9). This reef environment presented a diverse habitat with slight dominance of hard bottom (32%), high cover of rubble and boulders (25%), slightly less cover of soft bottom (15%) and a good cover of live coral (28%, Table 4.6 and Figure 4.22).

Table 4.9: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Mataiea

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.12 ±0.03	11.9 ±2.1
	Zebrasoma scopas	Twotone tang	0.01 ±0.00	1.0 ±0.3
Scaridae	*Scarus psittacus*	Common parrotfish	0.07 ±0.02	13.8 ±3.6
	Chlorurus sordidus	Daisy parrotfish	0.04 ±0.03	4.8 ±3.2

The density of finfish in the back-reefs of Mataiea was similar to values recorded at the other study sites (second-highest value of average density, 0.4 fish/m^2 for back-reefs, where values range between 0.3 and 0.6 fish/m^2), while biomass was the lowest (43 g/m^2), although average size ratio was the highest (58%). Biodiversity displayed intermediate value with 25 species/transect. Size ratio was below the 50% value for Labridae and Lethrinidae. The trophic structure in Mataiea back-reefs was dominated by herbivorous species. Acanthuridae and Scaridae displayed very high values of density. Carnivores were very scarce and mainly represented by Mullidae. The back-reef of Mataiea displayed a fairly high percentage of hard bottom (32%) as well as rubble and boulders (25%) and a lower cover of soft bottom (15%). The dominance of hard bottom can be seen as favouring the higher biomass of herbivores.

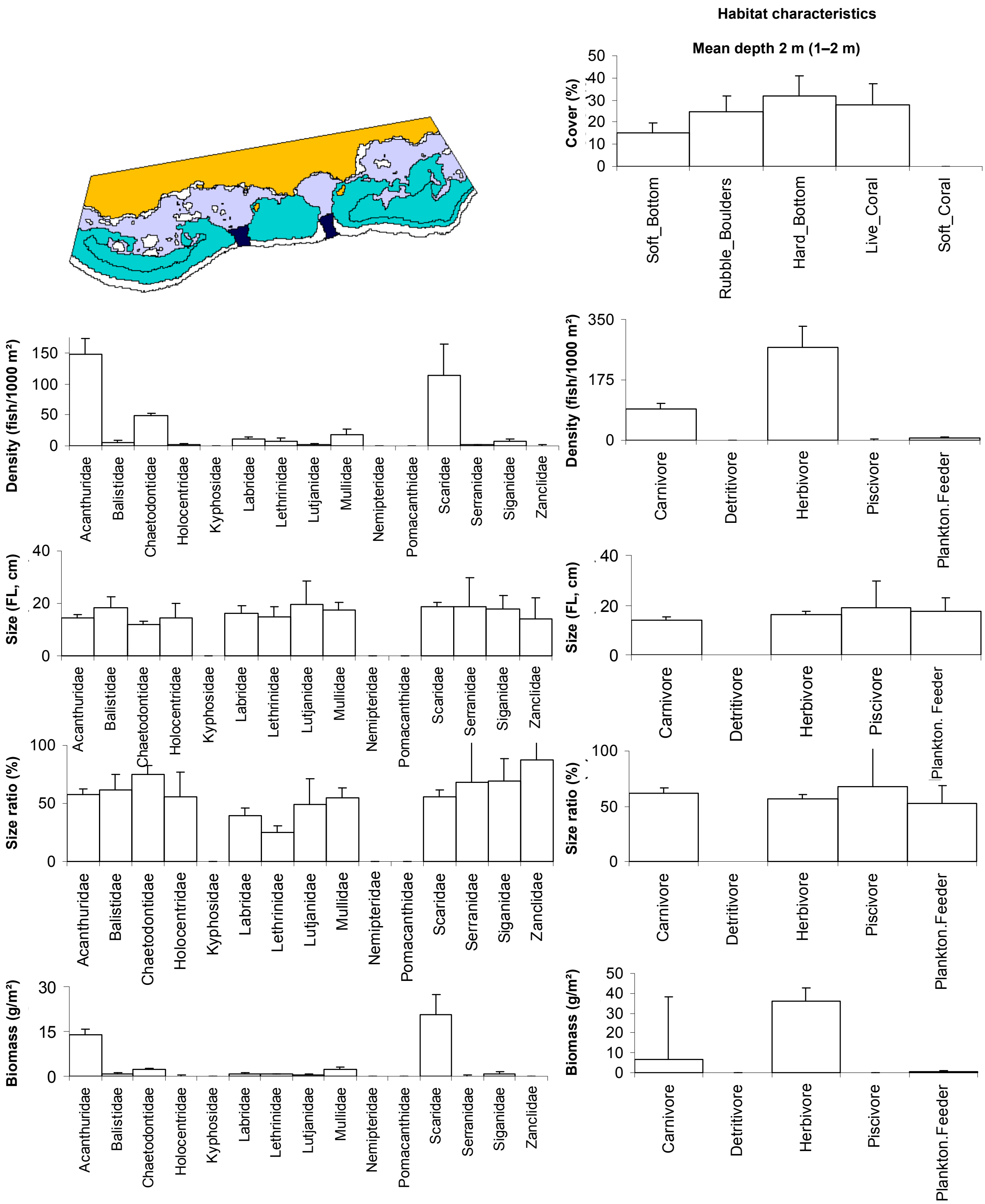

Figure 4.22: Profile of finfish resources in the back-reef environment of Mataiea.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Mataiea

The outer reef of Mataiea was dominated by carnivorous Balistidae and, to a lesser extent, Lethrinidae and Chaetodontidae (these latter only in terms of density), and by herbivorous Acanthuridae and Scaridae (Figure 4.23). These five families were represented by 32 species; particularly high abundance and biomass were recorded for *Melichthys vidua*, *Chlorurus sordidus*, *Gnathodentex aureolineatus*, *Naso lituratus*, *Melichthys niger*, *Odonus niger*, *Acanthurus blochii*, *Ctenochaetus striatus*, *A. nigricans* and *Sufflamen bursa* (Table 4.10). Hard bottom (61% cover) largely dominated habitat of this reef environment, which displayed a high cover of live coral as well (38%, Table 4.6 and Figure 4.23) but no soft bottom or rubble.

Table 4.10: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Mataiea

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Naso lituratus*	Orangespine unicornfish	0.02 ±0.01	7.9 ±3.4
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.02	4.7 ±4.4
	Ctenochaetus striatus	Striated surgeonfish	0.06 ±0.01	4.3 ±1.6
	Acanthurus nigricans	Whitecheeck surgeonfish	0.01 ±0.01	2.1 ±1.6
Balistidae	*Melichthys vidua*	Pinktail triggerfish	0.06 ±0.01	12.6 ±1.8
	Melichthys niger	Black triggerfish	0.02 ±0.01	7.1 ±2.6
	Odonus niger	Redtooth triggerfish	0.05 ±0.02	6.4 ±3.0
	Sufflamen bursa	Scythe triggerfish	0.02 ±0.01	2.0 ±0.6
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.02 ±0.02	8.5 ±5.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04 ±0.01	9.8 ±3.4

The density of finfish in the outer reef of Mataiea was the lowest among the outer reefs of the survey sites (0.4 fish/m^2, Table 4.6). Biomass was one of the lowest values, higher only than Tikehau. However, size and size ratios displayed the highest values (19 cm FL and 61% respectively). Biodiversity was the lowest of all outer reefs. Size ratio was higher than 50% for most families, except for Labridae, suggesting a low level of exploitation. The trophic structure was slightly dominated by herbivores, but carnivores (mainly Balistidae and Lethrinidae) were present in high number and biomass. Substrate composition showed a strong dominance of hard bottom with high cover of live coral, normally offering a perfect habitat for herbivorous families. This is the least fished of the four different habitats, with lowest fisher density, lowest annual catches and lowest fishing production, suggesting that the observed poverty of the environment was due to natural causes rather than human impacts.

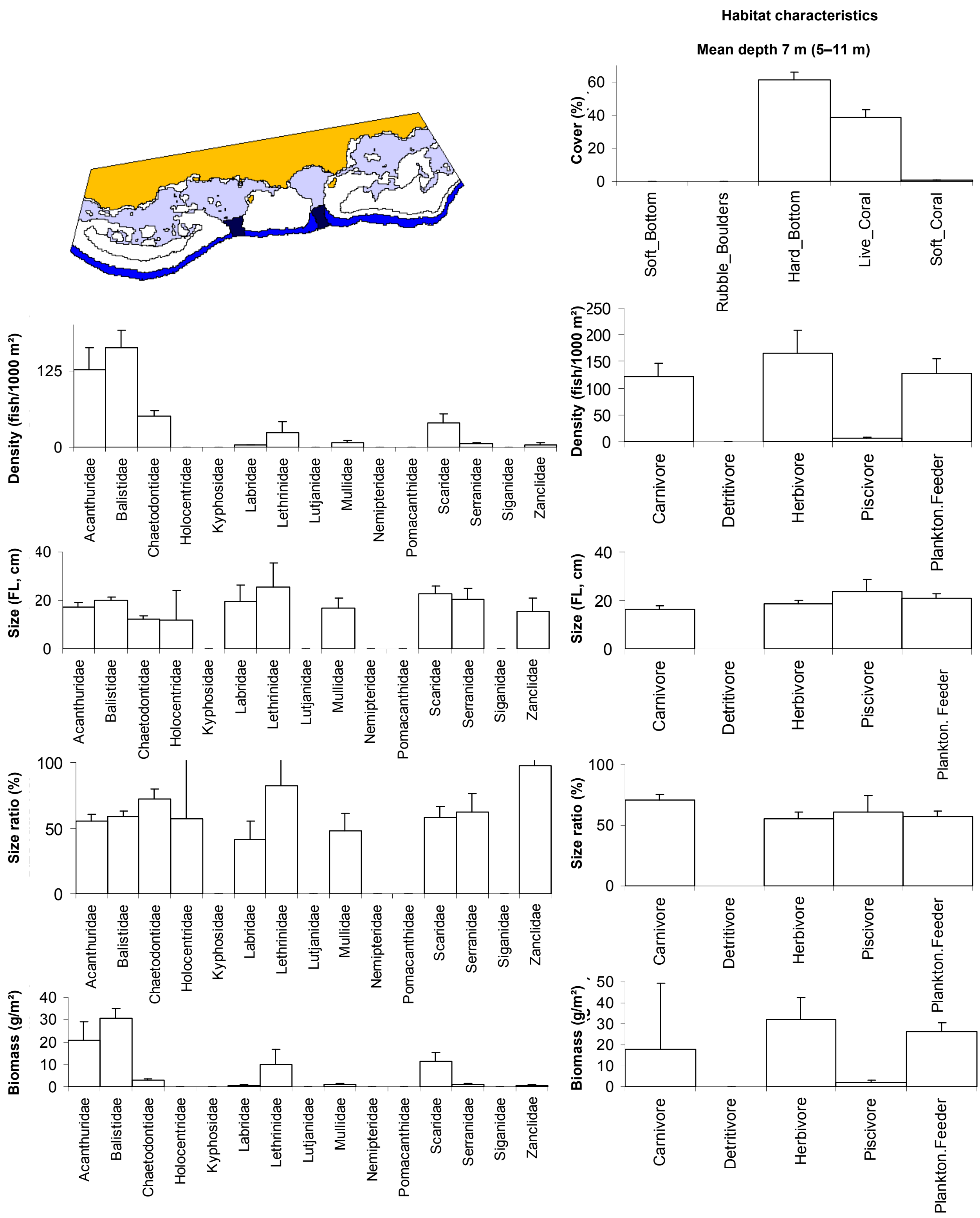

Figure 4.23: Profile of finfish resources in the outer-reef environment of Mataiea.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Mataiea

Overall, the fish assemblage of Mataiea was dominated by herbivorous Acanthuridae and Scaridae and to a much lesser extent carnivorous Balistidae (Figure 4.24). These three families were represented by a total of 38 species, dominated (in terms of density and biomass) by *Ctenochaetus striatus*, *Scarus psittacus*, *Chlorurus sordidus* and *Melichthys vidua* (Table 4.11). As expected, the overall fish assemblage in Mataiea shared characteristics of back-reefs (74% of total reef habitat), outer reefs (16%) and, to a smaller extent, coastal reefs (5%) and intermediate reefs (5%).

Table 4.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Mataiea (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.11	10.8
Scaridae	*Scarus psittacus*	Common parrotfish	0.05	10.5
	Chlorurus sordidus	Daisy parrotfish	0.04	5.2
Balistidae	*Melichthys vidua*	Pinktail triggerfish	0.01	2.3

Overall, Mataiea appeared to support a lower finfish resource than the other sites, with low value of density (at the lower end of the range for the five sites, with 0.4 fish/m^2), the lowest value of biomass (47 g/m^2), and second-lowest value of average size (16 cm FL), and the lowest biodiversity (23 species/transect). These results suggest that the finfish resource in Mataiea is in over fished. Detailed assessment at family level revealed a dominance of herbivorous Acanthuridae and Scaridae, and very low abundance of carnivorous families. The average trophic structure for this site was strongly dominated by herbivores in both density and biomass terms. In general the substrate was dominated by hard bottom (average 37%) and showed a high live coral cover (29%). In Mataiea, both population and fisher density are high and the fishing pressure imposed by only the subsistence needs of the community is alarming. These results obtained by both the socioeconomic surveys and the finfish assessments support the concerns of the local people on the perceived significant decrease of the marine resources.

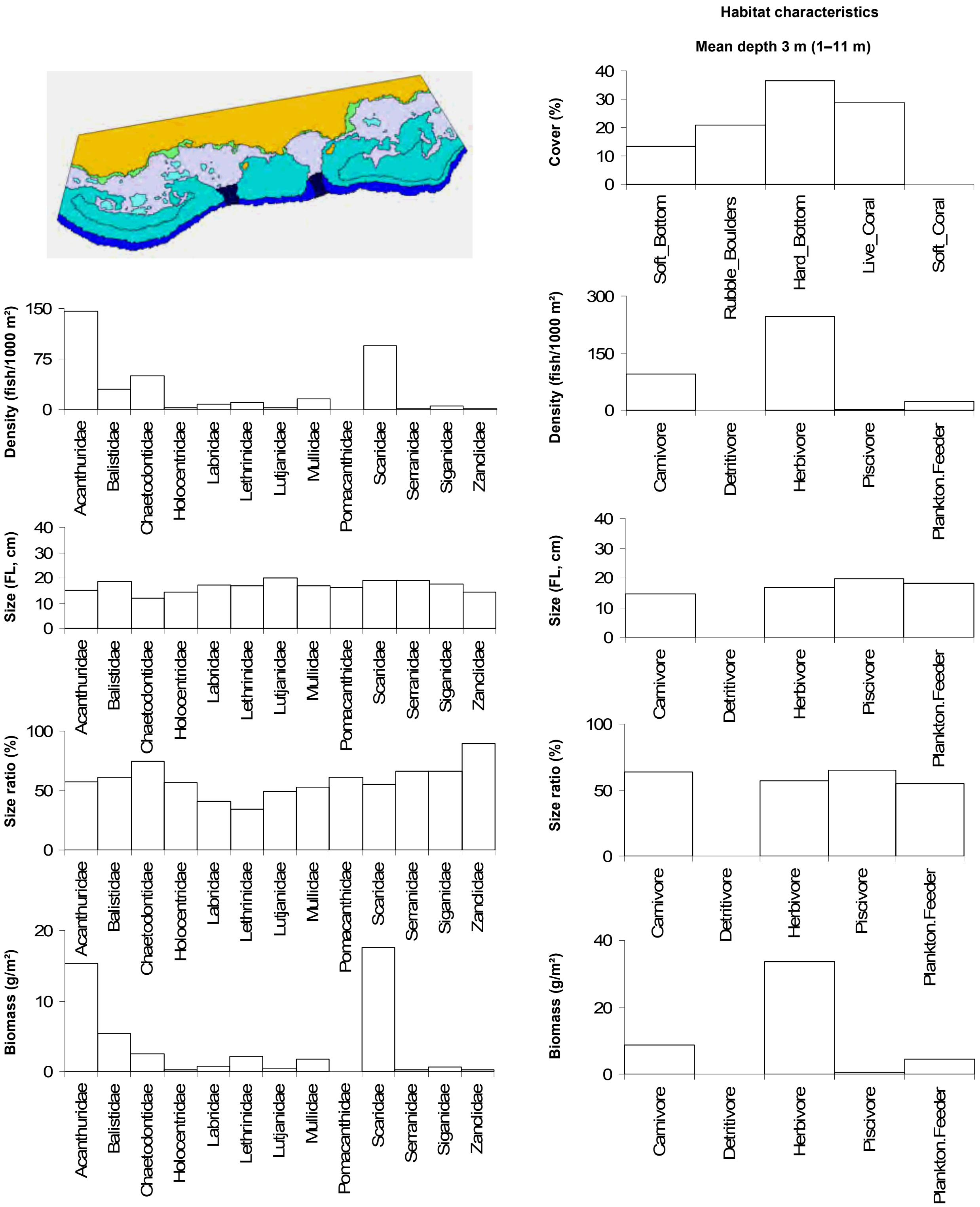

Figure 4.24: Profile of finfish resources in the combined reef habitats of Mataiea (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Mataiea

The assessment indicated that the status of finfish resources in Mataiea is poorer than the other sites, with lowest values of both density and biomass of fish. Moreover, detailed assessment at reef level also revealed a systematic lower-than-average abundance of carnivores, especially Labridae, Lutjanidae and Lethrinidae, with Mullidae showing slightly higher abundance in coastal and intermediate reefs. Preliminary results suggest that this trend could be due to greater-than-average impact from fishing carnivorous species (Lutjanidae, Serranidae, and Labridae) in Mataiea. Fishing in Mataiea is mostly carried out for sustenance purposes. The impact on fish resources is however already elevated due to the high densities of both the population and the fishers. Target carnivores species appeared to suffer initial depletion.

- Overall, Mataiea's finfish resources appeared to be in poor condition. The reef habitat seemed relatively rich but the supported finfish resources were impacted by heavy fishing, especially in the lagoon and coastal areas.

- Populations of snappers (Lutjanidae), emperors (Lethrinidae) and goatfish (Mullidae) were systematically low and groupers (Serranidae) practically absent.

4.4 Invertebrate resource surveys: Mataiea

The diversity and abundance of invertebrate species at the site were independently determined using a range of survey techniques (Table 4.12): broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 4.25) and finer-scale assessment of specific reef and benthic habitats (Figures 4.25 and 4.26).

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

Table 4.12: Number of stations and replicate measures completed at Mataiea

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	13	78 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)	2	12 search periods
Reef-front searches (RFs)	0	0 search period
Sea cucumber night searches (Ns)	2	12 search periods
Sea cucumber day searches (Ds)	3	18 search periods

Figure 4.25: Broad-scale survey stations for invertebrates in Mataiea.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 4.26: Fine-scale reef-benthos transect survey stations for invertebrates in Mataiea.
Black circles: reef-benthos transect stations (RBt).

Figure 4.27: Fine-scale survey stations for invertebrates in Mataiea.
Grey circles: sea cucumber night search stations (Ns);
grey stars: sea cucumber day search stations (Ds);
grey squares: mother-of-pearl search stations (MOPs);
black squares: mother-of-pearl transect stations (MOPt).

Thirty-two species or species groupings (groups of species within a genus) were recorded in the Mataiea invertebrate surveys: 4 bivalves, 10 gastropods, 9 sea cucumbers, 5 urchins, 2 sea stars, and 1 cnidarian (Appendix 4.3.1). Information on key families and species is detailed below.

4.4.1 Giant clams: Mataiea

Broad-scale sampling provided an overview of giant clam distribution at Mataiea. Shallow-reef habitat that is suitable for giant clams was very extensive (13.6 km^2: approximately 10.4 km^2 within the lagoon and 3.2 km^2 on the reef front or slope of the barrier). Unlike the atoll PROCFish/C sites of Tikehau and Fakarava, inshore areas at Mataiea were greatly influenced by inputs from the land. These influences, in the form of allochthonous inputs and nutrients, were less obvious as one moved through patch reefs towards the barrier. Although the lagoon was not overly shallow and relatively well protected, Mataiea faced the prevailing swells, and there was dynamic water movement across the barrier and through the numerous passes of the lagoon.

Reef at Mataiea held one species of giant clam: the elongate clam, *Tridacna maxima*. Records from broad-scale sampling revealed that *T. maxima* was widely distributed (found in 11 of 13 stations and 38 of 78 transects). The average station density of *T. maxima* in broad-scale assessments was 32.7 /ha ±16.9, Figure 4.28).

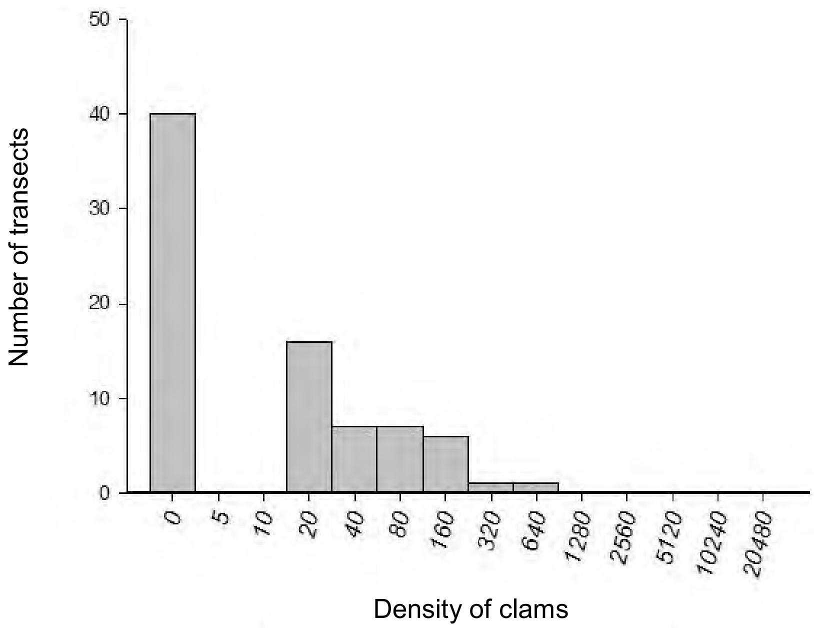

Figure 4.28: Frequency plot of density per 300 m transect measures (per ha) for *Tridacna maxima* clams at Mataiea, based on all broad-scale assessment stations.
Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 4.29). In these reef-benthos assessments (RBt) *T. maxima* was present in 86% of stations at a mean density of 1512.8 /ha ±532.7.

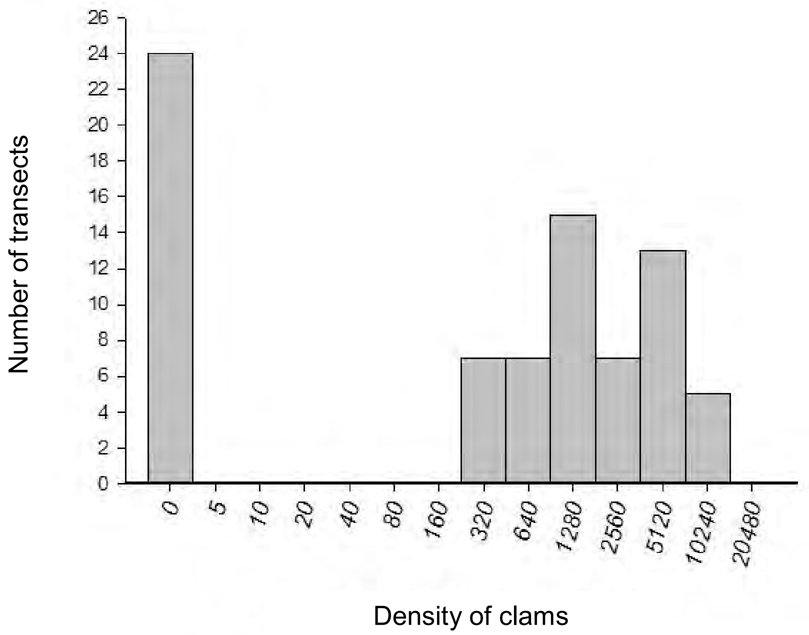

Figure 4.29: Frequency plot of density per 40 m transect measures (per ha) for *Tridacna maxima* clams at Mataiea, based on all fine-scale reef-benthos transect assessment stations. Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

T. maxima were found at the highest density at RBt stations on the shallow-reef areas that stretched out behind the reef crests. The greatest density of clams per 40 m^2 transect in Mataiea was at such a station (9250 /ha, or just less than 1 clam/m^2).

Of the 541 records taken during all assessment techniques, the average length of *T. maxima* was 8.1 cm ±0.2. The mean from shallow reef-benthos stations was slightly lower at 7.3 cm ±0.1. A full range of lengths for *T. maxima* were recorded in survey, although clams were generally smaller than found in other parts of the Pacific. Larger clams (≥16 cm) were rare in shallow water and were mainly restricted to reefs in more exposed locations (mean clam size from mother-of-pearl SCUBA surveys was 12.4 cm, Figure 4.30).

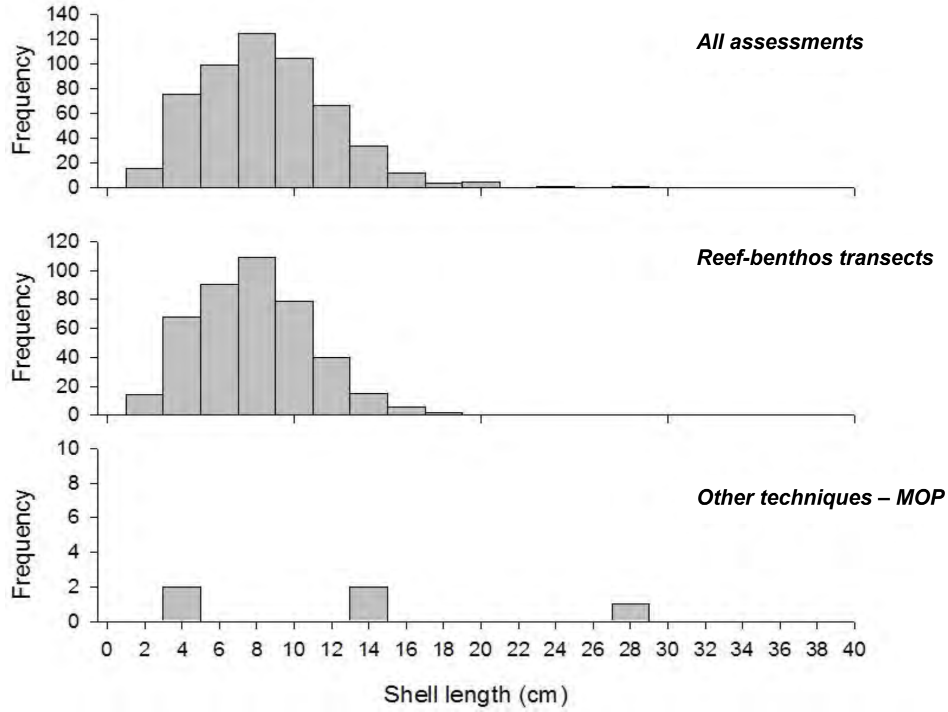

Figure 4.30: Size frequency histogram of giant clam shell length (cm) for Mataiea.

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

Mataiea, located at approximately 18°S is well within the latitude of the commercial topshell (*Trochus niloticus*) in the Pacific. However, trochus do not naturally occur in French Polynesia, their natural distribution stopping at Wallis Island, which is over 2000 km to the west. However, 40 trochus were introduced in November 1957 to the Tautira district of Tahiti from Port Vila (Vanuatu). The purpose of this introduction was to counteract the gradual depletion of pearl shell stocks in French Polynesia (Cheneson 1997). Not until 14 years after its introduction to French Polynesia in November 1971 did commercial harvesting begin on Tahiti.

The outer and lagoon reef at Mataiea constitute extensive benthos suitable for *T. niloticus* (15.3 km lineal distance of exposed reef perimeter), and this area could potentially support significant populations of this commercial species. PROCFish/C survey work revealed that *T. niloticus* was present on both the barrier reef (outer-reef slope and reeftop) and on reef within passages and the lagoon (Table 4.13). The suitability of reefs for grazing gastropods was highlighted by trochus and green snail records, but there were no results for green topshell (*Tectus pyramis*), as this species only extends as far east as Tuvalu, Samoa and Tonga.

Table 4.13: Presence and mean density of *Trochus niloticus*, *Turbo marmoratus and Pinctada margaritifera* in Mataiea
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	166.5	53.5	10/13 = 77	41/78 = 53
RBt	1727.6	1064.1	10/13 = 77	32/78 = 41
MOPs	41.7	41.7	1/2 = 50	2/12 = 17
MOPt	745.8	258.9	5/5 = 100	24/30 = 80
Turbo marmoratus				
B-S	0.9	0.4	4/13 = 46	4/78 = 5
RBt	80.1	80.1	1/13 = 8	6/78 = 8
MOPs	3.8	3.8	1/2 = 50	1/12 = 8
MOPt	16.7	16.7	1/5 = 20	2/30 = 7
Pinctada margaritifera				
B-S	0.2	0.2	1/13 = 8	1/78 = 1
RBt	0	0	0/13 = 0	0/78 = 0
MOPs	0	0	0/2= 0	0/12 = 0
MOPt	0	0	0/5 = 0	0/30 = 0

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

Trochus were numerous and found at various locations around Mataiea (total n = 1487 individuals recorded). Aggregations of trochus found in surveys were mainly on the lagoon side of the barrier and on the back-reef behind the barrier in less exposed areas. The greatest density, averaging >1 /m^2 for a single reef-benthos station, was recorded in the eastern passage of the Mataiea study area. Few trochus were seen in front of the barrier, where the shallow water is subject to very large swells and epiphytic growth on the substrate is limited. From this survey the indication is that there is scope for trochus fishing in Mataiea. Although reports from the late 1990s claimed that trochus stocks of the island of Tahiti had been eroded, particularly as a result of uncontrolled fishing (Cheneson 1997), stocks at Mataiea can be fished at areas where they are at their highest densities, especially if the gauntlet fishery is adhered to (i.e. only shells with a basal width between 8 and 11 cm are taken.).

Although small trochus are very cryptic, shell size-class results (Figure 4.31) indicate that recruitment is taking place and ‘new’ young trochus are entering the population (first maturity of trochus is at 7–8 cm, or ~3 years of age). The mean basal width of trochus at Mataiea was 10.1 cm ±0.01 (n = 190). The presence of 21% of the measured stock above the legal size of 11 cm highlights the older, mature portion of the broodstock that would be protected from fishing if there were commercial harvests. This estimate of the protected portion of the population is conservative, as shallow-reef assessments would not necessarily yield many measures of older shells, which mainly live deeper than smaller, younger trochus.

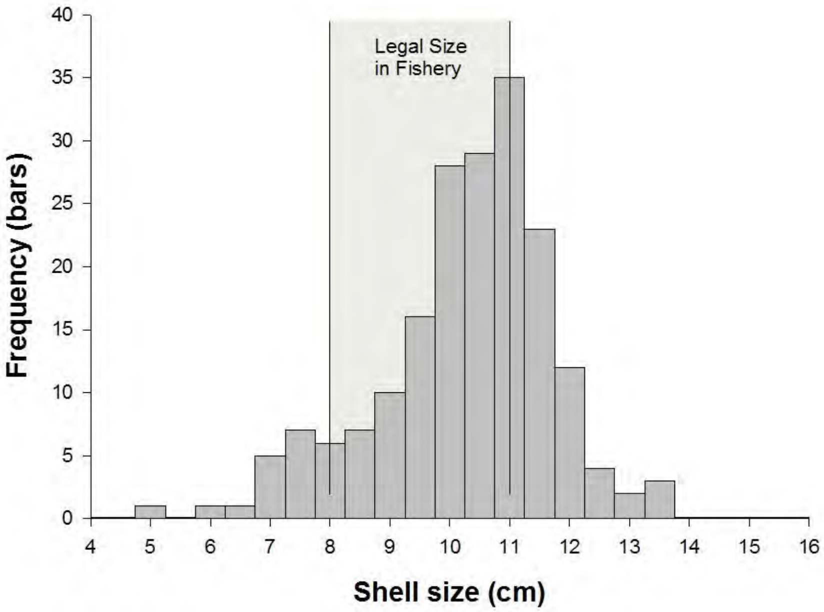

Figure 4.31: Size frequency histogram of giant clam shell base diameter (cm) for Mataiea.

The great green turban, *Turbo marmoratus*, was also recorded in Mataiea. The bulk of the stock was recorded on shallow reef near the passages, although they were also sparsely distributed outside of the barrier reef in deeper water. The greatest density (between one and nine for each 40 m transect) was recorded at a single reef-benthos station, like the trochus, in the eastern passage of the Mataiea study area (also observed outside of transects at a second reef-benthos station). The size of great green turbans can be a little tricky to measure. Although the regulations in French Polynesia stipulate that the *T. marmoratus* shell length should be between 160 mm minimum and 180 mm maximum (longest diameter) for legal fishing, on occasion, the largest gape on the shell mouth (whorl opening) of *Turbo* spp. is measured (Samoan regulations). *T. marmoratus* in Mataiea were seen at a range of adult sizes (10–18.9 cm) and had a mean size of 13.6 cm ±0.6, (average whorl opening of 7.8 cm ±0.4).

4.4.3 Infaunal species and groups: Mataiea

The soft-benthos coastal margin of the shallow-water lagoon was sandy without seagrass or muddy areas, and did not hold concentrations of in-ground resources (shell 'beds') such as arc shells *Anadara* spp. or venus shells *Gafrarium* spp. Therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made on soft benthos.

4.4.4 Other gastropods and bivalves: Mataiea

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded at medium density in broad-scale and finer-scale surveys (25 individuals recorded), but *Lambis lambis* and the strawberry or red lipped conch *Strombus luhuanus* was not present (Appendices 4.3.1 to 4.3.7). Out of the small turbans (e.g. *Turbo argyrostomus*, *T. chrysostomus* and *Turbo setosus*) only *Turbo setosus* was recorded, and this was at low density in shallow-reef stations. It was not possible to do reef-front swims on the reef fronts in Mataiea as the swells made this work too dangerous; however, the species also did not show up in MOP surveys. Other resource species targeted by fishers (e.g. *Astralium*, *Conus*, *Cypraea*, *Thais* and *Vasum*) were also recorded during independent survey (Appendices 4.3.1 to 4.3.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as

Chama and *Spondylus*, are also in Appendices 4.3.1 to 4.3.7. No creel survey was conducted at Mataiea, although fishers were seen diving and collecting small numbers of *T. marmoratus*, presumably for personal consumption or local handicraft sale of shells.

4.4.5 Lobsters: Mataiea

Mataiea had 15 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef represents a moderate amount of habitat for lobsters. Lobsters are an unusual invertebrate species, which can recruit from near and distant reefs as their larvae drift in the ocean for 6–12 months (up to 22 months) before settling as transparent, miniature versions of the adult (pueruli, 20–30 mm in length).

There was no dedicated night reef-front search (Ns) for lobsters (See Methods.), and no lobsters (*Panulirus* spp. or *Parribacus* spp.) were recorded in the survey. Night searches (Ns) for nocturnal sea cucumber species were conducted, which offered a further opportunity to see lobster species, but none were observed.

4.4.6 Sea cucumbers[9]: Mataiea

Mataiea has an extensive and complex lagoon system bordering a large land mass. Reef margins, and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) was extensive in the lagoon; however, outside the barrier reef the reef slope shelved off relatively steeply and was subject to very large swell. The outer lagoon was exposed to oceanic conditions in the outer sectors, whereas there was significant land influence close to shore. Riverine input was not obvious but there was heavy algal and epiphytic growth on these substrates. At Mataiea, eight commercial and one indicator species of sea cucumber were recorded during in-water assessments (Table 4.14), a similar amount to that found at other PROCFish/C sites in French Polynesia, independent of whether sites were high islands or atolls.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 4.14, Appendix 4.3, also see Methods.). The presence of sea cucumber species reflected the easterly position of French Polynesia, which has limited species numbers compared to sites closer to the centre of biodiversity situated further west. However, the varied environment of the lagoon, pools and passages of Mataiea suited many of these deposit-feeding sea cucumber species (which eat organic matter in the upper few mm of bottom substrates). In deep-water assessments (average depth 27 m), white teatfish (*Holothuria fuscogilva*) were present at low-to-moderate density. Of the three sea cucumber day searches completed, white teatfish were found in the deep-water pools in reefs on the easterly side of the study area, and unusually, not within the passage that was surveyed. Prickly redfish (*Thelenota ananas*), which is found in deep and shallow water, was present across the study area at moderate-to-low density (total of 24 individuals seen).

Of the other species, those associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were very common (found in 65–85% of fine- and broad-scale

[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.

assessments) and often at high density, indicating a stock that is not under fishing pressure. However, the high-value black teatfish (*Holothuria nobilis*) was rare, despite there being significant suitable areas within the back-reef for this species (only found on sea cucumber day search in deep water – 27 m). Stocks of this high-value sea cucumber can usually be found in shallow water and are highly susceptible to fishing pressure. Surf redfish, *Actinopyga mauritiana* was recorded across the site although a high-density aggregation was only found in one reef-benthos station (3625 individuals/ha ±1022, or a mean of >1 every three metres). The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was not found at any sites in French Polynesia.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon did not include blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), pinkfish (*H. edulis*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*), although lower-value species, e.g. lollyfish (*H. atra*) and false sandfish (*Bohadschia similes*), were moderately common.

4.4.7 Other echinoderms: Mataiea

Edible urchins, such as the collector urchin *Tripneustes gratilla* and slate urchin *Heterocentrotus mammillatus* were rare or absent. Other urchins that can be used within assessments as a food source or potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at relatively high levels (in broad-scale and reef-benthos stations, Appendices 4.3.1 to 4.3.7).

Starfish were sparsely distributed at Mataiea; the blue starfish *Linckia laevigata* was absent and, although pincushion stars *Culcita novaeguineae* were noted across the site (in 77% of broad-scale stations) they were not at high density. Only a single record of another coralivore (coral eating) starfish, the crown of thorns (*Acanthaster planci*) was noted (See presence and density estimates in Appendices 4.3.1 to 4.3.7.).

Table 4.14: Sea cucumber species records for Mataiea

Species	Common name	Commercial value [5]	B-S transects n = 78			Reef-benthos stations n = 13			Other stations 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	1.1	20.8	5	362.2	2354	15						
Bohadschia argus	Leopardfish	M	71.4	109.2	65	153.8	181.8	85	41.7	69.4	60 MOPt	53.3 2.4	53.3 7.1	100 Ns 33 Ds
Bohadschia similis	False sandfish	L										431.1	431.1	100 Ns
Bohadschia vitiensis	Brown sandfish	L												
Holothuria atra	Lollyfish	L	126.3	703.6	18	16.0	104.2	15						
Holothuria fuscogilva [4]	White teatfish	H										15.5	23.2	66 Ds
Holothuria leucospilota	-	M												
Holothuria nobilis [4]	Black teatfish	H										1.2	3.6	33 Ds
Stichopus horrens	Peanutfish	M										4.4	8.9	50 Ns
Synapta spp.	-	-	0.4	16.7	1									
Thelenota ananas	Prickly redfish	H							12.5	31.3	40 MOPt	8.3	25.0	33 Ds
Thelenota anax	Amberfish	M												

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

4.4.8 Discussion and conclusions: invertebrate resources in Mataiea

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 in the body of the invertebrate chapter.

- The lagoon areas of Mataiea and especially the shallow-water back-reef areas were very suitable for the elongate clam *Tridacna maxima*, and giant clam density was reasonable for *T. maxima* for a high-island, open-lagoon site. The coverage and density were not remarkable compared to densities commonly found elsewhere in French Polynesia and local reports claim clam numbers and sizes have decreased in recent years. Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the number of large-sized clams was relatively small, supporting the assumption that clam stocks are impacted by fishing pressure.

- Despite blacklip pearl oysters, *Pinctada margaritifera,* being cryptic and normally sparsely distributed in open lagoon systems (such as found at Mataiea), they were still surprisingly rare, with only a single shell recorded in survey.

- Trochus, *Trochus niloticus,* and green snail or great green turban, *Turbo marmoratus*, are mainly limited to within the passes and lagoon but are relatively common at Mataiea. Both are species of commercial value to inshore fishers. The protection of trochus broodstock (sizes 11 cm and up), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Mataiea are in the healthy condition found during the survey. Periodic harvests (with fishing quotas/lagoon), along with strict size controls has proved a successful strategy for stock management in French Polynesia.

- There is a restricted range of sea cucumber species at Mataiea (due to biogeographical influence), and no clear picture of pressure on stocks emerged. A good density of lower-value leopard or tigerfish (*Bohadschia argus*) was recorded, but black teatfish (*Holothuria nobilis*), a more valuable species, was only found at a single location in survey. Prickly redfish (*Thelenota ananas*), which has a slightly lower value than black teatfish, was not uncommon, but still at moderate-to-low density.

4.5 Overall recommendations for Mataiea

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

- Further development of reef finfish fisheries would not be sustainable and resources need to be allowed to recover if food security needs are to be met in the future.

- Recovery should be achieved through the establishment of restrictive marine resource management measures. Marine protected areas should be considered as a primary management tool. The efficiency of this trial should then be evaluated through ongoing resource monitoring.

- Use of gillnets and night spearfishing should be strictly regulated.

- Intermediate and coastal reefs should be the focus of recovery and protection since the natural poverty of the outer reefs would not release pressure on sheltered coastal and back-reefs.

- The density and size range of trochus noted in the survey suggest that limited fishing could be made at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing.

- No commercial fishing of green snail, *Turbo marmoratus*, is recommended as the range of this species is very limited.

- Older fishers could be interviewed to identify areas that traditionally held trochus and green snail stocks, but which are now overfished. This might allow the range of these resources to be extended locally, by transplanting adults to these areas.

- Further assessment is needed of the stocks of the deeper-water white teatfish (*Holothuria fuscogilva*) to assess the potential for commercial harvesting of this species.

5. PROFILE AND RESULTS FOR RAIVAVAE

5.1 Site characteristics

Raivavae is a high-island in the Austral Islands, situated at 23°53'S and 147°40'W (Figure 5.1). The island has an area of 16 km², and its highest point is Mount Hiro (437 m). The island is surrounded by a small lagoon, with two passes, one in the north and one in the south. Four reef habitats are present: sheltered coastal reef, intermediate reef, back-reef and outer reef, with a total reef area of ~93 km². Both the eastern and the southern parts of the island are dominated by *motu*, small coralline islets. The local economy is based on agricultural produce for food; fisheries; and handicrafts. Population (1050 people) is distributed over four districts, with Rairua being the most important.

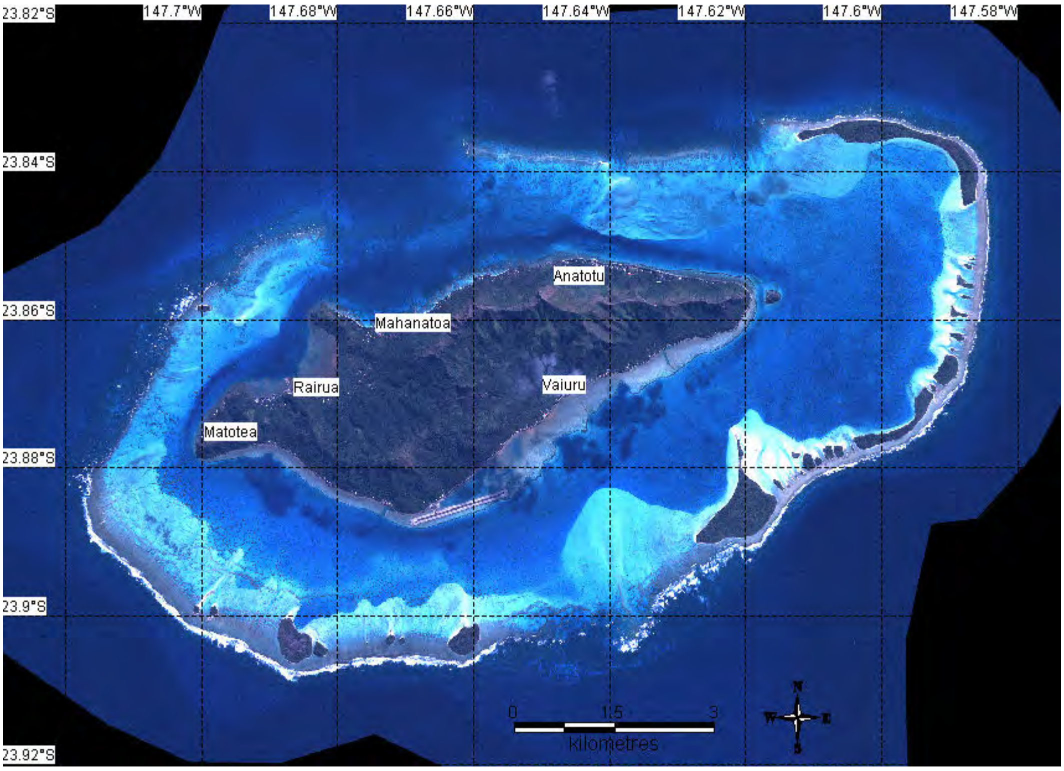

Figure 5.1: Map of Raivavae.

5.2 Socioeconomic surveys: Raivavae

Socioeconomic fieldwork was carried out on the island of Raivavae in February 2004. The survey covered a total of 30 households including 152 people, representing about 14% of the community's households (212) and total population (1074).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 18 individual interviews of finfish fishers (17 males, 1 female) and 28 invertebrate fishers (16 males, 12 females) were conducted. These fishers belonged to one of the 30 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 5.1) suggest an average of 2–3 fishers/household. If we apply this average (2.53) to the total number of households, we arrive at a total of 536 fishers on Raivavae. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 21 fishers who fish only for finfish (males), a total of 212 fishers who harvest only invertebrates (males, females) and 303 fishers (males, females) who fish for both finfish and invertebrates.

Over 75% of all households on Raivavae own a boat, and most are motorised (96%), very few do not have an outboard engine fitted (~4%).

Ranked income sources (Figure 5.2) suggest that fisheries are not an important income source. Only 7% of the households investigated rely on fisheries as either first or second income source. In contrast, salaries are the most important source of revenue for 43% of all households and another 33% of all households surveyed obtain their major cash income from other sources, i.e. small business and retirement and social fees. Agricultural production plays some role; in fact about 30% of the families depend on agriculture, some (13%) as the primary and others (17%) as the secondary source of income.

The importance of fisheries is, however, shown in the fact that all households reported eating fresh fish, most eat invertebrates and about 2/3 of all households also consume canned fish. The fish that is consumed is caught by a member of the household (87%), rarely bought (17%), and sometimes received as a gift (33%). The proportion of invertebrates caught by a member of the household where consumed is lower (77%), and they are very rarely bought (3%) or received as a gift (17%). In fact, people on Raivavae still enjoy a very traditional lifestyle as far as social networking is concerned. Reef fish has traditionally been a non-monetary commodity and people still continue to follow this tradition. However, as far as pelagic fish species are concerned, a local price has been established. The fact that pelagic fishers have normally higher investments for larger boats and outboard engines and spend more time and thus fuel while fishing may explain why people regard pelagic fish differently from reef fish. Also, people seem to increasingly favour pelagic fish as the risk of ciguatera has increased over the past years.

The average household expenditure level on Raivavae is below the average across all PROCFish/C sites in French Polynesia. This is somewhat surprising as Raivavae is the furthest and most isolated of all sites that we investigated and thus bears the highest cost for imported items. However, the fact that Raivavae is both a high island with agricultural production potential and an atoll with a reef and lagoon system that supports extensive fisheries, may explain why people have less household expenses than elsewhere, particularly for primary food items.

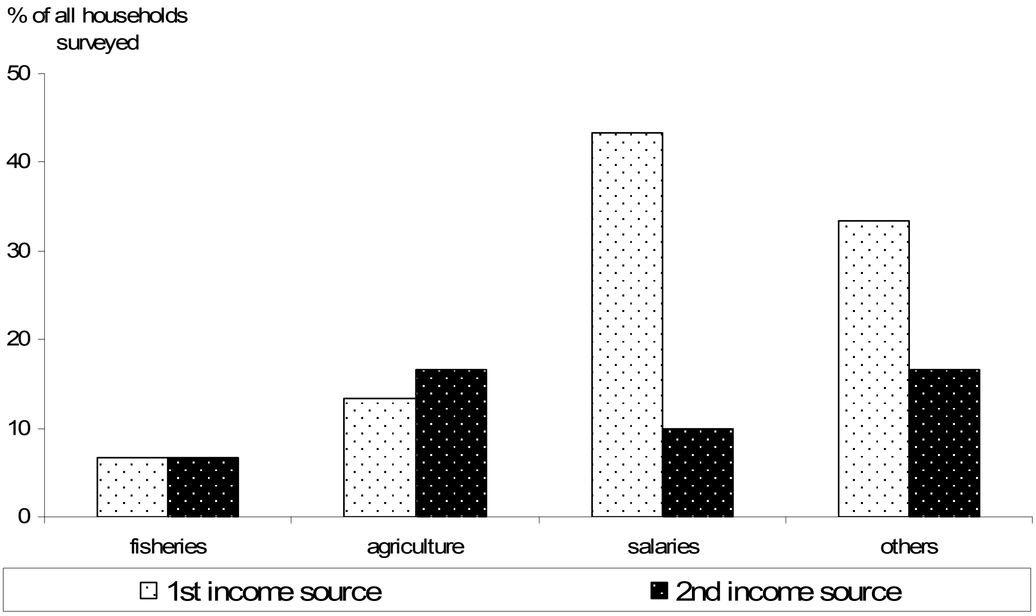

Figure 5.2: Ranked sources of income (%) in Raivavae.
Total number of households = 30 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small businesses.

The per capita consumption of fresh fish (~46 kg/capita/year ±12.9) on Raivavae is above the regional average (FAO 2008) (Figure 5.3), but lower than the average consumption across all PROCFish/C sites in French Polynesia. The consumption of invertebrates (meat only) on the other hand, is outstandingly high (18 kg/capita/year ±9.34). This seems to be a very special situation that has not been found elsewhere in the country. The local preference for giant clam meat and the abundance of giant clams in the lagoon and reef system may be possible explanations (Figure 5.4). The canned fish consumption is relatively low but highest across all PROCFish/C sites in the country (~4.3 kg/capita/year ±1.23) (Table 5.1).

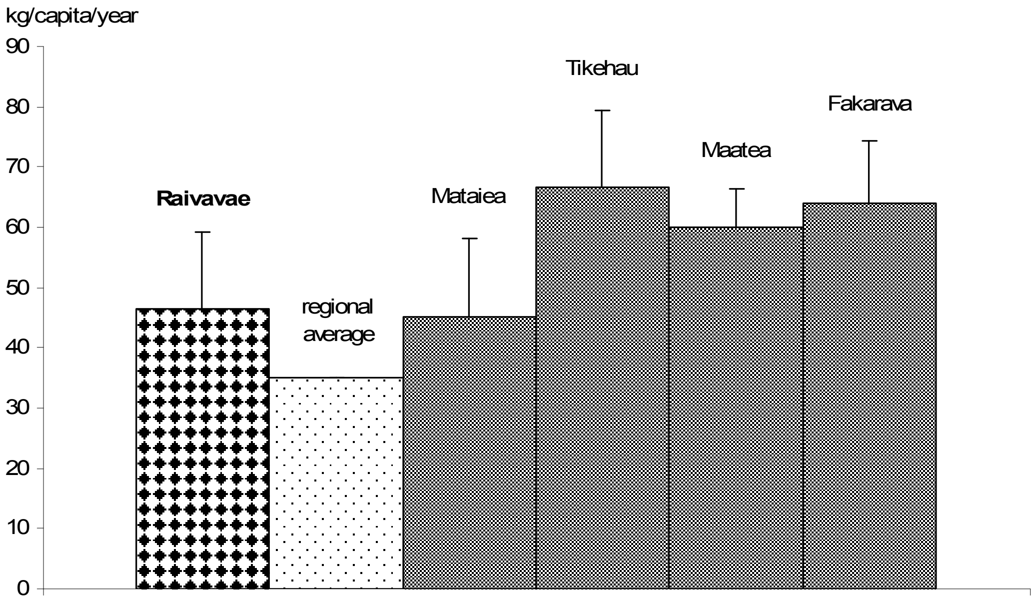

Figure 5.3: Per capita consumption (kg/year) of seafood in Raivavae (n = 30) compared to the regional averages (FAO 2008) and the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

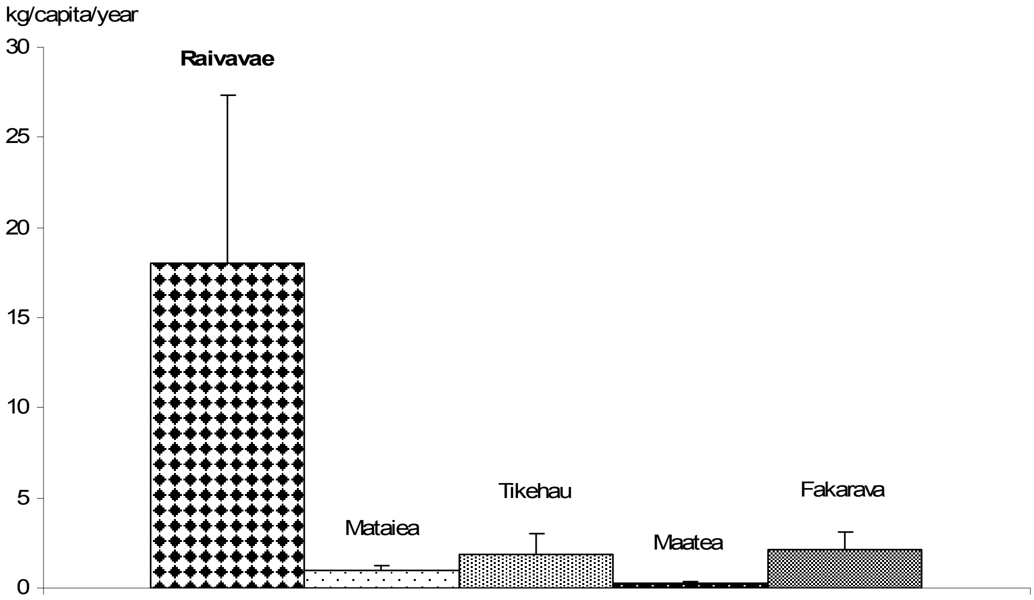

Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Raivavae (n = 30) compared to the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Comparison of results between Raivavae and the average of all five PROCFish/C sites in French Polynesia (Table 5.1) suggests that the people of this island are less dependent on fisheries for income generation and eat less fresh fish. However, Raivavae people have an extremely high consumption of invertebrates. The local household expenditure level is below the average across all PROCFish/C sites in French Polynesia and external financial input in the form of remittances hardly plays any role.

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

Survey coverage	Site (n = 30 HH)	Average across sites (n = 138 HH)
Demography		
HH involved in reef fisheries (%)	93.3	85.5
Number of fishers per HH	2.53 (±0.29)	1.71 (±0.12)
Male finfish fishers per HH (%)	3.9	33.9
Female finfish fishers per HH (%)	0.0	9.7
Male invertebrate fishers per HH (%)	1.3	0.4
Female invertebrate fishers per HH (%)	38.2	14.0
Male finfish and invertebrate fishers per HH (%)	52.6	35.2
Female finfish and invertebrate fishers per HH (%)	3.9	6.8
Income		
HH with fisheries as 1st income (%)	6.7	14.5
HH with fisheries as 2nd income (%)	6.7	11.6
HH with agriculture as 1st income (%)	13.3	11.6
HH with agriculture as 2nd income (%)	16.7	13.8
HH with salary as 1st income (%)	43.3	46.4
HH with salary as 2nd income (%)	10.0	8.7
HH with other source as 1st income (%)	33.3	26.8
HH with other source as 2nd income (%)	16.7	34.1
Expenditure (USD/year/HH)	8741.51 (±1097.97)	9752.58 (±468.27)
Remittance (USD/year/HH) (1)	729.54 (±351.26)	1055.66 (±393.52)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	46.42 (±12.90)	55.55 (±4.16)
Frequency fresh fish consumed (times/week)	2.35 (±0.32)	3.28 (±0.16)
Quantity fresh invertebrate consumed (kg/capita/year)	18.03 (±9.34)	4.91 (±4.16)
Frequency fresh invertebrate consumed (times/week)	1.10 (±0.28)	0.38 (±0.07)
Quantity canned fish consumed (kg/capita/year)	4.28 (±1.23)	3.95 (±0.59)
Frequency canned fish consumed (times/week)	0.47 (±0.12)	0.65 (±0.10)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	93.3	82.6
HH eat canned fish (%)	76.7	79.0
HH eat fresh fish they catch (%)	86.7	84.0
HH eat fresh fish they buy (%)	16.7	56.0
HH eat fresh fish they are given (%)	33.3	44.0
HH eat fresh invertebrates they catch (%)	76.7	44.0
HH eat fresh invertebrates they buy (%)	3.3	8.0
HH eat fresh invertebrates they are given (%)	16.7	8.0

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

5.2.2 Fishing strategies and gear: Raivavae

Degree of specialisation in fishing

Fishing on Raivavae is mainly performed by males; females hardly ever go fishing (Figure 5.5). This not only shows in the fact that males are the only exclusive finfish fishers (~5%), but also the very small percentage of female fishers targeting both finfish and invertebrates (<5%). However, as regards exclusively targeting invertebrates, females play the major role (~40%); males rarely fish for invertebrates only.

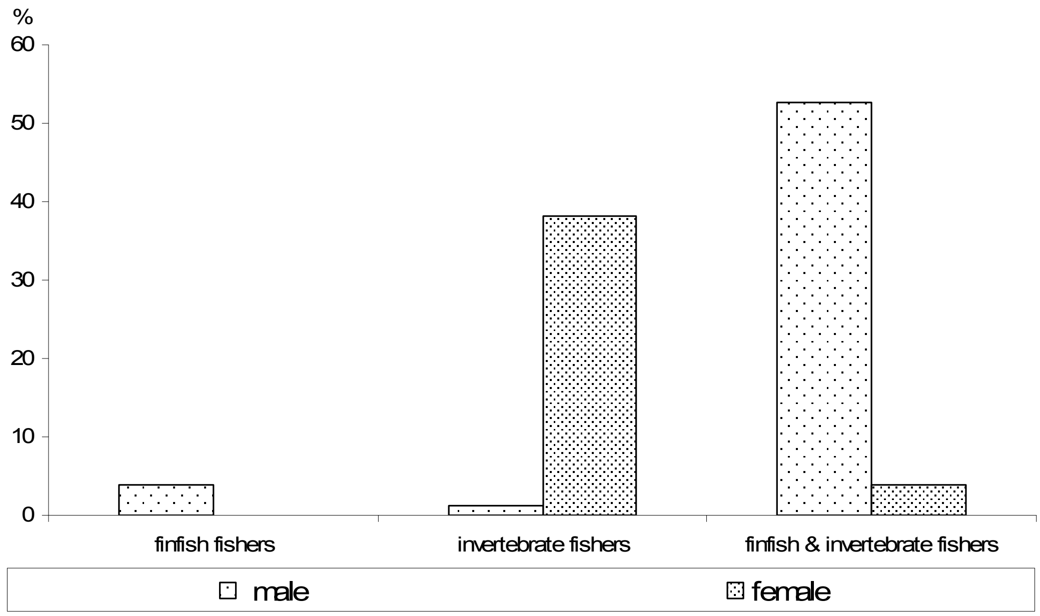

Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Raivavae.
All fishers = 100%.

Targeted stocks/habitat

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Raivavae on their fishing grounds (Table 5.2).

Table 5.2: Proportion (%) of interviewed male and female fishers harvesting finfish and invertebrate stocks across a range of habitats (reported catch) in Raivavae

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef	64.7	100.0
	Sheltered coastal reef & outer reef	5.9	0.0
	Outer reef	17.6	0.0
	Outer reef & passage	17.6	0.0
Invertebrates	Reeftop	6.3	8.3
	Intertidal	6.3	83.3
	Lobster	43.8	0.0
	Other	81.3	8.3

'Other' refers to the giant clam and sea urchin fisheries.
Finfish fisher interviews, males: n = 17; females: n = 1. Invertebrate fisher interviews, males: n = 16; females: n = 12.

Fishing patterns and strategies

Our survey sample suggests that fishers in Raivavae can choose between sheltered coastal reef and outer-reef habitats, including some passages. Fishers do not seem to clearly distinguish between habitats targeted. While most fishers (~65%) apparently stay close to the island and target the sheltered coastal reefs, others venture between both the sheltered coastal and outer reefs (~6%) or combine passage and outer-reef fishing (~18%) in one trip. A few fishers also target the outer reef only (~18%). Although there are not many female finfish fishers, females seem to exclusively stay close to shore; if they fish at all, they focus only on the sheltered coastal reef.

Invertebrate fisheries are not diverse and data suggest that fishers in Raivavae target two major habitats. Firstly, reeftops and reefs are used to glean, harvest lobsters and dive for giant clams. In fact, as shown in Figure 5.6, most fishers (41%) target giant clams and sea urchins by free diving ('other' fishery) while reeftop gleaning does not play a major role (6%). Secondly, intertidal sandy areas (32% of all fishers) are used for either *Anadara* shell collection or for the collection of dead shells of very small specimens locally called *poupou* that are used for local shell handicrafts. There is also a clear gender distinction between the different types of collection. Female invertebrate collectors mainly collect dead shells for handicrafts, and *Anadara* shells; to a much lesser extent they also collect other specimens found on the reef, such as sea urchins and giant clams. On the other hand, lobsters are a major target (21% of all fishers) but dived for only by males. Most males dive also for giant clams and perhaps some sea urchins rather than collect from reeftops or intertidal habitats (Figure 5.7).

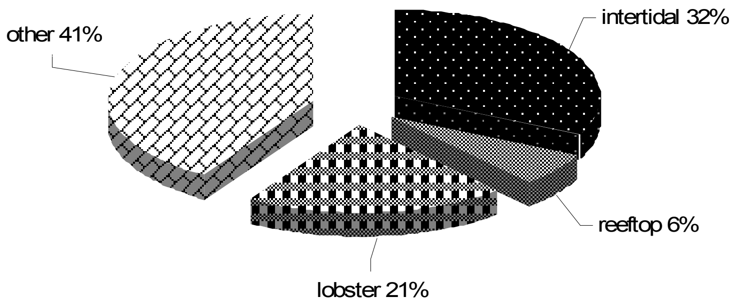

Figure 5.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Raivavae.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; 'other' refers to the giant clam and sea urchin fisheries.

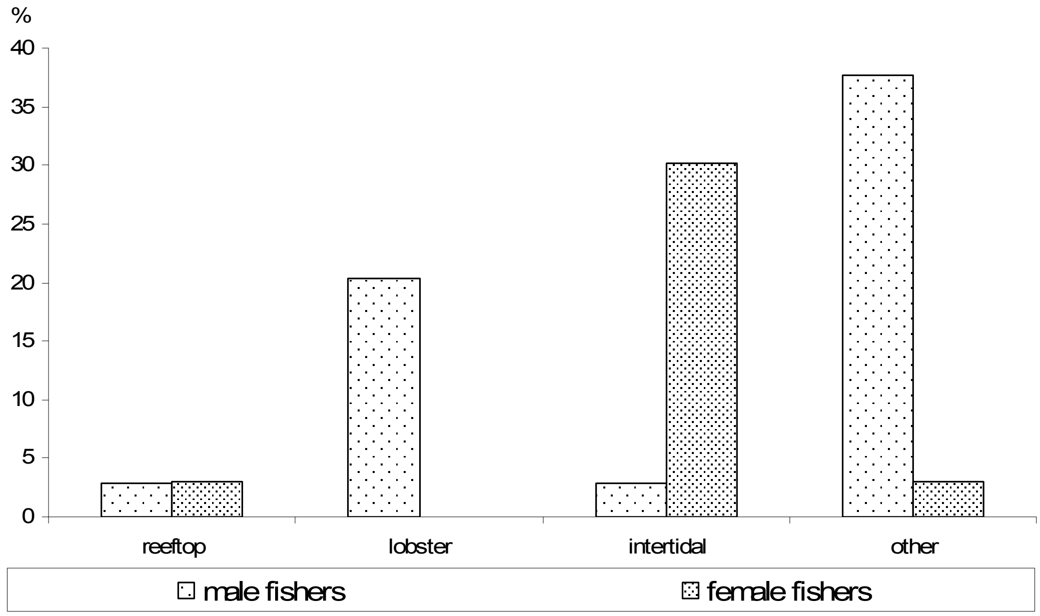

Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Raivavae.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 16 for males, n = 12 for females; 'other' refers to the giant clam and sea urchin fisheries.

Gear

Figure 5.8 shows that fishing methods vary considerably among habitats targeted. Fishers targeting the sheltered coastal reef usually use a variety of methods, with handlining and spear diving being perhaps the most frequent. Spear diving is the main technique used if a fisher combines both sheltered coastal and outer reefs in one trip; spear diving combined with handlining are used for fishing the outer reefs as well as the combined outer reef and passages. All fishers use a boat; males always use motorised boats and females usually non-motorised.

Gleaning and free diving for invertebrates is done using very simple tools only. Lobsters and giant clams are picked up by hand and, if done by free diving, use dive mask, fins, snorkel and possibly dive suit. Diving does not involve any SCUBA gear. Invertebrate fishing relies on boat transport; boats are mostly motorised and used by both male and female fishers. In this context it is worth mentioning that the collection of dead shells (*poupou*) is done on the small *motu* (coral islands) at the outer barrier reef. Motorised boat transport is needed to reach any of these small atolls; however, the actual collection is done by walking.

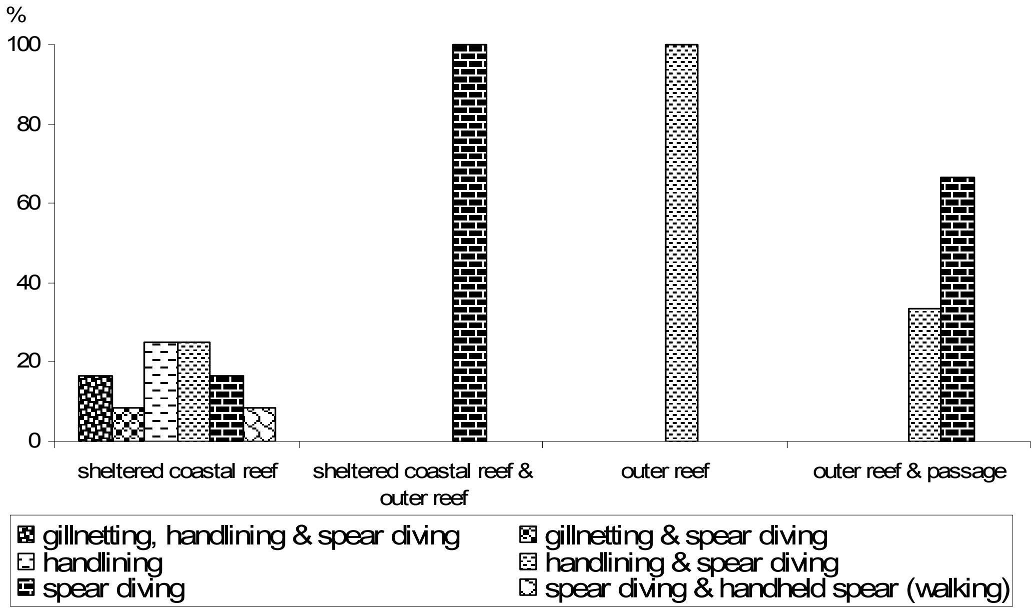

Figure 5.8: Fishing methods commonly used in different habitat types in Raivavae.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 5.3 fishers visit areas close to the main island more frequently than areas further offshore; trips to the sheltered coastal reef or in combination with the outer reef are usually made on average twice a week. However, if the outer reef and passages are targeted, fishers go less often, on average less than once a week. Invertebrate collection is also done less frequently and in general once or twice a month only as far as males are concerned. Females collect invertebrates more often and may do so once or twice a week. Fishing trips vary considerably and may take on average 3–6 hours each. Invertebrate collection trips are a bit shorter, at least if males dive for lobsters, giant clams or collect on reeftops, which take on average three hours each. Females often take longer and may stay 5–6 hours to harvest intertidal areas or to collect giant clams and sea urchins.

Finfish fishing is mainly performed during the day, but some fishers may also go out day and night, depending on the tides. Most fishers reported that they stop fishing during certain months in the year, often due to engagement in agricultural production. Species in intertidal habitats as well as giant clams and sea urchins are collected exclusively during the day. Lobsters and reeftop species are fished either at night or, as in almost half of all cases, also during the day. Most invertebrate fishers venture out during the entire year, but dead shells for artisanal purposes are usually collected during the summer season only when families camp out on the *motu*.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.84 (±0.51)	1.00 (n/a)	4.05 (±0.52)	5.00 (n/a)
	Sheltered coastal reef & outer reef	2.00 (n/a)	0	2.50 (n/a)	0
	Outer reef	0.83 (±0.17)	0	6.00 (±0.29)	0
	Outer reef & passage	0.83 (±0.17)	0	4.17 (±0.93)	0
Invertebrates	Reeftop	0.58 (n/a)	1.00 (n/a)	3.00 (n/a)	3.00 (n/a)
	Intertidal	0.08 (n/a)	0.21 (±0.07)	6.00 (n/a)	6.20 (±0.47)
	Lobster	0.46 (±0.15)	0	3.00 (±0.00)	0
	Other	0.69 (±0.15)	1.00 (n/a)	3.77 (±0.39)	5.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated; 'Other' refers to the giant clam and sea urchin fisheries.
Finfish fisher interviews, males: n = 17; females: n = 1. Invertebrate fisher interviews, males: n = 16; females: n = 12.

5.2.3 Catch composition and volume – finfish: Raivavae

Overall, reported catches are not very diverse; a few main species play major roles: Scaridae, Acanthuridae, Serranidae and Kyphosidae. The fact that the diversity of the reported catch composition is highest for sheltered coastal reef fishing may be explained by the great variety of techniques used here, while all other habitats are almost exclusively fished by handlines, or by spear diving or a combination of both. Catches from the sheltered coastal reef include a variety of different fish species but Scaridae (37%) and Acanthuridae (23%) determine almost 60% of the total reported catch. Carangidae, Kyphosidae, Holocentridae and Siganidae are also major contributors. If the sheltered coastal and the outer reefs are jointly fished during one trip, the reported catch composition shifts in favour of Acanthuridae (*Naso unicornis*: 54%), Scaridae and Kyphosidae. Reported catches from the outer reef are determined by Serranidae (62%), Siganidae and Acanthuridae and, if the outer reef and passages are jointly targeted, Scaridae (34%), Serranidae (23%), Kyphosidae and Acanthuridae represent the major shares (Detailed data are provided in Appendix 2.4.1.).

Our survey sample of finfish fishers interviewed represents about 6% of the projected total number of finfish fishers in Raivavae. Fishing in Raivavae is not commercial with the exception of pelagic fishing. There is little opportunity to export fresh finfish to Papeete as there is no special air cargo arrangement for Raivavae. Also, during the past years, ciguatera has increasingly been recognised as a problem. In total, 39 cases of serious ciguatera poisoning were recorded by the local health service at Rairua in 2003. Local people held responsible recent road and airport constructions, as well as dynamiting to improve the harbour entrance. As a result, certain areas, in particular the passage of Teavaraa and the coastal reef west and east of these passages, are no longer targeted by the local fishers. Although fishing is basically a subsistence-oriented activity, we have included a number of very active fishers who share a considerable portion of their catch with others. For this reason, together with the small sample size, we refrain from extrapolating our figures but here represent only the catch data reported by the survey respondents.

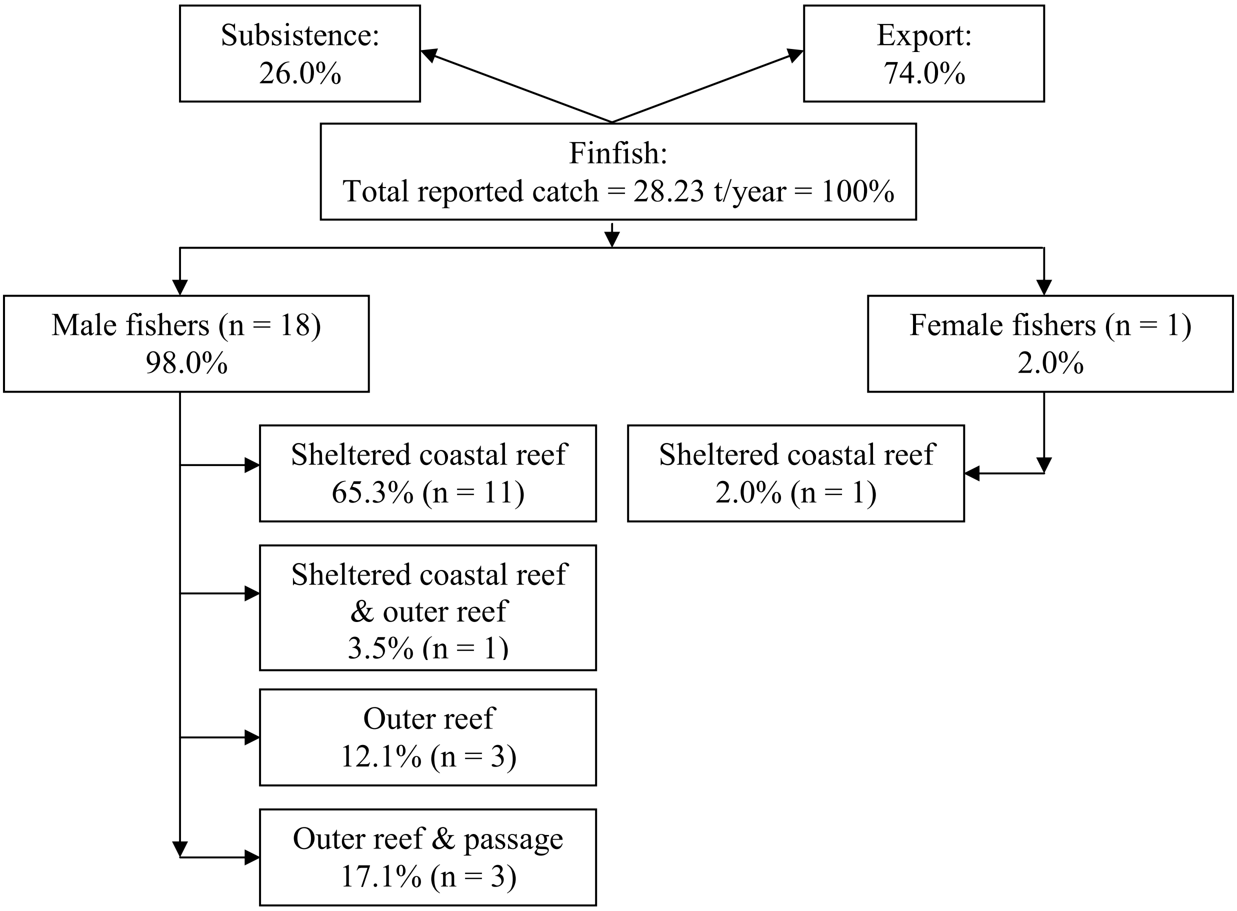

Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Raivavae.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

As shown in Figure 5.9 respondents caught more fish than they consumed; about 74% is usually distributed among community members, and some share may be either exported as a frozen product to be given to relatives on Tahiti or sold at the market in Papeete. The recorded export by sea transport of fish to Tahiti in 2003, for example, amounted to 14.4 t. From this volume, the share of gifts and thus mainly reef fish is estimated at 25%, i.e. 3.6 t/year, while 75% (~10.8 t/year) is estimated to be pelagic species. In total, there are seven fishers on Raivavae who catch for sale at the Tahiti market; their average commercial catch is estimated at about 30–32 kg/fisher/week (information provided by the Service de Développement Rural Raivavae). The total value of the 14.4 t/year fish export to Tahiti in 2003 is estimated at XPF 8.6 million (based on an average price of XPF 600 /kg fresh fish). As already mentioned before, reef fish are never sold on Raivavae, only pelagic fish. Thus, some of the fish species caught when visiting the passages or outer reef, in particular Carangidae (Appendix 2.4.1), may be sold among the local residents. However, this is a rather small proportion and is included in the distribution and export figure. These figures also show that finfish fisheries are an almost exclusive male business on Raivavae and that females hardly fish. Furthermore, the highest impact is imposed on the sheltered coastal reef (67%) and least on the outer reef (~27%). The fact that the fisheries are strongly subsistence-oriented, and that trips to the outer reef incur considerable fuel and boat-maintenance costs,

not to mention the added time involved and the possibility of adverse weather and sea conditions, may explain why fishing is mostly done close to shore.
The high impact on the combined sheltered coastal reef and lagoon fisheries is a function of the number of fishers targeting these areas rather than the average annual catch rate. As shown in Figure 5.10, average annual catches for male fishers are about 600–800 kg/fisher/year for both sheltered coastal reef and outer reef (perhaps combined with passages) fishing. The few females who do actually fish take far smaller catches than males.

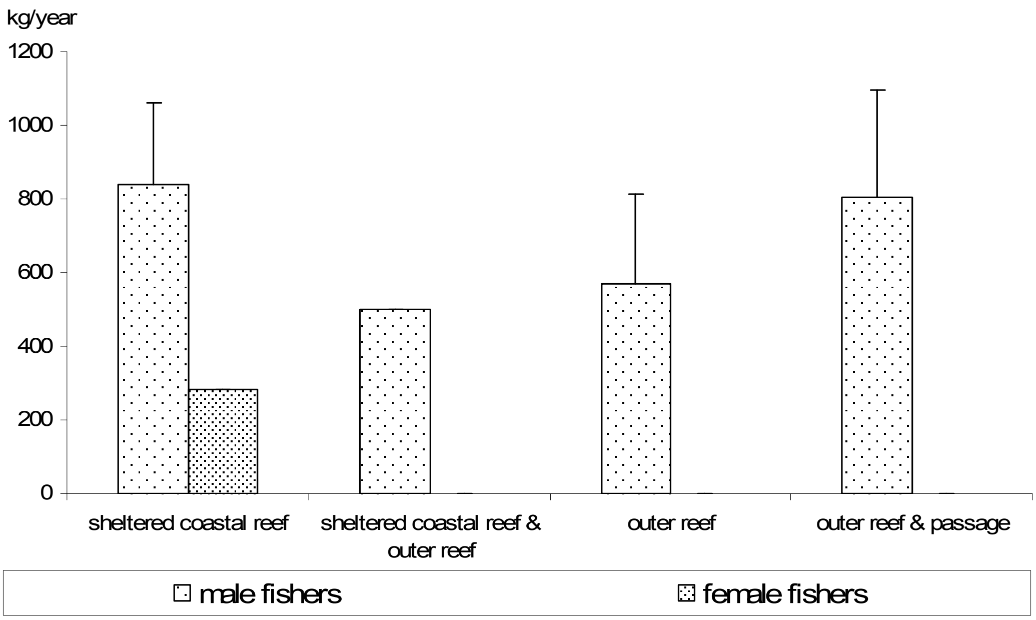

Figure 5.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Raivavae (based on reported catch only).

Comparing catch efficiency among different habitats, CPUE from the sheltered coastal reef is high (~4 kg/hour of fishing trip). In comparison, fishers targeting the outer reef have a lower CPUE (~3 kg/hour of fishing trip). Fishers who target both passages and the outer reef reach the highest CPUE (an average of 5 kg/hour fished). The few female fishers reported much smaller annual catches than males (Figure 5.10) and also much lower CPUE (2.5 kg/hour fished) from sheltered coastal reef areas (Figure 5.11).

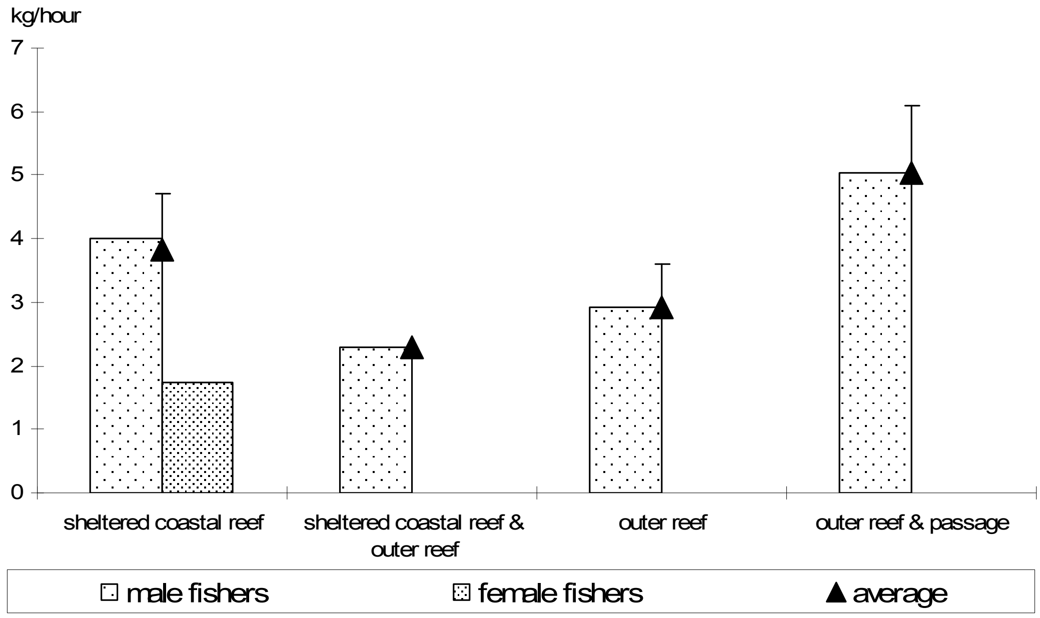

Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat type in Raivavae.
Effort includes time spent transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data confirm that no finfish fishing at all is conducted for commercial interests. Fishing in order to share catches on a non-monetary basis is as important as fishing to supply the family's needs. In fact, fishing on the outer reef and passages is conducted far more often for gift-giving than for subsistence needs. However, as already mentioned above, some fish species are now accepted for sale, in particular pelagic fish (e.g. Carangidae) that may also be caught at the outer reef and in passages. The local population is more and more interested in buying pelagic fish since the incidence of ciguatera has increased. This development may result in more fishers targeting the outer reef and passages in the future (Figure 5.12).

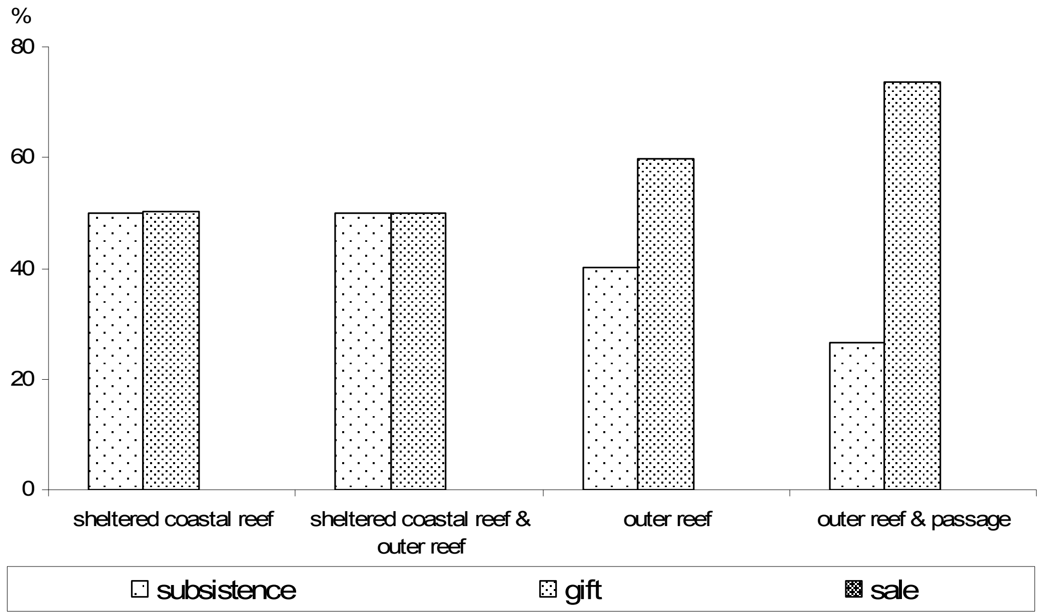

Figure 5.12: The use of finfish catches for subsistence, gifts and sale, by habitat in Raivavae.
Proportions are expressed in % of the total number of trips per habitat.

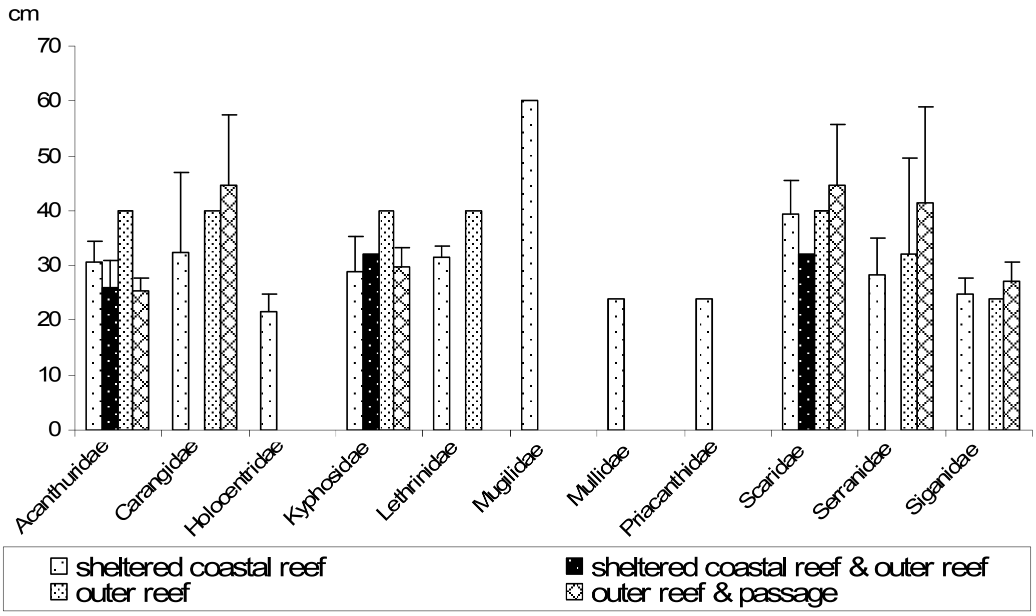

Figure 5.13: Average sizes (cm fork length) of fish caught by family and habitat in Raivavae.
Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat (Figure 5.13) show average fish sizes from the outer reef are larger than those from the sheltered coastal reef. This is not only true for pelagic species that may venture around reef areas, such as Carangidae, but also for reef-associated species of the families of Acanthuridae, Lethrinidae and Serranidae. In the case of Scaridae and Siganidae, average fish sizes do not seem to vary among habitats. Scaridae are particularly targeted by spear divers, and spear diving is a preferred technique for Raivavae fishers targeting the outer reef and passages. The lack of increase in the size of Scaridae may therefore be related to the much higher impact of spearfishing at the outer reef and passages as compared to the sheltered coastal reef, where fishers use a variety of techniques as well as spear diving. Some families were reported only from sheltered coastal reef catches, such as Mugilidae, Mullidae and Priacanthidae. Overall, average fish sizes are large and often exceed 30 cm.

Some parameters chosen to assess the current fishing pressure on Raivavae living reef resources are shown in Table 5.4. The comparison of habitat surfaces shows that the outer-reef area is the largest habitat available, five times larger than the sheltered coastal reef area. The total lagoon area is also substantial and contributes to the large difference between the total reef area and the total fishing ground area. Despite these size variations among habitats, fisher density remains relatively low. Fisher density is highest at the sheltered coastal reef (which is the smallest area with the highest number of fishers) and lowest at the outer reef. Overall, however, fisher density is low with 3 fishers/km^2 if calculated for either the total reef or the total fishing ground area. The same is true for the population density. The total fishing pressure imposed by the island's subsistence needs (total of >36.5 t/year) is 0.3 to 0.4 t/km^2/year, which is considered low. Because reef fisheries in Raivavae are not commercial and there is no outside market accessible, we can assume that the current (and presumably also the future) fishing pressure is not detrimental to Raivavae reef and lagoon finfish resources.

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

Parameters	Habitat						
	Sheltered coastal reef	Sheltered coastal reef & outer reef	Lagoon	Outer reef	Outer reef & passage	Total reef area	Total fishing ground (1)
Fishing ground area (km^2)	9.43		49.17	58.81		95.05	117.41
Density of fishers (number of fishers/km^2 fishing ground) (1)	22			1		3	3
Population density (people/km^2) (2)						11	9
Average annual finfish catch (kg/fisher/year) (3)	791.57 (±209.44)	499.16 (n/a)	0.00 (±0.00)	569.79 (±244.23)	803.06 (±290.77)		
Total fishing pressure of subsistence catches (t/km^2)						0.38	0.31

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 1074, total number of fishers = 325; total subsistence demand = 36.59 t/year; (3) catch figures are based on recorded data from survey respondents only.

5.2.4 Catch composition and volume – invertebrates: Raivavae

Calculations of the recorded annual catch rates per species groups are shown in Figure 5.14. The graph shows that the only major impact by wet weight is due to giant clams and lobster catches, i.e. *Panulirus* spp. By comparison, catches reported for *poupou*, i.e. small shells used for handicrafts, *Parribacus antarcticus* a slipper lobster, crabs, arc shells *Anadara* spp., sea urchins and octopus are of minor if not insignificant importance (Detailed data are provided in Appendices 2.4.2 and 2.4.3.).

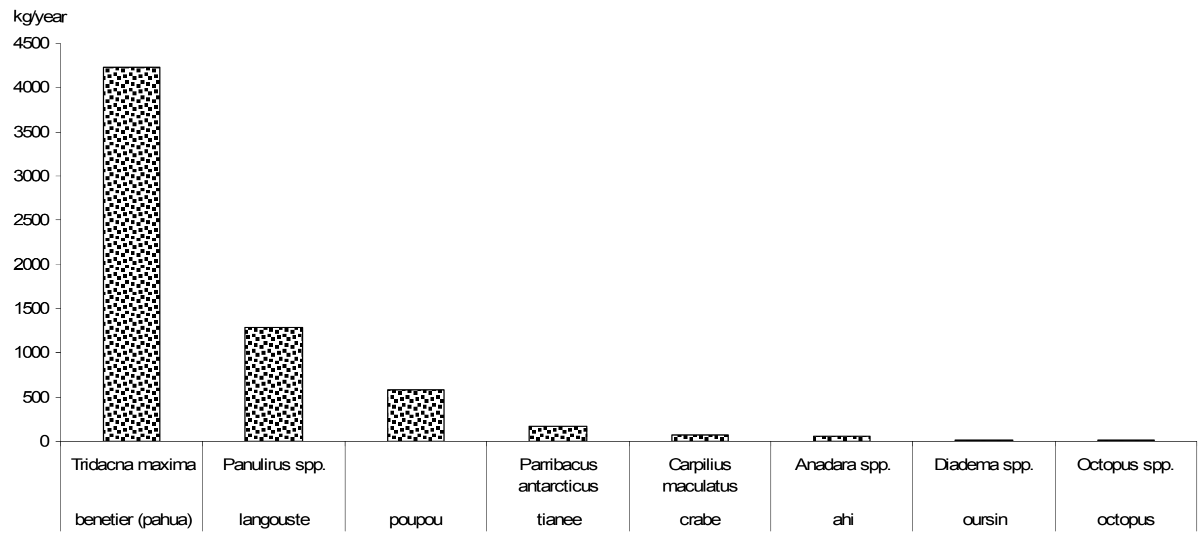

Figure 5.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Raivavae.

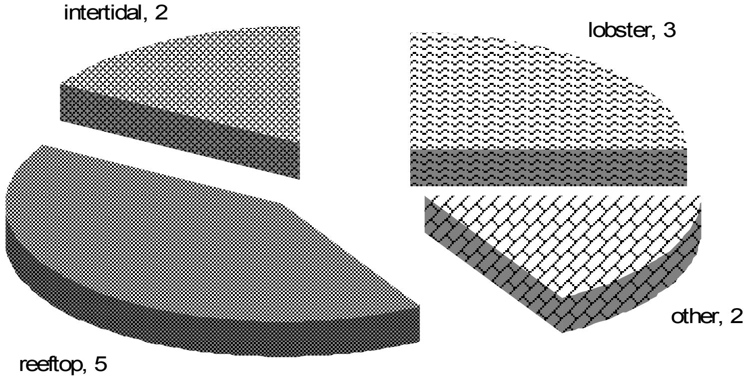

Figure 5.15: Number of vernacular names recorded for each invertebrate fishery in Raivavae.
'Other' refers to the giant clam and sea urchin fisheries.

Although invertebrate fisheries play a major role on Raivavae in terms of total catch and per capita consumption, as in other sites surveyed in French Polynesia, the number of target species is very limited. Reeftop gleaners cited the highest number of vernacular names, including lobster, giant clams, octopus, and sea urchins. Lobster fishers mainly focus on two different species, but they also reported picking up crabs at times. Intertidal fishers collect either *Anadara* spp. for consumption or dead *poupou* shells for handicraft purposes (Figure 5.15).

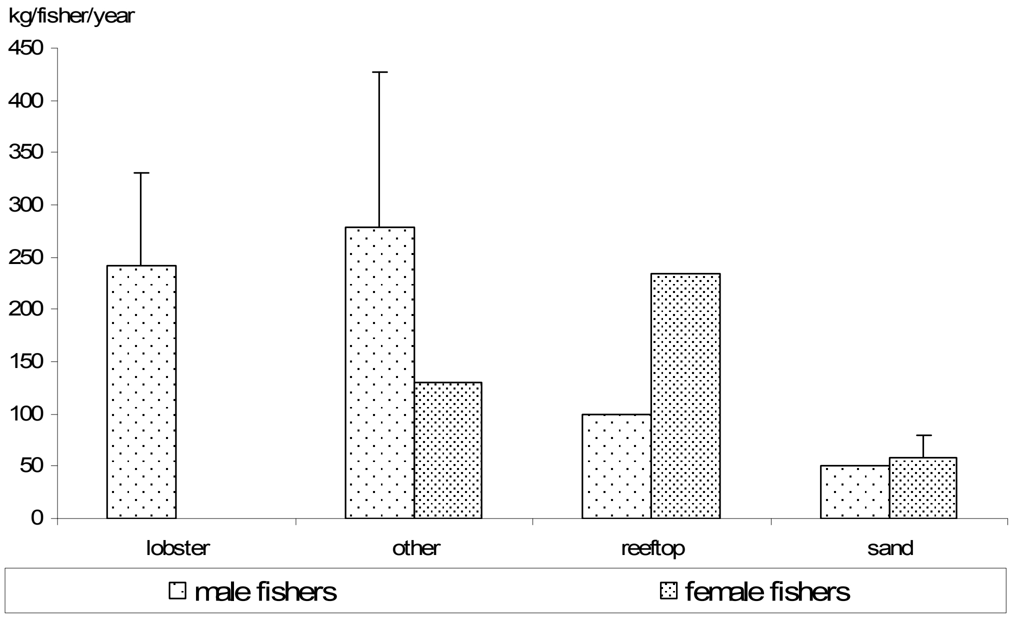

Figure 5.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Raivavae.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 22 for males, n = 12 for females). 'Other' refers to the giant clam and sea urchin fisheries.

Figure 5.16 shows that average annual catches by invertebrate fishers are generally low, 100–200 kg/fisher/year. Catch rates also vary considerably as shown by the large standard errors. Because we only interviewed one female reef gleaner, we do not include females' reeftop gleaning data in our comparison. Thus, we can conclude that male fishers targeting lobsters and giant clams are the most productive fishers with 200–250 kg catch/fisher/year.

Females who collect giant clams and sea urchins are less productive and may reach only about 100 kg catch/fisher/year. Intertidal catches, mainly of dead shells for handicrafts, are rather small by wet weight. These figures also include a very small proportion of *Anadara* shells that are sometimes collected for consumption.

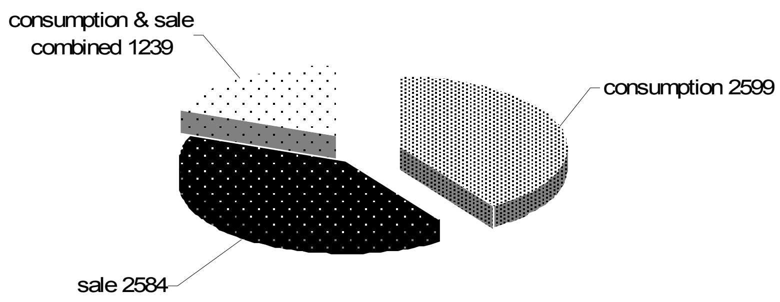

Figure 5.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Raivavae.

In contrast to finfish fisheries, invertebrate fisheries are commercially oriented. Giant clam meat is harvested and frozen for export to the Papeete urban market. A local price of XPF 10,000 was reported for about 15 kg in 2004. Lobster, by comparison, yielded as much as XPF 2500 /kg fresh weight when exported and XPF 1000 /kg when sold locally. The total export value of giant clam meat in 2003 was estimated to be XPF 5.2 million, and that of lobster at XPF 1.8 million. Unlike finfish, giant clam meat is accepted as a frozen product and thus does not depend on air cargo but can also be shipped by sea. This situation explains the large amount of invertebrate catch, 40% of the total reported annual catch, that is exclusively for sale (Figure 5.17). The share that is sold may reach 50% of the total annual reported catch if we assume that half of the catch in the category 'consumption and sale combined' is also sold. Taking into account the high percentage of catch for export to the Papeete market, and the fact that this export is mainly due to giant clam meat and, to a lesser extent, lobsters, it is obvious that the existing fishing pressure, at least on Raivavae's giant clam resources, is largely determined by external rather than internal demand.

In this context, it should be noted that the dead shells (*poupou*) collected by females on the small coral islands (*motu*) at the barrier reef, represent a substantial, but somehow unaccounted for income source for the population of Raivavae. A package of 10 necklaces made from *poupou* is sold for XPF 2000 to 4000 locally or to people who may sell them for an even higher price at the Papeete market. Based on our survey results it is estimated that over 60% (>120 households) of all households on Raivavae have females who make such necklaces, and about 74 of these households also sell them, either frequently or irregularly. A household may thus earn up to XPF 120,000 /year from sales of shell necklaces alone.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) is moderately high, reaching 11.55 t/year by wet weight (Figure 5.18). Male fishers determine the major impact, taking ~85% of the reported annual catches. Females are the main fishers collecting *poupou*, which account for ~10% of the total annual reported catch by wet weight. As already explained, the highest impact by wet weight is on 'other' fisheries, mainly giant clams. Giant clams and some sea urchins for local consumption contribute about 56% to the total annual reported catch. Lobster catches are also substantial, reaching 26% of the total annual reported catch by wet weight. Lobster fishing, however, is more seasonal and peaks at end-of-year festivities, funerals, marriages and other important events.

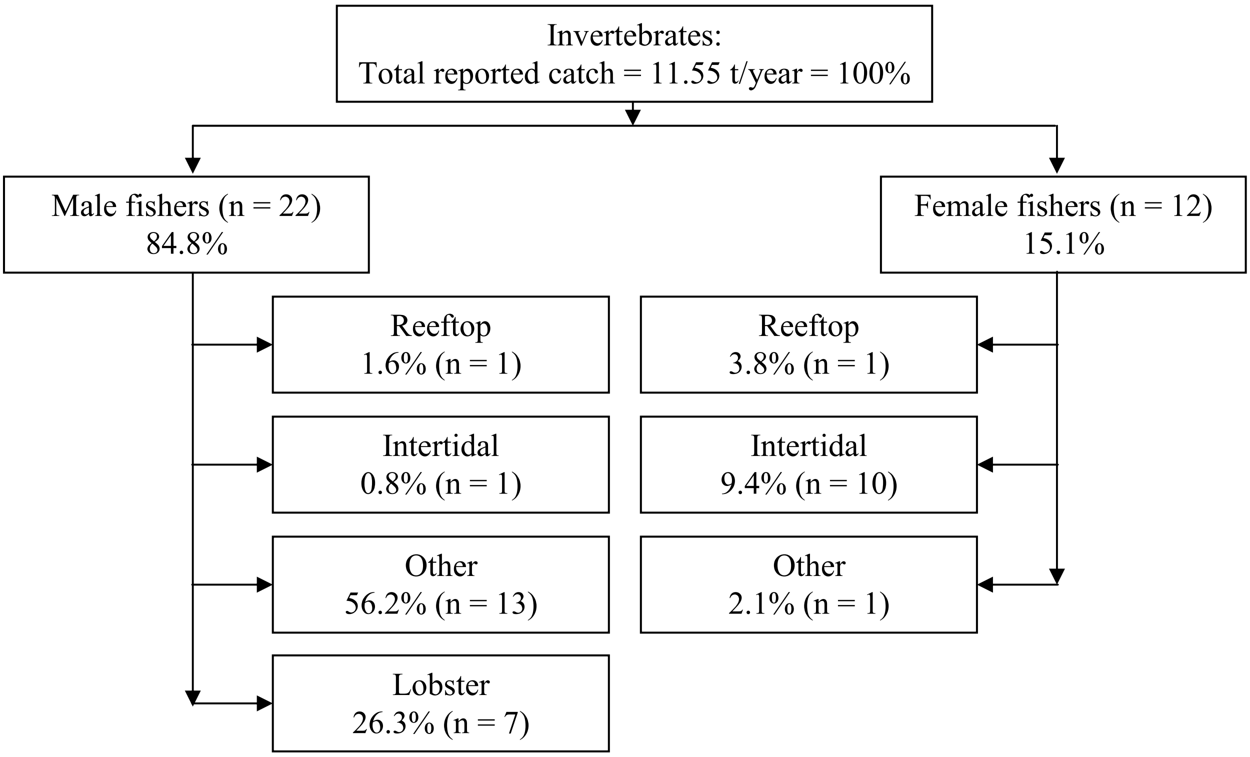

Figure 5.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Raivavae.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to the giant clam and sea urchin fisheries.

The parameters presented in Table 5.5 show that the major fisheries in Raivavae are supported by moderately large habitat areas or reef length. Taking into consideration the low average recorded annual catch/fisher (wet weight) and density of fishers, the current fishing pressure on reef surfaces is reasonably low or, in the case of giant clams, moderate. There is no reason to assume that the invertebrate resources at Raivavae are currently over fished. However, the annual reported catch of giant clams is surprisingly high. Although the density of giant clams may also be outstandingly high, such an exploitation level may cause problems in the near future. As shown in the case of the Fangatau atoll study, an exploitation rate of 4 t/year was not considered threatening, as stocks were estimated at about 364 t ±86 (Andréfouët *et al.* 2005). As also pointed out in the same study from the Fangatau atoll, consequences of the fishery on recruitment and growth rates as well as stability of the population need to be investigated further to the stock assessments that were made as a combined approach of *in situ* (transect) measurements and remote sensing data analysis (high resolution, broadband multispectral sensors). Thus, in order to better estimate any potential detrimental impact on the giant clam fishery in Raivavae, the socioeconomic and resource status data need to be jointly evaluated.

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

Parameters	Fishery / Habitat			
	Reeftop	Intertidal	Other	Lobster
Fishing ground area (km^2)	8.86	n/a	8.86	39.45 [(3)]
Number of fishers (per fishery) [(1)]	37	207	254	127
Density of fishers (number of fishers/km^2 fishing ground)	4.17	n/a	28.7	3
Average annual invertebrate catch (kg/fisher/year) [(2)]	166.69 (±66.74)	57.40 (±19.46)	268.66 (±137.17)	242.30 (±88.70)

Figures in brackets denote standard error; n/a = no information available; [(1)] total number of fishers is extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only; [(3)] linear measure km reef length; 'Other' refers to the giant clam and sea urchin fisheries.

5.2.5 Discussion and conclusions: socioeconomics in Raivavae

- The community of Raivavae still enjoys a rather traditional lifestyle as far as cultural values are concerned, despite having a modern infrastructure in keeping with the generally high living standard in French Polynesia (public electricity, water, telecommunication systems, transport, housing, medical and schooling services). This traditional lifestyle is not only due to Raivavae being one of the most distant islands and therefore isolated from Tahiti, but also by the relatively small size of the community (~1100 people) and the combination of good agricultural land and rich lagoon and reef systems.

- The more traditional lifestyle of the Raivavae community is revealed by the high consumption of invertebrates; the very limited income generation from fisheries; the common practice of exchanging seafood without payment among community members; and a low household expenditure level. Consumption of finfish is rather low (~46 kg/person/year) compared to other communities surveyed in French Polynesia, but this is because agriculture provides a good alternative food source;

- Households that depend on fisheries for income generation mainly target giant clams for export to Papeete or, to some extent, pelagic fish. Lately, the consumption of pelagic fish has increased on the island due to the increased risk of ciguatera from certain reef fish species.

- The different roles of finfish fisheries and invertebrate fisheries show in the data from fisher interviews. The finfish fishery mainly targets the sheltered coastal reef, i.e. the habitat that requires the least time and money to fish. The main fishing costs are incurred by the common practice of using motorised boats for almost all fishing trips. Finfish are caught mainly for subsistence and also for sharing with other community members. An even greater proportion of the catch is shared with others when fishing is done in distant habitats, e.g. in passages and on the outer reef.

- Most fishing, for both finfish and invertebrates, is done by males; overall, females are less involved, but may participate in weekend and leisure fishing or collection. Lobster diving and, to a great extent, giant clam collection (mostly diving) is exclusively performed by males. Females, on the other hand, are the main collectors of *poupou* (small marine snail shells) from the *motu* (small coral islands) at the barrier reef, which they use to make handicrafts. Various techniques are used to fish for finfish, with handlining and spear diving the most frequent.

- The highest fishing pressure is on the sheltered coastal reef and, to some extent, on the outer reef, including the passages. This impact is more the effect of the number of fishers targeting each of these habitats rather than the average annual catch, which is rather low, around 600–800 kg/year. The CPUE from the sheltered coastal reef is higher than from the outer reef. However, the highest CPUEs are from fishing trips that targeted both the passages and outer reef in one trip. Overall, fishing pressure (expressed in annual subsistence needs per reef and fishing ground area) is low, only 0.3 to 0.4 t/km^2. The reported average sizes of fish caught in the different habitats are generally rather large and larger on the outer reef and passages than on the sheltered coastal reef. For Scaridae, there was no difference in average size reported between these major habitats. The fact that spear diving is mainly practised at the outer reef, targeting larger Scaridae, may explain why the expected size increase is not apparent, as Scaridae are here under higher pressure than at the sheltered coastal reef.

- Due to the isolated character of the island, we can rule out any additional fishing pressure imposed by external fishers. Hence, the current fishing pressure is imposed by the island's resident population and, in the case of finfish fisheries, mainly determined by the residents' consumption needs and their social obligations towards family members elsewhere.

- Invertebrate fisheries vary considerably from finfish fisheries. About half of the reported annual catch is targeted for the export market in Papeete. Most of the invertebrates exported are giant clams, which are exported by sea as a frozen product. Lobsters are also exported either by air or frozen and shipped by sea, but amounts vary according to seasonal demands, such as end-of-year festivities. The collection of *poupou* (shells) for artisanal purposes also provides a major income source for Raivavae households. However, this collection is considered to have no adverse environmental or resource impact because no live shellfish are taken and collection is onshore.

- Highest current fishing pressure was found for giant clams and, to some extent, lobsters. However, the relatively large habitat that supports both these fisheries; the relatively low-to-moderate fisher densities; and the low-to-moderate annual catch rates/fisher engaged in each fishery, do not raise major concerns. However, without combining socioeconomic and resource data, no final conclusion can be drawn regarding the current and future status of the island's giant clam and lobster resources. It is worth mentioning that the annual catches of giant clams reported from the Raivavae fishing ground are outstandingly high.

- In general, respondents seem to be very satisfied with the status of their natural resources, and major concern was voiced only about the increasing number of ciguatera incidents.

- From the survey results presented above, it is concluded that current fishing pressure on Raivavae reef and lagoon resources has not reached critical levels. As far as finfish are concerned, future production is limited due to the lack of marketing opportunities for fresh produce and may be mainly determined by local consumption. The local consumption pattern, however, is likely to change due to the increased risk of ciguatera fish poisoning. This has not only resulted in certain areas being no longer fished, but also in a considerable number of households (5 from 30 surveyed in the beginning of 2004) no longer eating reef fish but, instead, only pelagic fish. Thus, fishing pressure on reef finfish resources may decrease. What effect this development may have on the Raivavae community's social network among members is open to speculation; however, reef fish continue to be a non-commercial commodity on the island.

- On the other hand, the high demand from the Papeete market for frozen giant clam meat, and perhaps lobsters, together with the high prices these resources fetch, may pose a future risk of overexploitation of these resources. At the time of the survey, the total reported catches of giant clams and lobsters were surprisingly high. If these invertebrates continue to be a major export and revenue source, overexploitation may be likely. However, before reaching any final conclusions on the level of fishing impact, the findings of the finfish resource survey need to be considered.

- The use of *poupou* (shells) collected on the shores of *motu* at the outer barrier reef may also continue to be an important source of revenue for a great number of households on Raivavae. No detrimental environmental impact occurs from the collection of these shells because they do not contain live animals.

5.3 Finfish resource surveys: Raivavae

Finfish resources and associated habitats were assessed 9–15 March 2004 from a total of 24 transects (6 sheltered coastal, 12 back- and 6 outer-reef transects, see Figure 5.19 and Appendix 3.4.1 for transect locations and coordinates respectively.). A real lagoon patch-reef structure is not present in this site, therefore intermediate reefs were not sampled.

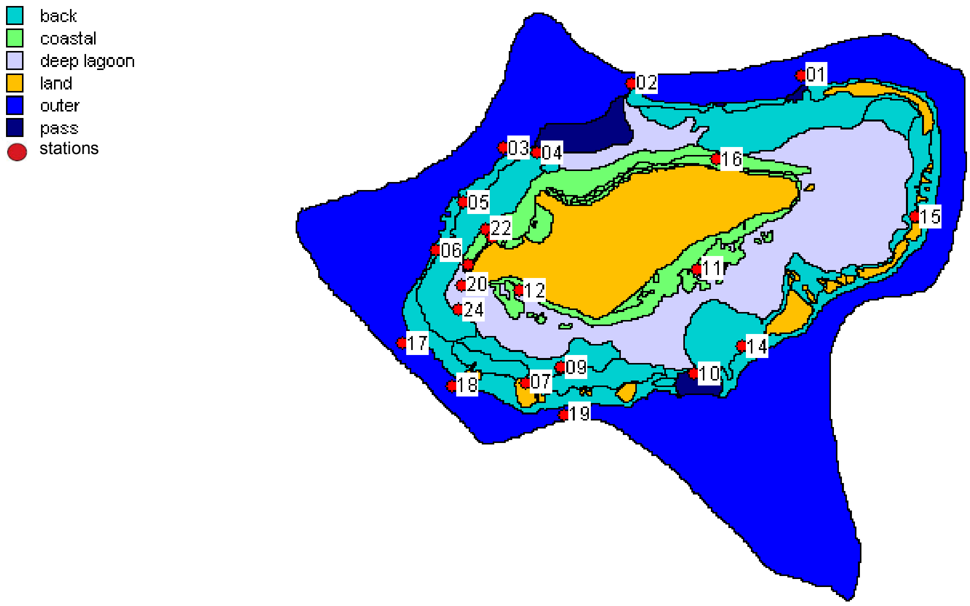

Figure 5.19: Habitat types and transect locations for finfish assessment in Raivavae.

5.3.1 Finfish assessment results: Raivavae

A total of 18 families, 42 genera, 115 species and 5743 fish were recorded in the 24 transects (See Appendix 3.4.2 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, 107 species and 5703 individuals.

Finfish resources varied slightly among the three reef environments found in Raivavae (Table 5.6). The back-reef contained the lowest density (0.4 fish/m^2), biomass (55 g/m^2), size (16 cm), size ratio (54%) and biodiversity (26 species/transect) of all three habitats. In contrast, the outer reefs displayed the highest of all values: density (0.5 fish/m^2), size (19 cm), size ratio (60%), biomass (130 g/m^2) and biodiversity (34 species/transect). Coastal reefs displayed intermediate values between the two other habitats.

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

Parameters	Habitat			
	Sheltered coastal reef [(1)]	Back-reef [(1)]	Outer reef [(1)]	All reefs [(2)]
Number of transects	6	12	6	24
Total habitat area (km^2)	9.4	26.8	56.3	92.5
Depth (m)	2 (1–5) [(3)]	3 (1–5) [(3)]	7 (3–11) [(3)]	5 (1–11) [(3)]
Soft bottom (% cover)	24 ±6	17 ±4	2 ±1	9
Rubble & boulders (% cover)	10 ±5	21 ±6	18 ±11	18
Hard bottom (% cover)	42 ±8	49 ±6	53 ±9	50
Live coral (% cover)	24 ±3	13 ±3	26 ±4	22
Soft coral (% cover)	0 ±0	0 ±0	2 ±1	1
Biodiversity (species/transect)	29 ±2	26 ±3	34 ±4	29 ±2
Density (fish/m^2)	0.4 ±0.1	0.4 ±0.0	0.5 ±0.1	0.4
Size (cm FL) [(4)]	17 ±1	16 ±1	19 ±1	18
Size ratio (%)	57 ±3	54 ±2	60 ±3	58
Biomass (g/m^2)	79.3 ±20.4	55.4 ±10.4	130.6 ±39.9	103.7

[(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.

Sheltered coastal reef environment: Raivavae

The sheltered coastal reef environment of Raivavae was dominated by five families in terms of density and biomass: herbivorous Acanthuridae and Scaridae and carnivorous Lethrinidae, Mullidae and, in terms of density only, Chaetodontidae (Figure 5.20). These five families were represented by 43 species; highest abundance and biomass were recorded for *Gnathodentex aureolineatus*, *Mulloidichthys vanicolensis*, *Ctenochaetus striatus*, *Scarus schlegeli*, *S. psittacus*, *Chlorurus sordidus*, *Naso unicornis* and *Parupeneus multifasciatus* (Table 5.7). This reef environment presented almost equal proportions of hard bottom (31%), rubbles boulders (27%) and soft substrate (19%), and a very high cover of live coral (31%). Such diversity of habitat was reflected in the diversity of the fish community composition (Table 5.7 and Figure 5.20).

Table 5.7: Finfish species contributing most to main families in terms of densities and biomass in the sheltered coastal reef environment of Raivavae

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Naso unicornis*	Bluespine unicornfish	0.01 ±0.00	5.7 ±3.0
	Ctenochaetus striatus	Striated surgeonfish	0.05 ±0.01	3.5 ±1.0
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.07 ±0.03	27.2 ±11.4
Scaridae	*Scarus schlegeli*	Schlegel's parrotfish	0.02 ±0.01	11.7 ±5.5
	Chlorurus sordidus	Daisy parrotfish	0.01 ±0.00	2.1 ±0.7
	Scarus psittacus	Common parrotfish	0.01 ±0.01	1.5 ±0.7
Mullidae	*Mulloidichthys vanicolensis*	Yellowfin goatfish	0.02 ±0.01	4.6 ±3.6
	Parupeneus multifasciatus	Many bar goatfish	0.01 ±0.00	2.5 ±0.8

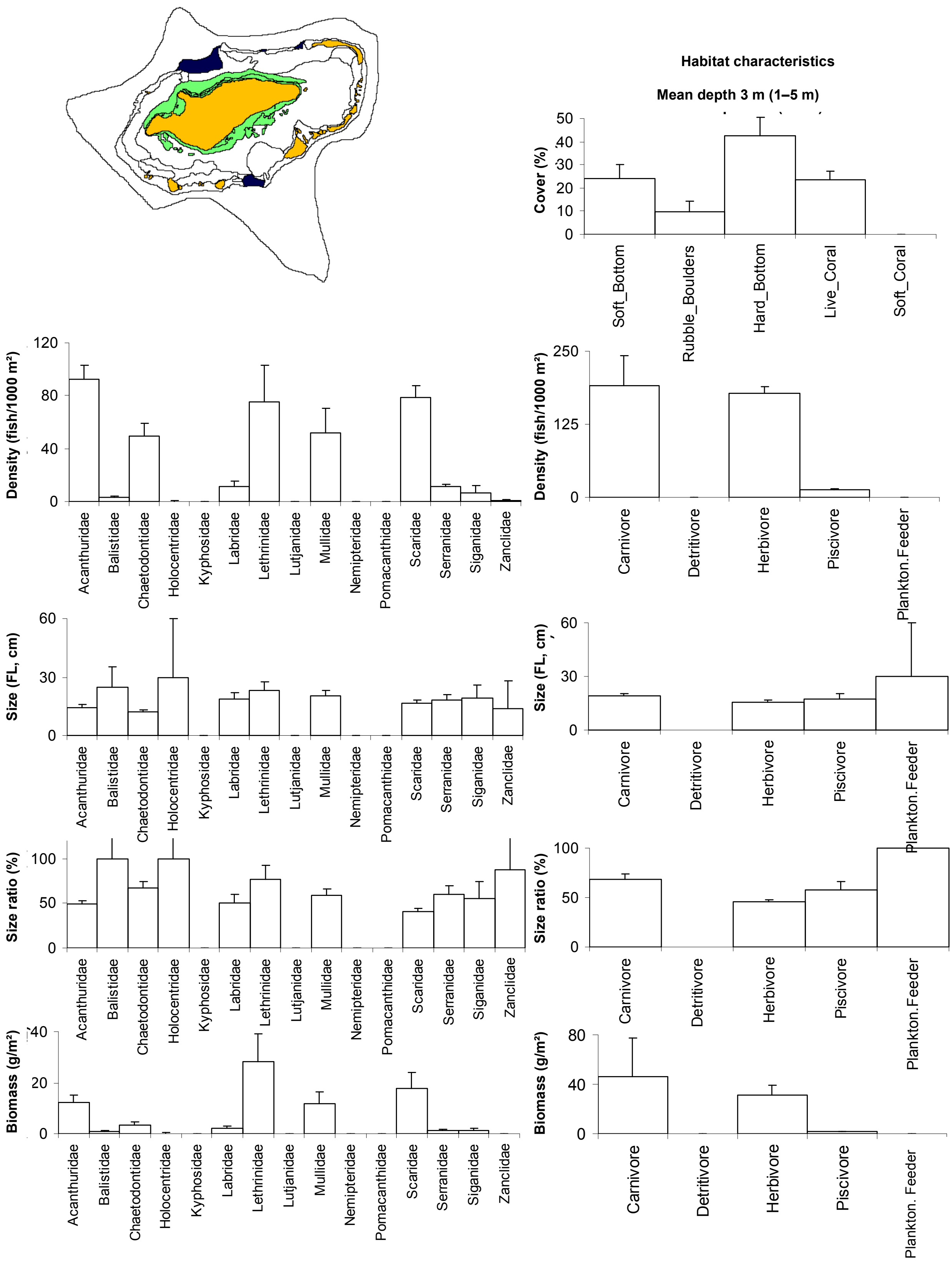

Figure 5.20: Profile of finfish resources in the sheltered coastal reef environment of Raivavae. Bars represent standard error (+SE); FL = fork length.

The density, size, and biomass of fish in the coastal reefs of Raivavae were the second-highest in the country, while biodiversity displayed the second-lowest value, higher only than in Mataiea. Herbivores and carnivores were similar in density but biomass was dominated by carnivores, due to the high biomass of both Lethrinidae and Mullidae. Size ratio was high for many families and below 50% only for Scaridae, which are one of the favourite fish families caught. The substrate was almost equally composed of hard bottom, soft bottom, and rubbles, offering different habitats and explaining partially the high diversity of the fish community. The high cover of live coral (31%), highest of the five sites, explains the striking abundance of butterflyfish.

Back-reef environment: Raivavae

The back-reef environment of Raivavae was dominated by three families in terms of both density and biomass: herbivorous Acanthuridae and Scaridae and carnivorous Lethrinidae, and by two more families in terms of density only: Chaetodontidae and Mullidae (Figure 5.21). These five families were represented by 48 species; particularly high abundance and biomass were recorded for *Gnathodentex aureolineatus*, *Acanthurus nigroris*, *Ctenochaetus striatus*, *Acanthurus triostegus*, *Mulloidichthys flavolineatus*, *Chlorurus sordidus*, *Scarus psittacus* and *S. schlegeli* (Table 5.8). The back-reef was a moderately diverse habitat, mainly covered by hard bottom (41%), with a relatively high proportion of live coral (26%), the highest among the back-reefs in the five sites.

Table 5.8: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Raivavae

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.06 ±0.01	4.7 ±1.1
	Acanthurus nigroris	Bluelined surgeonfish	0.03 ±0.02	3.7 ±1.8
	Acanthurus triostegus	Convict tang	0.04 ±0.01	2.3 ±0.5
Scaridae	*Scarus schlegeli*	Schlegel's parrotfish	0.01 ±0.00	4.8 ±2.8
	Scarus psittacus	Common parrotfish	0.02 ±0.00	3.8 ±1.2
	Chlorurus sordidus	Daisy parrotfish	0.02 ±0.01	3.6 ±1.4
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.04 ±0.03	8.0 ±4.5
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.02 ±0.01	2.2 ±1.1

The density and biodiversity of fish in the back-reefs of Raivavae were second-highest compared to the back-reefs of the other sites. However, fish sizes and biomass were among the lowest. Herbivorous fish dominated the trophic structure of the fish community, both in terms of density and biomass. Carnivorous Lutjanidae were present in extremely low numbers and biomass, suggesting high fishing pressure on these fish. Lethrinidae and Mullidae made up the majority of the carnivore population. The substrate was composed mainly of hard bottom and corals but the good cover of soft bottom (17%) might explain the high density of these carnivores. Size ratio was about 50% for most of families, only slightly lower for Kyphosidae, Labridae, Mullidae and Scaridae. The Scaridae family is one of the most targeted food species.

Figure 5.21: Profile of finfish resources in the back-reef environment of Raivavae.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Raivavae

The outer-reef environment of Raivavae was dominated by two families of herbivorous fish: Scaridae (higher density) and Acanthuridae (higher biomass, Figure 5.22). These families were represented by 25 species; particularly high density and biomass were recorded for *Chlorurus sordidus*, *Scarus psittacus*, *Ctenochaetus striatus*, *S. altipinnis*, *S. frenatus*, *A. nigroris*, *S. schlegeli*, *S. rivulatus* and *Naso unicornis* (Table 5.9). The outer reef had a very large cover of hard bottom (53%) and more than 25% live coral (Table 5.6 and Figure 5.22).

Table 5.9: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Raivavae

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.12 ±0.02	11.5 ±4.3
	Scarus altipinnis	Filamentfinned parrotfish	0.02 ±0.01	11.3 ±6.1
	Acanthurus nigroris	Bluelined surgeonfish	0.10 ±0.08	9.2 ±7.1
Scaridae	*Scarus schlegeli*	Schlegel's parrotfish	0.01 ±0.01	8.7 ±4.8
	Scarus rivulatus	Rivulated parrotfish	0.02 ±0.01	7.5 ±4.0
	Scarus frenatus	Bridled parrotfish	0.01 ±0.01	6.4 ±4.0
	Chlorurus sordidus	Daisy parrotfish	0.01 ±0.01	9.4 ±6.9
	Scarus psittacus	Common parrotfish	0.05 ±0.02	17.5 ±5.8
	Naso unicornis	Bluespine unicornfish	0.05 ±0.04	15.3 ±11.3

The biomass and size in the outer reefs of Raivavae were the highest recorded for outer reefs among all five sites. Although density at the outer reef was the highest of all habitats in Raivavae, it ranked fourth of the five sampled outer reefs of French Polynesia. The trophic structure in Raivavae outer reefs was strongly dominated by herbivorous species. Acanthuridae were the highest in density and Scaridae the highest in biomass, with many species of large size. All carnivores were extremely rare, except for *Gnathodentex aureolineatus*, which, remarkably, was present in high numbers. Size ratio was low for Labridae, Mullidae and Serranidae. Groupers are the most targeted carnivores in this habitat and their lower-than-average size could be a first sign of fishing impact. The almost total lack of soft bottom (2% cover) could explain the absence of families associated with sand, such as Lethrinidae and Mullidae.

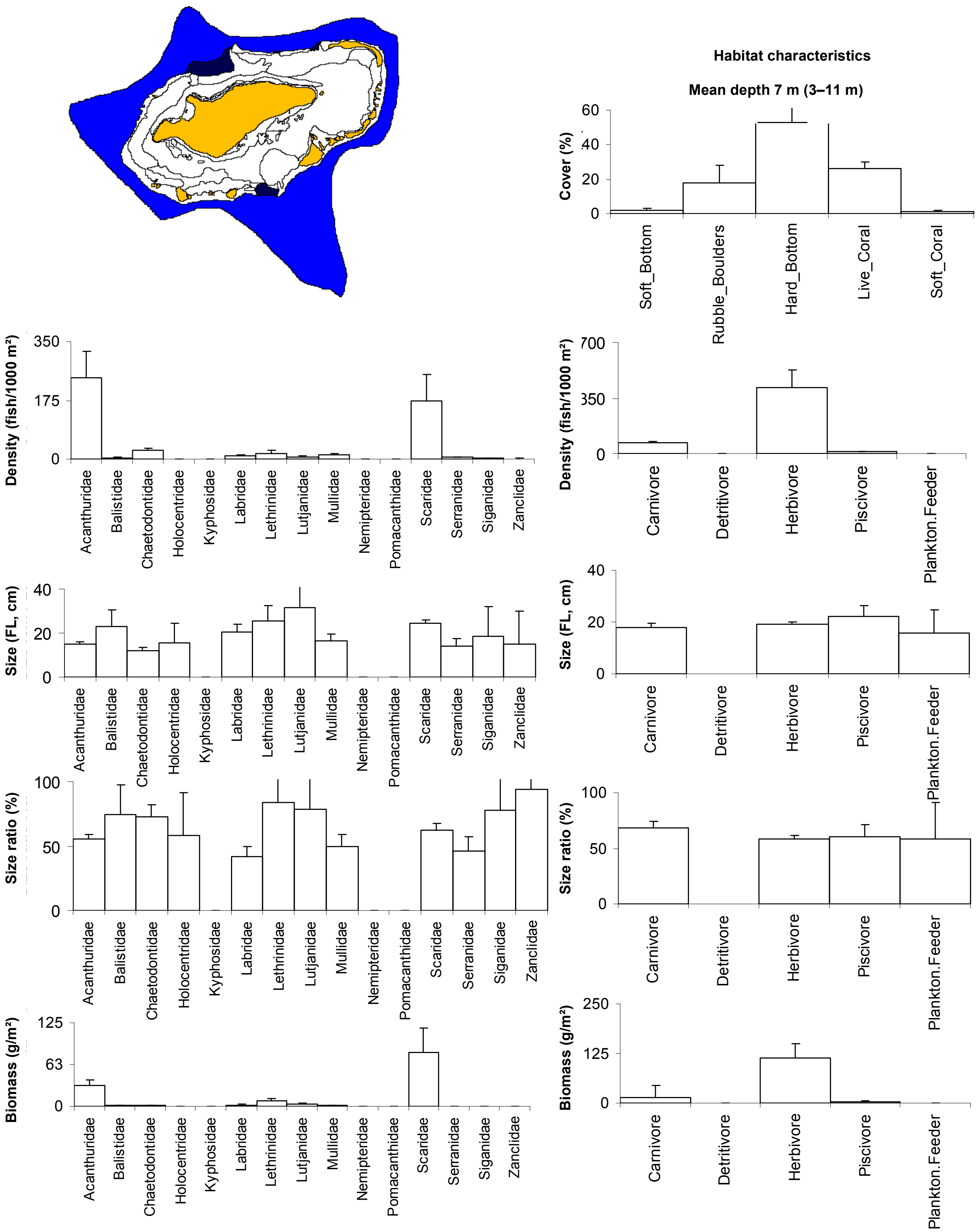

Figure 5.22: Profile of finfish resources in the outer-reef environment of Raivavae.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Raivavae

Overall, the fish assemblage of Raivavae was dominated by Scaridae and Acanthuridae (both in terms of density and biomass, Figure 5.23). These two families were represented by a total of 29 species, dominated (in terms of density and biomass) by *Ctenochaetus striatus*, *Acanthurus nigroris*, *Chlorurus sordidus*, *Scarus psittacus*, *S. altipinnis* and *S. schlegeli* (Table 5.10). As expected, the overall fish assemblage in Raivavae mainly shared characteristics of outer reefs (61% of habitat), rather than of back-reefs (29%), and only to a small extent of coastal reefs (10%). The habitat was predominantly composed of hard bottom, with almost a quarter of the surface covered by live coral.

Table 5.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Raivavae (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04	11.8
	Scarus psittacus	Common parrotfish	0.03	10.5
	Scarus altipinnis	Filamentfinned parrotfish	0.01	7.3
	Scarus schlegeli	Schlegel's parrotfish	0.01	8.0
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.09	8.7
	Acanthurus nigroris	Bluelined surgeonfish	0.07	6.6

Overall, Raivavae appears to support a healthy finfish resource, richer than the other sites, with the highest fish biomass, average size and size ratio (103 g/m^2, 18 cm FL and 58% respectively). While these results suggest that the finfish resource in Raivavae is in good condition, detailed assessment at site level revealed the richest fish population in the outer and the poorest in the back-reefs. The average trophic structure for this site was strongly dominated by herbivores in terms of both density and biomass, mainly represented by Acanthuridae and Scaridae. The almost total absence of carnivores in the overall structure can be explained by the very scarce presence of Lethrinidae and Mullidae in the largest reef habitat, the outer reef. This is most probably due to the almost total lack of soft bottom as these families are usually associated with soft bottom. Lutjanidae were almost absent throughout the site.

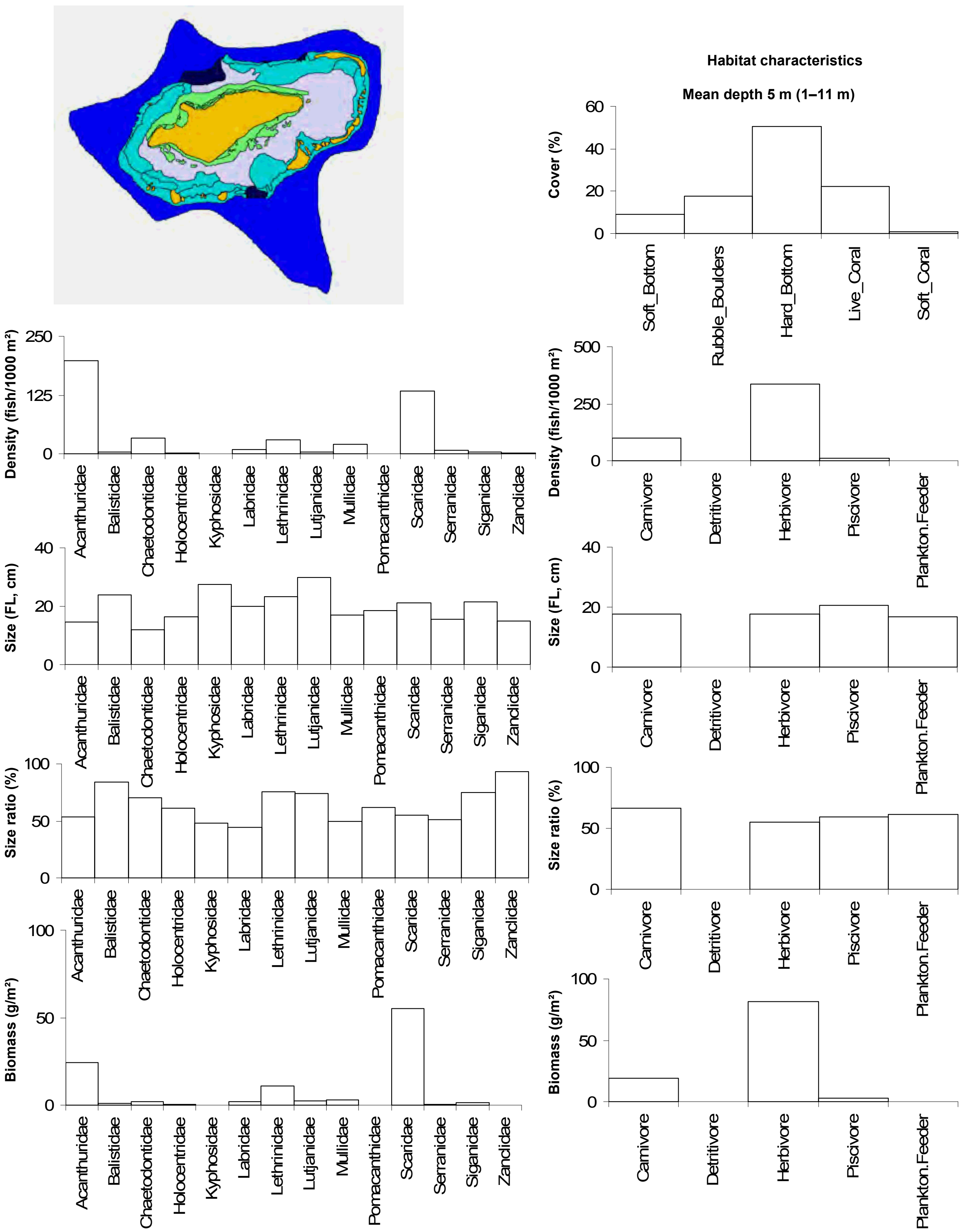

Figure 5.23: Profile of finfish resources in the combined reef habitats of Raivavae (weighted average).
FL = fork length.

5.3.2 Discussion and conclusions: finfish resources in Raivavae

Survey results indicate that the status of finfish resources in Raivavae is better than the average across French Polynesia study sites. Detailed assessment at reef level also revealed a systematic high or average abundance and biomass, except for the back-reefs (the poorest environment at this site). Average biomass of both herbivores and carnivores were the highest among the five sites, and this is even more significant when we consider Raivavae is lacking the intermediate-reef habitat. Average sizes and size ratios were the highest of all sites, suggesting that resources are healthy. Fishing at the present rate is not impacting the resources; in fact, of all the survey sites, the Raivavae community was the least dependent on fisheries for income generation and consumed the least amount of fresh fish. Moreover, fishing for reef fish is becoming less important than fishing for pelagic fish because of the increase in ciguatera. Density of fishers/habitat was among the lowest in the country and was mostly concentrated in the coastal reefs.

- Overall, Raivavae finfish resources appeared to be in good condition. The reef habitat seemed relatively rich and the biomass and abundance of fish were relatively high compared to the other country sites.

5.4 Invertebrate resource surveys: Raivavae

The diversity and abundance of invertebrate species at the site were independently determined using a range of survey techniques (Table 5.11): broad-scale assessment (using the ‘manta tow’ technique; locations shown in Figure 5.24) and finer-scale assessment of specific reef and benthic habitats (Figures 5.25 and 5.26).

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

Table 5.11: Number of stations and replicate measures completed at Raivavae

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	12	72 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	4	24 search periods
Reef-front searches (RFs)	4	24 search periods
Sea cucumber night searches (Ns)	2	12 search periods
Sea cucumber day searches (Ds)	0	0 search period

Figure 5.24: Broad-scale survey stations for invertebrates in Raivavae.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 5.25: Fine-scale reef-benthos transect survey stations and soft-benthos survey stations for invertebrates in Raivavae.
Black circles: reef-benthos transect stations (RBt); black stars: soft-benthos stations.

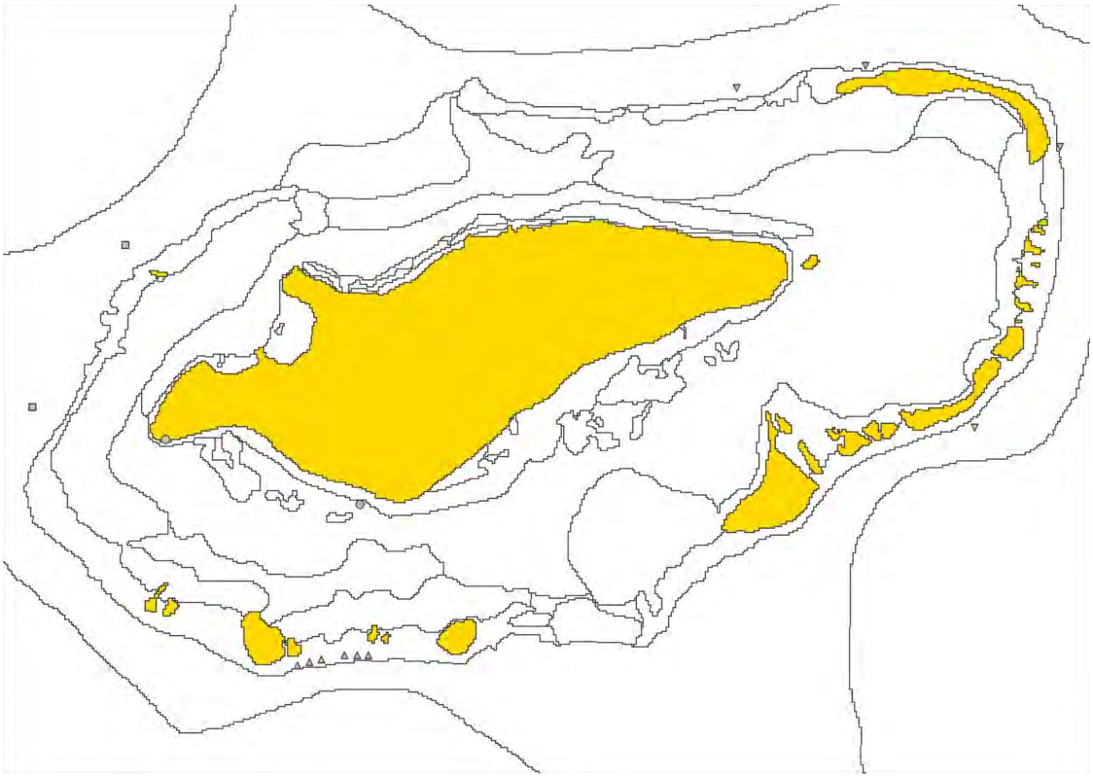

Figure 5.26: Fine-scale survey stations for invertebrates in Raivavae.
Grey circles: sea cucumber night search stations (Ns);
grey triangles: reef-front search stations (RFs);
inverted grey triangles: reef-front search by walking stations (RFs_w);
grey squares: mother-of-pearl search stations (MOPs).

Twenty-four species or species groupings (groups of species within a genus) were recorded in the Raivavae invertebrate surveys: 4 bivalves, 8 gastropods, 6 sea cucumbers, 3 urchins, 1 sea star, and 1 cnidarian (Appendix 4.4.1). Information on key families and species is detailed below.

5.4.1 Giant clams: Raivavae

Broad-scale sampling provided an overview of giant clam distribution at Raivavae. Shallow reef habitat that is suitable for giant clams was extensive (52.7 km^2: approximately 13.3 km^2 within the lagoon and 39.4 km^2 on the reef front or slope of the barrier). Unlike the other PROCFish/C high-island site of Mataiea, the lagoon at Raivavae retained a strongly oceanic influence, especially on the southern side of the island (in some ways more comparable to the atoll sites of Tikehau and Fakarava). The lagoon was relatively shallow and more protected than other PROCFish/C sites due to the high island, which reached 437 m at Mount Hiro (The island measures 8.5 km x 2.3 km.). Water flow between the lagoon and open ocean was dynamic as the barrier reef was relatively open, with passes in both the north and south.

Reefs at Raivavae held one species of giant clam: the elongate clam *Tridacna maxima*. Records from broad-scale sampling revealed that *T. maxima* was widely distributed (found in all 12 stations and 66 of 72 transects).

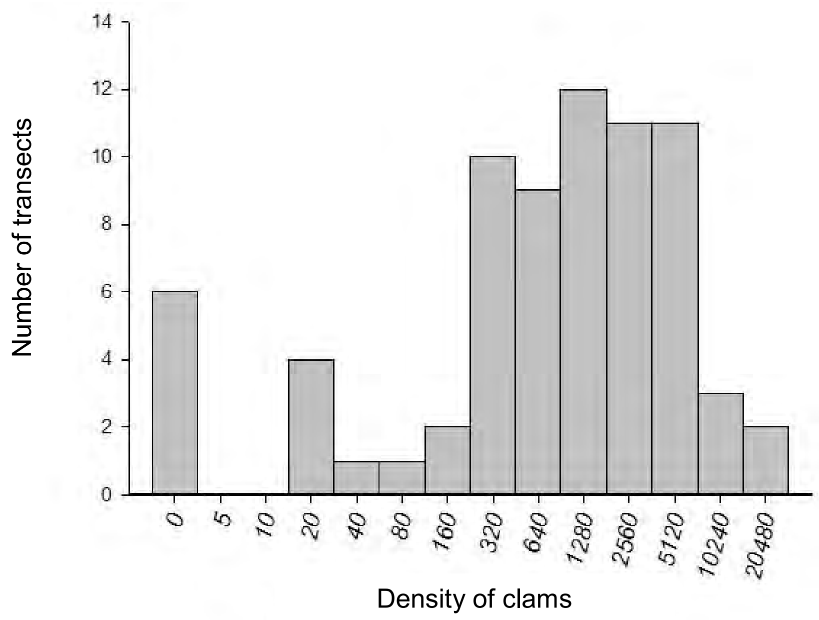

Figure 5.27: Frequency plot of density per 300 m transect measures (per ha) for *Tridacna maxima* clams at Raivavae, based on all broad-scale assessment stations.
Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

The average station density of *T. maxima* in broad-scale assessments was 1607.1 /ha ±551.1 (Figure 5.27), but clams were not found at the same density throughout the lagoon. Fringing reefs (inner) recorded the lowest mean density (<300 /ha), whereas most clams were found on mid-lagoon patch reefs or on the barrier. Based on the findings of the broad-scale survey, finer-scale surveys targeted shallow-water reef and specific areas of clam habitat (Figures 5.24 and 5.27). In these reef-benthos assessments (RBt) the density of *T. maxima* ranged from 542 to 27,917 /ha for the 12 stations assessed (mean density of 15,996.5 /ha ±3072.7).

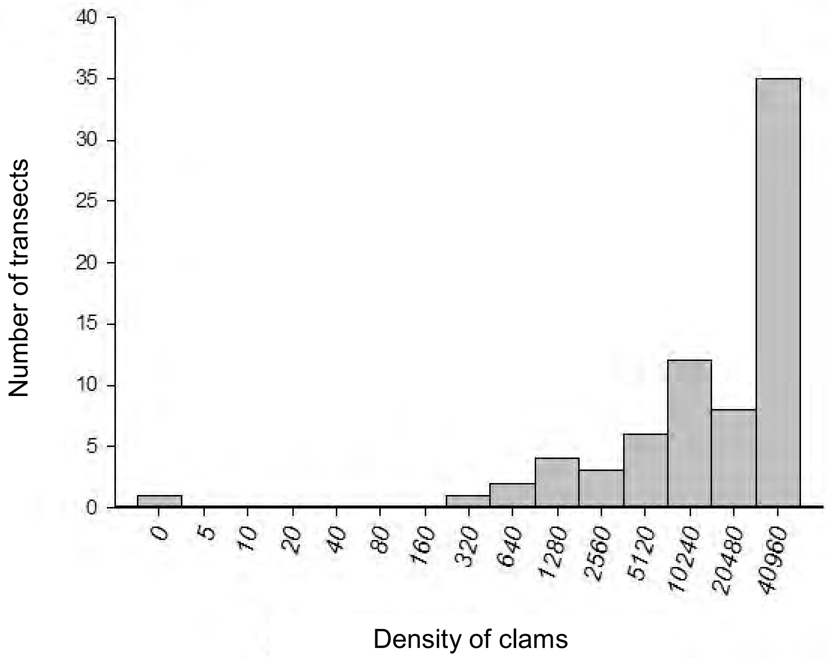

Figure 5.28: Frequency plot of density per 40 m transect measures (per ha) for *Tridacna maxima* clam at Mataiea, based on all fine-scale reef-benthos transect assessment stations. Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

T. maxima were found at the highest density at RBt stations on the shallow-reef areas that stretched out behind the reef crests in the southwest and west of the lagoon. The greatest density of clams /40 m^2 transect in Raivavae was at such a station, averaging 3.6 clams/m^2. There were also high densities of clams in the surge zone on the barrier reeftop, although this area was only submerged for part of the tidal cycle. In this case, reef-front search walks returned an estimated density of 244–2611 /ha for search periods (average station density 1025.9 /ha ±68.5). Low densities of clams were found on inshore reefs, and reefs near the passage north of Raivavae. At the one area that had reasonable densities of clams on the northern barrier reef, the density was 542 /ha ±175.8.

Of the 1711 records taken during all assessment techniques, the average length of *T. maxima* was 14.9 cm ±0.1. The mean from shallow reef-benthos stations was slightly lower at 7.3 cm ±0.1. A full range of lengths for *T. maxima* was recorded in survey, although clams were generally smaller than found in other parts of the Pacific. Larger clams (≥16 cm) were rare in shallow water and were mainly restricted to reefs in more exposed locations (mean clam size from mother-of-pearl SCUBA surveys was 12.4 cm, Figure 5.29).

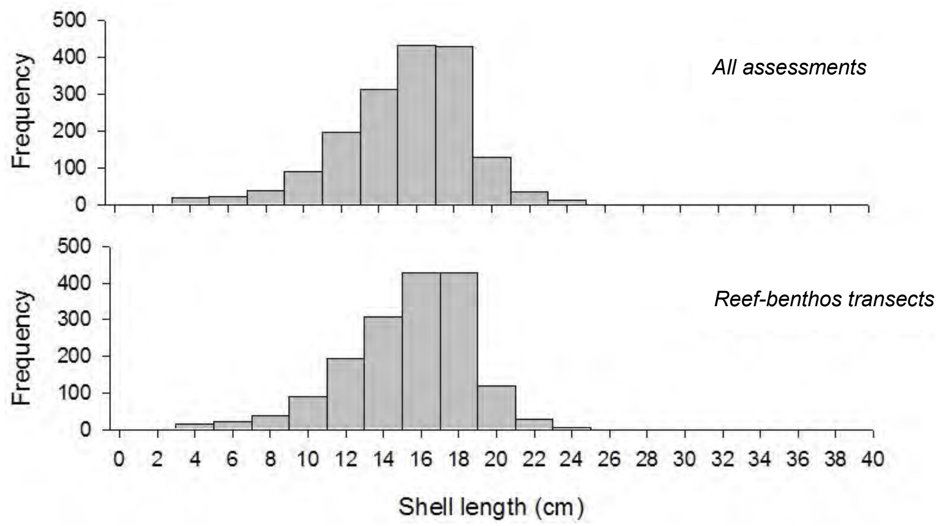

Figure 5.29: Size frequency histograms of giant clam shell length (cm) for Raivavae.

5.4.2 Mother-of-pearl species (MOP) – trochus and pearl oysters: Raivavae

Raivavae is located right on the Tropic of Capricorn (23°27'N) and is on the southern boundary for the distribution of the commercial topshell, *Trochus niloticus*, in the Pacific. However, French Polynesia is well to the east of the natural distribution of this species, and populations of trochus were only established after translocations were made from Vanuatu in November 1957 from Port Vila (Cheneson 1997, Yen 1985). The translocation of great green turban snails, *Turbo marmoratus* (more commonly called green snail), and trochus were also made to Raivavae, although no official records were found to verify the dates or numbers of shell in the literature.

The outer and lagoon reef at Raivavae constitute extensive suitable benthos for *T. niloticus*, and this area could potentially support significant populations of this commercial species (39.4 km lineal distance of exposed reef perimeter). PROCFish/C survey work concentrated on conducting SCUBA searches (MOPs, see Methods and Appendix 1.3.) on the area where the placement of shells was reported. The reefs in this location were suitable for trochus, if a little exposed (low relief), but no live or dead mother-of-pearl shells were found. No results for green topshell (*Tectus pyramis*) can be reported, as this species only extends east as far as Tuvalu, Samoa and Tonga.

The only MOP shells recorded in survey were the blacklip pearl oyster, *Pinctada margaritifera*. Although this species is cryptic and generally found in low density in more open lagoon systems similar to Raivavae, eight individuals were recorded during broad-scale surveys (in 33% of broad-scale stations). The average density of blacklip pearl oysters found was 1.9 /ha ±0.9, with a mean anterior–posterior length of 15.8 cm ±2.1.

5.4.3 Infaunal species and groups: Raivavae

The soft-benthos coastal margin of the lagoon was sandy without seagrass or rich muddy areas that would hold concentrations of in-ground resources (shell beds). Therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made on soft benthos.

5.4.4 Other gastropods and bivalves: Raivavae

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was rare and recorded at low density in broad-scale and finer-scale surveys (four individuals recorded). However, *Lambis lambis* and the strawberry or red lipped conch *Strombus luhuanus* were not present (Appendices 4.4.2 to 4.4.7). *Turbo setosus* was recorded, but this species was not common and only found at low density (total of six individuals). Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Charonia*, *Conus*, *Cymatium* and *Cypraea*) were also recorded during independent survey (Appendices 4.4.2 to 4.4.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina* and *Chama*, are also in Appendices 4.4.2 to 4.4.7. No creel survey was conducted at Raivavae, although fishers were seen sifting piles of sand and shell on the shore to extract small shells that could be used for local handicrafts.

5.4.5 Lobsters: Raivavae

Raivavae had 39.5 km (lineal distance) of exposed reef front (barrier reef). This exposed reef front, with two major passages (*hoa*) and areas of submerged back-reef, represents a moderately extensive habitat for lobsters, which settle as transparent miniature versions of the adult (pueruli, 20–30 mm in length) after 6–12 months of floating in ocean currents.

There are generally no dedicated night reef-front searches made to assess lobsters because one-off, snapshot assessments for these species are unlikely to yield reliable indicators of stock health (See Methods.). However, two hours were spent walking the southern reef front at night; only two lobsters were seen, and none were taken. In general survey, four lobsters (*Panulirus* spp.) were recorded; one during broad-scale assessments in the lagoon and three during RFs and MOPs on the reef outside the barrier. During night searches for nocturnal sea cucumber species (Ns) conducted on near-shore reefs, no lobsters were observed.

5.4.6 Sea cucumbers[10] : Raivavae

Raivavae has a complex lagoon system that is relatively open to oceanic influence but bordered in the centre by a large land mass (16 km^2). Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) are extensive in the lagoon, and shallow shoals are found extending seawards from the barrier reef. Despite the protection afforded by the land mass of Raivavae, the lagoon was exposed to oceanic conditions in most sectors and conditions were very clear in the southern lagoon.

There was still noticeable influence from land close to shore. Riverine input was not obvious but there was algal and epiphytic growth on fringing reefs and lowered visibility extended to the dynamic northern reefs and passage. The island seemed to discharge most of the nutrients to the north, and the reef shoals outside the barrier to the north, northeast and west were often characterised by moderate to strong epiphyte growth. At Raivavae, five commercial and one indicator species of sea cucumber were recorded during in-water assessments (Table 5.12), a relatively small number compared to at other PROCFish/C sites in French Polynesia

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

(independent of whether they were high islands or atolls). This result partially reflects the easterly position of this site, which has a limited number of species compared to sites closer to the centre of biodiversity (i.e. those situated further west in the Pacific) but also the nutrient-poor, oceanic nature of most of the lagoon environment. As commercial sea cucumbers are generally deposit feeders, they rely on organic matter in the upper few mm of substrates as their food source.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.12, Appendix 4.4, also see Methods.). No deep-water assessments were conducted in the lagoon as both passes were very shallow (<12 m) and dives offshore were not possible as the locally recruited staff member on the mission experienced a kidney crisis, which limited activity. This limited our ability to find white teatfish (*Holothuria fuscogilva*), which may have been present in small numbers in the lagoon. The nature of the environment means there was very little likelihood of commercial densities of white teatfish being present on Raivavae. The lack of deep-water dives also decreased the chance of finding prickly redfish (*Thelenota ananas*) and amberfish (*T. anax*).

Of the other sea cucumber species recorded, those associated with shallow-reef areas, such as the medium/low-value leopardfish (*Bohadschia argus*) and high-value black teatfish (*Holothuria nobilis*), were rare and at low density. Leopardfish were located in <10% of fine- and broad-scale assessments, and only three black teatfish were recorded, all within the shallow back-reef in the southwest of the lagoon. The converse was true for another reef species, surf redfish, *Actinopyga mauritiana*. This species, which is associated with oceanic shallow-reef fronts and reeftops, was common at Raivavae (total of 467 recorded in surveys). In 17% of RFs and MOPs search periods, surf redfish were recorded at densities >500 /ha, and to a maximum of approximately 2000 /ha. Unlike in Mataiea, where surf redfish were concentrated inside the lagoon, at Raivavae they were mainly aggregated outside the lagoon on the broad outer-reef shoal in the northeast and west (in <8 m of water). At both sites they were patchily distributed and located where there was some protection from the very large prevailing ocean swells. The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was not found at any sites in French Polynesia.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon did not include brown sandfish (*Bohadschia vitiensis*), blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), pinkfish (*Holothuria edulis*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*), although the low-value lollyfish (*H. atra*) was very common throughout the lagoon and found at very high density (24% of transects had a mean of >1 /m^2 in broad-scale survey).

5.4.7 Other echinoderms: Raivavae

Edible urchins, such as the slate urchin *Heterocentrotus mammillatus* were rare or absent. The collector urchin *Tripneustes gratilla*, on the other hand, was relatively plentiful in shallow-water reef assessments (50% of RBt stations). The mean density at the six stations where collector urchins were found was 326.4 /ha ±124.7. Other urchins that can be used within assessments as a food source or potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at moderate-to-high levels (at broad-scale and reef-benthos stations, Appendices 4.4.2 to 4.4.7).

Starfish were sparsely distributed at Raivavae and rare. Only the blue starfish *Linckia laevigata* was recorded (one record) and coralivore (coral eating) starfish, e.g. the pincushion star (*Culcita novaeguineae*) and the crown of thorns (*Acanthaster planci*) was not recorded (See presence and density estimates in Appendices 4.4.2 to 4.4.7.).

Table 5.12: Sea cucumber species records for Raivavae

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef stations n = 12			Other stations RFs = 4; RFs_w = 2; MOPs = 4			Other stations Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	6.2	49.5	13	13.9	83.3	17	145.1 63 416.7	193.5 63 41,416.7	75 RFs 100 RFs_w 100 MOPs			
Bohadschia argus	Leopardfish	M	0.7	16.7	4	3.5	41.7	8						
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L												
Holothuria atra	Lollyfish	L	6,097	8,130	75	2729	3275	83	182.4 555.6 458.3	182.4 555.6 458.3	100 RFs 100 RFs_w 100 MOPs	160	160	100
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria leucospilota	-	L				6.9	83.3	8						
Holothuria nobilis [4]	Black teatfish	H				10.4	41.7	25						
Stichopus horrens	Peanutfish	M												
Synapta spp.	-	-	0.2	15.5	1	3.5	41.7	8						
Thelenota ananas	Prickly redfish	H												
Thelenota anax	Amberfish	M												

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

5.4.8 Discussion and conclusions: invertebrate resources in Raivavae

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 in the body of the invertebrate chapter.

- The mid-lagoon patch-reef areas and especially the shallow-water back-reef of Raivavae were very suitable for the elongate clam *Tridacna maxima*. Clams were not present on all reefs, but densities in the south and west of the lagoon were exceptional for a high-island, open-lagoon environment. *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment. Clams are relatively slow growing (approximately 6–8 years old when legal size is reached 12 cm), and recruitment is likely to proceed in pulses with good and poor years. The number of large-sized clams in the stock suggests that clam stocks are only marginally impacted by fishing pressure. However clams over 22 cm in shell length were rarely found.

- Trochus, *Trochus niloticus*, and the great green turban, *Turbo marmoratus*, have not established viable populations in the areas where they were reported to have been introduced.

- The blacklip pearl oyster, *Pinctada margaritifera*, was not common at Raivavae, but was found regularly in the lagoon.

- The wide, shallow offshore shoals and the extensive reeftops on the barrier present excellent habitat for lobsters at Raivavae.

- There is a restricted range of sea cucumber species at Raivavae (due to biogeographical influence), and it appears that the lack of significant numbers of leopardfish (*Bohadschia argus*) and black teatfish (*Holothuria nobilis*) is more related to the unsuitability of the habitat than to any fishing pressure. The widespread distribution and high abundance of surf redfish (*Actinopyga mauritiana*) recorded during surveys, indicate that there is a potential for commercial fishing of this stock at Raivavae. There are also significant numbers of lollyfish (*Holothuria atra*).

- Although both edible and 'other' urchins were recorded in moderate-to-high density, starfish were sparsely distributed and rare.

5.5 Overall recommendations for Raivavae

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

- The density and size of Serranidae in the outer reefs should be monitored to detect any decreases, as there are early signs that this fish family is decreasing in abundance.

- The current level of fishing for reef finfish for sustenance and to fulfil social obligations can be maintained, as it appears to be sustainable.

- Further assessment is needed to assess deeper-water white teatfish stocks (*Holothuria fuscogilva*); however, the preliminary investigation did not highlight any very promising options for this species.

- Although for giant clams no sustainability issues were identified and exploitation rates are below any rate critical to commercial fishing, a management plan designed to rest certain areas is recommended. A system of rotational closures (introduced with local consultation) could operate at variable time periods, depending on the state of the reef (its condition and its location), but will need to take into account the growth rate of clams, to allow clams time to reach maturity.

- Any future introductions of the commercial topshell (*Trochus niloticus*) should consider first placing the trochus on inshore reefs in the north of the island to protect them after the move until they acclimatise to local conditions, and then relocating them to reef on the northeast corner of the island. In addition, any future translocations should be made with the active support of fishers and the community, to ensure there is a general understanding of the potential benefits of these stocks becoming established.

6. PROFILE AND RESULTS FOR TIKEHAU

6.1 Site characteristics

Located in the Tuamoto Archipelago near Rangiroa, this atoll has an annular shape and is positioned at 15°00'06S and 148°10'37W (Figure 6.1). It is 26 km long and 19.8 km wide. Its lagoon, which has a mean depth of about 20 m, covers an area of 400 km² and the submerged areas represent 20 km². The highest point of the *motu* is 8 m. Population is 417 people, which represents a density of ~20 people/km²; most of the population lives in the village of Tuheraera, in the southwest of the atoll. There is only one passage in the west, the Tuheiava passage. Only three habitats are represented since there is no high island and therefore no terrigenous influence: intermediate reef, back-reef and outer reef, with a total reef area of ~76 km².

People from Tikehau make their living from fisheries and operate traditional *parcs* (permanent fish traps), which allow them to better manage the export of their products in Tahiti. Pearl culture, together with tourism and copra production, also makes an important contribution to the economy.

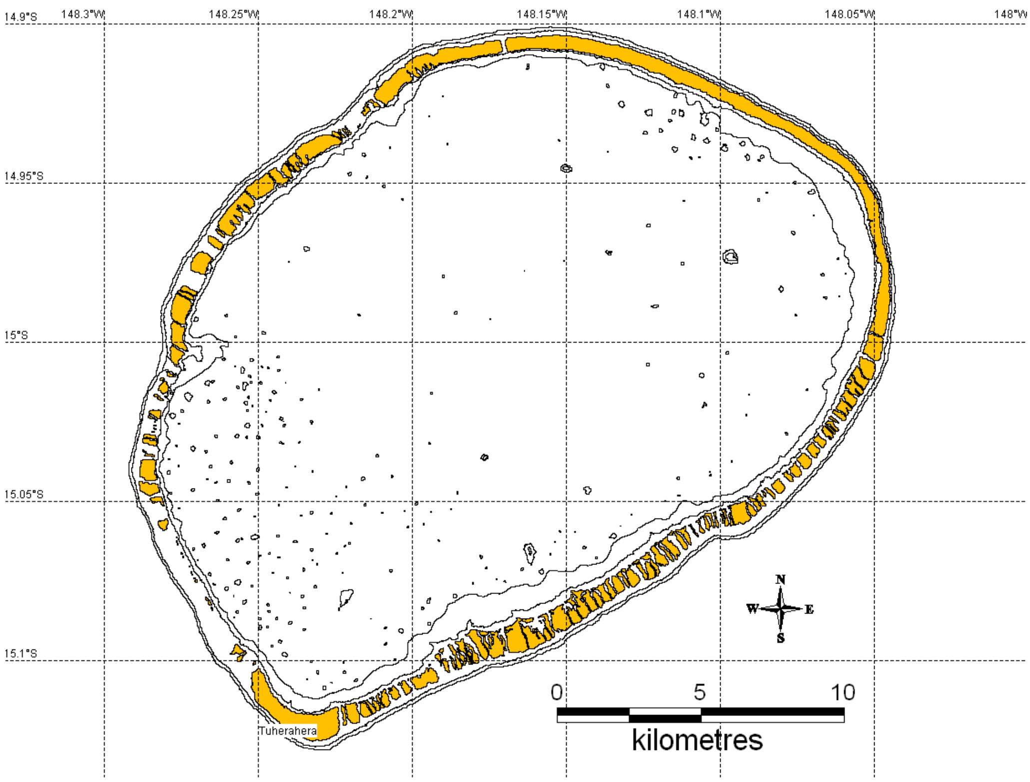

Figure 6.1: Map of Tikehau.

6.2 Socioeconomic surveys: Tikehau

Socioeconomic fieldwork was carried out on the island of Tikehau in January 2004. The survey covered a total of 24 households, including 138 people. Based on the census data from 2003, the survey sample represents about 32% of all households (74) and 39% of the total permanent resident population (350).

Household interviews aimed to collect general demographic, socioeconomic and consumption parameters. A total of 16 individual interviews of finfish fishers (12 males, 4 females) and 10 invertebrate fishers (5 males, 5 females) were conducted. These fishers belonged to one of the 24 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 6.1) suggest an average of 1–2 fishers/household. If we apply this average (1.63) to the total number of households, we arrive at a total of 121 fishers on Tikehau. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 81 fishers who fish only for finfish (males, females), a total of 6 fishers who harvest only invertebrates (females) and 34 fishers who fish for both finfish and invertebrates (males, females).

About 75% of all households in Tikehau own a boat, and all boats are motorised.

Ranked income sources (Figure 6.2) suggest that fisheries are an important sector. In fact, 38% of all households interviewed depend on fisheries as first source of income, and another 13% as second source of income. Other sources, mainly small businesses (shops, restaurants, etc.) and social fees or retirement payments, are next in importance; over 50% of all households either depend on these as first (29%) or second source of income (33%). Salaries also provide almost half of the Tikehau population with cash income; over 20% of all households generate their first income from these, and another 25% use salaries as a second income source. Agriculture, which is mainly copra production, is less important, providing 13% of all households with either first or second income.

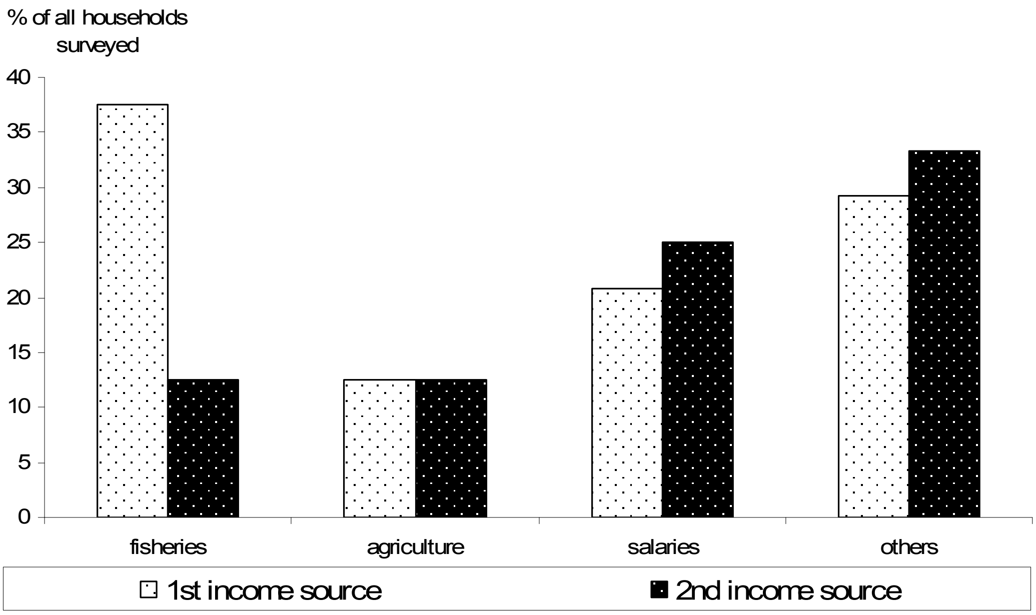

Figure 6.2: Ranked sources of income (%) in Tikehau.
Total number of households = 24 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small businesses.

Fisheries are also important for consumption. All households reported eating fresh fish, 80% invertebrates and 70% canned fish. The consumption of fresh fish among Tikehau's population (67 kg/capita/year ±8.86) is well above the regional average (FAO 2008) (Figure 6.3) and the highest across all PROCFish/C survey sites in French Polynesia. Invertebrate consumption (Figure 6.4), however, is low (1.90 kg/capita/year ±1.11) (for meat only) and below the average across all PROCFish/C sites in the country (Table 6.1). Not much canned fish is consumed, the amount being similar to elsewhere in French Polynesia. The high dependency of the Tikehau community on fisheries as a source of income, and the fact that a considerable number of households depends on salaries for income may explain why not all households (only 83%) consume fresh fish they have caught, while over 50% of all households buy fresh fish regularly or at least some times. The practice of giving away fresh fish still continues; ~46% of all households reported sometimes receiving fresh fish as a gift. In the case of invertebrates, only 33% of all households catch their own, 17% buy invertebrates (mainly lobsters), and only ~13% of households receive them as a gift.

Previous studies have suggested a much higher consumption than the estimate from the current survey. Lagadec (2003) estimated a consumption of 139 kg which he compared to 150 kg/capita/year as estimated earlier by Morize (1984) cited in Lagadec (2003).

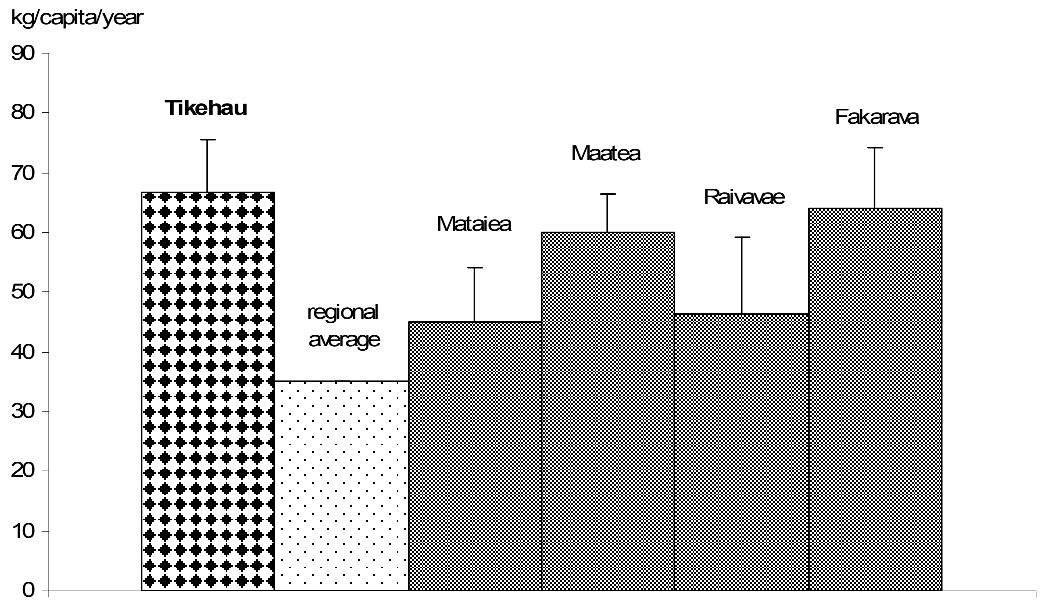

Figure 6.3: Per capita consumption (kg/year) of fresh fish in Tikehau (n = 24) compared to the regional average (FAO 2000) and the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

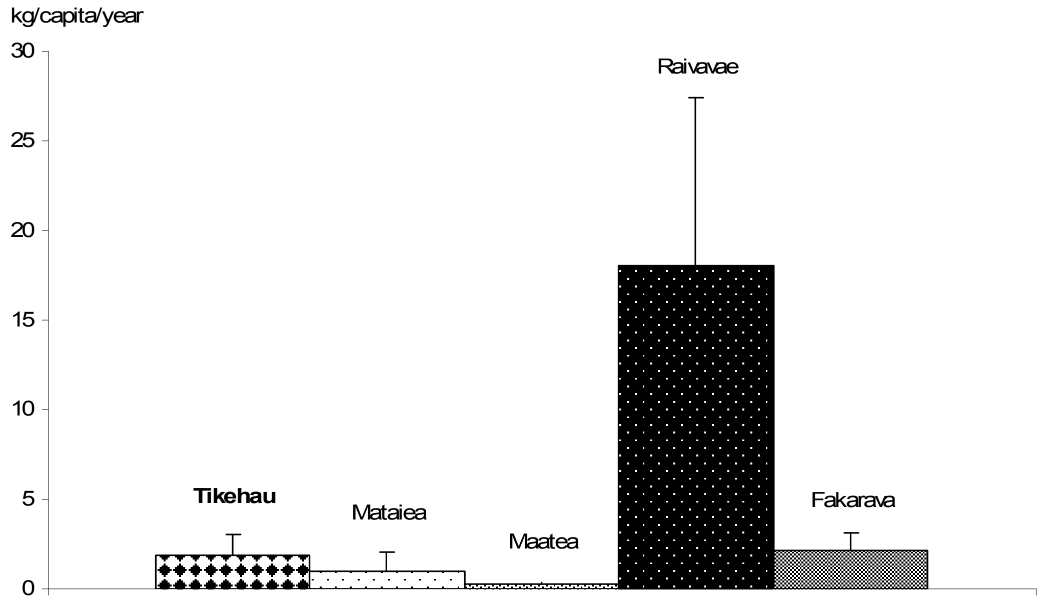

Figure 6.4: Per capita consumption (kg/year) of invertebrates (meat only) in Tikehau (n = 24) compared to the other four PROCFish/C sites in French Polynesia.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Comparing results between Tikehau and the average of all five PROCFish/C sites in French Polynesia (Table 6.1), the people of Tikehau are the most dependent on fisheries for income generation, benefit less than the average from salary income, and are among the highest consumers of fresh fish. Data show a much lower average household expenditure level while remittances play double the role on average. The comparison suggests that Tikehau is a rather traditional community with limited alternatives to income generation other than fisheries, and with people who are still enjoying a more rural lifestyle as compared to other PROCFish/C sites surveyed in French Polynesia.

Table 6.1: Fishery demography, income and seafood consumption patterns in Tikehau

Survey coverage	Site (n = 24 HH)	Average across sites (n = 138 HH)
Demography		
HH involved in reef fisheries (%)	91.7	85.5
Number of fishers per HH	1.63 (±0.29)	1.71 (±0.12)
Male finfish fishers per HH (%)	41.0	33.9
Female finfish fishers per HH (%)	25.6	9.7
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	5.1	14.0
Male finfish and invertebrate fishers per HH (%)	17.9	35.2
Female finfish and invertebrate fishers per HH (%)	10.3	6.8
Income		
HH with fisheries as 1st income (%)	37.5	14.5
HH with fisheries as 2nd income (%)	12.5	11.6
HH with agriculture as 1st income (%)	12.5	11.6
HH with agriculture as 2nd income (%)	12.5	13.8
HH with salary as 1st income (%)	20.8	46.4
HH with salary as 2nd income (%)	25.0	8.7
HH with other sources as 1st income (%)	29.2	26.8
HH with other sources as 2nd income (%)	33.3	34.1
Expenditure (USD/year/HH)	6295.66 (±665.27)	9752.58 (±468.27)
Remittance (USD/year/HH) (1)	2161.60 (n/a)	1055.66 (±393.52)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	66.59 (±8.86)	55.55 (±4.16)
Frequency fresh fish consumed (times/week)	3.96 (±0.39)	3.28 (±0.16)
Quantity fresh invertebrate consumed (kg/capita/year)	1.90 (±1.11)	4.91 (±4.16)
Frequency fresh invertebrate consumed (times/week)	0.16 (±0.06)	0.38 (±0.07)
Quantity canned fish consumed (kg/capita/year)	4.08 (±1.44)	3.95 (±0.59)
Frequency canned fish consumed (times/week)	0.70 (±0.18)	0.65 (±0.10)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	79.2	82.6
HH eat canned fish (%)	70.8	79.0
HH eat fresh fish they catch (%)	83.3	84.0
HH eat fresh fish they buy (%)	54.2	56.0
HH eat fresh fish they are given (%)	45.8	44.0
HH eat fresh invertebrates they catch (%)	33.3	44.0
HH eat fresh invertebrates they buy (%)	16.7	8.0
HH eat fresh invertebrates they are given (%)	12.5	8.0

HH = household; n/a = standard error not calculated; (1) average sum for households that receive remittances; numbers in brackets are standard error.

6.2.2 Fishing strategies and gear: Tikehau

Degree of specialisation in fishing

Fishing in Tikehau is performed by both males and females (Figure 6.5) although, overall, there are more males. Most fishers, regardless of gender, are exclusive finfish fishers and only a few females focus on invertebrate collection. About 25% of fishers (males and females) fish for both finfish and invertebrates.

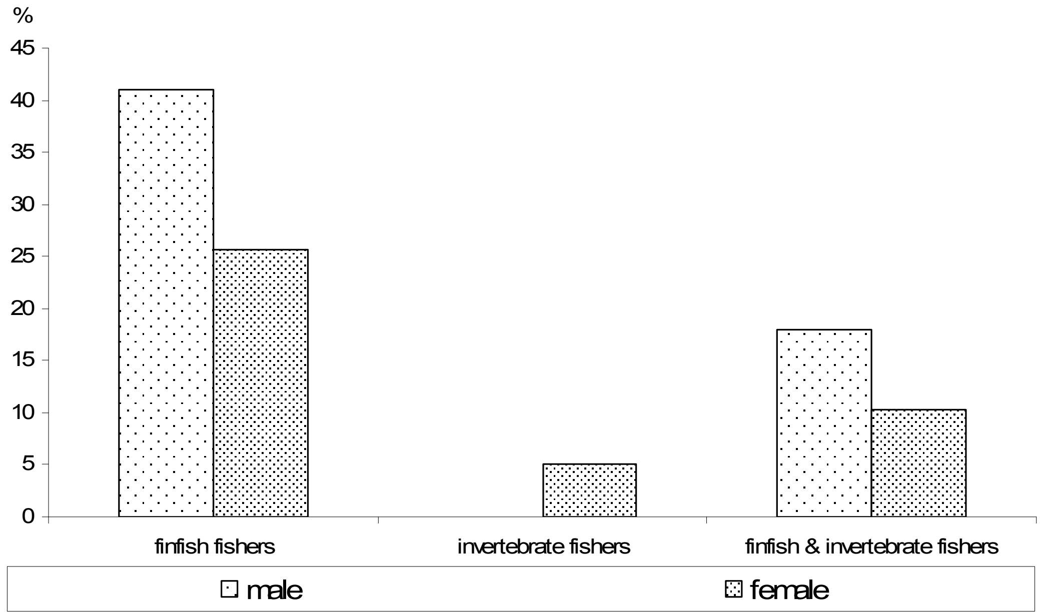

Figure 6.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Tikehau.
All fishers = 100%.

Targeted stocks/habitat

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Tikehau on their fishing grounds (Table 6.2).

Table 6.2: Proportion (%) of male and female fishers harvesting finfish and invertebrate stocks across a range of habitats (reported catch) in Tikehau

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef	0.0	25.0
	Sheltered coastal reef & lagoon	8.3	0.0
	Lagoon	25.0	75.0
	Lagoon & passage	8.3	0.0
	Outer reef	8.3	0.0
	Passage	58.3	0.0
Invertebrates	Reeftop	40.0	0.0
	Intertidal	0.0	100.0
	Lobster	80.0	0.0
	Other	40.0	0.0

'Other' refers to the *Tridacna maxima* fishery.
Finfish fisher interviews, males: n = 12; females: n = 4. Invertebrate fisher interviews, males: n = 5; females: n = 5.

Fishing patterns and strategies

Our survey sample suggests that fishers in Tikehau can choose among sheltered coastal reef, a lagoon area, passages and the outer-reef habitats. In fact, there are three main groups of fishers on Tikehau: those who fish for subsistence and leisure (males and females), those who fish for commercial purposes by spear diving, handlining and gillnetting (males only) and commercial fishers who maintain *parcs* (fish traps). Eight fishers are in the latter group, six who operate *parcs* in the passages and two who have *parcs* installed at the sheltered coastal reef.

Invertebrate fisheries are not diverse and are less important than finfish fisheries. The small number of species targeted is mostly found on the reefs. Most males collect giant clams, lobsters and other invertebrates on the reef, or dive for lobsters and giant clams. Most, if not all, females collect shells in the intertidal beach areas. These shells are used for artisanal and handicrafts. Jewellery and other items made are often sold to tourists on Tikehau or on the main island at the Papeete market. In general, most fishers target lobsters (>30%) or reef resources (15% by walking, 15% by diving) and 38% of all invertebrate fishers collect shells mainly for artisanal purposes (Figure 6.6). Figure 6.7 shows the clear gender differentiation between male fishers targeting edible invertebrates and females collecting shells at the intertidal beach areas mainly for jewellery making.

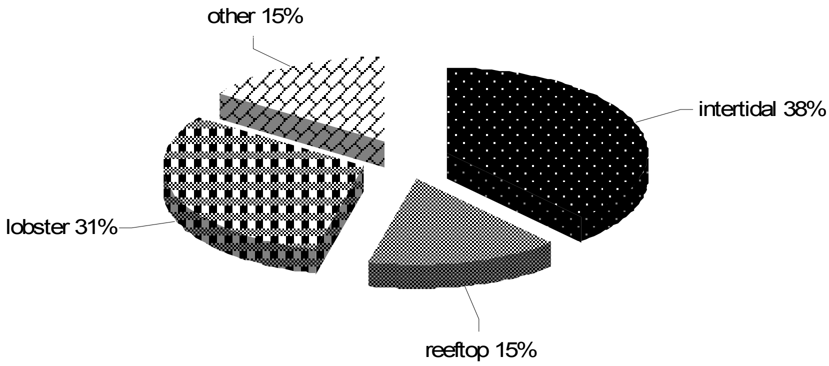

Figure 6.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Tikehau.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the *Tridacna maxima* fishery.

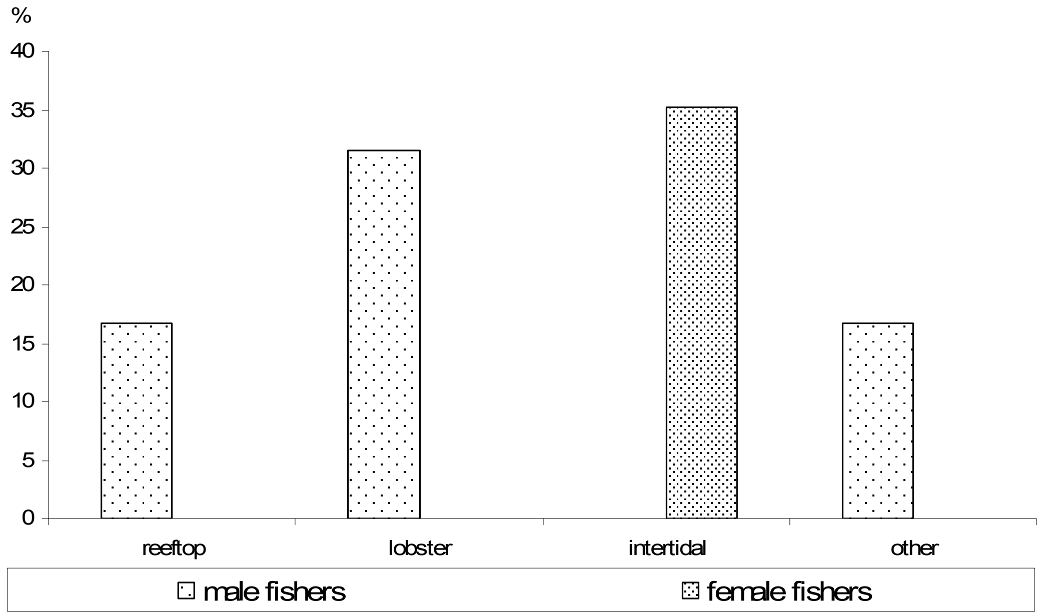

Figure 6.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Tikehau.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 5 for males, n = 5 for females; 'other' refers to the *Tridacna maxima* fishery.

Gear

Figure 6.8 shows that fishing strategies vary considerably among habitats targeted. As mentioned above, there are three main fisher groups. Fishers targeting the sheltered coastal reef, lagoon, and a combination of both mainly use gillnets, handlines and perhaps spear diving; sometimes two techniques are combined. In addition, there are two highly commercial fishers who maintain *parcs* (fish traps). Fishing in the passages and at the outer reef is either done by spear diving or, as in most commercial cases, using fish traps called *parcs* complemented by handlines and spears. Spear divers and handline fishers, sometimes also gillnet fishers, may also be commercially oriented. All male and female fishers reported that they always use motorised boats for all fishing trips. In fact, to go to the *parcs*, modern fibreglass boats, very well equipped with an 80–100 hp outboard engine, are used. These boats have a high investment cost as well as high maintenance and operational costs. However, they reduce travel time and allow speedy delivery, freight and air transport of catch. The emptying of the *parcs* themselves is done by using smaller half-hull boats, often referred to as flat-bottom boats ('bateau à fond plat') that are equipped with much smaller outboard engines (30–40 hp), which are less costly. These boats are used by most other commercial and non-commercial fishers too.

Gleaning and free diving for invertebrates is done using very simple tools only. Lobsters and giant clams are picked up by hand, often using a torch at night. If lobsters and giant clams are collected by free diving, divers use dive masks, fins, snorkels and possibly dive suits. No SCUBA gear is used. Diving for lobster and giant clams is always done using motorised boats. Half of all reeftop gleaning trips are conducted by walking; half using motorised boats.

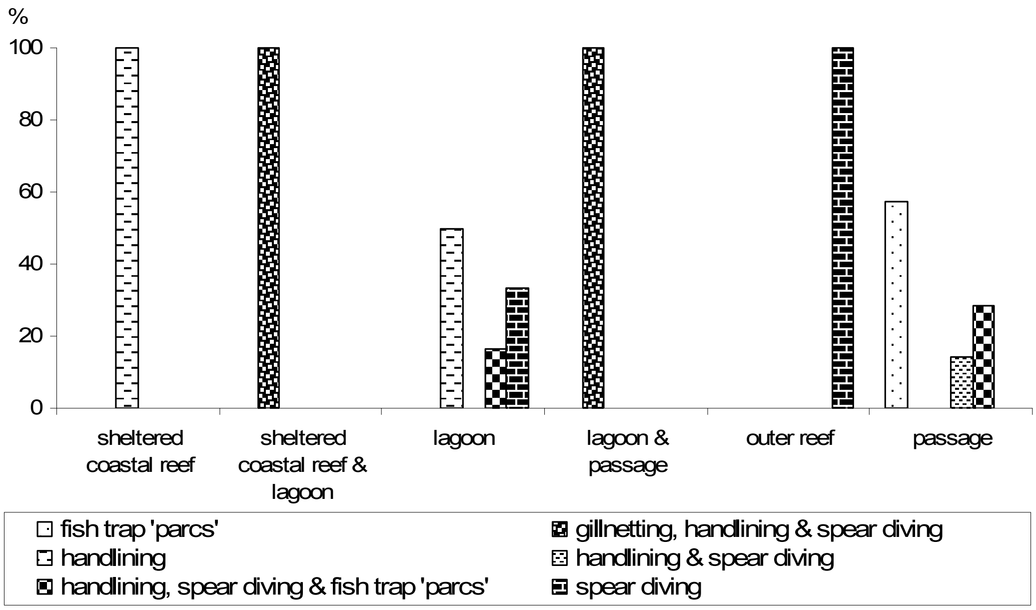

Figure 6.8: Fishing methods commonly used in different habitat types in Tikehau.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 6.3, male fishers from Tikehau go out frequently, i.e. between two to four times per week. Commercial fishers who maintain *parcs* in passages visit these between three to four times per week. Female finfish fishers mainly target the sheltered coastal reef about three times per week on average. Invertebrate fishers go out much less often, about once a fortnight. Often, lobsters are collected for special festivities only; Christmas and New Year feasts are the main seasons. Females collect shells for handicrafts about once a month on average. Fishing trips for finfish and invertebrates are relatively long (>3 hours or 4–6 hours). Commercial fishers are more focused, often operate in groups of 4–6 people and may therefore return with their catch within 3–4 hours.

Finfish fishing is mainly performed during the day, except for a few fishers who sometimes target the lagoon or the outer reef at night. These are usually young male spear divers. Most fishing is continuously performed throughout the year.

Invertebrate fishing is usually done during the day except for lobster fishing which is only done at night, with a torch. Most invertebrate fishers fish for nine months only, pausing for the copra harvest.

Table 6.3: Average frequency and duration of fishing trips reported by male and female fishers in Tikehau

Resource	Fishery / Habitat	Trip Frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef		3.00 (n/a)		2.50 (n/a)
	Sheltered coastal reef & lagoon	4.00 (n/a)	0	12.00 (n/a)	0
	Lagoon	1.77 (±1.62)	0.71 (±0.29)	6.17 (±1.17)	4.33 (±2.33)
	Lagoon & passage	4.00 (n/a)	0	4.50 (n/a)	0
	Outer reef	2.00 (n/a)	0	6.00 (n/a)	0
	Passage	3.71 (±0.61)	0	2.86 (±0.40)	0
Invertebrates	Reeftop	0.56 (±0.44)	0	5.50 (±0.50)	0
	Intertidal (beach)	0	0.25 (±0.12)	0	4.80 (±0.73)
	Lobster	0.08 (±0.05)	0	5.75 (±0.25)	0
	Other	0.62 (±0.38)	0	3.00 (±0.00)	0

Figures in brackets denote standard error; n/a = no standard error calculated; 'other' refers to *Tridacna maxima* fishery.
Finfish fisher interviews, males: n = 12; females: n = 4. Invertebrate fisher interviews, males: n = 5; females: n = 5.

6.2.3 Catch composition and volume – finfish: Tikehau

The reported catch compositions from the various habitats closely correspond to the different fisher groups. Catches from sheltered coastal reef and lagoon are dominated by Lutjanidae, Lethrinidae, Scaridae, and Acanthuridae. Catches from *parcs* (fish traps), passages and outer reefs contain a large amount of Carangidae. For example, Carangidae make up to 45% of reported catches from passages, and about 20% from the outer reef. However, the proportion of Lutjanidae, Acanthuridae, Lethrinidae and Scaridae is still prominent and each may contribute up to 20% of the reported catches (Detailed data are provided in Appendix 2.5.1.).

Our survey sample of finfish fishers interviewed represents about 20% of the projected total number of finfish fishers on Tikehau. Due to the great difference between the organised commercial fishers (who mainly operate *parcs*) and the subsistence or occasional commercial fishers, we have not extrapolated our survey data, to avoid overestimation. Because we have included a number of the very active and productive commercial fishers in our survey sample, we believe, however, that the reported catch figures may provide an almost comprehensive picture of the scale of the current fishing pressure on the Tikehau reef resources. Due to the fact that the calculation of the annual catch per fisher is based on average catches, and that many of our respondents are large commercial producers, our figures may be overestimated. For instance, our total annual catch figure of almost 400 t exceeds the air cargo freight volume of 120–140 t that corresponded to records provided by Air Tahiti for 2003. However, considering that the export of fresh fish or seafood from Tikehau to the country's main market Papeete is mainly done by air freight, and that the daily flight offers a guaranteed volume of 1 t/day for fresh fish produce, and that the obtained records for 2003 may not be complete, then our calculations may be realistic.

It is worthwhile noting that none of the respondents expressed any concern regarding the local finfish or invertebrate resources. Lobsters may however be an exception, as some fishers reported that in earlier days lobster collection was much easier than nowadays. Nevertheless, many fishers still claimed that they had no major problems collecting lobsters at low tide and during the night. On the other hand, the local population was very disturbed by information that they had received in conversation with visiting researchers on the dwindling resources and on the visible impact of their past and current fishing. Local people did not seem to share any of these opinions. However, major concern was frequently expressed due to such external assessment in view of possible consequences for local fishers, i.e. in particular the possibility of fishing restrictions being imposed by fisheries management.

As shown in Figure 6.9, finfish fishing on Tikehau is for export to serve the high demand for fresh reef fish in Papeete, the country's capital market. Only ~4% of the catch is consumed locally. In other words, any impact imposed by finfish fishing on the island's resources is due to external demand rather than a consequence of the population density and the high per capita consumption by the atoll's residents. According to earlier explanations, commercial fishing is performed particularly in passages, using *parcs*, and it is therefore not surprising that the highest impact (>90% of the reported catches) falls on this habitat. Subsistence fishing that mainly targets the sheltered coastal reef and lagoon areas is insignificant by comparison, not exceeding 7% of the total reported catch. Outer-reef fishing also plays an insignificant role. Figure 6.9 also shows that the participation of female finfish fishers is for subsistence needs, although they do often take an active role in organised commercial fishing activities, as they may be in charge of handling, transport from landing to the airport, and freight of the catch.

Comparison of the above estimates on total annual catch with other estimates shows that the percentage of subsistence needs on Tikehau may be much lower but the total annual catch is similar to estimates made by Lagadec (2003) and Stein (1988). Historic data show great fluctuations in the lagoon fishery production of Tikehau atoll. Total annual finfish catch records were about 40 t/year before 1966, 160 t/year from 1966 to 1970, and an average of 350 t/year from 1971 to 1982. A record catch of 479 t/year was reported in 1973.

The development of export fisheries on Tikehau has also prompted the introduction of a local fish price. The commercialisation of reef produce on Tikehau exists alongside the traditional, non-monetary exchange of catch among members of the community. However, it was reported that this tradition is becoming more and more confined to close family members. Nevertheless, the local price for fresh fish of XPF ~150 to 200 /fish string is 2–4 times below the price at the Papeete market.

All costs incurred in transporting the fresh fish from Tikehau to Papeete are met by the Tahiti-based buyers or agents, including ice boxes and ice for the transport, air freight (XPF 105 /kg if the freight volume exceeds 50 kg; prices as for January 2004) and transport and marketing costs upon arrival at Tahiti. The fisher covers the costs of establishing and maintaining the *parcs*, sea and road transport costs on Tikehau, and labour costs.

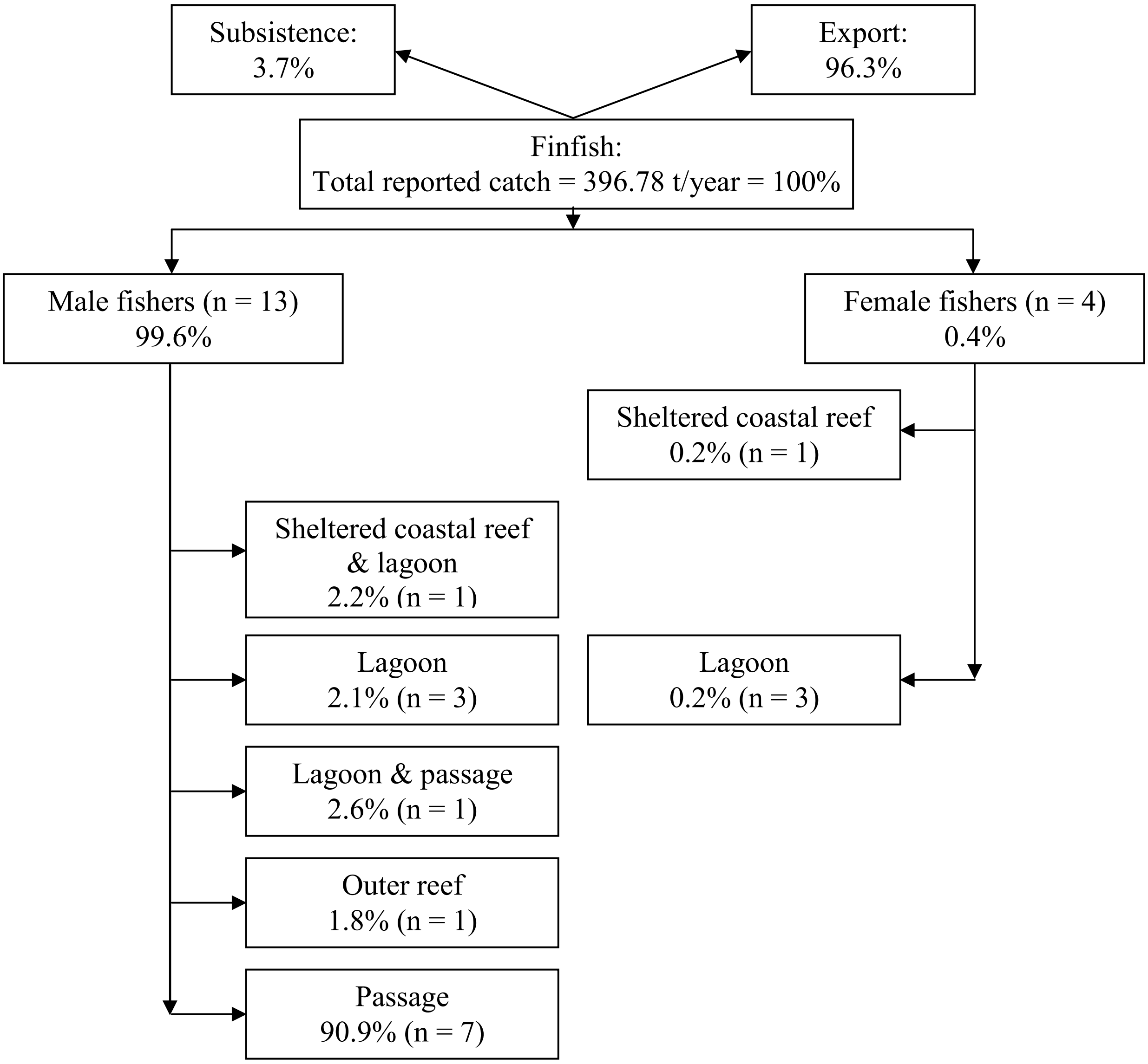

Figure 6.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Tikehau.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The high impact on the passages is a function of the fishing strategy, i.e. the use of permanent *parcs* (fish traps) and their high productivity, rather than the number of fishers and the annual catch rate. As shown in Figure 6.10, average annual catches from *parcs* may reach as high as 25 t/year each, more by far than from any other fishing activities. Nevertheless, if regarding the average annual catch rates of fishers, some of whom may occasionally fish commercially, and who use other techniques to target the sheltered coastal reef and lagoon habitats, we still find relatively high rates of up to 5 t/year. Subsistence fishers, in particular female finfish fishers, do not get close to any of these average annual catch rates.

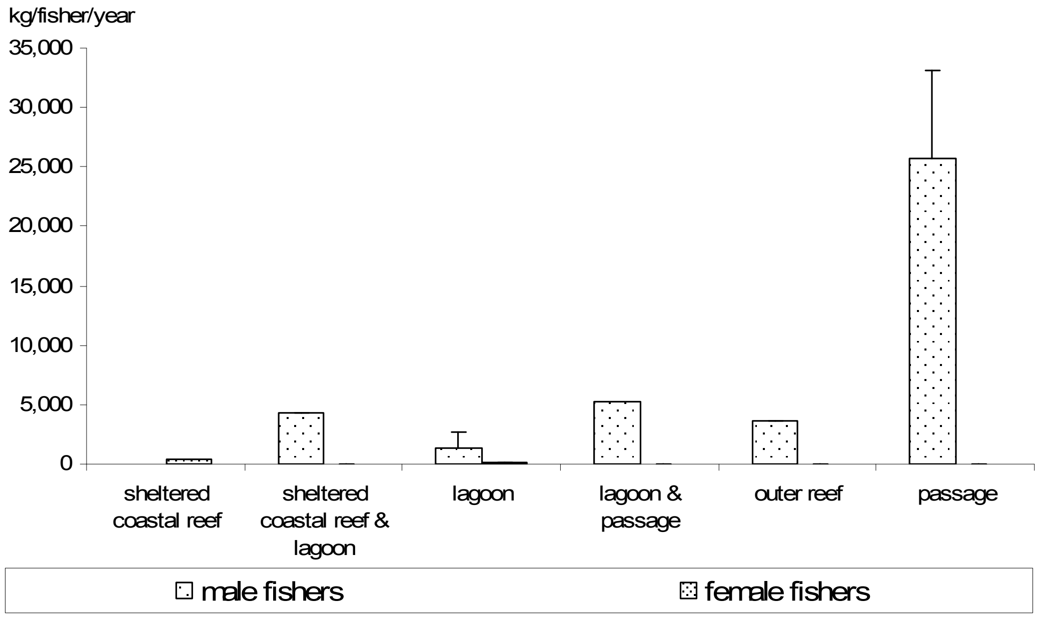

Figure 6.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Tikehau.
Bars represent standard error (+SE).

Comparing the CPUE calculated for the different habitats fished shows the same trend (Figure 6.11). Passage fishers (*parc* fishers) are highly productive and may take up to 60 kg/hour of fishing trip while any other fishing yields 2–10 kg per hour of fishing trip. It should be noted that the high figures obtained for the fishing of passages are only due to the specific use of *parcs* and are an exception to any other reef fishing in French Polynesia or elsewhere in the Pacific as observed within the framework of PROCFish/C programme.

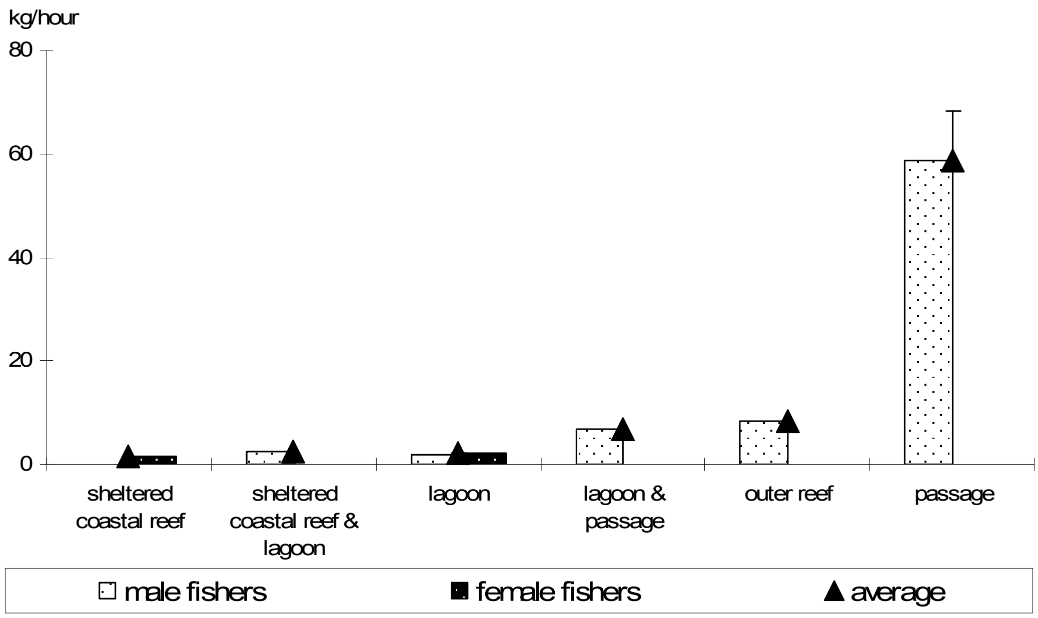

Figure 6.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Tikehau.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

In keeping with the above observations, most of the catch is taken for commercial purposes. Fishing the outer reef and passages is mainly for commercial purposes and only a small share of the catch is consumed by the families of the fishers involved or shared with other members of the community as a gift. Sheltered coastal reef fishing is exclusively performed by female fishers and is only for subsistence and social purposes, never sold. However, some of the catch from the close-to-shore areas may also be sold locally as shown in Figure 6.12 for the combined habitat of sheltered coastal reef and lagoon.

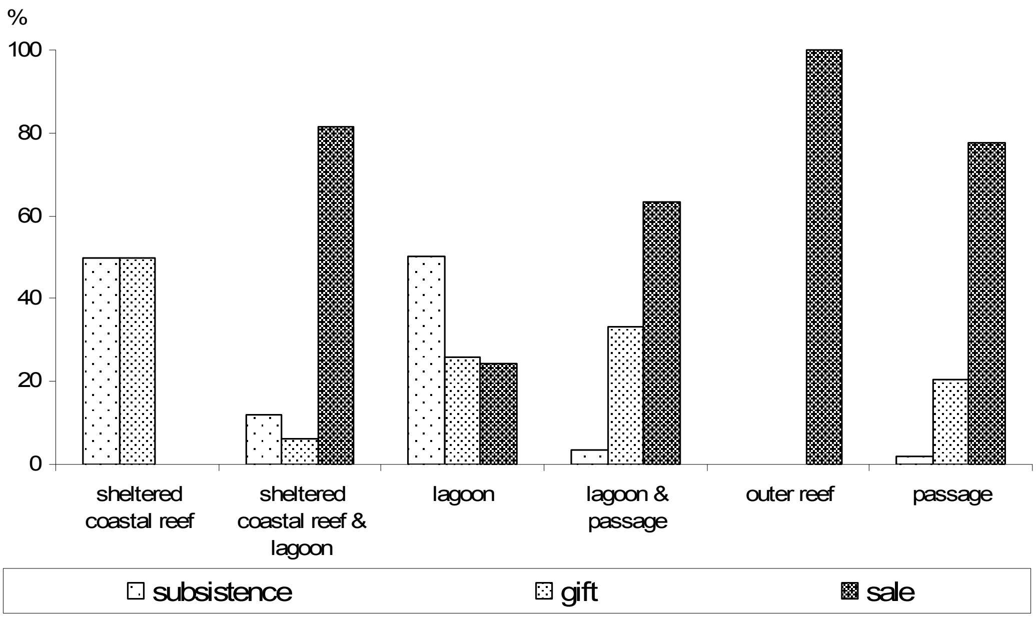

Figure 6.12: The use of finish catches for subsistence, gift and sale, by habitat in Tikehau. Proportions are expressed in % of the total number of trips per habitat.

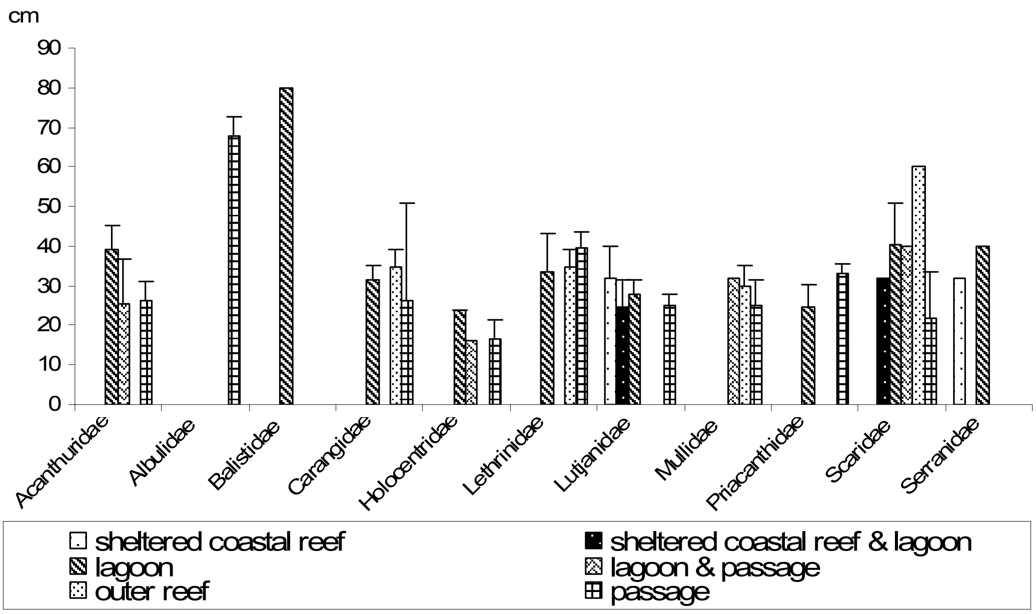

Figure 6.13: Average sizes (cm fork length) of fish caught by family and habitat in Tikehau. Bars represent standard error (+SE).

Data on the average reported finfish sizes by family and habitat as shown in Figure 6.13 are difficult to compare as most families were not reported from all habitats targeted. In the case of Scaridae, the reported average fish size is generally large (>30–60 cm on average), and there is a general increase in the average reported fish size from the sheltered coastal reef to the outer reef. Given the facts that outer-reef fishing in Tikehau is often done by spear diving; that it is commercially oriented; and that overall the impact of fishing at the outer reef is small; these reported figures for Scaridae indicate that there is no visible impact from current fishing pressure. There are some slight declining trends in the reported average fish size from the coast to the passages, i.e. for Mullidae, Lethrinidae and Acanthuridae. However, the interpretation of this observation may need further clarification by the results from the underwater finfish resource survey. Data as shown in Figure 6.13 are highly variable (large SE) and may lead to misinterpretation. Overall, however, the average reported fish sizes are rather large, usually around 30 cm or even larger.

Some parameters chosen to assess current fishing pressure on the Tikehau reef resources are shown in Table 6.4. The comparison of habitat surfaces shows that the lagoon is the largest habitat, while the sheltered coastal reef and outer reef are considerably smaller. However, considering the number of fishers targeting each habitat, fisher density is uniformly low. Also, overall population density either per reef-surface area or per total fishing ground is low by any means calculated, and so is the annual catch for subsistence purposes. Nevertheless, subsistence needs only represent 3.7% of the total annual catch. Most, if not all of the commercial catch is sourced from passages. Passages may act as catchments of reef, lagoon and pelagic fish. Thus, it can be assumed that, although total fishing pressure will be considerably higher, it may, however, still remain within moderate limits.

Table 6.4: Parameters used in assessing fishing pressure on finfish resources in Tikehau

Parameters	Habitat							
	Sheltered coastal reef	Sheltered coastal reef & lagoon	Lagoon	Lagoon & passage	Outer reef	Passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	31.17	n/a	422.82	n/a	9.20	0.20	40.58	463.39
Density of fishers (number of fishers/km^2 fishing ground) (1)	<1		<1		5		3	0
Population density (people/km^2) (2)							9	1
Average annual finfish catch (kg/fisher/year) (3)	369.28 (n/a)	4342.86 (n/a)	764.13 (±647.30)	5211.43 (n/a)	3619.05 (n/a)	25,752.11 (±7327.0)		
Total fishing pressure of subsistence catches (t/km^2)							0.74	0.06

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 = 350; total number of finfish fishers = 115; total subsistence demand = 30.09 t/year; (3) catch figures are based on recorded data from survey respondents only.

6.2.4 Catch composition and volume – invertebrates: Tikehau

Calculations of the total recorded annual catch per species groups are shown in Figure 6.14. The graph shows that the only major impact by wet weight is from lobster catches, i.e. *Panulirus* spp., reaching over 300 kg; about half as much (~150 kg) on average is from giant clams (*Tridacna maxima*). By comparison, catches reported for *Cypraea tigris*, *Nerita polita*, *Turbo marmoratus* and *Cypraea annulus*, which are mainly gathered for handicrafts, are negligible (25–<50 kg each) (Detailed data are provided in Appendices 2.5.2 and 2.5.3.).

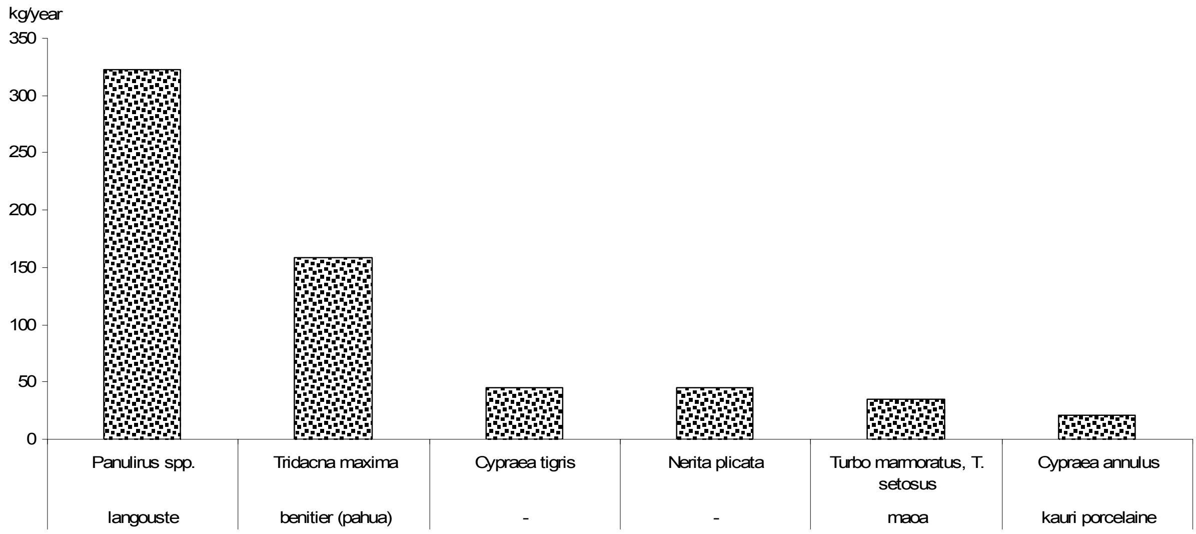

Figure 6.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Tikehau.

As already stated, invertebrate fisheries are limited and not of great importance in Tikehau. Accordingly, the limited biodiversity reported for catches is not surprising. Catches from the reeftop fishery, 'other' dive fisheries and the lobster fishery, each include one species reported by vernacular name, i.e. representing *Turbo* spp., *Panulirus* spp. and *Tridacna maxima* respectively, while the intertidal shell fishery ('sand') has three vernacular names, which represent *Cypraea* spp. and *Nerita* spp. used for artisanal purposes (Figure 6.15).

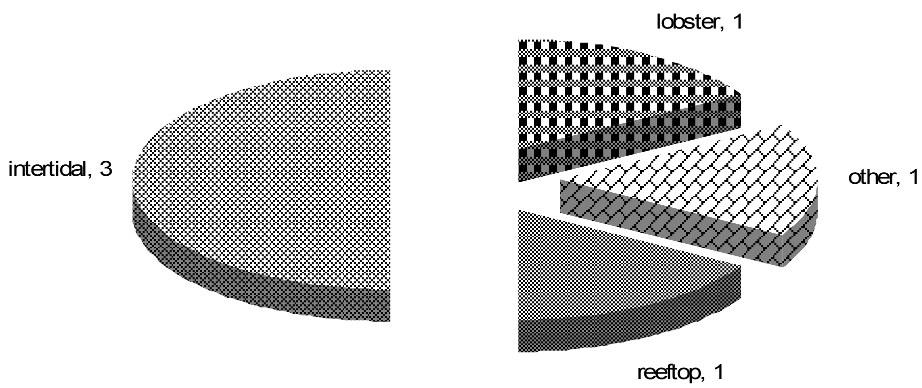

Figure 6.15: Number of vernacular names recorded for each invertebrate fishery on Tikehau.
'Other' refers to *Tridacna maxima* fishery.

Figure 6.16 shows that average annual catches by invertebrate fishers are generally low and highly variable. The highest average annual catches by wet weight are obtained by lobster and giant clam divers, who each collect about 80 kg/year, while reeftop gleaners and intertidal shell collectors may only harvest around 20 kg of invertebrates by wet weight on an annual average each. Females are the exclusive intertidal shell collectors, while all other invertebrate harvesting is performed exclusively by males.

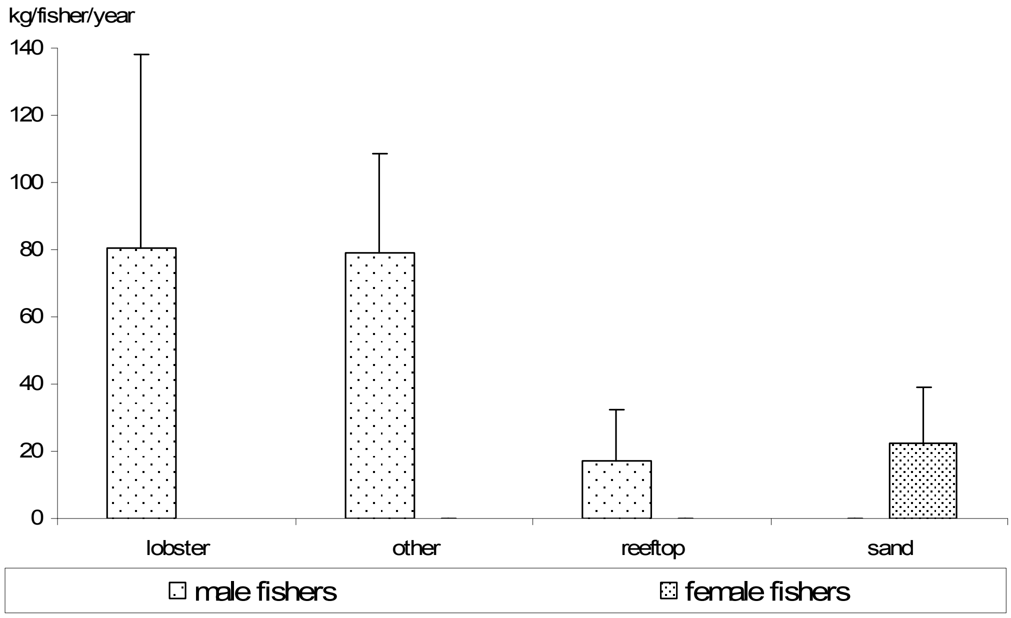

Figure 6.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Tikehau.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 6 for males, n = 5 for females). 'Other' refers to *Tridacna maxima* fishery.

In contrast to the finfish fisheries on Tikehau, invertebrates are mainly collected for subsistence needs or sold locally (Figure 6.17). A total of 111 kg is reported for sale only, which corresponds to about 18% of the total annual catch. Taking into account that some of the catch may be used either for subsistence or for commercial purposes, the commercial share of invertebrates caught on Tikehau may not exceed a total of 42%, i.e. less than the proportion consumed by the fishers themselves. Invertebrates are mainly sold on Tikehau, i.e. lobsters, which are sold to restaurants and to individual clients; only some are marketed at Papeete (e.g. lobsters and shells for handicrafts).

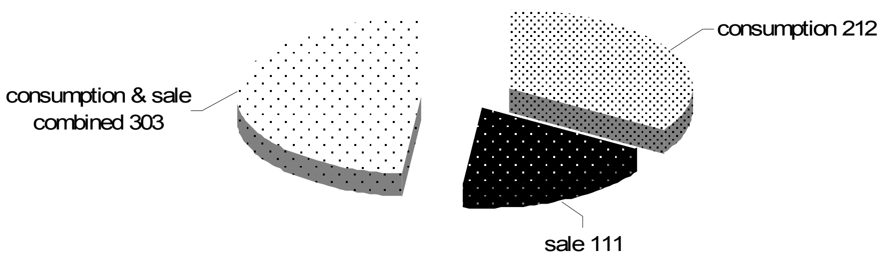

Figure 6.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Tikehau.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) is very small (0.63 t/year) (Figure 6.18). Lobster catches exclusively caught by males, make up >50% of the total annual reported catch, while giant clams make up 25% and intertidal shell collection by females is ~18%. Overall, females' contribution to the reported invertebrate catch in Tikehau is small (~18%).

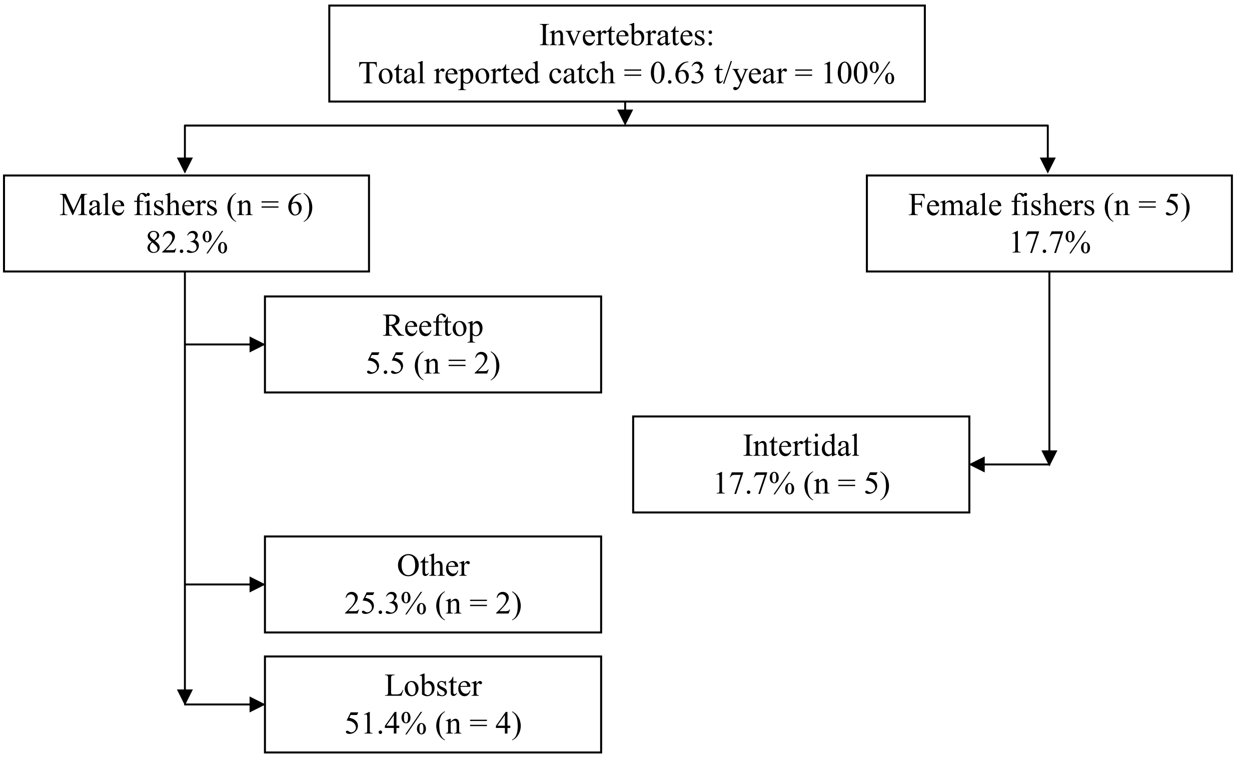

Figure 6.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Tikehau.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to *Tridacna maxima* fishery.

The parameters presented in Table 6.5 show a high variability in the size of the available fishing grounds for the various fisheries. However, generally speaking, the available fishing ground areas are large, especially the reef length available for the lobster fishery. Taking into consideration the generally low average recorded annual catch/fisher (wet weight) and the equally low fisher density, the current fishing pressure on reef and intertidal areas is low if not negligible. Also, because Tikehau is an isolated atoll island we can rule out any other external impact that may add to the fishing pressure imposed by the island's resident population. Our conclusion largely supports the perception of local people, i.e. that their invertebrate resources are in a good state, and that they are hardly targeted, except for lobsters and giant clams.

Table 6.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Tikehau

Parameters	Fishery / Habitat			
	Reeftop	Intertidal	Other	Lobster
Fishing ground area (km^2)	19.25	14.50 (1)	19.25	36.37 (1)
Number of fishers (per fishery) (2)	9	19	9	17
Density of fishers (number of fishers/km^2 fishing ground)	0.45	1.28	0.45	0.47
Average annual invertebrate catch (kg/fisher/year) (3)	17.33 (±15.24)	22.24 (±16.96)	79.27 (±29.30)	80.60 (±57.29)

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

6.2.5 Discussion and conclusions: socioeconomics in Tikehau

- People living on the atoll island of Tikehau still enjoy a more traditional lifestyle, as shown by the relatively low household expenditure level, even though the island offers hardly any potential for agricultural subsistence production. However, the daily airflights to the country's capital city, a guaranteed freight volume and air cargo price for fresh seafood produce has prompted the substantial development of a commercial reef fisheries. Fisheries are the most important income source, followed by social fees and salaries.

- The high dependence of the Tikehau community on their marine resources also shows in the high per capita consumption (67 kg/year) of fresh fish. However, the consumption of invertebrates and canned fish was found to be of minor, if any, importance.

- The development of commercial fisheries on Tikehau has contributed to a decrease in the traditional practice of exchanging seafood without payment. Only 46% of all households reported sometimes receiving fresh fish as a gift, and only 13% of all households benefited from gifts of invertebrates. The local fish price, however, is still 2–4 times lower than the price paid at the Papeete market.

- Survey data showed that invertebrate fisheries are much less important, in fact even marginal, as compared to finfish fisheries. Very few people regularly collect invertebrates, and then only lobsters, giant clams, some *Turbo* spp. shells and other shells collected for handicrafts. Lobsters are in particularly high demand during major festivities and special occasions, such as end-of-year celebrations.

- Regarding finfish fisheries, there are three major fisher groups found on Tikehau: subsistence and leisure fishers, commercial fishers using spear diving, handlines and gillnets, and commercial fishers who operate *parcs* (fish traps) mainly in the passages (and also some located in the sheltered coastal reef area). The differences between these groups are the fishing techniques used, the type of motorised boat transport, investment and operational costs, and productivity.

- Highest impact on the island's finfish resources was found to be imposed by *parc* fishers. The total annual impact may be as high as 400 t, ~96% of which is for export and ~4% for consumption by Tikehau residents only.

- Differences among the three fisher groups also shows in the CPUEs, which are extremely high for *parcs* fishers and even higher for commercial fishers (e.g. spear-divers at the outer reef) as compared to subsistence fishers. No major conclusions could be drawn regarding reported average fish sizes for catches from the various habitats. In general, however, fish sizes were reported to be large and Scaridae in particular, the major target species for spear diving, did not show any detectable impact from fishing.

- Fishing pressure was found to be generally low; however, if any detrimental impact from fishing is imposed on the island's marine resources, it is due to export demand. No impact at all is imposed by the subsistence needs of the local population.

- Similarly, no fishing pressure was detected by comparing data on the available supporting habitats and the estimated quantities of invertebrates fished. This was true for all recorded target species, including lobsters, giant clams, shells of *Turbo* spp. and a small variety of shells collected for handicrafts.

- The socioeconomic data describe a generally satisfying picture of reef resources in Tikehau, and give no reason for concern regarding the level of fishing pressure on any of the atoll's marine resources. The fact that the commercial fisheries are controlled by the daily air freight allowance between Tikehau and Papeete may also limit the level of exploitation. The availability and frequency of air transport, guaranteed volume and export prices for fresh seafood could also be regulated, and this could be an effective management tool should any problems emerge in the future.

6.3 Finfish resource surveys: Tikehau

Finfish resources and associated habitats were assessed 06–11 October 2003 from a total of 24 transects (6 intermediate-, 12 back- and 6 outer-reef transects, see Figure 6.19 and Appendix 3.5.1 for transect locations and coordinates respectively.).

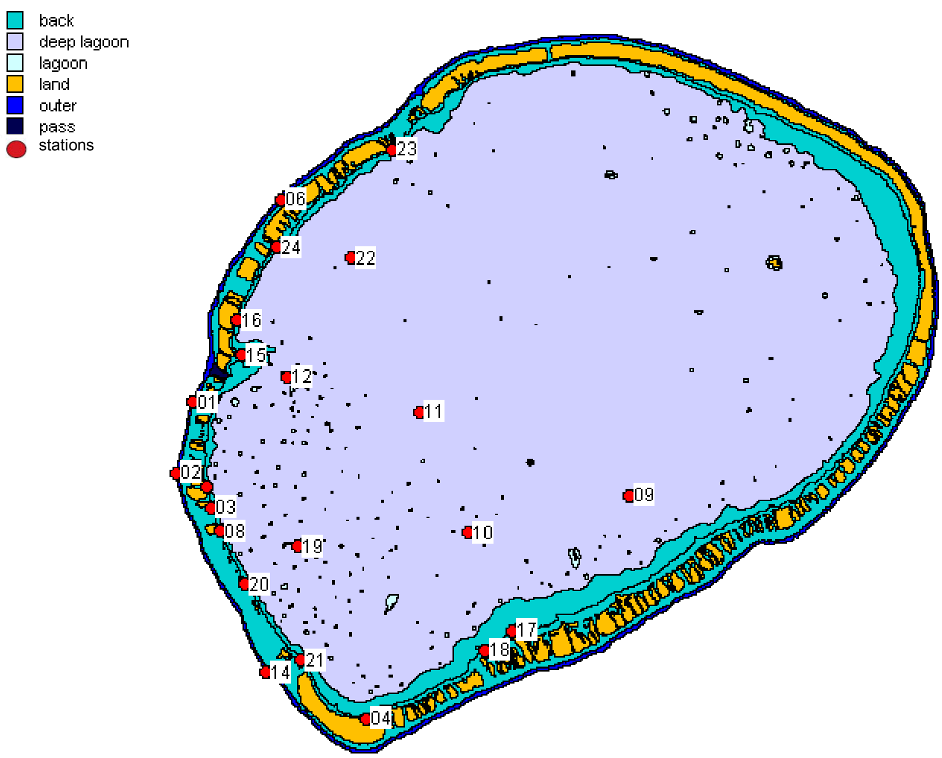

Figure 6.19: Habitat types and transect locations for finfish assessment in Tikehau.

6.3.1 Finfish assessment results: Tikehau

A total of 23 families, 52 genera, 117 species and 6459 fish were recorded in the 24 transects (See Appendix 3.5.2 for list of species.). Only data on the 12 most dominant families are presented below, representing 38 genera, 100 species and 6322 individuals.

Finfish resources differed slightly among the three reef environments found in Tikehau (Table 6.6). The intermediate reef contained the largest biomass (86 g/m^2), second-highest density (0.5 fish/m^2) and second-highest biodiversity (32 species/transect). The outer reefs displayed the highest density (0.6 fish/m^2) and biodiversity (34 species/transect) but the lowest biomass (70 g/m^2). Back-reefs displayed the lowest values of density (0.4 fish/m^2) and biodiversity (23 species/transect) and an intermediate value of biomass (75 g/m^2).

Table 6.6: Primary finfish habitat and resource parameters recorded in Tikehau (average values ±SE)

Parameters	Habitat			
	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	12	6	24
Total habitat area (km^2)	2.5	67.1	9.2	78.8
Depth (m)	2 (1–6) (3)	2 (1–4) (3)	7 (5–10) (3)	3 (1–10) (3)
Soft bottom (% cover)	16 ±3	31 ±4	2 ±1	27
Rubble & boulders (% cover)	22 ±7	30 ±6	3 ±1	27
Hard bottom (% cover)	52 ±7	33 ±6	54 ±5	36
Live coral (% cover)	9 ±2	5 ±1	39 ±5	9
Soft coral (% cover)	0 ±0	0 ±0	0 ±0	0
Biodiversity (species/transect)	32 ±4	23 ±3	34 ±5	28 ±5
Density (fish/m^2)	0.5 ±0.1	0.4 ±0.1	0.6 ±0.0	0.4
Size (cm FL) (4)	18 ±1	18 ±1	16 ±1	18
Size ratio (%)	55 ±2	55 ±3	54 ±2	55
Biomass (g/m^2)	86.1 ±27.6	75.2 ±18.3	69.8 ±13.6	62.4

(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: Tikehau

The intermediate-reef environment of Tikehau was dominated by four families: herbivores Acanthuridae and Scaridae and, to a much lesser extent, carnivores Mullidae and Lethrinidae (Figure 6.21). These four families were represented by 38 species; particularly high abundance and biomass were recorded for *Chlorurus sordidus*, *Ctenochaetus striatus*, *Scarus altipinnis*, *Mulloidichthys flavolineatus*, *Monotaxis grandoculis*, *Naso annulatus*, *Acanthurus triostegus*, *A. blochii* and *S. psittacus* (Table 6.8). This reef habitat was moderately diverse; half of the substrate surface was covered by hard bottom (51%) and the remainder by soft bottom and rubbles in similar proportions (Table 6.6 and Figure 6.21). The dominance of hard bottom usually favours the presence of herbivores, as was observed here.

Table 6.8: Finfish species contributing most to main families in terms of densities and biomass in the intermediate-reef environment of Tikehau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.07 ±0.01	7.4 ±1.0
	Naso annulatus	Whitemargin unicornfish	0.02 ±0.01	5.0 ±2.6
	Acanthurus triostegus	Convict tang	0.07 ±0.02	4.5 ±1.3
	Acanthurus blochii	Ringtail surgeonfish	0.01 ±0.01	2.8 ±1.1
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.08 ±0.01	13.7 ±2.5
	Scarus altipinnis	Filamentfinned parrotfish	0.01 ±0.01	6.9 ±5.3
	Scarus psittacus	Common parrotfish	0.01 ±0.01	2.6 ±1.8
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.02 ±0.01	5.6 ±3.8
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.03 ±0.02	5.4 ±4.1

The density (0.5 fish/m^2) and average size of fish (18 cm) in the intermediate reefs of Tikehau were the highest and biomass (86 g/m^2) the second-highest recorded among the five similar habitats surveyed in the country. Biodiversity was also relatively high (32 species/transect, Table 6.6), the second-highest value after Fakarava. Size ratios were low for Lethrinidae and Scaridae and similar to the ratios on coastal reefs. Along with Acanthuridae and Lutjanidae, these are targeted families. The decrease in sizes of emperor fish and parrotfish is an early warning sign of overfishing. Herbivorous fish strongly dominated the trophic structure of the fish community in this habitat, both in terms of density and biomass. Carnivorous fish were present in very low numbers with two main species: *Monotaxis grandoculis* and *Mulloidichthys flavolineatus*. The substrate was dominated by hard bottom, but had a good amount of sandy bottom (16%, Table 6.6), therefore suitable for both herbivores and carnivores.

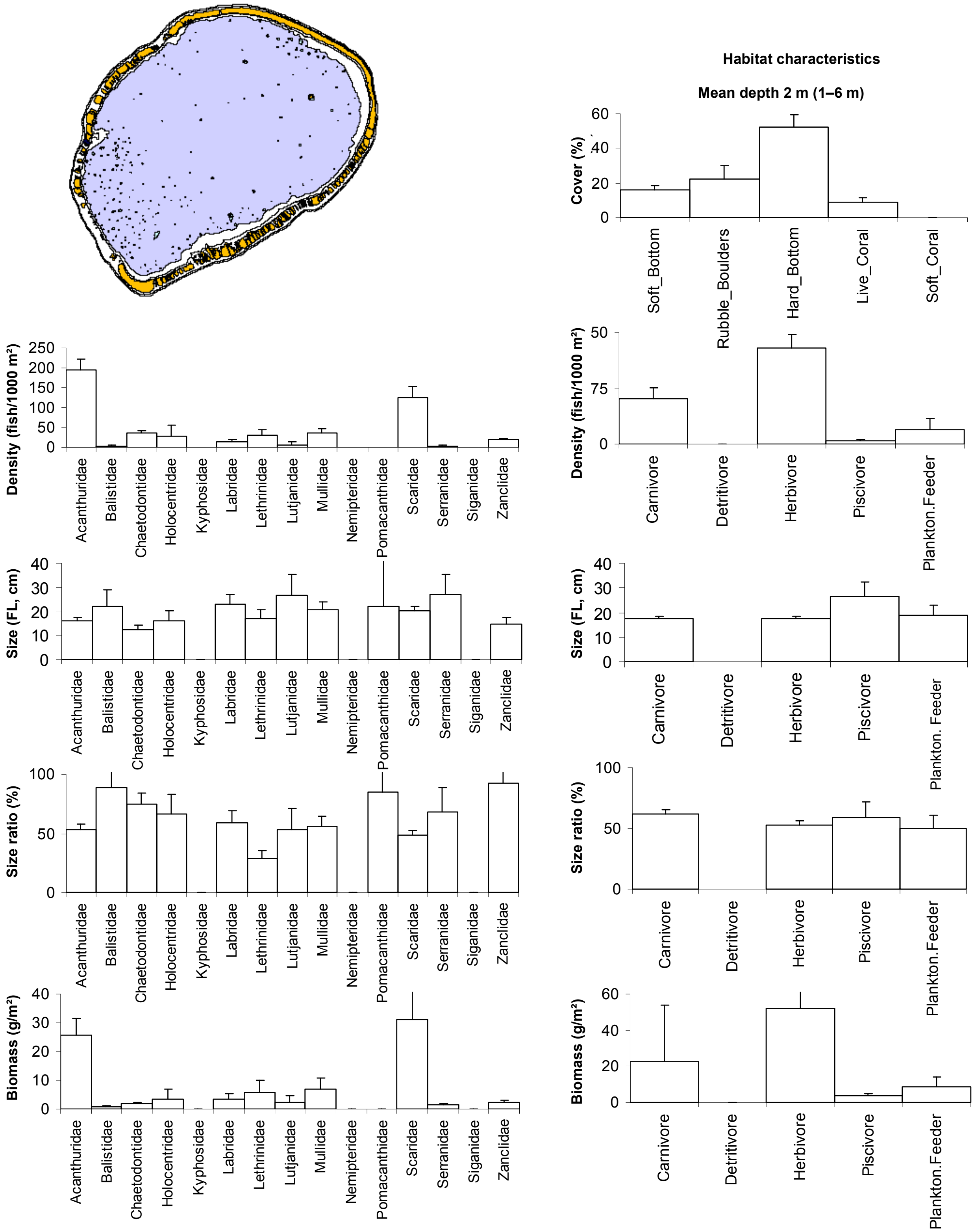

Figure 6.21: Profile of finfish resources in the intermediate-reef environment of Tikehau.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Tikehau

The back-reef environment of Tikehau was dominated by five families: two herbivores Acanthuridae and Scaridae, and three carnivores, Lutjanidae, Lethrinidae and Balistidae (Balistidae only in terms of biomass, Figure 6.22). These five families were represented by 36 species; particularly high abundance and biomass were recorded for *Acanthurus triostegus*, *Ctenochaetus striatus*, *Chlorurus sordidus*, *Lutjanus fulvus*, *L. monostigma*, *A. blochii*, *Pseudobalistes flavimarginatus* and *Lethrinus olivaceus* (Table 6.9). This reef environment presented a very diverse habitat, covered in equal proportion by rubble and boulders (30%), hard bottom (33%), and soft bottom (31%). Live-coral coverage was very low (5%, Table 6.6 and Figure 6.22).

Table 6.9: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment in Tikehau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus triostegus*	Convict tang	0.09 ±0.02	5.8 ±1.5
	Acanthurus blochii	Ringtail surgeonfish	0.01 ±0.01	3.2 ±1.2
	Ctenochaetus striatus	Striated surgeonfish	0.03 ±0.01	3.0 ±0.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04 ±0.01	5.0 ±2.1
Balistidae	*Pseudobalistes flavimarginatus*	Yellowmargin triggerfish	0.01 ±0.01	7.0 ±6.1
Lethrinidae	*Lethrinus olivaceus*	Long face emperor	0.01 ±0.01	3.1 ±1.7
Lutjanidae	*Lutjanus fulvus*	Flametail snapper	0.01 ±0.01	3.5 ±2.3
	Lutjanus monostigma	Onespot snapper	0.01 ±0.01	2.4 ±1.1

The size and biomass of finfish in the back-reefs of Tikehau were the highest of all the study sites (18 cm and 75 g/m^2), while density was the second highest (0.4 fish/m^2); on the other hand, biodiversity was lowest (23 versus 30 species/transect in Maatea). The trophic structure in Tikehau back-reefs was only slightly dominated by herbivore families in terms of density, and equally composed of carnivores and herbivores in terms of biomass, due to the presence of large-sized Lethrinidae and Lutjanidae (Table 6.9). Similar to the intermediate reefs, Lethrinidae had small average size ratios (34%), suggesting overexploitation. The back-reef of Tikehau had a rather high coverage of mobile bottom (61%) and a relatively high cover of hard bottom (33%). Such differences in substrate may explain the rather diverse composition of families and feeding guilds (both herbivores and carnivores).

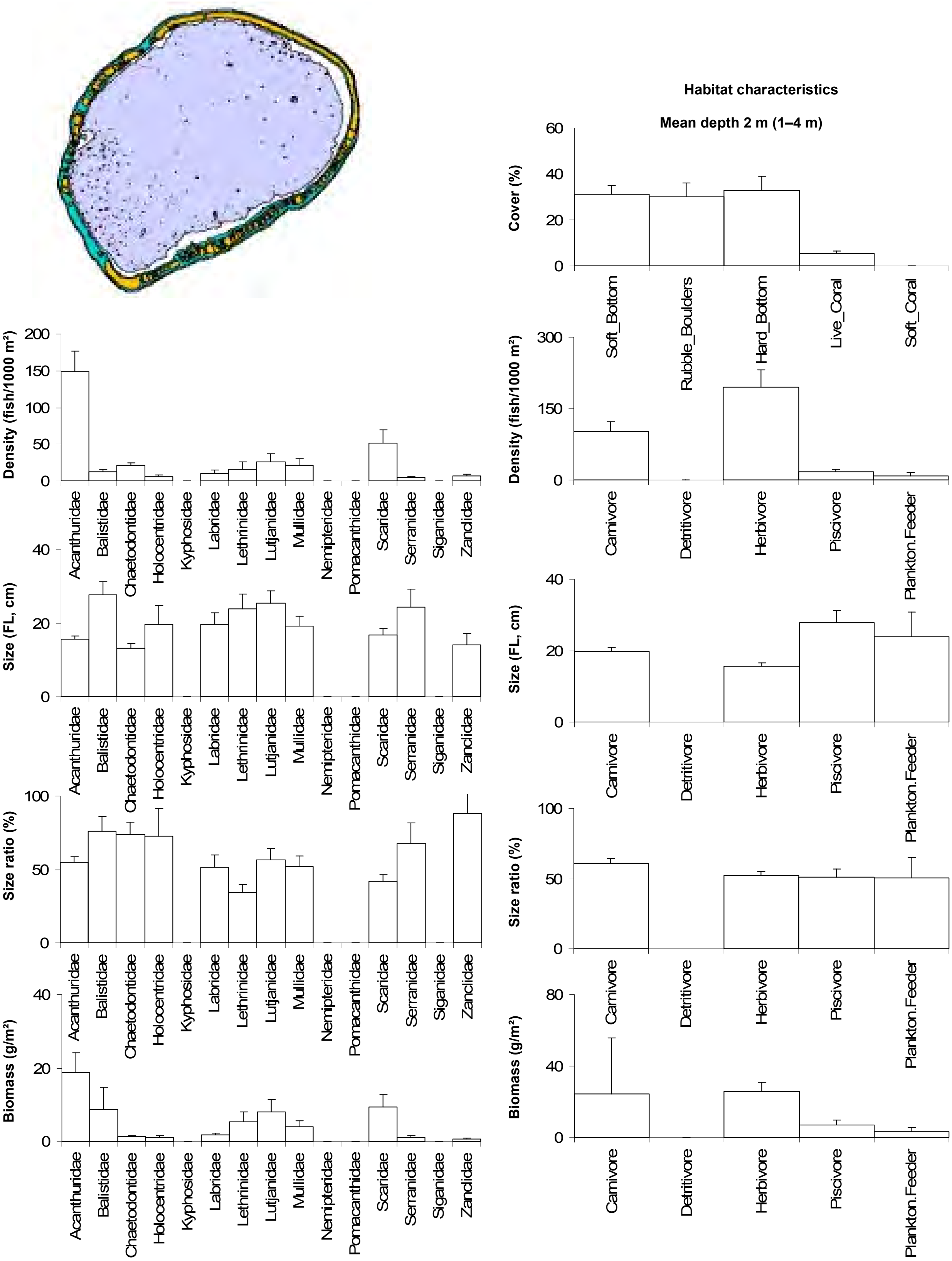

Figure 6.22: Profile of finfish resources in the back-reef environment of Tikehau.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Tikehau

The outer reef of Tikehau was dominated in terms of density and biomass by Acanthuridae and Balistidae and, to a lesser extent and only in terms of biomass, by Scaridae and Serranidae (Figure 6.23). These four families were represented by 32 species; particularly high abundance and biomass were recorded for *Melichthys niger*, *M. vidua*, *Acanthurus nigroris*, *Naso lituratus*, *Hipposcarus longiceps*, *Ctenochaetus striatus*, *Balistapus undulatus*, *A. triostegus*, *Balistoides viridescens*, *Sufflamen bursa*, *A. olivaceus*, *Cephalopholis argus* and *Odonus niger* (Table 6.10). Hard bottom (54% cover) largely dominated this reef habitat, which had a good cover of live corals as well (39 %, Table 6.6 and Figure 6.23).

Table 6.10: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Tikehau

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus nigroris*	Bluelined surgeonfish	0.11 ±0.04	6.4 ±1.9
	Naso lituratus	Orangespine unicornfish	0.01 ±0.01	4.7 ±3.8
	Ctenochaetus striatus	Striated surgeonfish	0.05 ±0.02	3.7 ±1.5
	Acanthurus triostegus	Convict tang	0.05 ±0.01	2.7 ±0.6
	Acanthurus olivaceus	Orangeband surgeonfish	0.01 ±0.00	2.2 ±2.0
Balistidae	*Melichthys niger*	Black triggerfish	0.11 ±0.02	12.2 ±3.3
	Melichthys vidua	Pinktail triggerfish	0.07 ±0.01	6.8 ±1.0
	Balistapus undulatus	Orangestriped triggerfish	0.02 ±0.00	2.9 ±0.6
	Balistoides viridescens	Titan triggerfish	0.00 ±0.00	2.3 ±0.8
	Sufflamen bursa	Scythe triggerfish	0.03 ±0.00	2.3 ±0.2
	Odonus niger	Redtooth triggerfish	0.01 ±0.01	1.7 ±1.7
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.00 ±0.00	4.6 ±2.9
Serranidae	*Cephalopholis argus*	Peacock grouper	0.01 ±0.00	1.9 ±1.0

The density of finfish in the outer reef of Tikehau was the second highest (0.6 fish/m^2) among the outer reefs surveyed in French Polynesia, and equal to Fakarava (Table 6.6). Biomass was, however, the lowest of all sites (70 g/m^2). Biodiversity was the second highest for outer reefs, with 34 species/transect. Size and size ratios displayed intermediate values. However, size ratio was below 50% for Lethrinidae (36%). The trophic structure was dominated by herbivores, and plankton feeders displayed higher density and biomass than carnivores, due mainly to the very high abundance of Balistidae, particularly important in this environment. Serranidae appeared to be more abundant than the other carnivores: Lethrinidae, Lutjanidae and Mullidae. The low abundance of carnivores, especially Lutjanidae and Lethrinidae, is probably a consequence of them being highly targeted in this type of reef. Catches from the outer reefs are mainly for the export market; the use of permanent fish traps is highly productive, therefore imposing a high impact on these resources. The nature of the substrate, mainly hard bottom with a good cover of live coral, provides a perfect habitat for herbivores, here mainly represented by surgeonfish.

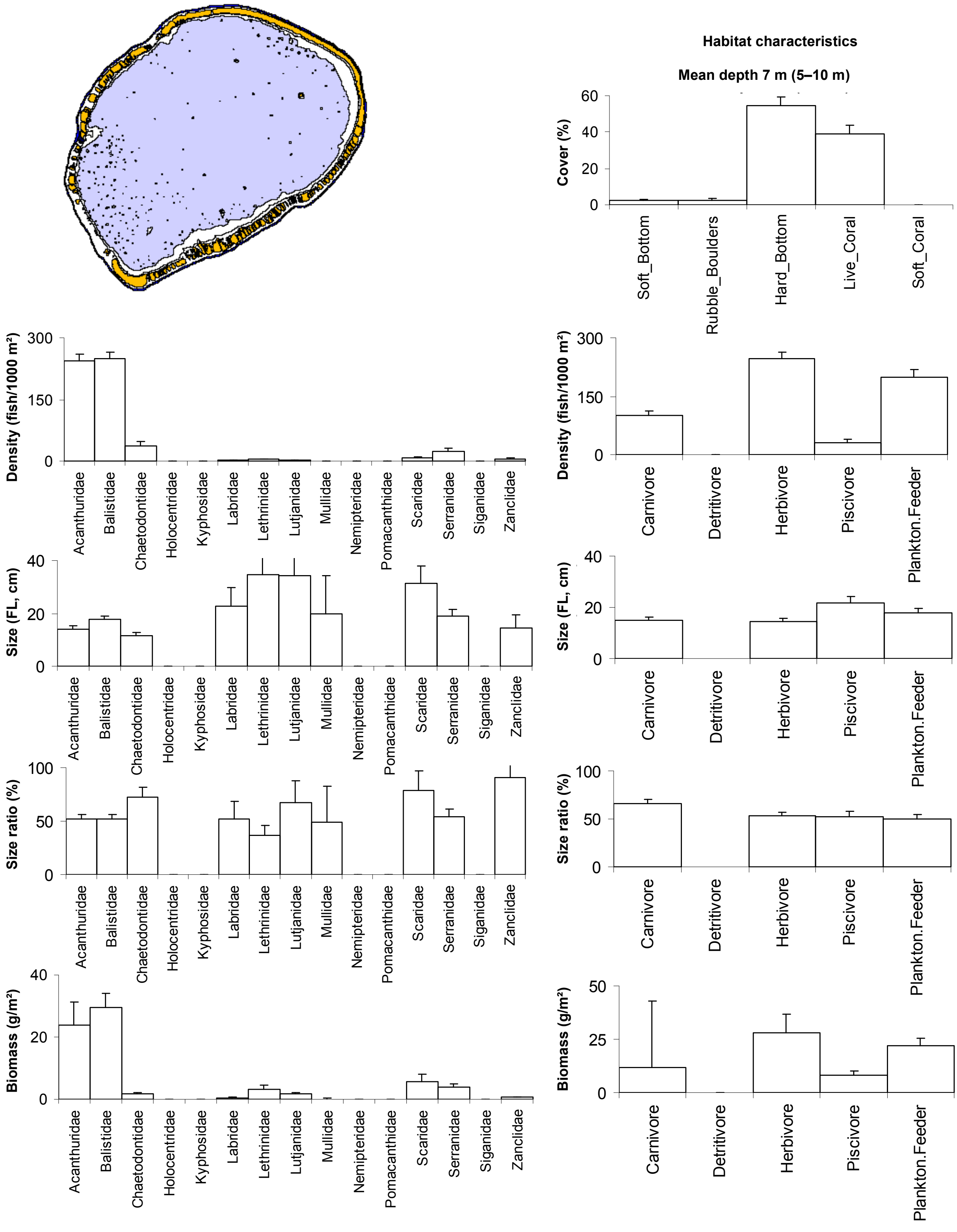

Figure 6.23: Profile of finfish resources in the outer-reef environment of Tikehau.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Tikehau

Overall, the fish assemblage of Tikehau was dominated by Acanthuridae and Scaridae (both in terms of density and biomass) and Balistidae (in term of biomass only, Figure 6.24). These three families were represented by a total of 37 species, dominated (in terms of density and biomass) by *Acanthurus triostegus*, *Chlorurus sordidus*, *Ctenochaetus striatus*, *A. nigroris*, *Melichthys niger*, *A. blochii* and *Pseudobalistes flavimarginatus* (Table 6.11). As expected, the overall fish assemblage in Tikehau shared characteristics of back-reefs (85% of habitat), outer reefs (12%), and to a small extent, back-reefs (3%).

Table 6.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Tikehau (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus triostegus*	Convict tang	0.08	5.4
	Ctenochaetus striatus	Striated surgeonfish	0.03	3.2
	Acanthurus blochii	Ringtail surgeonfish	0.01	2.9
	Acanthurus nigroris	Bluelined surgeonfish	0.02	2.1
Balistidae	*Pseudobalistes flavimarginatus*	Yellow-margin triggerfish	0.01	6.0
	Melichthys niger	Black triggerfish	0.01	1.4
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04	4.8

Overall, Tikehau appeared to support a poorer finfish resource than the other sites, better only than Mataiea, with lowest value of density (0.4 fish/m^2), second-lowest value of biomass (62 versus 103 g/m^2 in Raivavae), and second-lowest biodiversity (28 species/transect versus 33 in Fakarava, Table 6.6). While these results already suggest that the finfish resource in Tikehau is in a poor condition, detailed assessment at family level revealed also a dominance of herbivorous surgeonfish and parrotfish and carnivorous triggerfish (only for biomass), and a very low abundance of other carnivorous families. The average trophic structure for this site was highly dominated by herbivores in both density and biomass terms. Size structure revealed low size ratios for Lethrinidae and Scaridae, indicating a high exploitation of these target families. The substrate composition was dominated by hard bottom (36%) with also a high percentage of soft bottom (27%); this combination would generally ensure good habitat choice for both herbivores and carnivores. As a consequence, the scarcity of carnivores is probably due to high fishing pressure.

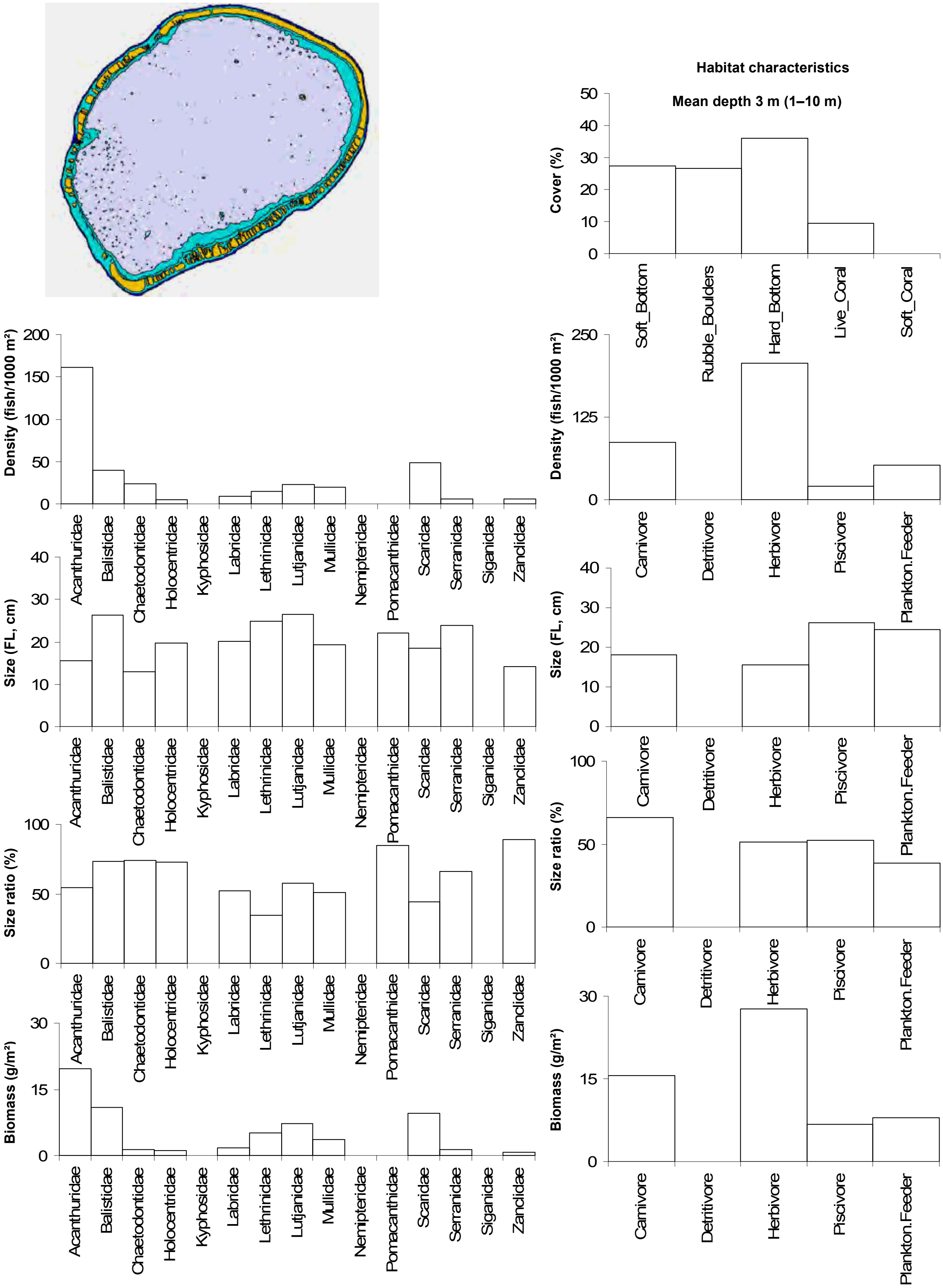

Figure 6.24: Profile of finfish resources in the combined reef habitats of Tikehau (weighted average).
FL = fork length.

6.3.2 Discussion and conclusions: finfish resources in Tikehau

The finfish resource survey indicated that the status of finfish resources in Tikehau was poorer than the average across French Polynesia study sites. Density, biomass and biodiversity were similar to values found at Mataiea, the lowest recorded in the country. Tikehau reefs displayed among the lowest values of density and biomass of all herbivores, especially Acanthuridae and Scaridae. Density of carnivores was also in the lower range, which cannot be explained by the type of habitat, since in general this is composed of a similar cover of hard and soft bottom. The low density of carnivores and, indeed, of all fish in general, is directly related to intense fishing imposed upon these reefs, especially on the internal reefs, which has impacted the fish populations in terms of abundance and size and therefore total biomass.

- Overall, Tikehau finfish resources appeared to be in a rather poor condition. Although reef habitats seemed relatively rich, the finfish resources, especially those in the back- and intermediate reefs, displayed among the lowest values in the country.

- The populations of Lutjanidae, Lethrinidae and Mullidae were extremely low, although this is a general trend for all sites in the country. This cannot possibly be due to a lack of suitable habitats, since all types of substrate are well represented in Tikehau. This site has the highest average cover of soft bottom, which generally favours carnivores, such as Lethrinidae and Mullidae. The cause of this scarcity is related to the fishing pressure.

6.4 Invertebrate resource surveys: Tikehau

The diversity and abundance of invertebrate species at the site were independently determined using a range of survey techniques (Table 6.12): broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 6.25) and finer-scale assessment of specific reef and benthic habitats (Figures 6.26 and 6.27).

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

Table 6.12: Number of stations and replicate measures completed at Tikehau

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	13	78 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)	2	12 transects
Mother-of-pearl searches (MOPs)	2	12 search periods
Reef-front searches by walking (RFs_w)	4	24 search periods
Sea cucumber day searches (Ds)	2	12 search periods
Sea cucumber night searches (Ns)	2	12 search periods

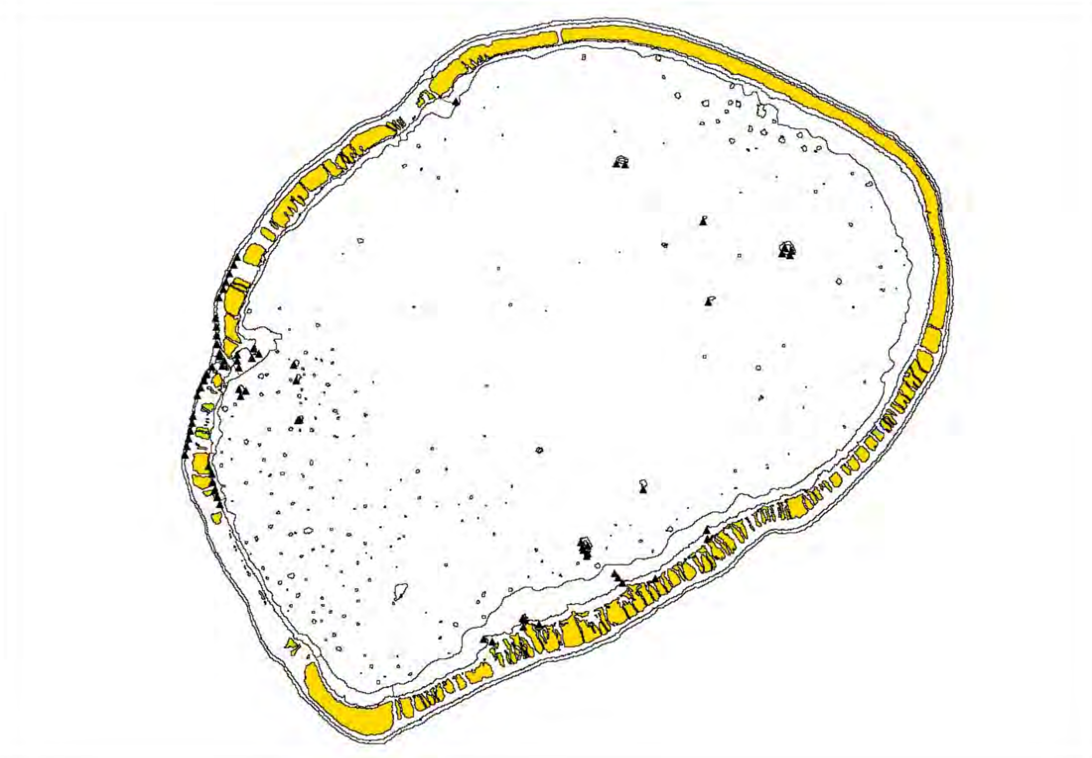

Figure 6.25: Broad-scale survey stations for invertebrates in Tikehau.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

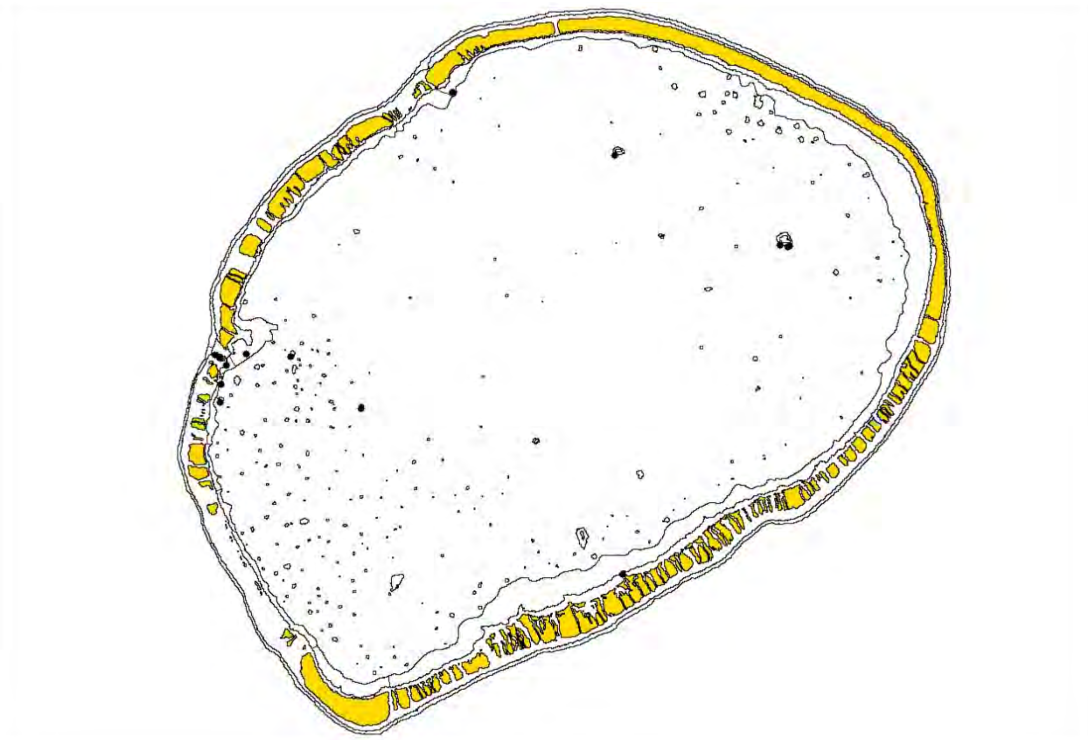

Figure 6.26: Fine-scale reef-benthos transect survey stations for invertebrates in Tikehau.
Black circles: reef-benthos transect stations (RBt).

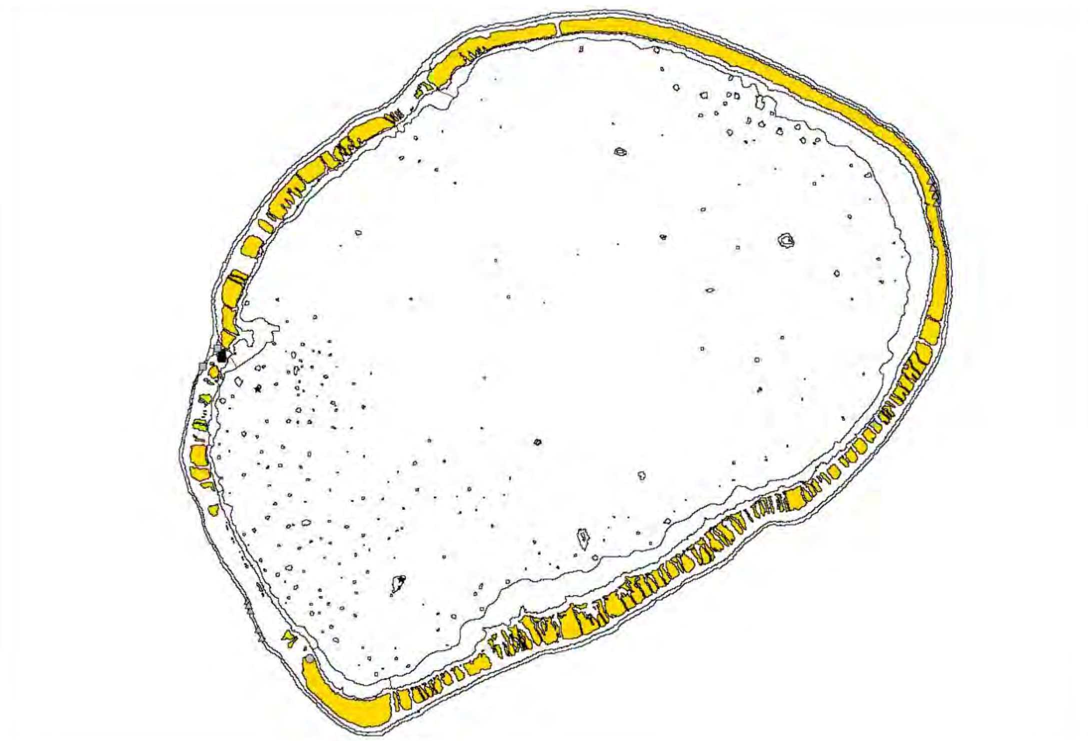

Figure 6.27: Fine-scale survey stations for invertebrates in Tikehau.
Inverted grey triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
black squares: mother-of-pearl transect stations (MOPt);
grey circles: sea cucumber night search stations (Ns; one circle as no boat support);
grey stars: sea cucumber day search stations (Ds).

Twenty-one species or species groupings (groups of species within a genus) were recorded in the Tikehau invertebrate surveys: 4 bivalves, 7 gastropods, 5 sea cucumbers, 3 urchins, and 1 sea star (Appendix 4.5.1). Information on key families and species is detailed below.

6.4.1 Giant clams: Tikehau

Broad-scale sampling provided an overview of giant clam distribution at Tikehau. Shallow-reef habitat that is suitable for giant clams was not as extensive as it first appeared as there were significant amounts of sandy areas; however, there was approximately 37.7 km^2 (approximately 21.1 km^2 within the lagoon and 16.6 km^2 on the reef front or slope of the barrier). Unlike the high-island PROCFish/C sites of Mataiea and Raivavae, the lagoon at Tikehau was relatively deep and greatly influenced by oceanic conditions. Although the barrier reef almost fully enclosed the lagoon (with one major passage), the low island site was relatively open to the elements and had very dynamic water flow at the westerly pass and across the barrier at various *hoa* (Part of the island was under water at high tide.). Various patch reefs (and *motu*) could be found along the stretch between the pass and the more enclosed southern side of the atoll, near the main settlement. There were no rivers on the low lying atoll, although the effects of run-off (nutrients) were noticeable on inshore reefs close to the main settlement.

Reefs at Tikehau held one species of giant clam: the elongate clam *Tridacna maxima*. Records from broad-scale sampling revealed that *T. maxima* was widely distributed (found in 13 of 13 stations and 72 of 78 transects). The average station density of *T. maxima* in broad-scale assessments was 559.4 /ha ±153.9, Figure 6.28).

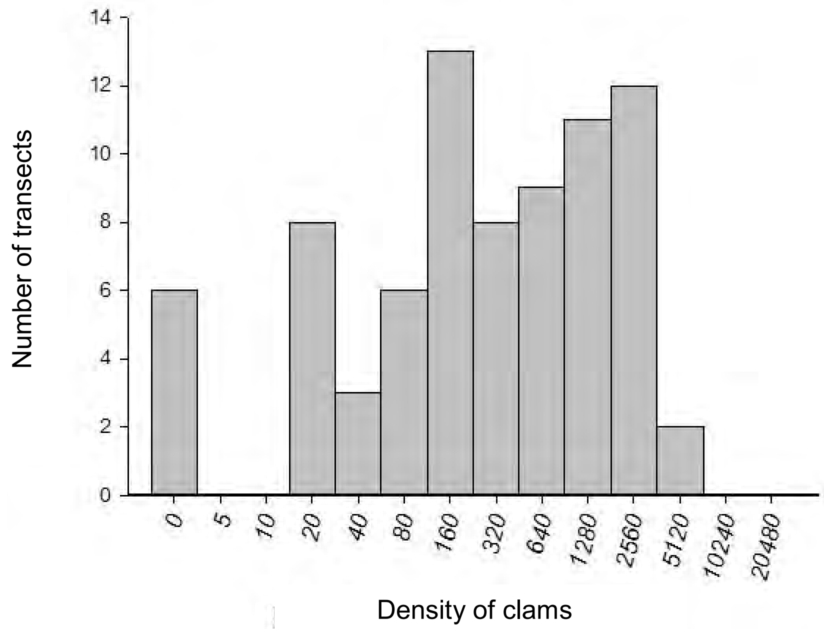

Figure 6.28: Frequency plot of density per 300 m transect measures (per ha) for *Tridacna maxima* clam at Tikehau, based on all broad-scale assessment stations.
Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 6.29). In these reef-benthos assessments (RBt), *T. maxima* was present in 85% of stations at a mean density of 2945.5 /ha ±878.2.

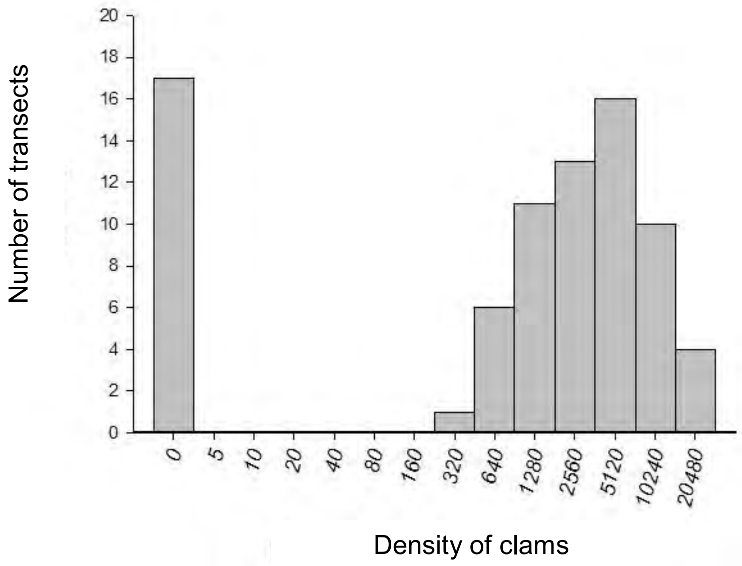

Figure 6.29: Frequency plot of density per 40 m transect measures (per ha) for *Tridacna maxima* clam at Tikehau, based on all fine-scale reef-benthos transect assessment stations. Density = numbers/ha, recorded on a geometric progression with common ratio 2, i.e. each interval is double the value of the previous.

At the seven RBt stations with the greatest mean density of *T. maxima* (range 2042–10,833 /ha), the top five were situated in the current, on patch reefs near the pass (as might be expected); the other two were found in a more enclosed area in the north of the lagoon. The greatest density of clams per 40 m^2 transect in Tikehau was at a station close to the pass (13,500 clams/ha, or >1.3 clams/m^2).

Of the 541 records taken during all assessment techniques, the average length of *T. maxima* was 8.1 cm ±0.2. The mean from shallow reef-benthos stations was slightly lower at 7.3 cm ±0.1. A full range of lengths for *T. maxima* was recorded in survey, although clams were generally smaller than found in other parts of the Pacific. Larger clams (≥16 cm) were rare in shallow water and were mainly restricted to reefs in more exposed locations (Mean clam size from mother-of-pearl SCUBA surveys was 12.4 cm, Figure 6.30.).

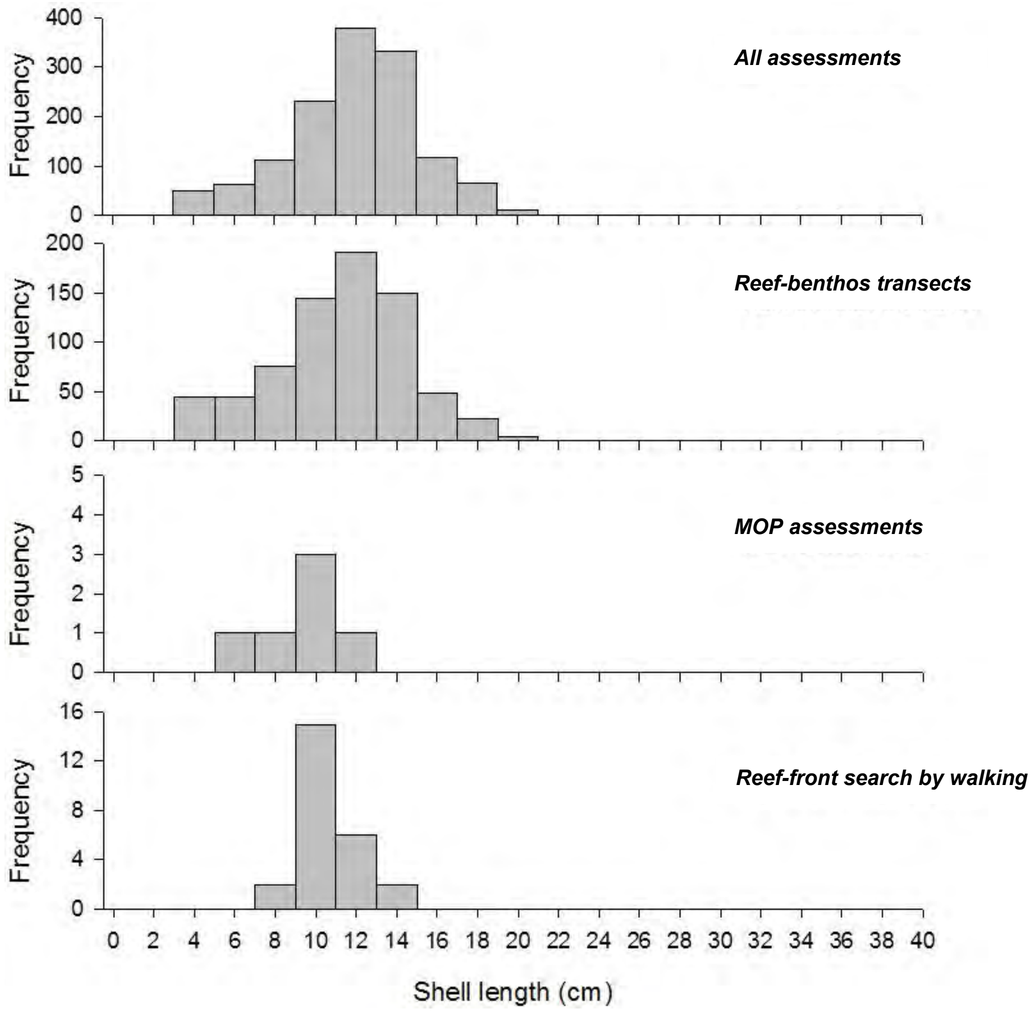

Figure 6.30: Size frequency histograms of giant clam shell length (cm) for Tikehau.

6.4.2 Mother-of-pearl species (MOP) – trochus and pearl oysters: Tikehau

Tikehau, located at approximately 15°S, is well within the latitude of the commercial topshell, *Trochus niloticus* in the Pacific, but French Polynesia is positioned to the east of the natural distribution of this species. Although not endemic, 60 *T. niloticus* shells were introduced to Tikehau in 1969, from the stock originally transplanted from Port Vila (Vanuatu) to Tahiti in 1957 (Yen 1988). The purpose of introducing trochus was to counteract the gradual depletion of pearl shell stocks in French Polynesia (Cheneson 1997).

The outer and lagoon reefs at Tikehau constitute extensive benthos suitable for *T. niloticus*, and this area could potentially support significant populations of this commercial species (79.6 km lineal distance of exposed reef perimeter). PROCFish/C survey work revealed that *T. niloticus* was mainly present at reefs around the main passage at Tikehau, although some were found on reefs in the lagoon. The outer-reef slope and barrier reeftops did not hold significant numbers of trochus (Table 6.13). The suitability of reefs for grazing gastropods was highlighted by trochus records, but there were no results for the great green turban, *Turbo marmoratus*, which has not been successfully introduced to Tikehau, or for the green topshell, *Tectus pyramis*, a species that does not extend as far east as French Polynesia (only as far east as Tuvalu, Samoa and Tonga).

Table 6.13: Presence and mean density of *Trochus niloticus* and *Pinctada margaritifera* in Tikehau
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Trochus niloticus				
B-S	15.0	7.5	5/13 = 38	11/78 = 14
RBt	1253.2	572.3	9/13 = 69	36/78 = 46
RFs_w	0	0	0/4 = 0	0/24 = 0
MOPs	7.6	7.6	1/2 = 50	2/12 = 17
MOPt	364.6	72.9	2/2 = 100	9/12 = 75
Pinctada margaritifera				
B-S	1.3	0.4	6/13 = 46	6/78 = 8
RBt	16.0	7.5	4/13 = 31	5/78 = 6
RFs_w	0	0	0/4 = 0	0/24 = 0
MOPs	0	0	0/2 = 0	0/12 = 0
MOPt	0	0	0/2 = 0	0/12 = 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; MOPt = mother-of-pearl transect.

The distribution of trochus was not limited across the lagoon in Tikehau (total n = 483 individuals recorded); however, the majority of the stock was localised to the inside arms of the main passage. The density of trochus at three stations at the south arm of the passage ranged from 2083 to 6667 individuals/ha. No stations had a density nearing 1 /m^2, as was found in Mataiea, despite five of the 13 RBt stations having densities over 600 /ha. This threshold of 600 /ha is the suggested minimum density that main aggregations should be found at before commercial fishing should be considered. However, as already mentioned, the distribution of high-density aggregations was spatially skewed in Tikehau. Trochus were mainly found in the pass; few were seen on the extensive reef slope and barrier reeftop at Tikehau. It is suggested that the very large oceanic swells (related to the morphology of reef) and the low levels of epiphytic growth on these substrates might limit the presence of trochus in these more oceanic-influenced locations. The overall picture of distribution, and the density of aggregations should be taken into account if fishing is considered. There may be greater merit in transplanting trochus from the passage to other suitable areas of Tikehau to stimulate growth of stock.

Although small trochus are very cryptic, shell size-class results (Figure 6.31) indicate that recruitment is taking place and new, young trochus are entering the population (First maturity of trochus is at 7–8 cm, or approximately three years of age.). The mean basal width of trochus at Tikehau was 10.4 cm ±0.08 (n = 338). The presence of 35% of the measured stock above the legal size of 11 cm highlights the significant number of older mature shells (i.e. valuable broodstock) that would be protected from fishing if there were any commercial harvests. This estimate of the protected portion of the population is conservative, as shallow-reef assessments would not target larger shells, as they predominantly live deeper than smaller, younger trochus.

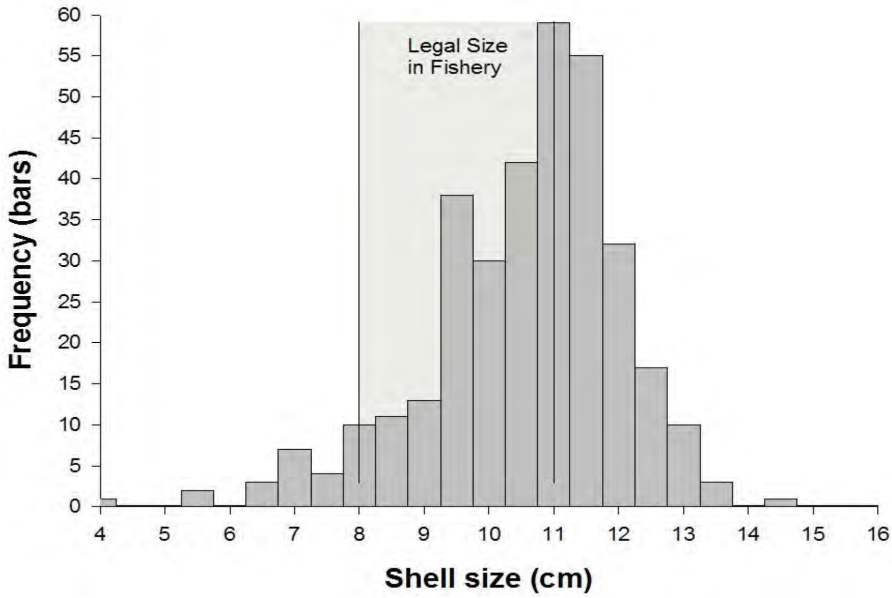

Figure 6.31: Size frequency histogram of trochus shell base diameter (cm) for Tikehau.

Despite blacklip pearl oysters, *Pinctada margaritifera,* being cryptic and normally sparsely distributed in open lagoon systems (such as those found at Tikehau), they were still surprisingly rare, with only eleven shells recorded in survey (mean anterior–posterior measure 12.7 cm ±0.7).

6.4.3 Infaunal species and groups: Tikehau

The soft-benthos coastal margin of the shallow-water lagoon was sandy, without seagrass or muddy areas, and did not hold concentrations of in-ground resources (shell 'beds') such as arc shells *Anadara* spp. or venus shells *Gafrarium* spp. Therefore no fine-scale assessments or infaunal stations (quadrat surveys) were made on soft benthos.

6.4.4 Other gastropods and bivalves: Tikehau

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded at low density in broad-scale and finer-scale surveys (six individuals recorded), but *Lambis lambis* and the strawberry or red lipped conch *Strombus luhuanus* were not present (Appendices 4.5.2 to 4.5.7). Of the small turban shells, only *Turbo setosus* was recorded, at medium density on RFs_w stations (272 individuals recorded, mean size 6 cm). Other species targeted by fishers (resource species, e.g. *Chicoreus*, *Conus*, *Cypraea* and *Thais*) were also recorded during independent survey (Appendices 4.5.2 to 4.5.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus*, are also in Appendices 4.5.2 to 4.5.7. No creel survey was conducted at Tikehau although there was a local icecream tub full of *T. setosus* meat to order at the time we were working in Tikehau.

6.4.5 Lobsters: Tikehau

Tikehau had 80 km (lineal distance) of exposed reef front (barrier reef). This exposed reef front, with *hoa* and areas of submerged back-reef, represents a significant habitat for lobsters, which settle as transparent miniature versions of the adult (pueruli, 20–30 mm in length) after 6–12 months of floating in ocean currents.

There was no dedicated night reef-front search for lobsters (See Methods and Appendix 1.3.), and no lobsters (*Panulirus* spp. or *Parribacus* spp.) were recorded in the survey. Night searches (Ns) for nocturnal sea cucumber species were conducted, which provided a further opportunity to see lobster species, but none were observed.

6.4.6 Sea cucumbers[11]: Tikehau

Tikehau is a relatively enclosed atoll reef system, with an extensive, deep-water lagoon (approximately 15–20 m deep in many places) with many patch reefs and *motu*. Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were common in the lagoon; however, outside the barrier reef, the reef slope shelved off relatively steeply and was subject to a very large swell. The whole system was generally oceanic, especially near the main passage and barrier overflows; however, large parts of the main lagoon were relatively stagnant. At Tikehau, only five commercial species of sea cucumber were recorded during in-water assessments (Table 6.14), the lowest number for PROCFish sites in French Polynesia.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 6.14, Appendix 4.5, also see Methods). The low range of sea cucumber species reflected the easterly position of French Polynesia compared to PROCFish sites in countries closer to the centre of biodiversity (situated further west in the Pacific) and also the lack of nutrient inputs in the atoll system to feed sea cucumbers (Many species eat organic matter in the upper few mm of bottom substrates.). However, the varied environment of the lagoon, passages and barrier reef of Tikehau suited some species that are more tolerant of oceanic influences. In deep-water assessments (average depth 17.7 m), white teatfish (*Holothuria fuscogilva*) were not found; and the benthos was quite soft (made up of settled, fine sediments) which is generally not preferred by this species. Prickly redfish (*Thelenota ananas*) was found in deep and shallow water at low density (only 4 individuals seen).

Of the other species, those associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were relatively uncommon (found in 17% of broad-scale but not in fine-scale assessments), and no high-value black teatfish (*Holothuria nobilis*) were recorded, despite there being significant areas within the back-reef suitable for this species. Only surf redfish (*Actinopyga mauritiana*) was recorded at any reasonable density. On RFs_w assessments of the barrier, especially in the exposed southwest area of Tikehau, water originating from surf and spray kept the reeftop and pools near the reef front replenished with sea water. At these locations, 12 search replicates yielded density estimates ranging from 22 to 144 /ha. On the northeastern reeftop surf redfish were less common. The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was not found at any sites in French Polynesia.

More protected areas of reef and soft benthos in the more enclosed areas of the lagoon did not include blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), pinkfish (*Holothuria edulis*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*) although lower-value species, e.g. lollyfish (*H. atra*) and brown sandfish (*Bohadschia vitiensis*), were moderately

[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.

common. The brown sandfish is well suited to the softer benthos that covers the lagoon floor in less dynamic areas of the lagoon (noted during the sea cucumber deep dive in the southeast of the lagoon).

6.4.7 Other echinoderms: Tikehau

Edible urchins, such as the slate urchin *Heterocentrotus mammillatus*, were very common on the barrier reef front. Very high densities were noted. A single collector urchin, *Tripneustes gratilla*, was recorded in assessments. Other urchins that can be used within assessments as a food source or as potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at relatively low levels (broad-scale and reef-benthos stations, see Appendices 4.5.1 to 4.5.7).

Starfish were very rare at Tikehau; the blue starfish (*Linckia laevigata*) was absent and only three pincushion stars (*Culcita novaeguineae*) were noted in the species group of coralivore starfish. No crown of thorns (*Acanthaster planci*) was noted.

Table 6.14: Sea cucumber species records at Tikehau

Species	Common name	Commercial value [5]	B-S transects n = 78			Reef stations n = 13			Other RFs_w = 4			Other Ds = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	1.7	66.7	3	38.5	250.0	15	30.1	40.1	75			
Bohadschia argus	Leopardfish	M	3.6	21.8	17									
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L	24.8	96.7	26	16	52.1	31						
Holothuria atra	Lollyfish	L	18.6	181.3	10	28.8	187.5	15						
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria leucospilota	-	M												
Holothuria nobilis [4]	Black teatfish	H												
Stichopus horrens	Peanutfish	M												
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H	0.2	16.7	1							5.4	10.7	50
Thelenota anax	Amberfish	M												

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

6.4.8 Discussion and conclusions: invertebrate resources in Tikehau

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 in the body of the invertebrate chapter.

- Tikehau had extensive reef suitable for the elongate clam, *Tridacna maxima*. Clams were common and at high density in the passage area, and were also found at reasonably high density on reefs in the lagoon. However, in comparison, clam densities can be higher for partially enclosed atoll systems in other parts of French Polynesia. *T. maxima* displayed a 'full' range of size classes, although there was no build-up of large clams. This supports the assumption that clam stocks are marginally impacted by fishing pressure. The number of small clams in the size range indicates that spawning and recruitment are not generally affected.

- Trochus, *Trochus niloticus*, were relatively common at Tikehau but mainly limited to within the pass and lagoon. The protection of trochus broodstock (sizes 11 cm and up), and the 'resting' of stock between commercial fishing periods are considered the main reasons why stocks at Tikehau are in the condition found during survey.

- The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Tikehau.

There is a restricted range of sea cucumber species at Tikehau (due to biogeographical influence), and not good potential for commercial harvesting of sea cucumbers.

6.5 Overall recommendations for Tikehau

- While respondents were generally content with the status of their marine resources as well as with the income opportunities that they provide, major concern was expressed about statements to the opposite by visiting researchers and scientists. People were concerned that these misconceptions might cause fisheries managers to put in place regulations to limit their current and future fishing activities. Community meetings and discussions between Fisheries and Community Authorities and the Tikehau community members and fishers are recommended to clarify these concerns, to exchange information and data available and to jointly discuss any necessary fisheries management measures.

- The current level of exploitation of fisheries appeared to be dangerously high and impacting the resources. This should be carefully managed, to ensure stocks are conserved for future generations. The present level of fishing for export appears to be unsustainable in the long term.

- Use of *parcs* (fish traps) should be regulated since they are targeting carnivorous species in a too efficient manner. Spearfishing should be banned and also the use of gillnets in the inner reefs. Although the density of fishermen is still low in these reef habitats, the impacts are already apparent as low density and biomass in coastal as well as intermediate reefs.

- A recovery approach to fisheries management may consist in trying to limit catch of snappers, emperors and goatfish in the inner reefs (back, intermediate and coastal reefs).

- Considering the high quality of habitat in Tikehau, marine protected areas should be considered as a primary management tool.

- The density and size range of trochus noted in survey suggests that limited fishing could be made at areas of greatest abundance, as a density figure of 500–600 /ha is suggested as a threshold for the commencement of fishing. If harvests are considered, some movement of stock from the pass to other suitable areas within Tikehau (possibly reeftop of barrier) may be beneficial to extending the range of trochus in Tikehau.

- Surf redfish abundance should be monitored, as there is some potential for harvests of this species.

- Further assessment is needed for the deeper water white teatfish stock (*Holothuria fuscogilva*); however the preliminary investigation did not highlight promising results for this species.

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APPENDIX 1: SURVEY METHODS

1.1 Socioeconomic surveys, questionnaires and average invertebrate wet weights

1.1.1 Socioeconomic survey methods

Preparation

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

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

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

Approach

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

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

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

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

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

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

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

Sampling

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

Data collection and analysis

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

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

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

The questionnaires are designed to allow a minimum dataset to be developed for each site, one that allows:

- the community's dependency on marine resources to be characterised;
- assessment of the community's engagement in and the possible impact of finfish and invertebrate harvesting; and
- comparison of socioeconomic information with data collected through PROCFish/C resource surveys.

Household survey

The major objectives of the household survey are to:

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

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

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

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

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

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

The frequency and amount of remittances received from family members working elsewhere in the country or overseas enable us 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 and 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).

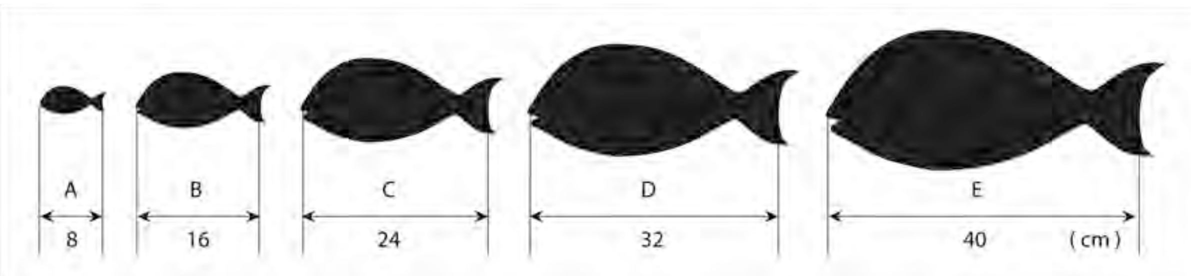

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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 $class_i$

Appendix 1: Survey methods
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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

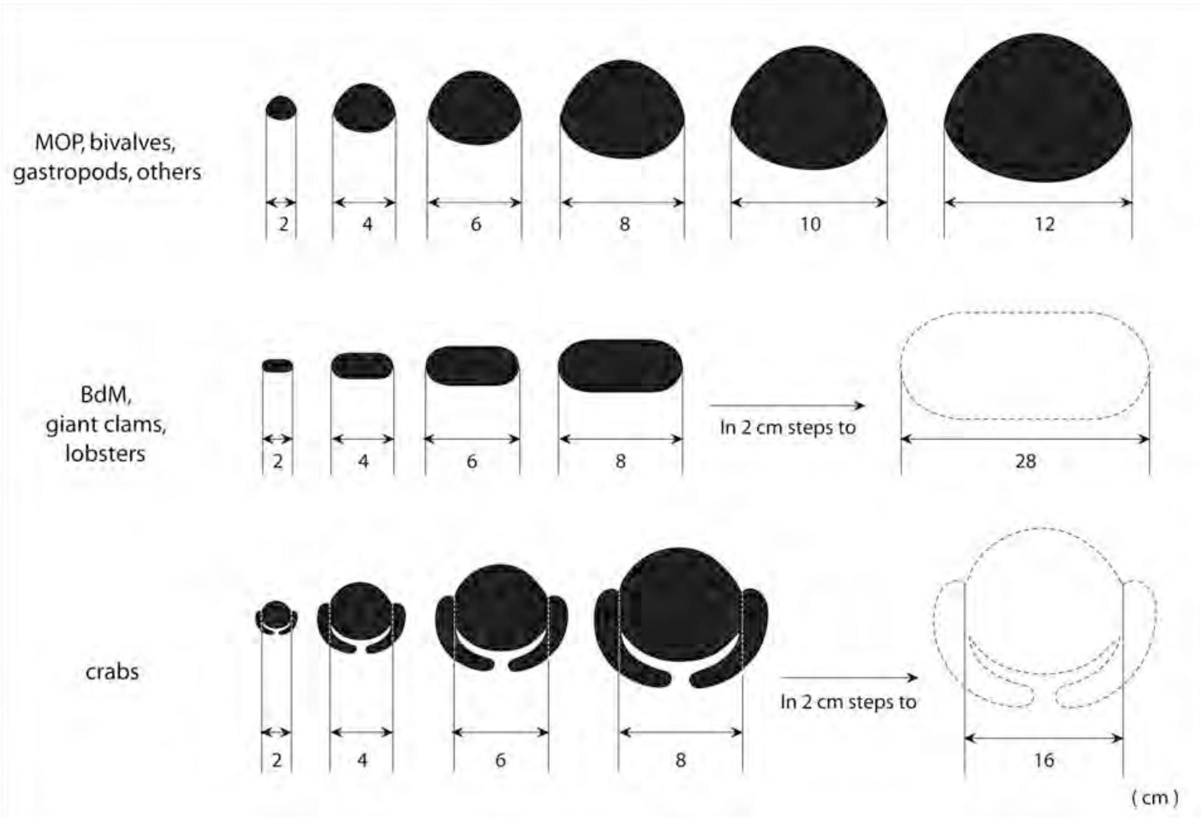

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

Appendix 1: Survey methods
Socioeconomics

Finfish fisher survey

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

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

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

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

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

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

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

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

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

Determination of fishing strategies includes:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Socioeconomics

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

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

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

Total annual catch (t/year):

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

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

Where:

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

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

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

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

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

<u>Total annual finfish export:</u>

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

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.

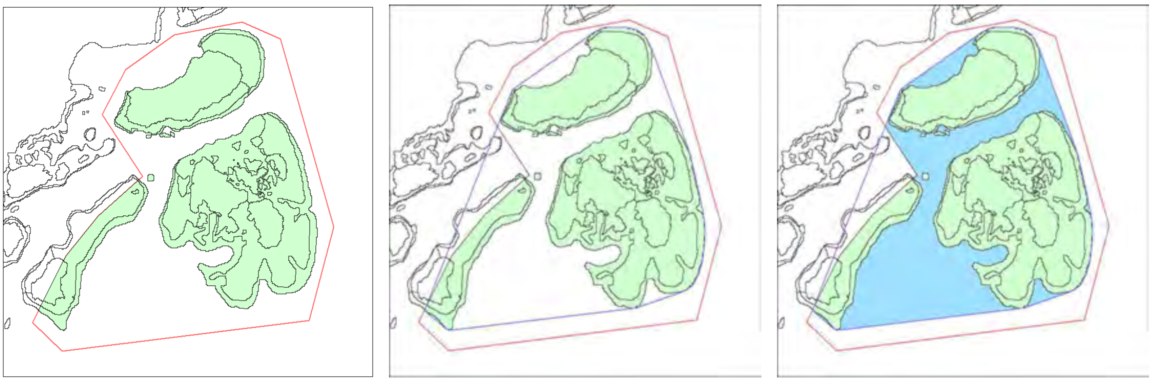

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as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

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:

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

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:

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

$I_{inv}f_h$ = number of interviews of female invertebrate fishers for habitat$_h$ (total numbers of interviews where female invertebrate fishers provided detailed information for habitat$_h$)
f_i = frequency of fishing trips (trips/week) as reported in interview$_i$

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

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

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

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

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

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

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

Data entry and analysis

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

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

1.1.2 Socioeconomic survey questionnaires

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

HOUSEHOLD CENSUS AND CONSUMPTION SURVEY

HH NO. ☐

Name of head of household: ________________ Village: _________________

Name of person asked: _____________________ Date: __________________

Surveyor's ID: __________________

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

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

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

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

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

5. Does this household have any agricultural land?

yes ☐ no ☐

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

for permanent/regular cultivation ☐ (unit)

for permanent/regular livestock ☐ (unit)

type of animals__________ no. ☐

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

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

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

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

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

Fishing/seafood collection ☐

Agriculture (crops & livestock) ☐

Salary ☐

Others (handicrafts, etc.) ☐ specify: ____________________

11. Do you get remittances? yes ☐ no ☐

12. How often?

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

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

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

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

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

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

CONSUMPTION SURVEY

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

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

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

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

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

Other seafood

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

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

☐ medium

☐ big

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

Fish:

☐ caught by myself/member of this household

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

☐ buy it at ______________________

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

Invertebrates:

☐ caught by myself/member of this household

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

☐ buy it at ______________________

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

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

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

–THANK YOU–

FISHING (FINFISH) AND MARKETING SURVEY

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

Name of head of household: _______________________ Village: ______________

Surveyor's name: _____________________ Date: ______________

1. Which areas do you fish?

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

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

Yes ☐ no ☐

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

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

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

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

5. Do you use a boat for fishing?

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

6. If you use a boat, which one?

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

coastal reef ☐ lagoon ☐ outer reef ☐

2
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

3
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

7. How many fishers ALWAYS go fishing with you?

Names:____
____
____
____

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 <u>don't</u> you fish?

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

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

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep bottom line ☐ poison: which one? ______________

☐ other, specify: ____

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

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

____

8. Do you use ice on your fishing trips?

☐ always ☐ sometimes ☐ never

☐ is it homemade? ☐ or bought?

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

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

10. Do you sell fish? yes ☐ no ☐

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

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

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

kg ☐ <u>OR:</u>

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

and the rest you gift? yes ☐

how much? kg ☐ <u>OR:</u>

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

and/or sell? yes ☐

how much? kg ☐ <u>OR</u>:

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

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

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

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

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

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

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

Specify the number by size

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

20. Do you also fish invertebrates?

Yes ☐ no ☐ <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?

(if the fisher can't specify, tick the box)

	times/week		duration in hours <2	2–4	4–6	>6	glean/dive at D	N	D&N	fish no. of months/year
☐ seagrass gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mangrove & mud gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ sand & beach gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ reeftop gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ bêche-de-mer diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ lobster diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mother-of-pearl diving trochus, pearl shell, etc.	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ other diving (clams, octopus)	☐	____	☐	☐	☐	☐	☐	☐	☐	________

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

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

   yes ☐ no ☐

   If yes, where? ____

5. Do you finfish? yes ☐ no ☐

   for: ☐ consumption? ☐ sale?

   at the same time? yes ☐ no ☐

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

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

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

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

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

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

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

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				

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

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

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

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

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

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

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

FISHERIES (FINFISH AND INVERTEBRATE AND SOCIOECONOMICS) GENERAL INFORMATION SURVEY

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

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

a) legal/Ministry of Fisheries

b) traditional/community/village determined:

2. What do you think – do people obey:

traditional/village management rules?

mostly ☐ sometimes ☐ hardly ☐

legal/Ministry of Fisheries management rules?

mostly ☐ sometimes ☐ hardly ☐

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

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

a) finfishing

gillnets – most-used mesh sizes:

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

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

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

Seasonality of species

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

Vernacular name	Scientific name(s)	Months NOT fished

Seasonality of species

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

Vernacular name	Scientific name(s)	Months NOT fished

Appendix 1: Survey methods
Socioeconomics

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

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

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

GLEANING (soft bottom = seagrass)

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other __________

GLEANING (soft bottom = mangrove & mud)

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other __________

GLEANING (soft bottom = sand & beach)

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

GLEANING (hard bottom = reeftop)

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

DIVING (bêche-de-mer)

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

DIVING (lobster)

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

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

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

DIVING (other, such as clams, octopus)

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

Any traditional/customary/village fisheries?

Name:

Season/occasion:

Frequency:

Quantification of marine resources caught:

Species name	Size	Quantity (unit?)

1.1.3 Average wet weight applied for selected invertebrate species groups

Unit weights used in conversions for invertebrates.

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

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

Unit weights used in conversions for invertebrates.

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

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

Unit weights used in conversions for invertebrates.

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

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

1.2 Methods used to assess the status of finfish resources

Fish counts

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

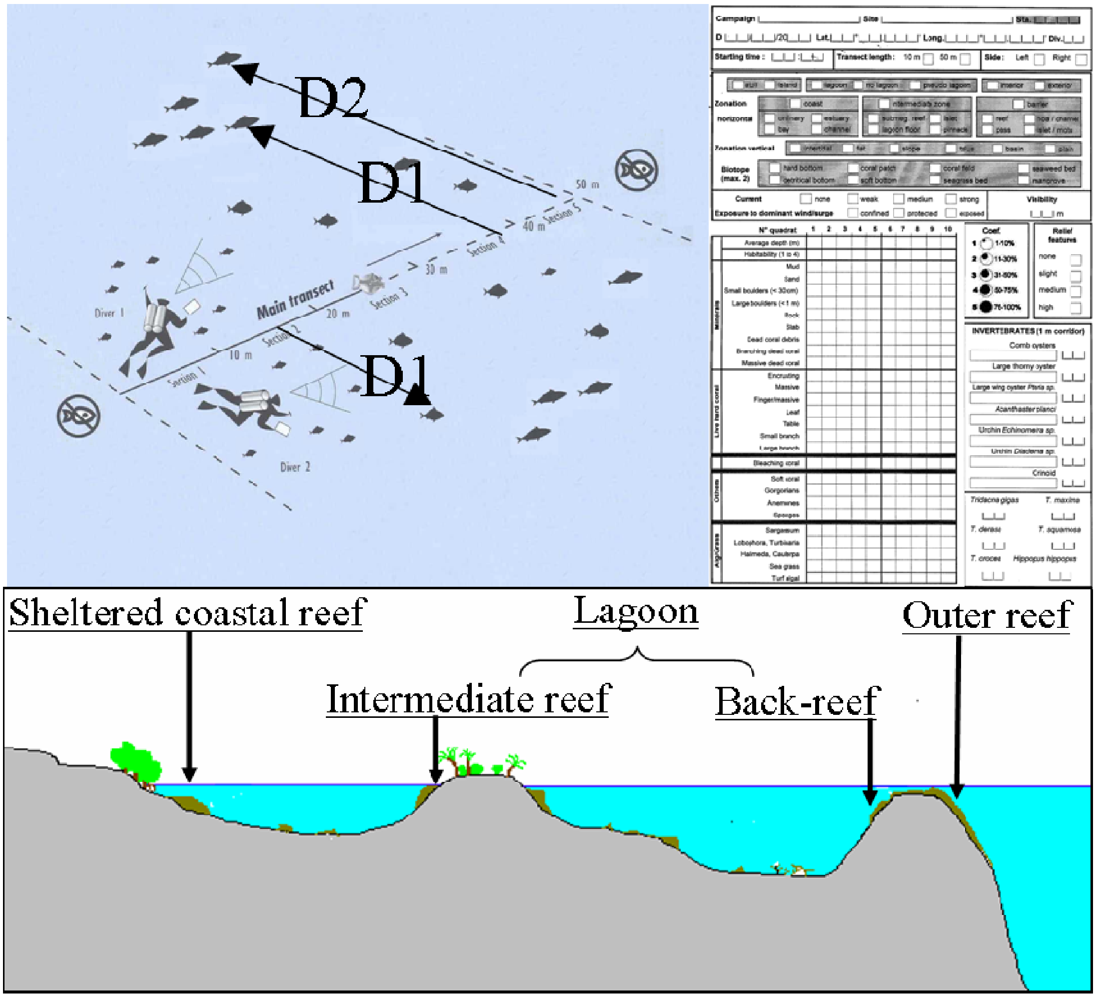


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

Species selection

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

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

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

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

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 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 1,000 categories. These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the needs of the finfish resource assessment, MCRMP reef types were grouped into the four main coralline geomorphologic structures found in the Pacific (Figure A1.2.2):

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

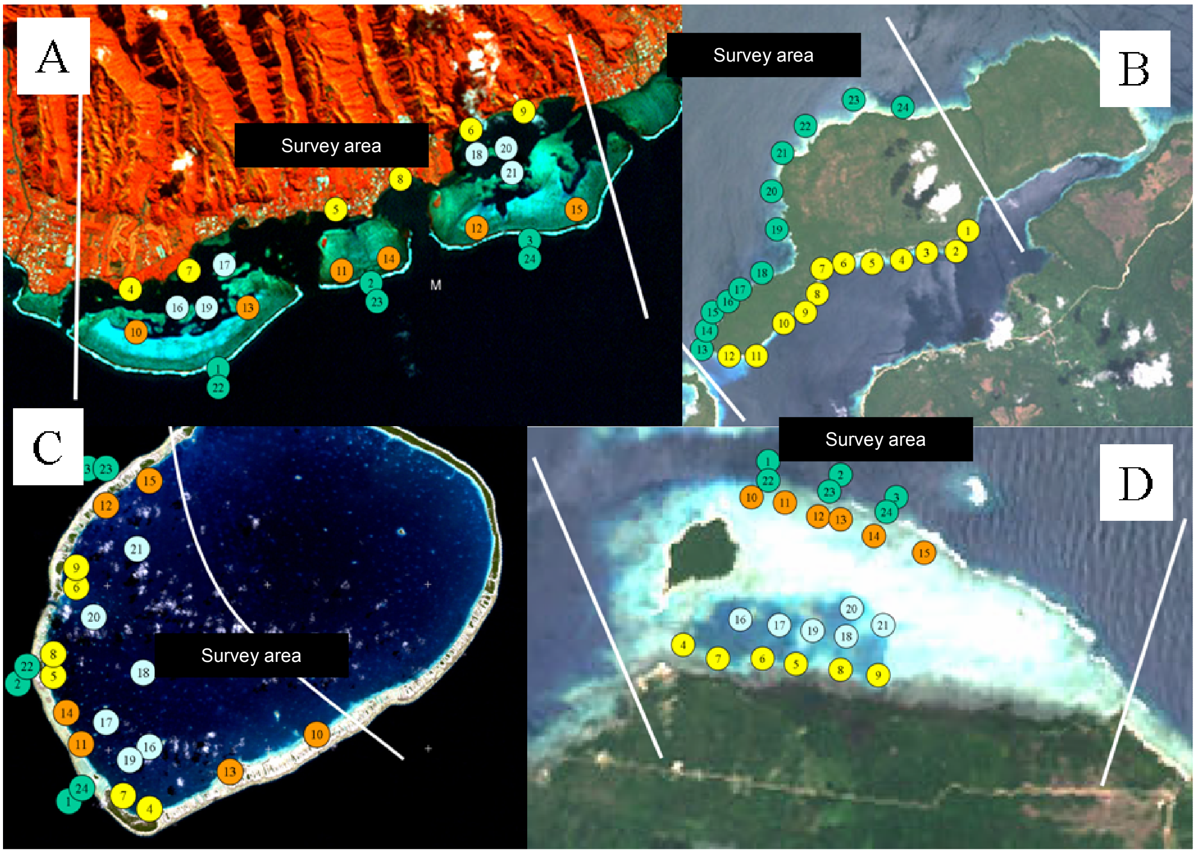


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon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

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

Scaling

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

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

Where:

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

A comparative approach only

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

Campaign |______________| Site |______________________| Diver |__|__| Transcect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|' Long.|__|__|__|°|__|__|,|__|__|__|' WT |__|__|__|

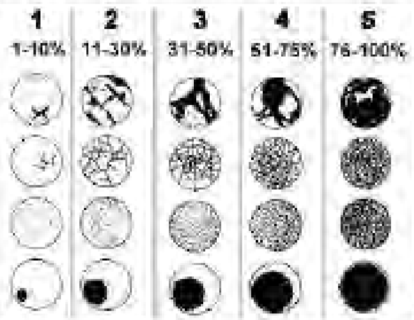
Starting time : |__|__|:|__|__|	Visibility |__|__| m	Side : Left ☐ Right ☐

☐ 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

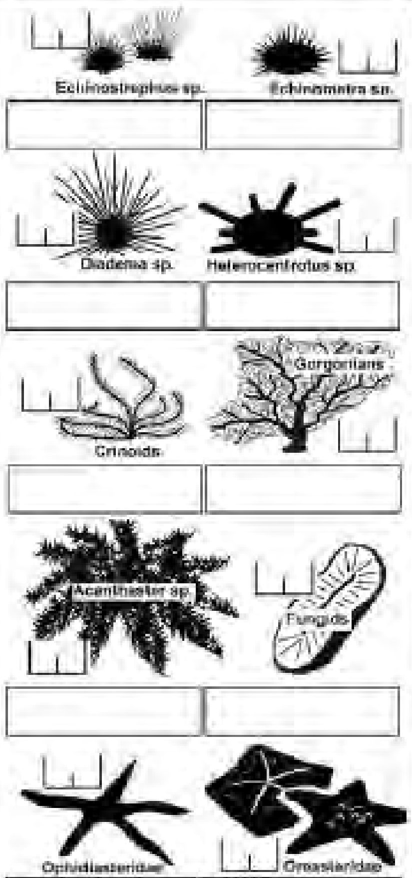
☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

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



Appendix 1: Survey methods
Finfish

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

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

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

1.3 Invertebrate resource survey methods

1.3.1 Methods used to assess the status of invertebrate resources

Introduction

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

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

Field methods

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Generic terminology used for surveys: site, station and replicates

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

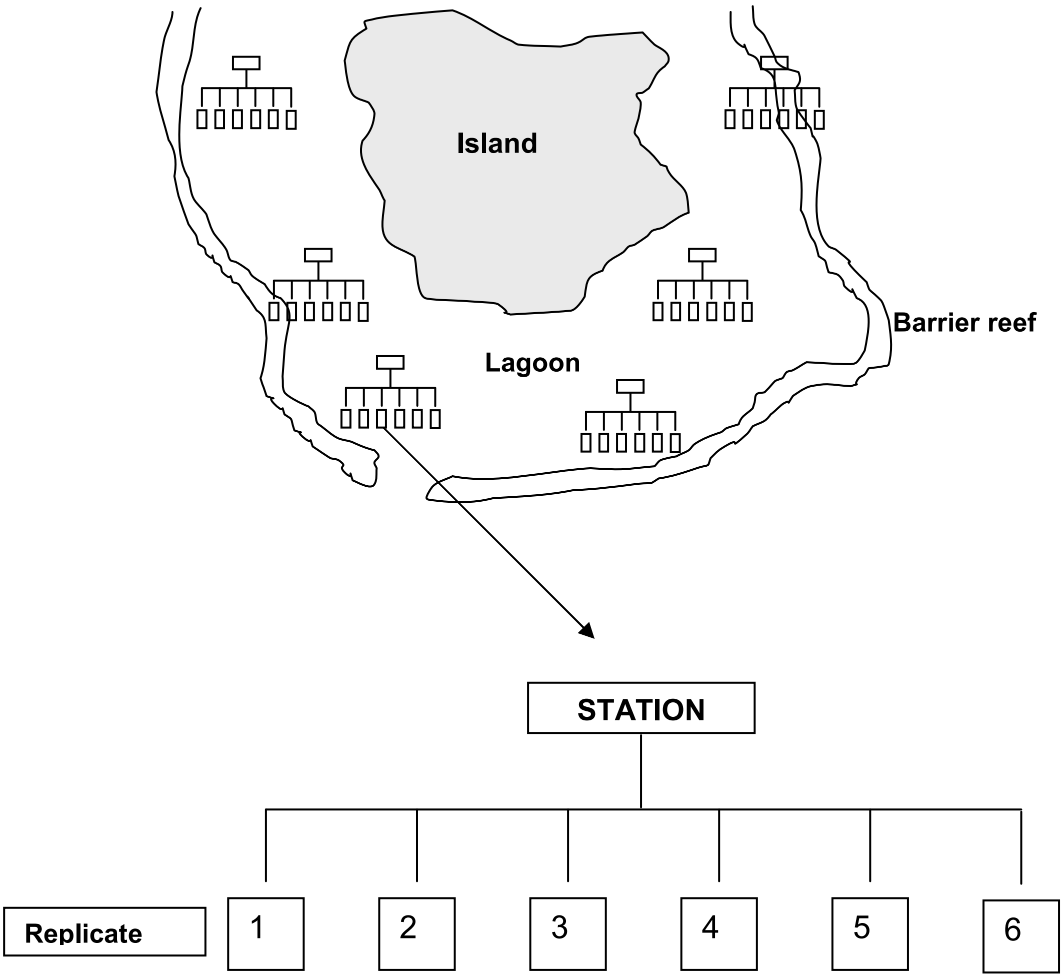


Figure A1.3.1: Stations and replicate measures at a given site.
Note: a replicate measure could be a transect, search period or quadrat group.

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).

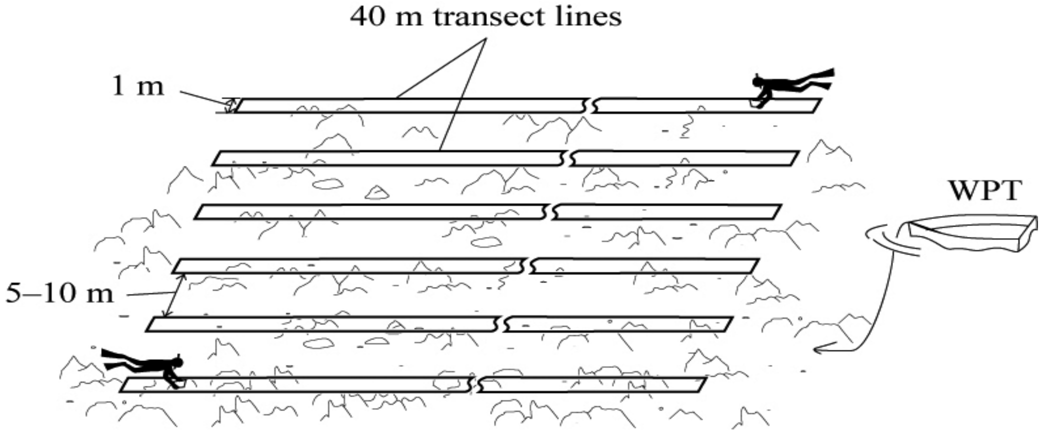


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

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^2 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.

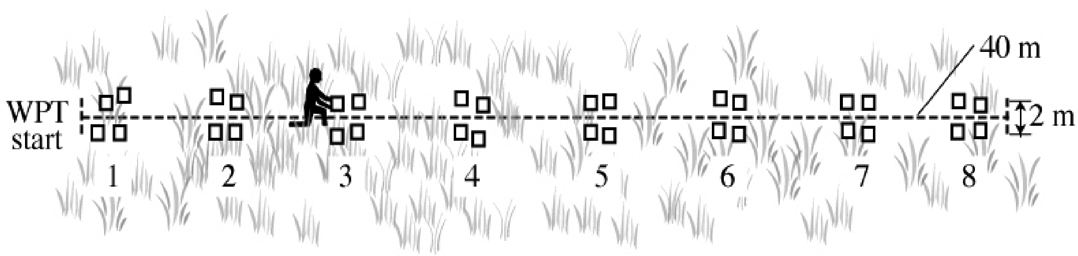


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<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 (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).

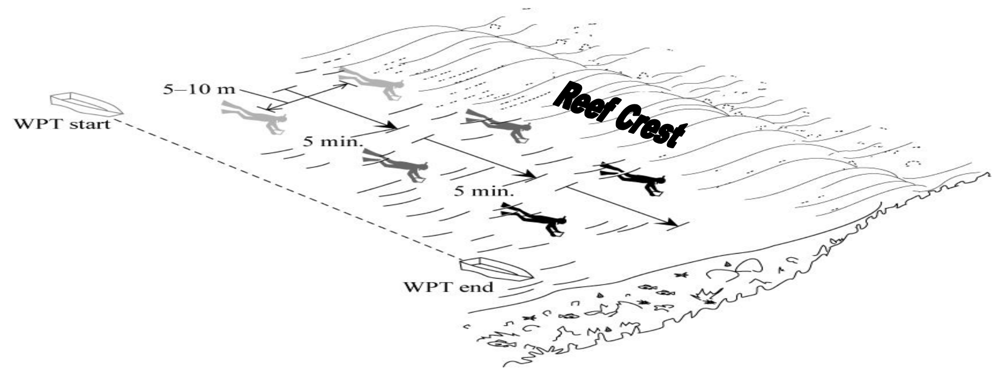


Figure A1.3.4: Reef-front search (RFs) station.

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.

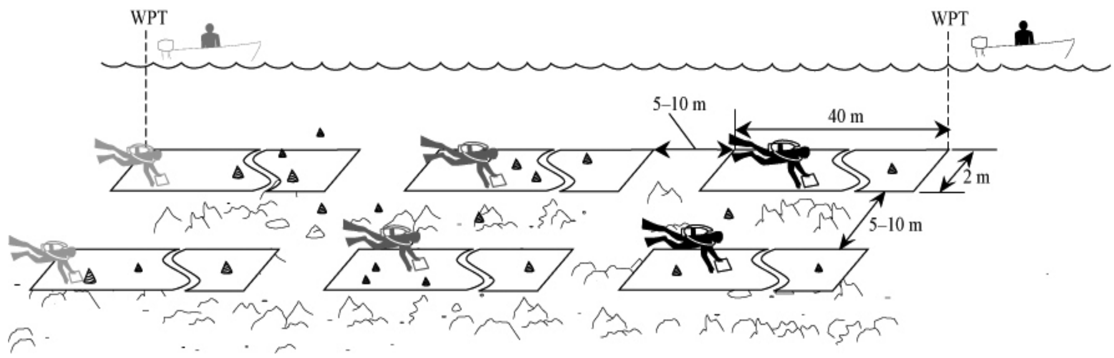


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

<u>Sea cucumber day search (Ds)</u>

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.

<u>Sea cucumber night search (Ns)</u>

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

Reporting style

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

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

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

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

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

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

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

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

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

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

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

1.3.2 General fauna invertebrate recording sheet with instructions to users

DATE		RECORDER		Pg No	

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

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

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

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

1.3.3 Habitat section of invertebrate recording sheet with instructions to users

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

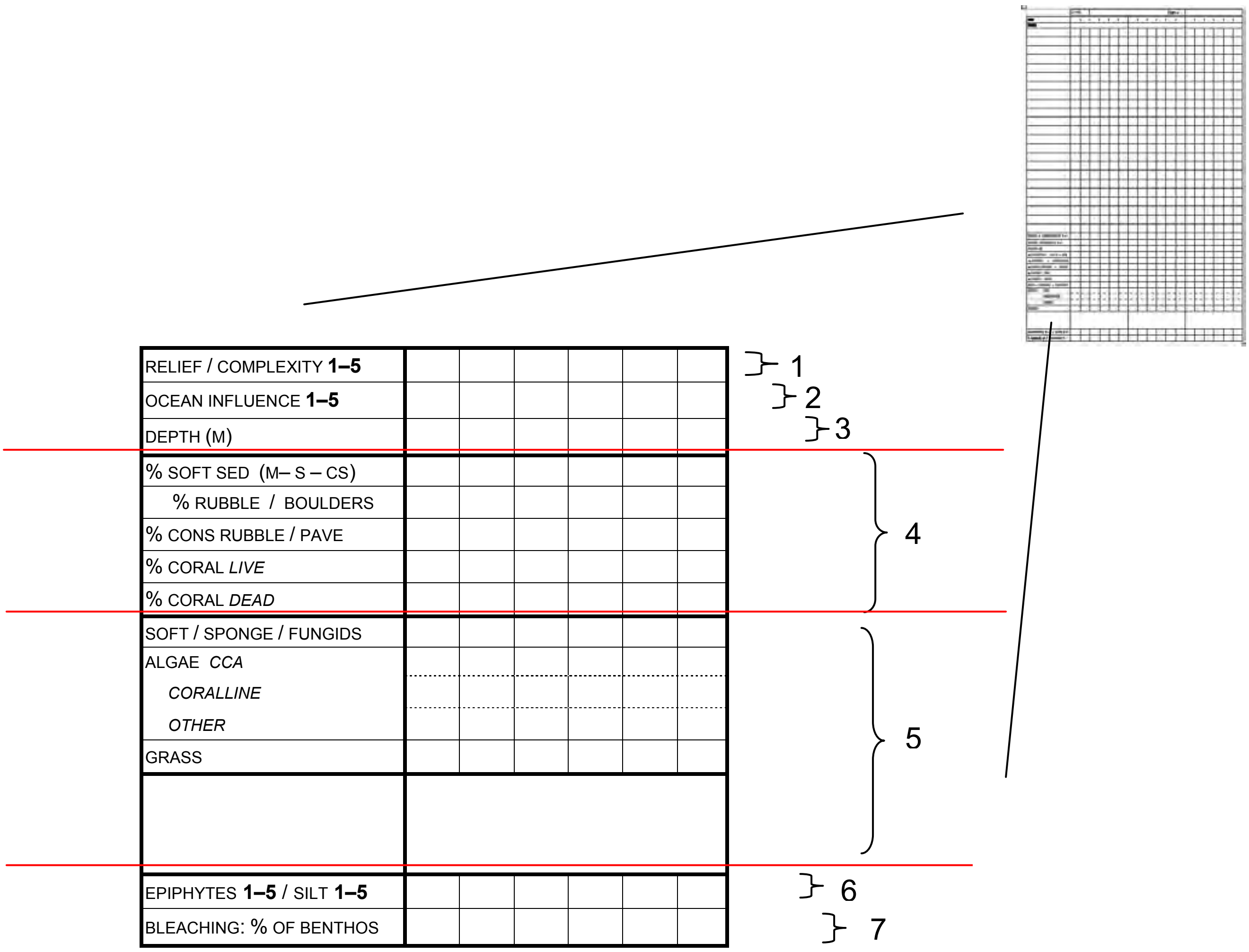


Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

Relief and complexity (section 1 of form)

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

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

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

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

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

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

Ocean influence (section 2 of form)

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

Depth (section 3 of form)

Average depth in metres

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

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

Elements to consider:

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

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

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

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

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

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

Coral live is any live hard coral.

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

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

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

Elements to consider:

Cover	Soft coral
Cover	Sponge
Cover	Fungids
Cover	Crustose-nongeniculate coralline algae
Cover	Coralline algae
Cover	Other (algae like sargassum, caulerpa and padina)
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 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 Fakarava socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat – Fakarava
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Paati	Scaridae	*Scarus* spp.	1103	31.13
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	706	19.92
Paaihere	Carangidae	*Caranx melampygus*	543	15.33
Apai	Holocentridae	*Sargocentron spiniferum*	434	12.26
Parai	Acanthuridae	*Acanthurus xanthopterus*	347	9.80
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	271	7.66
Merou	Serranidae	*Epinephelus* spp.	104	2.94
Marava	Siganidae	*Siganus argenteus*	18	0.52
Ume	Acanthuridae	*Naso unicornis*	15	0.43
Total:			**3542**	**100.00**
Lagoon				
Paati	Scaridae	*Scarus* spp.	1866	25.62
Ume	Acanthuridae	*Naso unicornis*	1324	18.17
Herepoti	Acanthuridae	*Naso annulatus*	585	8.03
Parai	Acanthuridae	*Acanthurus xanthopterus*	521	7.16
Tonu	Serranidae	*Plectropomus laevis*	361	4.95
Iihi	Holocentridae	*Myripristis* spp.	321	4.41
Paaihere	Carangidae	*Caranx melampygus*	312	4.29
Urio	Caesionidae	*Pterocaesio tile*	261	3.58
Taea	Lutjanidae	*Lutjanus gibbus*	231	3.17
Tarao	Serranidae	*Epinephelus merra*	174	2.39
Oeo	Lethrinidae	*Lethrinus olivaceus*	174	2.39
Bec de cane	Lethrinidae	*Lethrinus olivaceus*	170	2.33
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	152	2.09
Kito	Serranidae	*Epinephelus polyphekadion*	150	2.06
Mu	Lethrinidae	*Monotaxis grandoculis*	150	2.06
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	130	1.79
Apai	Serranidae	*Cephalopholis argus*	130	1.79
Apai	Holocentridae	*Sargocentron spiniferum*	122	1.67
Merou	Serranidae	*Epinephelus* spp.	84	1.15
Kuripo	Acanthuridae	*Naso hexacanthus*	36	0.50
Ume tarei	Acanthuridae	*Naso lituratus*	29	0.40
Total:			**7282**	**100.00**

2.1.1 Annual catch (kg) of fish groups per habitat – Fakarava (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef				
Paati	Scaridae	*Scarus* spp.	217	54.01
Paaihere	Carangidae	*Caranx melampygus*	124	30.80
Herepoti	Acanthuridae	*Naso annulatus*	15	3.80
Kuripo	Acanthuridae	*Naso hexacanthus*	15	3.80
Vau	Scombridae	*Gymnosarda unicolor*	12	3.04
Tapatai	Carangidae	*Alectis ciliaris*	12	3.04
Iihi	Holocentridae	*Myripristis* spp.	6	1.52
Total:			**402**	**100.00**
Passage				
Paati	Scaridae	*Scarus* spp.	858	19.23
Ume tarei	Acanthuridae	*Naso lituratus*	601	13.47
Paaihere	Carangidae	*Caranx melampygus*	575	12.87
Ume	Acanthuridae	*Naso unicornis*	569	12.75
Iihi	Holocentridae	*Myripristis* spp.	569	12.75
Carangue	Carangidae	*Caranx* spp.	233	5.23
Uhu	Scaridae	*Chlorurus microrhinos*	217	4.86
Merou	Serranidae	*Epinephelus* spp.	198	4.43
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	152	3.41
Orare	Carangidae	*Selar crumenophthalmus*	148	3.31
Loche	Serranidae	*Epinephelus* spp.	144	3.22
Taea	Lutjanidae	*Lutjanus gibbus*	90	2.02
Ruhi	Carangidae	*Caranx lugubris*	32	0.71
Toau	Lutjanidae	*Lutjanus fulvus*	27	0.61
Apai	Holocentridae	*Sargocentron spiniferum*	18	0.41
Herepoti	Acanthuridae	*Naso annulatus*	12	0.26
Vau	Scombridae	*Gymnosarda unicolor*	12	0.26
Tarao	Serranidae	*Epinephelus merra*	8	0.19
Total:			**4464**	**100.00**

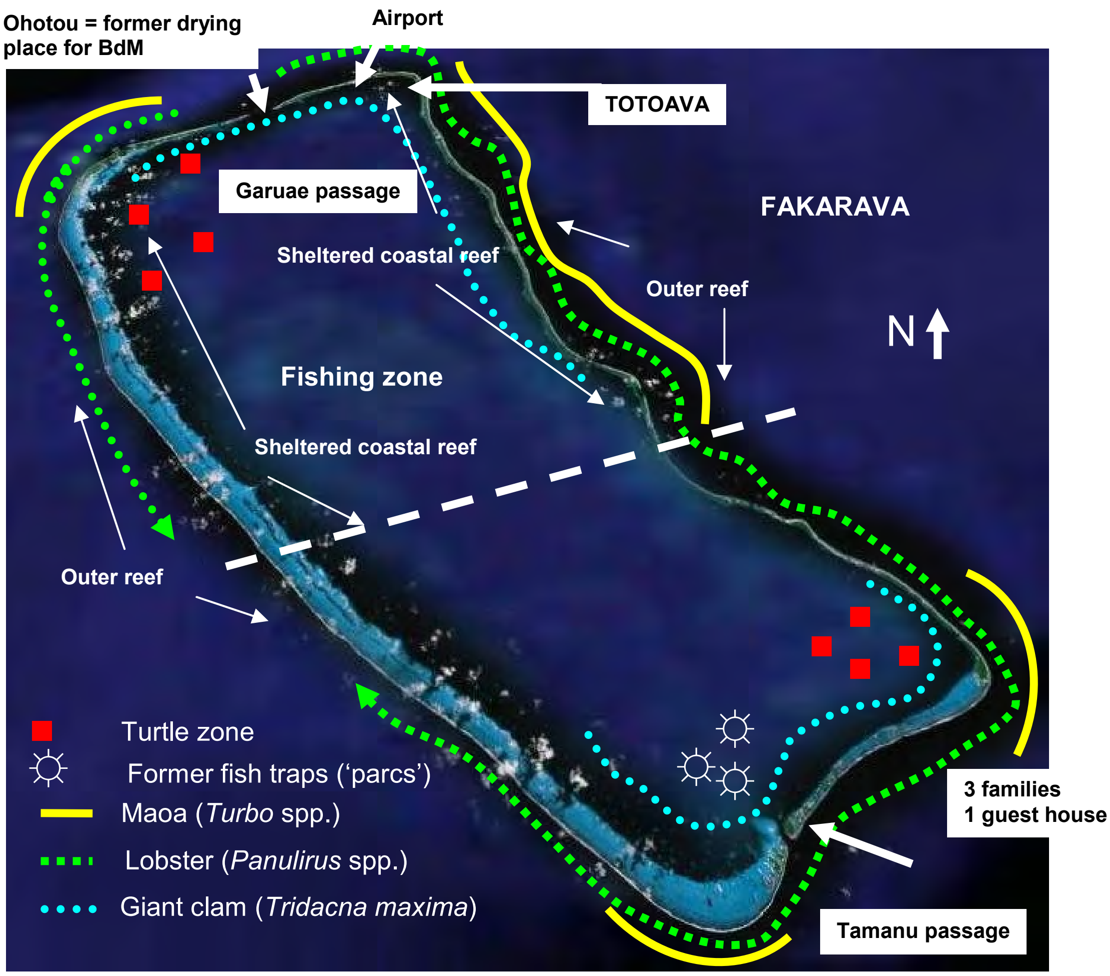
2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Fakarava

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Lobster	Langouste	*Panulirus* spp.	100.0	99.9	99.9	987.5	987.5
Other	Bénitier (pahua)	*Tridacna maxima*	100.0	10,522.2	1052.2	103,959.4	10,395.9
Reeftop	Langouste	*Panulirus* spp.	67.4	546.7	546.7	5401.6	5401.6
	Maoa	*Turbo marmoratus, Turbo setosus*	32.6	13,245.1	264.9	130,861.8	2617.2
Intertidal	Kauri porcelaine	*Cypraea annulus*	77.8	583.0	5.8	12,406.5	124.1
	-	*Nerita plicata*	22.2	333.2	1.7	7089.4	35.4

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Fakarava

Vernacular name	Scientific name	Size class	% of total catch (weight)
Bénitier (pahua)	*Tridacna maxima*	14-20 cm	4.7
		16-18 cm	20.6
		20 cm	0.8
		20-22 cm	61.9
		22 cm	11.9
Kauri porcelaine	*Cypraea annulus*	01 cm	100.0
Langouste	*Panulirus* spp.	18 cm	82.6
		20 cm	3.5
		22 cm	11.6
		24 cm	2.3
Maoa	*Turbo marmoratus, Turbo setosus*	06-08 cm	65.6
		08 cm	33.2
		20 cm	1.3
-	*Nerita plicata*	01 cm	100.0

2.1.4 Location of finfish and invertebrate fisheries in Fakarava



2.2 Maatea socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat – Maatea

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Ume	Acanthuridae	*Naso unicornis*	802	15.67
Paaihere	Carangidae	*Caranx melampygus*	732	14.30
Uhu	Scaridae	*Chlorurus microrhinos*	609	11.90
Roi	Serranidae	*Cephalopholis argus*	438	8.56
Toau	Lutjanidae	*Lutjanus fulvus*	436	8.52
Marava	Siganidae	*Siganus argenteus*	294	5.75
Tarao	Serranidae	*Epinephelus merra*	244	4.77
Mu	Lethrinidae	*Monotaxis grandoculis*	226	4.41
Paati	Scaridae	*Scarus* spp.	185	3.60
Oeo	Lethrinidae	*Lethrinus olivaceus*	182	3.55
Pahoro	Scaridae	*Scarus* spp.	181	3.54
Ume tarei	Acanthuridae	*Naso lituratus*	169	3.31
Paauara	Siganidae	*Siganus spinus*	151	2.96
Ahuru	Mullidae	*Parupeneus* spp.	143	2.79
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	88	1.73
Iihi	Holocentridae	*Myripristis* spp.	71	1.38
Ature	Carangidae	*Selar crumenophthalmus*	31	0.61
Carangue	Carangidae	*Caranx* spp.	29	0.57
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	26	0.52
Parai	Acanthuridae	*Acanthurus xanthopterus*	22	0.44
Maene	Lethrinidae	*Gnathodentex aureolineatus*	21	0.41
Tapio	Scaridae	*Calotomus carolinus*	13	0.25
Taivaiva	Lutjanidae	*Lutjanus monostigma*	11	0.21
Vete	Mullidae	*Mulloidichthys flavolineatus*	8	0.16
Papae	Labridae	*Cheilinus trilobatus*	2	0.04
Roeroe	Carangidae	*Elagatis bipinnulata*	2	0.04
Total:			**5120**	**100.00**
Lagoon				
Ume tarei	Acanthuridae	*Naso lituratus*	597	10.94
Tarao	Serranidae	*Epinephelus merra*	547	10.02
Vete	Mullidae	*Mulloidichthys flavolineatus*	530	9.72
Marava	Siganidae	*Siganus argenteus*	486	8.90
Paaihere	Carangidae	*Caranx melampygus*	473	8.66
Paati	Scaridae	*Scarus* spp.	470	8.61
Ume	Acanthuridae	*Naso unicornis*	436	7.99
Iihi	Holocentridae	*Myripristis* spp.	387	7.09
Ahuru	Mullidae	*Parupeneus* spp.	294	5.39
Ature	Carangidae	*Selar crumenophthalmus*	237	4.34
Toau	Lutjanidae	*Lutjanus fulvus*	162	2.96
Papae	Labridae	*Cheilinus trilobatus*	161	2.95
Roi	Serranidae	*Cephalopholis argus*	125	2.28
Carangue	Carangidae	*Caranx* spp.	117	2.15
Paauara	Siganidae	*Siganus spinus*	112	2.06

2.2.1 Annual catch (kg) of fish groups per habitat – Maatea (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	107	1.96
Pahoro	Scaridae	*Scarus* spp.	96	1.77
Parai	Acanthuridae	*Acanthurus xanthopterus*	77	1.41
Apai	Holocentridae	*Sargocentron spiniferum*	21	0.39
Maene	Lethrinidae	*Gnathodentex aureolineatus*	21	0.39
Total:			**5457**	**100.00**
Outer reef				
Ume	Acanthuridae	*Naso unicornis*	625	19.11
Oeo	Lethrinidae	*Lethrinus olivaceus*	468	14.31
Paaihere	Carangidae	*Caranx melampygus*	357	10.91
Iihi	Holocentridae	*Myripristis* spp.	346	10.59
Paati	Scaridae	*Scarus* spp.	208	6.37
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	199	6.09
Vau	Scombridae	*Gymnosarda unicolor*	199	6.09
Marava	Siganidae	*Siganus argenteus*	190	5.80
Carangue	Carangidae	*Caranx* spp.	183	5.59
Orare	Carangidae	*Selar crumenophthalmus*	135	4.12
Mu	Lethrinidae	*Monotaxis grandoculis*	106	3.25
Roi	Serranidae	*Cephalopholis argus*	100	3.04
Tuhara	Lutjanidae	*Lutjanus gibbus*	100	3.04
Tarao	Serranidae	*Epinephelus merra*	52	1.58
Toau	Lutjanidae	*Lutjanus fulvus*	3	0.09
Total:			**3269**	**100.00**

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Maatea

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Mangrove	Crabe	*Carpilius maculatus*	53.8	868.6	304.0	9112.2	3189.3
	Bénitier (pahua)	*Tridacna maxima*	46.2	2605.7	260.6	27,336.7	2733.7
Other	Bénitier (pahua)	*Tridacna maxima*	100.0	5239.4	523.9	54,966.8	5496.7
Reeftop	Maoa	*Turbo marmoratus, Turbo setosus*	100.0	651.4	13.0	6834.2	136.7
Sand	Crabe	*Carpilius maculatus*	64.3	70.0	24.5	734.0	256.9
	Poupou Tarona Tipauti Opareo		35.7	135.7	13.6	1139.0	113.9
Soft benthos	Oursin	*Diadema* spp.	100.0	5996.7	299.8	50,329.5	2516.5

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Maatea

Vernacular name	Scientific name	Size class	% of total catch (weight)
Bénitier (pahua)	*Tridacna maxima*	04-08 cm	8.3
		10-12 cm	66.4
		14 cm	2.3
		14-18 cm	22.9
Crabe	*Carpilius maculatus*	10 cm	92.5
		10-16 cm	7.5
Maoa	*Turbo marmoratus, Turbo setosus*	02-04 cm	100.0
Opareo	-	01 cm	
Poupou	-	01 cm	100.0
Oursin	*Diadema* spp.	12 cm	100.0
Tarona	-	01 cm	
Tipauti	-	01 cm	

2.3 Mataiea socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat – Mataiea
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	869	36.42
Paati	Scaridae	*Scarus* spp.	564	23.67
Ume	Acanthuridae	*Naso unicornis*	387	16.23
Paaihere	Carangidae	*Caranx melampygus*	126	5.27
Ume tarei	Acanthuridae	*Naso lituratus*	107	4.50
Marava	Siganidae	*Siganus argenteus*	70	2.95
Mu	Lethrinidae	*Monotaxis grandoculis*	70	2.93
Iihi	Holocentridae	*Myripristis* spp.	60	2.52
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	29	1.22
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	29	1.22
Carangue	Carangidae	*Caranx* spp.	26	1.10
Vete	Mullidae	*Mulloidichthys flavolineatus*	17	0.73
Toau	Lutjanidae	*Lutjanus fulvus*	14	0.57
Hoa	Serranidae	*Variola louti*	12	0.49
Tarao	Serranidae	*Epinephelus merra*	4	0.16
Total:			**2385**	**100.00**
Lagoon				
Carangue	Carangidae	*Caranx* spp.	1018	12.63
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	874	10.84
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	595	7.37
Tarao	Serranidae	*Epinephelus merra*	860	10.66
Toau	Lutjanidae	*Lutjanus fulvus*	602	7.46
Paati	Scaridae	*Scarus* spp.	542	6.72
Paaihere	Carangidae	*Caranx melampygus*	509	6.31
Papae	Labridae	*Cheilinus trilobatus*	419	5.19
Pahoro	Scaridae	*Scarus* spp.	400	4.96
Ume	Acanthuridae	*Naso unicornis*	92	1.14
Apai	Holocentridae	*Sargocentron spiniferum*	361	4.48
Vete	Mullidae	*Mulloidichthys flavolineatus*	356	4.41
Roi	Serranidae	*Cephalopholis argus*	336	4.17
Iihi	Holocentridae	*Myripristis* spp.	300	3.73
Mu	Lethrinidae	*Monotaxis grandoculis*	195	2.42
Ume tarei	Acanthuridae	*Naso lituratus*	158	1.96
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	145	1.79
Roeroe	Carangidae	*Elagatis bipinnulata*	105	1.30
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	75	0.93
Marava	Siganidae	*Siganus argenteus*	25	0.31
Operu	Carangidae	*Decapterus macarellus*	33	0.40
Mara	Labridae	*Cheilinus undulatus*	19	0.24
Paauara	Siganidae	*Siganus spinus*	17	0.21

2.3.1 Annual catch (kg) of fish groups per habitat – Mataiea (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon (continued)				
Faia	Mullidae	*Upeneus vittatus*	12	0.14
Tarao matapuu	Serranidae	*Epinephelus fasciatus*	8	0.10
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	8	0.10
Total:			**8063**	**100.00**
Outer reef				
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	122	22.50
Ume	Acanthuridae	*Naso unicornis*	107	19.72
Carangue	Carangidae	*Caranx* spp.	92	16.94
Parai	Acanthuridae	*Acanthurus xanthopterus*	92	16.94
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	92	16.94
Marava	Siganidae	*Siganus argenteus*	15	2.78
Iihi	Holocentridae	*Myripristis* spp.	13	2.32
Paati	Scaridae	*Scarus* spp.	10	1.85
Total:			**541**	**100**

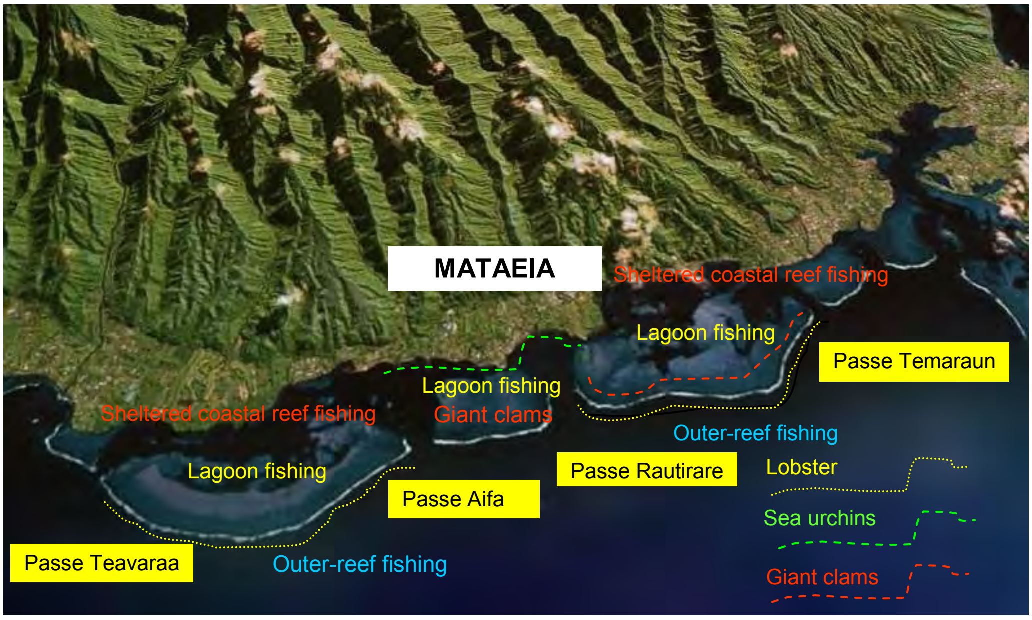
2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Mataiea

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Lobster	Langouste	*Panulirus* spp.	100.0	610.1	610.1	54,446.8	54,446.8
Other	Bénitier (pahua)	*Tridacna maxima*	49.6	655.2	65.5	37805.8	3780.6
	Maoa	*Turbo marmoratus, Turbo setosus*	27.6	1824.0	36.5	90,435.1	1808.7
	Oursin	*Diadema* spp.	22.7	599.7	30.0	29,732.1	1486.6
Reeftop	Bénitier (pahua)	*Tridacna maxima*	96.4	99.9	10.0	4955.3	495.5
	Maoa	*Turbo marmoratus, Turbo setosus*	3.6	18.7	0.4	1672.4	33.4

2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Mataiea

Vernacular name	Scientific name	Size class	% of total catch (weight)
Bénitier (pahua)	*Tridacna maxima*	10-12 cm	9.9
		10-14 cm	69.0
		14 cm	13.2
		14-16 cm	6.6
		16 cm	1.2
Langouste	*Panulirus* spp.	10-18 cm	41.0
		14 cm	8.2
		14-20 cm	16.4
		18-24 cm	15.4
		22 cm	2.7
		26-28 cm	16.4
Maoa	*Turbo marmoratus*, *Turbo setosus*	06-10 cm	94.3
		18 cm	1.0
		22-24 cm	4.7
Oursin	*Diadema* spp.	10 cm	100.0

2.3.4 Location of finfish and invertebrate fisheries in Mataiea



2.4 Raivavae socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat – Raivavae
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	2258	24.05
Paati	Scaridae	*Scarus* spp.	1230	13.10
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	1086	11.57
Ume	Acanthuridae	*Naso unicornis*	1010	10.76
Carangue	Carangidae	*Caranx* spp.	719	7.66
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	714	7.60
Iihi	Holocentridae	*Myripristis* spp.	521	5.55
Marava	Siganidae	*Siganus argenteus*	410	4.36
Anea	Mugilidae	*Crenimugil crenilabis, Mugil cephalus*	217	2.31
Tamure	Lethrinidae	*Lethrinus atkinsoni*	195	2.08
Haapu	Serranidae	*Epinephelus polyphekadion*	174	1.85
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	158	1.68
Paaihere	Carangidae	*Caranx melampygus*	158	1.68
Vete	Mullidae	*Mulloidichthys flavolineatus*	130	1.39
Merou	Serranidae	*Epinephelus* spp.	118	1.26
Apai	Holocentridae	*Sargocentron spiniferum*	100	1.07
Tarao	Serranidae	*Epinephelus merra*	79	0.84
Oeo	Lethrinidae	*Lethrinus olivaceus*	79	0.84
Manini	Acanthuridae	*Acanthurus triostegus*	14	0.15
Mu	Lethrinidae	*Monotaxis grandoculis*	9	0.10
Perroquet rouge	Scaridae	*Scarus rubroviolaceus*	7	0.07
Total:			**9387**	**100.00**
Sheltered coastal reef & outer reef				
Ume tarei	Acanthuridae	*Naso lituratus*	268	53.59
Paati	Scaridae	*Scarus* spp.	116	23.21
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	116	23.21
Total:			**499**	**100.00**
Outer reef				
Tonu	Serranidae	*Plectropomus laevis*	1055	62.47
Paauara	Siganidae	*Siganus spinus*	215	12.73
Ume	Acanthuridae	*Naso unicornis*	125	7.42
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	75	4.44
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	73	4.35
Tamure	Lethrinidae	*Lethrinus atkinsoni*	73	4.35
Carangue	Carangidae	*Caranx* spp.	52	3.06
Perroquet rouge	Scaridae	*Scarus rubroviolaceus*	20	1.18
Total:			**1689**	**100.00**

2.4.1 Annual catch (kg) of fish groups per habitat – Raivavae (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef & passage				
Perroquet bleu	Scaridae	*Chlorurus microrhinos*	824	34.01
Loche	Serranidae	*Epinephelus* spp.	551	22.74
Nanue	Kyphosidae	*Kyphosus bigibbus, Kyphosus cinerascens*	241	9.95
Ume	Acanthuridae	*Naso unicornis*	217	8.96
Marava	Siganidae	*Siganus argenteus*	157	6.46
Maito	Acanthuridae	*Acanthurus pyroferus, Ctenochaetus strigosus, Ctenochaetus striatus*	146	6.04
Haapu	Serranidae	*Epinephelus polyphekadion*	130	5.38
Paaihere	Carangidae	*Caranx melampygus*	130	5.38
Ume tarei	Acanthuridae	*Naso lituratus*	26	1.08
Total:			**2423**	**100.00**

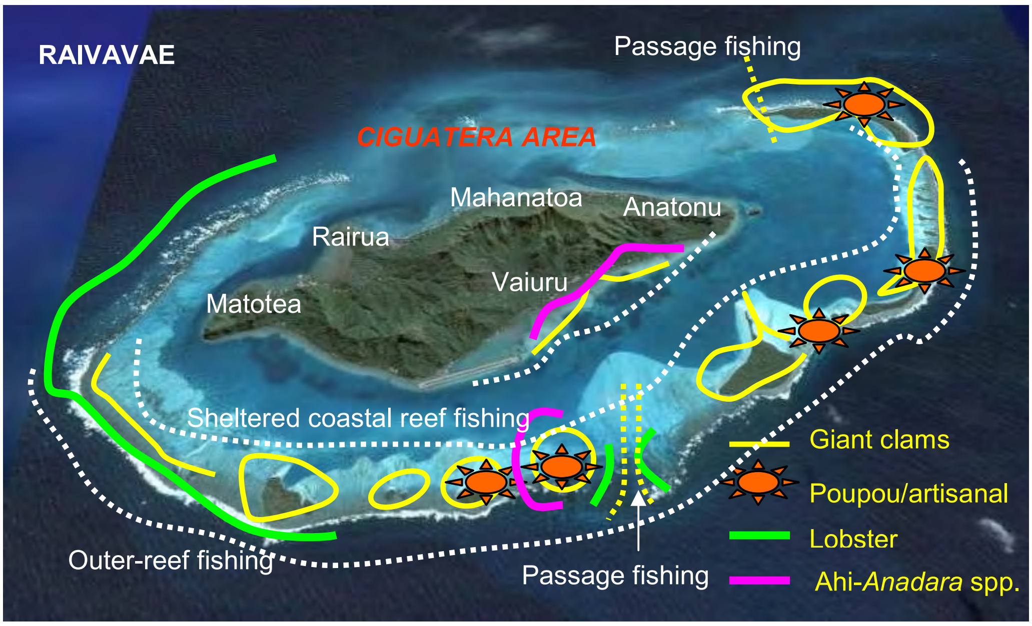
2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Raivavae

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Lobster	Langouste	*Panulirus* spp.	73.5	1246.1	1246.1	22,565.2	22,565.2
	Bénitier (pahua)	*Tridacna maxima*	22.4	3800.0	380.0	68,811.7	6881.2
	Crabe	*Carpilius maculatus*	4.1	199.9	70.0	3619.7	1266.9
Other	Bénitier (pahua)	*Tridacna maxima*	99.8	37,538.1	3753.8	680,711.5	68,071.2
	Oursin	*Diadema* spp.	0.2	149.9	7.5	2714.8	135.7
Reeftop	Tianee	*Parribacus antarcticus*	48.9	217.1	162.9	4091.9	3069.0
	Bénitier (pahua)	*Tridacna maxima*	31.3	1042.9	104.3	18,916.8	1891.7
	Langouste	*Panulirus* spp.	13.0	43.4	43.4	818.4	818.4
	Oursin	*Diadema* spp.	3.6	21.7	11.9	409.2	225.1
	Octopus	*Octopus* spp.	3.3	217.1	10.9	4091.9	204.6
Sand	Poupou	-	92.1	5813.8	581.4	109,558.2	10,955.8
	Ahi	*Asaphis violascens*	7.9	2379.6	50.0	43,091.4	904.9

2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Raivavae

Vernacular name	Scientific name	Size class	% of total catch (weight)
Ahi	*Asaphis violascens*	08 cm	100.0
Bénitier (pahua)	*Tridacna maxima*	08 cm	2.4
		14 cm	3.5
		18-22 cm	3.1
		20 cm	16.2
		20-24 cm	2.4
		20-28 cm	49.2
		22 cm	10.0
		22-24 cm	9.3
		24 cm	0.1
		24-26 cm	1.0
		26 cm	2.8
Crabe	*Carpilius maculatus*	20 cm	100.0
Langouste	*Panulirus* spp.	20 cm	3.4
		20-24 cm	0.4
		22-28 cm	31.0
		24 cm	6.2
		24-26 cm	19.6
		24-28 cm	7.8
		26 cm	23.6
		28-34 cm	8.1
Octopus	*Octopus* spp.	20 cm	100.0
Poupou	-	01 cm	100.0
Oursin	*Diadema* spp.	12 cm	100.0
Tianee	*Parribacus antarcticus*	16 cm	100.0

2.4.4 Location of finfish and invertebrate fisheries in Raivavae



2.5 Tikehau socioeconomic survey data

2.5.1 Annual catch (kg) of fish groups per habitat – Tikehau

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Utu	Lutjanidae	*Aprion virescens*	107	55.71
Haapu	Serranidae	*Epinephelus polyphekadion*	58	30.38
Toau	Lutjanidae	*Lutjanus fulvus*	27	13.90
Total:			**192**	**100.00**
Sheltered coastal reef & lagoon				
Toau	Lutjanidae	*Lutjanus fulvus*	395	69.58
Paati	Scaridae	*Scarus* spp.	86	15.21
Utu	Lutjanidae	*Aprion virescens*	86	15.21
Total:			**568**	**100.00**
Lagoon				
Taea	Lutjanidae	*Lutjanus gibbus*	1525	33.29
Bec de cane	Lethrinidae	*Lethrinus olivaceus*	1381	30.16
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	521	11.37
Paati	Scaridae	*Scarus* spp.	277	6.04
Ume	Acanthuridae	*Naso unicornis*	255	5.56
Oeo	Lethrinidae	*Lethrinus olivaceus*	214	4.67
Parai	Acanthuridae	*Acanthurus xanthopterus*	119	2.59
Haapu	Serranidae	*Epinephelus polyphekadion*	119	2.59
Paaihere	Carangidae	*Caranx melampygus*	113	2.47
Oiri	Balistidae	*Balistoides viridescens, Pseudobalistes flavimarginatus*	36	0.78
Apai	Holocentridae	*Sargocentron spiniferum*	16	0.35
Orare	Carangidae	*Selar crumenophthalmus*	3	0.06
Iihi	Holocentridae	*Myripristis* spp.	3	0.06
Total:			**4581**	**100.00**
Lagoon & passage				
Ume	Acanthuridae	*Naso unicornis*	2607	50.02
Ahuru	Mullidae	*Parupeneus* spp.	869	16.66
Paati	Scaridae	*Scarus* spp.	869	16.66
Rouget	Holocentridae	*Myripristis* spp., *Neoniphon* spp.	869	16.66
Total:			**5213**	**100.00**
Passage				
Orare	Carangidae	*Selar crumenophthalmus*	34,960	23.04
Paaihere	Carangidae	*Caranx melampygus*	32,371	21.34
Mataanaana	Priacanthidae	*Heteropriacanthus cruentatus*	27,251	17.96
Taea	Lutjanidae	*Lutjanus gibbus*	10,839	7.14
Ume	Acanthuridae	*Naso unicornis*	10,092	6.65
Iihi	Holocentridae	*Myripristis* spp.	8262	5.45
Oeo	Lethrinidae	*Lethrinus olivaceus*	6820	4.50
Ioio	Albulidae	*Albula neoguinaicus*	6044	3.98
Ahuru	Mullidae	*Parupeneus* spp.	6001	3.96
Paati	Scaridae	*Scarus* spp.	3654	2.41
Mu	Lethrinidae	*Monotaxis grandoculis*	3293	2.17

2.5.1 Annual catch (kg) of fish groups per habitat – Tikehau (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Passage (continued)				
Apai	Holocentridae	*Sargocentron spiniferum*	1135	0.75
Parai	Acanthuridae	*Acanthurus xanthopterus*	543	0.36
Vete	Mullidae	*Mulloidichthys flavolineatus*	451	0.30
Total:			**15,1715**	**100.00**
Outer reef				
Ahuru	Mullidae	*Parupeneus* spp.	1448	40.00
Paaihere	Carangidae	*Caranx melampygus*	724	20.00
Oeo	Lethrinidae	*Lethrinus olivaceus*	724	20.00
Paati	Scaridae	*Scarus* spp.	724	20.00
Total:			**3,619**	**100.00**

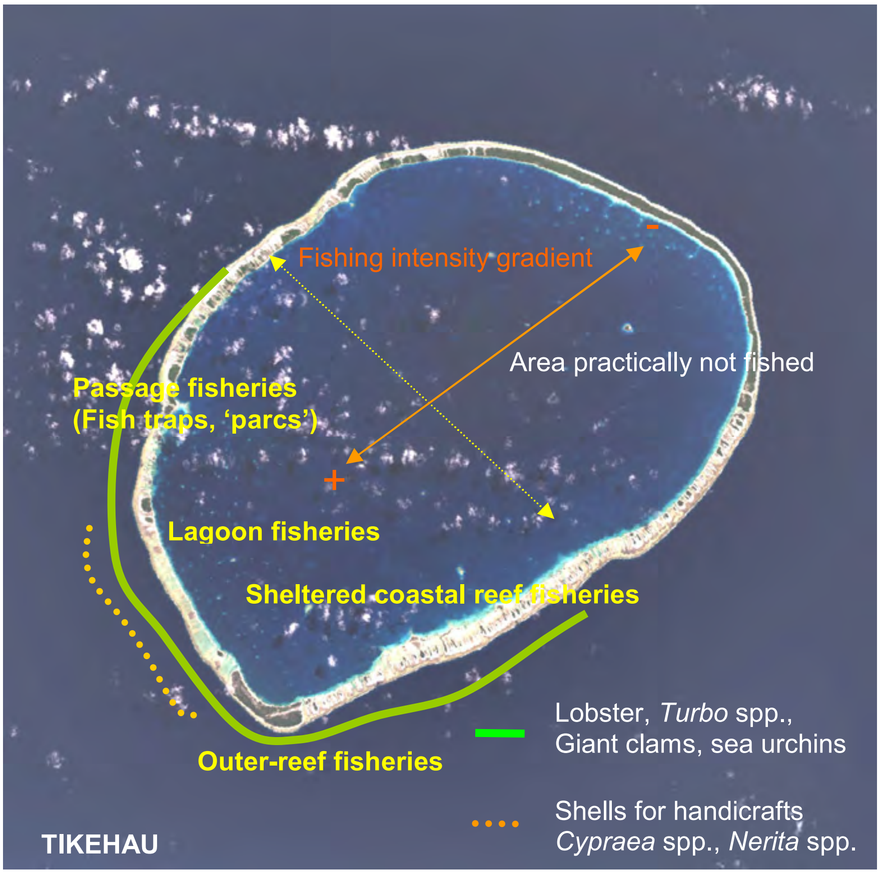
2.5.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Tikehau

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Lobster	Langouste	*Panulirus* spp.	100.0	322.4	322.4	1391.7	1391.7
Other	Bénitier (pahua)	*Tridacna maxima*	100.0	1585.4	158.5	6843.8	684.4
Reeftop	Maoa	*Turbo marmoratus, Turbo setosus*	100.0	1732.7	34.7	7479.4	149.6
Sand	-	*Cypraea tigris*	40.4	473.4	45.0	1751.7	166.4
	-	*Nerita plicata*	40.4	8995.1	45.0	33,281.7	166.4
	Kauri porcelaine	*Cypraea annulus*	19.1	2123.8	21.2	7858.2	78.6

2.5.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Tikehau

Vernacular name	Scientific name	Size class	% of total catch (weight)
Bénitier (pahua)	*Tridacna maxima*	12 cm	31.5
		20 cm	68.5
-	*Cypraea tigris*	01-02 cm	100.0
Kauri porcelaine	*Cypraea annulus*	02 cm	100.0
Langouste	*Panulirus* spp.	20 cm	77.5
		22 cm	0.5
		24 cm	22.0
Maoa	*Turbo marmoratus, Turbo setosus*	06 cm	94.0
		10 cm	6.0
-	*Nerita plicata*	01 cm	100.0

2.5.4 Location of finfish and invertebrate fisheries in Tikehau



APPENDIX 3: FINFISH SURVEY DATA

3.1 Fakarava finfish survey data

3.1.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Fakarava

Station name	Habitat	Latitude	Longitude
TRA01	Lagoon	14°56'14.28" S	148°13'17.3388" W
TRA02	Outer reef	14°57'11.4012" S	148°15'27.4212" W
TRA03	Outer reef	14°57'11.4012" S	148°15'27.4212" W
TRA04	Outer reef	14°58'05.88" S	148°15'32.76" W
TRA05	Outer reef	14°58'17.8212" S	148°14'06.1188" W
TRA06	Back-reef	14°59'28.3812" S	148°16'19.2" W
TRA07	Back-reef	15°00'07.56" S	148°16'13.8" W
TRA08	Back-reef	15°00'33.3612" S	148°15'20.52" W
TRA09	Back-reef	15°01'01.74" S	148°17'12.0588" W
TRA10	Back-reef	15°01'12.72" S	148°12'46.0188" W
TRA11	Lagoon	15°02'21.5988" S	148°17'30.2388" W
TRA12	Lagoon	15°02'37.5" S	148°16'55.1388" W
TRA13	Lagoon	15°02'47.3388" S	148°08'38.5188" W
TRA14	Lagoon	15°03'01.3212" S	148°16'49.8612" W
TRA15	Lagoon	15°03'28.1988" S	148°16'38.28" W
TRA16	Outer reef	15°03'29.6388" S	148°11'48.84" W
TRA17	Outer reef	15°03'45.54" S	148°15'08.28" W
TRA18	Back-reef	15°04'28.74" S	148°16'11.2188" W
TRA19	Coastal reef	15°05'21.1812" S	148°10'55.4988" W
TRA20	Coastal reef	15°05'43.5012" S	148°11'27.78" W
TRA21	Coastal reef	15°05'54.96" S	148°15'03.8988" W
TRA22	Coastal reef	15°06'08.2188" S	148°15'45.72" W
TRA23	Coastal reef	15°06'08.2188" S	148°15'45.72" W
TRA24	Coastal reef	15°07'00.7788" S	148°13'48.36" W

3.1.2 Weighted average density and biomass of all finfish species recorded in Fakarava (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus achilles*	0.0005	0.027
Acanthuridae	*Acanthurus albipectoralis*	0.0034	2.108
Acanthuridae	*Acanthurus blochii*	0.0034	0.487
Acanthuridae	*Acanthurus dussumieri*	0.0009	0.691
Acanthuridae	*Acanthurus lineatus*	0.0110	4.336
Acanthuridae	*Acanthurus nigricans*	0.0081	0.996
Acanthuridae	*Acanthurus nigricauda*	0.0107	4.524
Acanthuridae	*Acanthurus nigroris*	0.0026	0.187
Acanthuridae	*Acanthurus olivaceus*	0.0005	0.046
Acanthuridae	*Acanthurus pyroferus*	0.0086	0.314
Acanthuridae	*Acanthurus* spp.	0.0008	0.120
Acanthuridae	*Acanthurus thompsoni*	0.0079	0.563
Acanthuridae	*Acanthurus triostegus*	0.0379	1.272
Acanthuridae	*Ctenochaetus binotatus*	0.0038	0.193

3.1.2 Weighted average density and biomass of all finfish species recorded in Fakarava (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Ctenochaetus striatus*	0.0516	3.001
Acanthuridae	*Ctenochaetus strigosus*	0.0000	0.000
Acanthuridae	*Naso annulatus*	0.0017	0.320
Acanthuridae	*Naso brevirostris*	0.0011	0.073
Acanthuridae	*Naso lituratus*	0.0022	0.735
Acanthuridae	*Naso unicornis*	0.0013	1.072
Acanthuridae	*Naso vlamingii*	0.0025	1.186
Acanthuridae	*Zebrasoma scopas*	0.0027	0.081
Acanthuridae	*Zebrasoma veliferum*	0.0082	0.621
Balistidae	*Balistapus undulatus*	0.0037	0.966
Balistidae	*Balistoides viridescens*	0.0007	0.926
Balistidae	*Melichthys niger*	0.0060	1.489
Balistidae	*Melichthys vidua*	0.0037	1.038
Balistidae	*Odonus niger*	0.0005	0.060
Balistidae	*Pseudobalistes flavimarginatus*	0.0006	0.919
Balistidae	*Rhinecanthus aculeatus*	0.0025	0.298
Balistidae	*Rhinecanthus lunula*	0.0000	0.011
Balistidae	*Sufflamen bursa*	0.0010	0.144
Balistidae	*Sufflamen fraenatum*	0.0003	0.184
Chaetodontidae	*Chaetodon auriga*	0.0057	0.365
Chaetodontidae	*Chaetodon citrinellus*	0.0040	0.078
Chaetodontidae	*Chaetodon ephippium*	0.0016	0.082
Chaetodontidae	*Chaetodon lunula*	0.0001	0.002
Chaetodontidae	*Chaetodon lunulatus*	0.0096	0.396
Chaetodontidae	*Chaetodon mertensii*	0.0013	0.007
Chaetodontidae	*Chaetodon ornatissimus*	0.0002	0.004
Chaetodontidae	*Chaetodon pelewensis*	0.0042	0.173
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0013	0.073
Chaetodontidae	*Chaetodon reticulatus*	0.0016	0.076
Chaetodontidae	*Chaetodon trifascialis*	0.0018	0.084
Chaetodontidae	*Chaetodon ulietensis*	0.0033	0.094
Chaetodontidae	*Chaetodon unimaculatus*	0.0001	0.006
Chaetodontidae	*Forcipiger flavissimus*	0.0007	0.042
Chaetodontidae	*Forcipiger longirostris*	0.0003	0.018
Chaetodontidae	*Heniochus chrysostomus*	0.0000	0.001
Chaetodontidae	*Heniochus monoceros*	0.0014	0.051
Chaetodontidae	*Heniochus singularius*	0.0000	0.003
Holocentridae	*Myripristis berndti*	0.0001	0.032
Holocentridae	*Myripristis violacea*	0.0013	0.114
Holocentridae	*Neoniphon sammara*	0.0001	0.011
Holocentridae	*Sargocentron diadema*	0.0001	0.008
Holocentridae	*Sargocentron microstoma*	0.0003	0.007
Holocentridae	*Sargocentron* spp.	0.0000	0.002
Holocentridae	*Sargocentron spiniferum*	0.0000	0.002
Labridae	*Cheilinus chlorourus*	0.0054	0.187
Labridae	*Cheilinus trilobatus*	0.0001	0.015

3.1.2 Weighted average density and biomass of all finfish species recorded in Fakarava (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Labridae	*Cheilinus undulatus*	0.0002	0.634
Labridae	*Coris aygula*	0.0002	0.014
Labridae	*Coris gaimard*	0.0002	0.004
Labridae	*Epibulus insidiator*	0.0004	0.002
Labridae	*Hemigymnus fasciatus*	0.0000	0.012
Labridae	*Oxycheilinus digramma*	0.0002	0.003
Labridae	*Oxycheilinus unifasciatus*	0.0000	0.000
Lethrinidae	*Lethrinus nebulosus*	0.0002	0.155
Lethrinidae	*Lethrinus obsoletus*	0.0001	0.068
Lethrinidae	*Lethrinus olivaceus*	0.0006	0.473
Lethrinidae	*Lethrinus xanthochilus*	0.0015	1.328
Lethrinidae	*Monotaxis grandoculis*	0.0081	2.038
Lutjanidae	*Aphareus furca*	0.0004	0.300
Lutjanidae	*Aprion virescens*	0.0002	0.179
Lutjanidae	*Lutjanus argentimaculatus*	0.0002	0.104
Lutjanidae	*Lutjanus bohar*	0.0017	1.413
Lutjanidae	*Lutjanus fulviflamma*	0.0001	0.019
Lutjanidae	*Lutjanus fulvus*	0.0003	0.085
Lutjanidae	*Lutjanus gibbus*	0.0013	1.123
Lutjanidae	*Lutjanus monostigma*	0.0001	0.101
Mullidae	*Mulloidichthys flavolineatus*	0.0541	5.297
Mullidae	*Mulloidichthys vanicolensis*	0.0062	0.964
Mullidae	*Parupeneus barberinus*	0.0006	0.218
Mullidae	*Parupeneus indicus*	0.0001	0.075
Mullidae	*Parupeneus multifasciatus*	0.0122	0.593
Mullidae	*Parupeneus pleurostigma*	0.0007	0.052
Pomacanthidae	*Pygoplites diacanthus*	0.0000	0.006
Scaridae	*Cetoscarus bicolor*	0.0012	0.905
Scaridae	*Chlorurus microrhinos*	0.0068	7.321
Scaridae	*Chlorurus sordidus*	0.0451	3.917
Scaridae	*Hipposcarus longiceps*	0.0037	2.360
Scaridae	*Scarus altipinnis*	0.0074	6.654
Scaridae	*Scarus chameleon*	0.0000	0.007
Scaridae	*Scarus flavipectoralis*	0.0017	0.333
Scaridae	*Scarus frenatus*	0.0001	0.064
Scaridae	*Scarus ghobban*	0.0045	1.738
Scaridae	*Scarus globiceps*	0.0002	0.077
Scaridae	*Scarus niger*	0.0002	0.182
Scaridae	*Scarus psittacus*	0.0024	0.540
Scaridae	*Scarus rivulatus*	0.0009	0.525
Scaridae	*Scarus rubroviolaceus*	0.0010	0.664
Scaridae	*Scarus schlegeli*	0.0018	0.511
Scaridae	*Scarus* spp.	0.0000	0.000
Scaridae	*Scarus spinus*	0.0005	0.123
Serranidae	*Cephalopholis argus*	0.0044	1.621
Serranidae	*Cephalopholis urodeta*	0.0028	0.248

3.1.2 Weighted average density and biomass of all finfish species recorded in Fakarava (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Serranidae	*Epinephelus areolatus*	0.0002	0.025
Serranidae	*Epinephelus hexagonatus*	0.0000	0.003
Serranidae	*Epinephelus merra*	0.0003	0.012
Serranidae	*Epinephelus polyphekadion*	0.0018	1.478
Serranidae	*Plectropomus laevis*	0.0008	0.848
Serranidae	*Plectropomus leopardus*	0.0004	0.266
Serranidae	*Plectropomus maculatus*	0.0003	0.120
Serranidae	*Variola louti*	0.0001	0.069
Siganidae	*Siganus argenteus*	0.0016	1.139
Zanclidae	*Zanclus cornutus*	0.0023	0.259

3.2 Maatea finfish survey data

3.2.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Maatea

Station name	Habitat	Latitude	Longitude
TRA01	Lagoon	16°03'01.8" S	145°39'10.9188" W
TRA02	Coastal reef	16°03'06.0012" S	145°38'32.8812" W
TRA03	Coastal reef	16°03'34.6788" S	145°40'34.32" W
TRA04	Lagoon	16°03'37.5588" S	145°40'12.0612" W
TRA05	Lagoon	16°03'40.6188" S	145°37'16.5612" W
TRA06	Back-reef	16°05'22.2" S	145°43'44.22" W
TRA07	Lagoon	16°05'49.4412" S	145°44'38.3388" W
TRA08	Coastal reef	16°05'54.5388" S	145°45'58.9788" W
TRA09	Outer reef	16°06'07.6212" S	145°46'39.7812" W
TRA10	Outer reef	16°06'22.7412" S	145°47'28.5" W
TRA11	Outer reef	16°06'43.8588" S	145°46'48.6588" W
TRA12	Outer reef	16°06'49.2012" S	145°48'11.52" W
TRA13	Outer reef	16°07'10.6212" S	145°36'16.38" W
TRA14	Outer reef	16°08'26.2212" S	145°39'38.5812" W
TRA15	Back-reef	16°08'54.1788" S	145°42'08.46" W
TRA16	Coastal reef	16°09'25.4412" S	145°34'46.8012" W
TRA17	Lagoon	16°09'44.46" S	145°48'37.3788" W
TRA18	Coastal reef	16°10'38.8812" S	145°48'32.8788" W
TRA19	Lagoon	16°11'01.5612" S	145°41'26.4012" W
TRA20	Coastal reef	16°12'30.3012" S	145°47'31.56" W
TRA21	Back-reef	16°13'40.1988" S	145°47'02.8212" W
TRA22	Back-reef	16°14'20.2812" S	145°40'05.5812" W
TRA23	Back-reef	16°14'34.1412" S	145°46'36.7788" W
TRA24	Back-reef	16°14'52.8612" S	145°42'54.6588" W

3.2.2 Weighted average density and biomass of all finfish species recorded in Maatea (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus achilles*	0.0000	0.002
Acanthuridae	*Acanthurus blochii*	0.0000	0.000
Acanthuridae	*Acanthurus nigricans*	0.0033	0.176
Acanthuridae	*Acanthurus nigricauda*	0.0005	0.094
Acanthuridae	*Acanthurus nigrofuscus*	0.0009	0.023
Acanthuridae	*Acanthurus nigroris*	0.0362	2.615
Acanthuridae	*Acanthurus olivaceus*	0.0269	4.847
Acanthuridae	*Acanthurus pyroferus*	0.0010	0.070
Acanthuridae	*Acanthurus triostegus*	0.1013	8.079
Acanthuridae	*Ctenochaetus flavicauda*	0.0013	0.024
Acanthuridae	*Ctenochaetus striatus*	0.2028	14.087
Acanthuridae	*Ctenochaetus strigosus*	0.0002	0.007
Acanthuridae	*Naso lituratus*	0.0033	0.160
Acanthuridae	*Naso unicornis*	0.0005	0.073
Acanthuridae	*Zebrasoma scopas*	0.0197	1.395
Aulostomidae	*Aulostomus chinensis*	0.0002	0.065

3.2.2 Weighted average density and biomass of all finfish species recorded in Maatea (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Balistidae	*Balistapus undulatus*	0.0036	0.351
Balistidae	*Melichthys niger*	0.0177	2.430
Balistidae	*Melichthys vidua*	0.0181	2.306
Balistidae	*Odonus niger*	0.0055	0.612
Balistidae	*Rhinecanthus aculeatus*	0.0008	0.075
Balistidae	*Rhinecanthus rectangulus*	0.0008	0.045
Balistidae	*Rhinecanthus verrucosus*	0.0002	0.023
Balistidae	*Sufflamen bursa*	0.0055	0.299
Caesionidae	*Pterocaesio tessellata*	0.0001	0.005
Carangidae	*Caranx melampygus*	0.0002	0.025
Carangidae	*Scomberoides lysan*	0.0000	0.001
Carcharhinidae	*Carcharhinus melanopterus*	0.0002	2.117
Chaetodontidae	*Chaetodon auriga*	0.0005	0.035
Chaetodontidae	*Chaetodon citrinellus*	0.0093	0.096
Chaetodontidae	*Chaetodon ephippium*	0.0000	0.000
Chaetodontidae	*Chaetodon lunula*	0.0011	0.072
Chaetodontidae	*Chaetodon lunulatus*	0.0033	0.108
Chaetodontidae	*Chaetodon melannotus*	0.0000	0.000
Chaetodontidae	*Chaetodon mertensii*	0.0002	0.004
Chaetodontidae	*Chaetodon ornatissimus*	0.0078	0.268
Chaetodontidae	*Chaetodon pelewensis*	0.0052	0.028
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0061	0.151
Chaetodontidae	*Chaetodon reticulatus*	0.0100	0.248
Chaetodontidae	*Chaetodon trichrous*	0.0002	0.004
Chaetodontidae	*Chaetodon trifascialis*	0.0002	0.004
Chaetodontidae	*Chaetodon ulietensis*	0.0001	0.002
Chaetodontidae	*Chaetodon unimaculatus*	0.0041	0.100
Chaetodontidae	*Chaetodon vagabundus*	0.0024	0.161
Chaetodontidae	*Forcipiger longirostris*	0.0021	0.078
Chaetodontidae	*Heniochus acuminatus*	0.0001	0.004
Chaetodontidae	*Heniochus chrysostomus*	0.0036	0.203
Diodontidae	*Diodon hystrix*	0.0004	0.335
Holocentridae	*Myripristis kuntee*	0.0005	0.079
Holocentridae	*Myripristis* spp.	0.0003	0.015
Holocentridae	*Myripristis violacea*	0.0000	0.000
Holocentridae	*Neoniphon opercularis*	0.0009	0.077
Holocentridae	*Neoniphon sammara*	0.0013	0.148
Holocentridae	*Sargocentron caudimaculatum*	0.0002	0.009
Holocentridae	*Sargocentron diadema*	0.0006	0.037
Holocentridae	*Sargocentron spiniferum*	0.0000	0.001
Labridae	*Bodianus loxozonus*	0.0000	0.000
Labridae	*Cheilinus chlorourus*	0.0038	0.507
Labridae	*Cheilinus fasciatus*	0.0002	0.006
Labridae	*Cheilinus trilobatus*	0.0002	0.024
Labridae	*Cheilinus undulatus*	0.0003	0.410
Labridae	*Coris aygula*	0.0006	0.104

3.2.2 Weighted average density and biomass of all finfish species recorded in Maatea (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Labridae	*Coris gaimard*	0.0002	0.021
Labridae	*Epibulus insidiator*	0.0001	0.011
Labridae	*Hemigymnus fasciatus*	0.0002	0.015
Lethrinidae	*Gnathodentex aureolineatus*	0.0051	0.604
Lethrinidae	*Lethrinus obsoletus*	0.0002	0.056
Lethrinidae	*Monotaxis grandoculis*	0.0017	0.193
Lutjanidae	*Aphareus furca*	0.0002	0.024
Lutjanidae	*Lutjanus bohar*	0.0002	0.016
Lutjanidae	*Lutjanus fulvus*	0.0018	0.349
Lutjanidae	*Lutjanus kasmira*	0.0001	0.003
Mullidae	*Mulloidichthys flavolineatus*	0.0078	2.106
Mullidae	*Mulloidichthys vanicolensis*	0.0013	0.164
Mullidae	*Parupeneus barberinoides*	0.0002	0.007
Mullidae	*Parupeneus barberinus*	0.0003	0.049
Mullidae	*Parupeneus cyclostomus*	0.0002	0.029
Mullidae	*Parupeneus multifasciatus*	0.0052	0.527
Mullidae	*Parupeneus trifasciatus*	0.0014	0.130
Muraenidae	*Gymnothorax javanicus*	0.0002	0.601
Pomacanthidae	*Pygoplites diacanthus*	0.0001	0.004
Priacanthidae	*Priacanthus hamrur*	0.0000	0.000
Scaridae	*Calotomus carolinus*	0.0002	0.033
Scaridae	*Chlorurus microrhinos*	0.0000	0.005
Scaridae	*Chlorurus sordidus*	0.1114	14.082
Scaridae	*Scarus forsteni*	0.0006	0.265
Scaridae	*Scarus frenatus*	0.0011	0.327
Scaridae	*Scarus ghobban*	0.0000	0.002
Scaridae	*Scarus globiceps*	0.0006	0.080
Scaridae	*Scarus niger*	0.0000	0.005
Scaridae	*Scarus oviceps*	0.0011	0.361
Scaridae	*Scarus psittacus*	0.0493	8.072
Scaridae	*Scarus rubroviolaceus*	0.0000	0.012
Scaridae	*Scarus schlegeli*	0.0002	0.063
Scaridae	*Scarus* spp.	0.0001	0.009
Serranidae	*Aethaloperca rogaa*	0.0000	0.001
Serranidae	*Cephalopholis argus*	0.0073	1.734
Serranidae	*Cephalopholis urodeta*	0.0017	0.212
Serranidae	*Epinephelus hexagonatus*	0.0005	0.066
Serranidae	*Epinephelus merra*	0.0015	0.120
Serranidae	*Variola louti*	0.0005	0.063
Siganidae	*Siganus argenteus*	0.0001	0.009
Siganidae	*Siganus spinus*	0.0013	0.108
Zanclidae	*Zanclus cornutus*	0.0009	0.056

3.3 Mataiea finfish survey data

3.3.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Mataiea

Station name	Habitat	Latitude	Longitude
TRA01	Lagoon	17°34'11.3412" S	149°47'27.3012" W
TRA02	Coastal reef	17°34'14.2788" S	149°47'31.2" W
TRA03	Coastal reef	17°34'40.0188" S	149°47'46.7412" W
TRA04	Back-reef	17°34'51.78" S	149°47'21.3612" W
TRA05	Back-reef	17°35'03.7212" S	149°47'59.9388" W
TRA06	Lagoon	17°35'06.9" S	149°47'54.7188" W
TRA07	Lagoon	17°35'12.0588" S	149°47'16.44" W
TRA08	Outer reef	17°35'15.36" S	149°47'29.76" W
TRA09	Outer reef	17°35'19.68" S	149°47'59.64" W
TRA10	Coastal reef	17°35'29.2812" S	149°48'04.0212" W
TRA11	Back-reef	17°35'31.3188" S	149°48'10.8612" W
TRA12	Coastal reef	17°35'32.82" S	149°49'57.8388" W
TRA13	Outer reef	17°35'33.9612" S	149°47'31.6788" W
TRA14	Outer reef	17°35'40.0812" S	149°49'05.34" W
TRA15	Lagoon	17°35'47.04" S	149°49'53.94" W
TRA16	Back-reef	17°35'48.0012" S	149°47'51.4788" W
TRA17	Outer reef	17°35'57.12" S	149°50'09.4812" W
TRA18	Outer reef	17°36'00.0612" S	149°48'43.3188" W
TRA19	Coastal reef	17°36'02.2212" S	149°47'46.9212" W
TRA20	Coastal reef	17°36'09.6588" S	149°48'26.7588" W
TRA21	Back-reef	17°36'11.8188" S	149°49'21.18" W
TRA22	Back-reef	17°36'14.58" S	149°50'06.4788" W
TRA23	Lagoon	17°36'23.76" S	149°48'35.9388" W
TRA24	Lagoon	17°36'24.3" S	149°49'20.2188" W

3.3.2 Weighted average density and biomass of all finfish species recorded in Mataiea
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus achilles*	0.0001	0.029
Acanthuridae	*Acanthurus blochii*	0.0065	1.170
Acanthuridae	*Acanthurus lineatus*	0.0001	0.009
Acanthuridae	*Acanthurus mata*	0.0000	0.001
Acanthuridae	*Acanthurus nigricans*	0.0025	0.443
Acanthuridae	*Acanthurus nigricauda*	0.0002	0.118
Acanthuridae	*Acanthurus nigrofuscus*	0.0042	0.221
Acanthuridae	*Acanthurus olivaceus*	0.0009	0.157
Acanthuridae	*Acanthurus pyroferus*	0.0006	0.070
Acanthuridae	*Acanthurus thompsoni*	0.0002	0.007
Acanthuridae	*Acanthurus triostegus*	0.0058	0.350
Acanthuridae	*Acanthurus xanthopterus*	0.0000	0.003
Acanthuridae	*Ctenochaetus striatus*	0.1057	10.433
Acanthuridae	*Naso lituratus*	0.0047	1.710
Acanthuridae	*Zebrasoma scopas*	0.0132	0.944
Acanthuridae	*Zebrasoma veliferum*	0.0009	0.107

3.3.2 Weighted average density and biomass of all finfish species recorded in Mataiea (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Balistidae	*Balistapus undulatus*	0.0021	0.452
Balistidae	*Melichthys niger*	0.0046	1.472
Balistidae	*Melichthys vidua*	0.0139	2.895
Balistidae	*Odonus niger*	0.0099	1.313
Balistidae	*Pseudobalistes flavimarginatus*	0.0001	0.099
Balistidae	*Rhinecanthus aculeatus*	0.0002	0.029
Balistidae	*Rhinecanthus rectangulus*	0.0009	0.108
Balistidae	*Sufflamen bursa*	0.0058	0.566
Balistidae	*Sufflamen chrysopterum*	0.0000	0.002
Belonidae	*Strongylura leiura*	0.0000	0.018
Caesionidae	*Caesio teres*	0.0001	0.008
Carangidae	*Caranx melampygus*	0.0002	0.080
Carangidae	*Elagatis* spp.	0.0001	0.136
Carangidae	*Scomberoides lysan*	0.0001	0.026
Carcharhinidae	*Carcharhinus melanopterus*	0.0003	12.848
Chaetodontidae	*Chaetodon auriga*	0.0013	0.074
Chaetodontidae	*Chaetodon citrinellus*	0.0149	0.461
Chaetodontidae	*Chaetodon ephippium*	0.0004	0.023
Chaetodontidae	*Chaetodon flavirostris*	0.0000	0.002
Chaetodontidae	*Chaetodon kleinii*	0.0000	0.002
Chaetodontidae	*Chaetodon lunula*	0.0010	0.073
Chaetodontidae	*Chaetodon lunulatus*	0.0077	0.419
Chaetodontidae	*Chaetodon ornatissimus*	0.0028	0.206
Chaetodontidae	*Chaetodon pelewensis*	0.0017	0.073
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0031	0.131
Chaetodontidae	*Chaetodon reticulatus*	0.0014	0.084
Chaetodontidae	*Chaetodon trifascialis*	0.0000	0.000
Chaetodontidae	*Chaetodon ulietensis*	0.0009	0.044
Chaetodontidae	*Chaetodon unimaculatus*	0.0056	0.379
Chaetodontidae	*Chaetodon vagabundus*	0.0053	0.311
Chaetodontidae	*Forcipiger longirostris*	0.0014	0.096
Chaetodontidae	*Heniochus acuminatus*	0.0003	0.030
Chaetodontidae	*Heniochus chrysostomus*	0.0027	0.194
Chaetodontidae	*Heniochus varius*	0.0001	0.008
Diodontidae	*Diodon holocanthus*	0.0000	0.012
Diodontidae	*Diodon* spp.	0.0001	0.007
Ephippidae	*Platax orbicularis*	0.0002	0.038
Holocentridae	*Myripristis berndti*	0.0002	0.032
Holocentridae	*Myripristis violacea*	0.0004	0.058
Holocentridae	*Neoniphon sammara*	0.0014	0.109
Holocentridae	*Sargocentron caudimaculatum*	0.0003	0.020
Holocentridae	*Sargocentron diadema*	0.0002	0.016
Holocentridae	*Sargocentron spiniferum*	0.0004	0.064
Labridae	*Cheilinus chlorourus*	0.0057	0.434
Labridae	*Cheilinus fasciatus*	0.0001	0.005
Labridae	*Cheilinus trilobatus*	0.0003	0.113

3.3.2 Weighted average density and biomass of all finfish species recorded in Mataiea (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Labridae	*Coris aygula*	0.0013	0.116
Labridae	*Coris gaimard*	0.0002	0.017
Labridae	*Epibulus insidiator*	0.0001	0.018
Labridae	*Hemigymnus melapterus*	0.0000	0.002
Labridae	*Hemigymnus fasciatus*	0.0001	0.007
Lethrinidae	*Gnathodentex aureolineatus*	0.0049	1.811
Lethrinidae	*Lethrinus olivaceus*	0.0001	0.251
Lethrinidae	*Monotaxis grandoculis*	0.0059	0.532
Lutjanidae	*Lutjanus fulvus*	0.0019	0.291
Lutjanidae	*Lutjanus monostigma*	0.0003	0.049
Mugilidae	*Mugil* spp.	0.0000	0.007
Mullidae	*Mulloidichthys flavolineatus*	0.0018	0.123
Mullidae	*Mulloidichthys vanicolensis*	0.0009	0.116
Mullidae	*Parupeneus barberinus*	0.0002	0.031
Mullidae	*Parupeneus cyclostomus*	0.0000	0.008
Mullidae	*Parupeneus multifasciatus*	0.0105	1.225
Mullidae	*Parupeneus pleurostigma*	0.0016	0.196
Mullidae	*Parupeneus spilurus*	0.0002	0.031
Mullidae	*Parupeneus trifasciatus*	0.0018	0.278
Muraenidae	*Gymnothorax* spp.	0.0000	0.534
Ostraciidae	*Ostracion* spp.	0.0000	0.003
Pomacanthidae	*Pygoplites diacanthus*	0.0002	0.017
Scaridae	*Cetoscarus bicolor*	0.0000	0.011
Scaridae	*Chlorurus bleekeri*	0.0000	0.007
Scaridae	*Chlorurus sordidus*	0.0357	5.430
Scaridae	*Hipposcarus longiceps*	0.0001	0.002
Scaridae	*Scarus altipinnis*	0.0002	0.097
Scaridae	*Scarus chameleon*	0.0005	0.100
Scaridae	*Scarus frenatus*	0.0002	0.141
Scaridae	*Scarus ghobban*	0.0000	0.001
Scaridae	*Scarus oviceps*	0.0005	0.117
Scaridae	*Scarus psittacus*	0.0468	9.450
Scaridae	*Scarus rivulatus*	0.0033	1.125
Scaridae	*Scarus schlegeli*	0.0005	0.128
Scaridae	*Scarus spinus*	0.0003	0.079
Serranidae	*Cephalopholis argus*	0.0004	0.145
Serranidae	*Cephalopholis urodeta*	0.0006	0.041
Serranidae	*Epinephelus merra*	0.0012	0.111
Siganidae	*Siganus argenteus*	0.0000	0.002
Siganidae	*Siganus punctatus*	0.0007	0.161
Siganidae	*Siganus spinus*	0.0040	0.437
Zanclidae	*Zanclus cornutus*	0.0020	0.265

3.4 Raivavae finfish survey data

3.4.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Raivavae

Station name	Habitat	Latitude	Longitude
TRA01	Outer reef	17°45'39.06" S	149°22'31.6812" W
TRA02	Outer reef	17°45'50.1012" S	149°23'30.4188" W
TRA03	Outer reef	17°45'57.3588" S	149°23'19.6188" W
TRA04	Back-reef	17°46'13.8" S	149°22'58.62" W
TRA05	Back-reef	17°46'14.5812" S	149°23'57.5988" W
TRA06	Back-reef	17°46'27.9588" S	149°24'49.32" W
TRA07	Back-reef	17°46'36.3612" S	149°25'52.86" W
TRA08	Back-reef	17°46'45.2388" S	149°26'55.5" W
TRA09	Back-reef	17°46'46.02" S	149°23'23.5212" W
TRA10	Back-reef	17°46'46.0812" S	149°22'10.74" W
TRA11	Coastal reef	17°46'47.2188" S	149°26'27.4812" W
TRA12	Coastal reef	17°46'50.9988" S	149°27'23.94" W
TRA13	Back-reef	17°46'51.1212" S	149°24'24.84" W
TRA14	Back-reef	17°46'58.7388" S	149°22'58.3788" W
TRA15	Back-reef	17°46'58.7388" S	149°22'58.3788" W
TRA16	Coastal reef	17°47'01.7988" S	149°25'05.9412" W
TRA17	Outer reef	17°47'07.44" S	149°26'58.2" W
TRA18	Outer reef	17°47'07.9188" S	149°26'37.14" W
TRA19	Outer reef	17°47'10.7412" S	149°24'48.6" W
TRA20	Coastal reef	17°47'10.7412" S	149°24'48.6" W
TRA21	Coastal reef	17°47'17.6388" S	149°26'13.9812" W
TRA22	Back-reef	17°47'29.6988" S	149°27'40.0212" W
TRA23	Coastal reef	17°47'43.62" S	149°26'25.1988" W
TRA24	Back-reef	17°47'43.62" S	149°26'25.1988" W

3.4.2 Weighted average density and biomass of all finfish species recorded in Raivavae (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus guttatus*	0.0012	0.140
Acanthuridae	*Acanthurus nigricans*	0.0029	0.075
Acanthuridae	*Acanthurus nigrofuscus*	0.0003	0.002
Acanthuridae	*Acanthurus nigroris*	0.0823	7.863
Acanthuridae	*Acanthurus olivaceus*	0.0016	0.928
Acanthuridae	*Acanthurus triostegus*	0.0125	0.769
Acanthuridae	*Ctenochaetus striatus*	0.1028	10.036
Acanthuridae	*Naso lituratus*	0.0053	3.316
Acanthuridae	*Naso unicornis*	0.0065	4.342
Acanthuridae	*Zebrasoma scopas*	0.0013	0.059
Acanthuridae	*Zebrasoma veliferum*	0.0029	0.447
Balistidae	*Abalistes stellaris*	0.0011	0.407
Balistidae	*Rhinecanthus aculeatus*	0.0008	0.246
Balistidae	*Rhinecanthus rectangulus*	0.0013	0.380
Balistidae	*Sufflamen bursa*	0.0008	0.092
Caesionidae	*Caesio caerulaurea*	0.0000	0.007

3.4.2 Weighted average density and biomass of all finfish species recorded in Raivavae (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Caesionidae	*Pterocaesio tessellata*	0.0029	0.502
Carangidae	*Carangoides ferdau*	0.0000	0.030
Carangidae	*Caranx melampygus*	0.0004	0.533
Chaetodontidae	*Chaetodon auriga*	0.0026	0.141
Chaetodontidae	*Chaetodon baronessa*	0.0003	0.013
Chaetodontidae	*Chaetodon bennetti*	0.0010	0.068
Chaetodontidae	*Chaetodon citrinellus*	0.0006	0.017
Chaetodontidae	*Chaetodon ephippium*	0.0007	0.045
Chaetodontidae	*Chaetodon flavirostris*	0.0009	0.107
Chaetodontidae	*Chaetodon kleinii*	0.0000	0.001
Chaetodontidae	*Chaetodon lunula*	0.0001	0.003
Chaetodontidae	*Chaetodon lunulatus*	0.0008	0.049
Chaetodontidae	*Chaetodon mertensii*	0.0028	0.072
Chaetodontidae	*Chaetodon ornatissimus*	0.0012	0.052
Chaetodontidae	*Chaetodon pelewensis*	0.0030	0.122
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0005	0.033
Chaetodontidae	*Chaetodon reticulatus*	0.0063	0.447
Chaetodontidae	*Chaetodon trifascialis*	0.0012	0.067
Chaetodontidae	*Chaetodon ulietensis*	0.0006	0.015
Chaetodontidae	*Chaetodon unimaculatus*	0.0072	0.537
Chaetodontidae	*Chaetodon vagabundus*	0.0002	0.006
Chaetodontidae	*Forcipiger flavissimus*	0.0001	0.007
Chaetodontidae	*Forcipiger longirostris*	0.0005	0.031
Chaetodontidae	*Heniochus chrysostomus*	0.0001	0.002
Diodontidae	*Diodon hystrix*	0.0001	0.078
Diodontidae	*Diodon* spp.	0.0001	0.056
Holocentridae	*Myripristis berndti*	0.0004	0.197
Holocentridae	*Myripristis murdjan*	0.0003	0.004
Holocentridae	*Neoniphon argenteus*	0.0004	0.012
Holocentridae	*Neoniphon sammara*	0.0001	0.015
Holocentridae	*Sargocentron microstoma*	0.0001	0.002
Kyphosidae	*Kyphosus cinerascens*	0.0000	0.004
Kyphosidae	*Kyphosus vaigiensis*	0.0001	0.061
Labridae	*Anampses geographicus*	0.0029	0.006
Labridae	*Cheilinus chlorourus*	0.0038	0.498
Labridae	*Cheilinus fasciatus*	0.0013	0.280
Labridae	*Cheilinus trilobatus*	0.0001	0.036
Labridae	*Cheilio inermis*	0.0000	0.010
Labridae	*Coris aygula*	0.0020	0.835
Labridae	*Coris gaimard*	0.0003	0.107
Labridae	*Hemigymnus fasciatus*	0.0005	0.094
Labridae	*Hemigymnus melapterus*	0.0003	0.001
Labridae	*Hologymnosus longipes*	0.0003	0.004
Labridae	*Oxycheilinus digramma*	0.0005	0.020
Labridae	*Oxycheilinus unifasciatus*	0.0003	0.015
Labridae	*Thalassoma trilobatum*	0.0000	0.001

3.4.2 Weighted average density and biomass of all finfish species recorded in Raivavae (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Lethrinidae	*Gnathodentex aureolineatus*	0.0234	8.621
Lethrinidae	*Lethrinus atkinsoni*	0.0001	0.094
Lethrinidae	*Lethrinus genivittatus*	0.0000	0.005
Lethrinidae	*Lethrinus harak*	0.0000	0.021
Lethrinidae	*Lethrinus nebulosus*	0.0001	0.089
Lethrinidae	*Lethrinus* spp.	0.0000	0.007
Lethrinidae	*Monotaxis grandoculis*	0.0003	0.363
Lutjanidae	*Aphareus furca*	0.0045	2.568
Lutjanidae	*Lutjanus fulvus*	0.0004	0.182
Mullidae	*Mulloidichthys flavolineatus*	0.0028	0.371
Mullidae	*Mulloidichthys vanicolensis*	0.0020	0.295
Mullidae	*Parupeneus barberinus*	0.0000	0.019
Mullidae	*Parupeneus ciliatus*	0.0006	0.225
Mullidae	*Parupeneus cyclostomus*	0.0004	0.073
Mullidae	*Parupeneus indicus*	0.0000	0.009
Mullidae	*Parupeneus multifasciatus*	0.0047	0.517
Mullidae	*Parupeneus pleurostigma*	0.0039	0.262
Mullidae	*Parupeneus spilurus*	0.0009	0.384
Mullidae	*Parupeneus trifasciatus*	0.0025	0.368
Pomacanthidae	*Pomacanthus imperator*	0.0000	0.003
Pomacanthidae	*Pygoplites diacanthus*	0.0000	0.007
Scaridae	*Cetoscarus bicolor*	0.0024	1.726
Scaridae	*Chlorurus microrhinos*	0.0000	0.029
Scaridae	*Chlorurus sordidus*	0.0445	14.532
Scaridae	*Hipposcarus longiceps*	0.0000	0.015
Scaridae	*Scarus altipinnis*	0.0127	9.203
Scaridae	*Scarus chameleon*	0.0006	0.348
Scaridae	*Scarus flavipectoralis*	0.0008	0.432
Scaridae	*Scarus forsteni*	0.0013	1.056
Scaridae	*Scarus frenatus*	0.0082	7.498
Scaridae	*Scarus ghobban*	0.0107	0.846
Scaridae	*Scarus globiceps*	0.0061	2.095
Scaridae	*Scarus niger*	0.0019	1.873
Scaridae	*Scarus psittacus*	0.0403	12.805
Scaridae	*Scarus quoyi*	0.0000	0.003
Scaridae	*Scarus rivulatus*	0.0103	5.053
Scaridae	*Scarus rubroviolaceus*	0.0008	0.873
Scaridae	*Scarus schlegeli*	0.0103	8.244
Scaridae	*Scarus spinus*	0.0013	0.541
Serranidae	*Cephalopholis argus*	0.0005	0.087
Serranidae	*Cephalopholis urodeta*	0.0019	0.156
Serranidae	*Epinephelus areolatus*	0.0005	0.011
Serranidae	*Epinephelus hexagonatus*	0.0006	0.018
Serranidae	*Epinephelus maculatus*	0.0005	0.066
Serranidae	*Epinephelus merra*	0.0021	0.183
Siganidae	*Siganus argenteus*	0.0013	0.659

3.4.2 Weighted average density and biomass of all finfish species recorded in Raivavae (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Siganidae	*Siganus lineatus*	0.0000	0.009
Siganidae	*Siganus spinus*	0.0018	0.242
Siganidae	*Siganus vermiculatus*	0.0002	0.068
Zanclidae	*Zanclus cornutus*	0.0012	0.159

3.5 Tikehau finfish survey data

3.5.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Tikehau

Station name	Habitat	Latitude	Longitude
TRA01	Outer reef	23°49'53.04" S	147°37'03.8388" W
TRA02	Outer reef	23°49'59.6388" S	147°39'34.74" W
TRA03	Coastal reef	23°50'52.6812" S	147°41'29.3388" W
TRA04	Coastal reef	23°50'56.1588" S	147°40'59.4588" W
TRA05	Outer reef	23°51'01.3788" S	147°38'19.0788" W
TRA06	Outer reef	23°51'36.9" S	147°42'05.3388" W
TRA07	Coastal reef	23°51'48.6612" S	147°35'22.0812" W
TRA08	Back-reef	23°51'58.0788" S	147°41'45.24" W
TRA09	Lagoon	23°52'05.0412" S	147°41'38.8212" W
TRA10	Lagoon	23°52'15.78" S	147°42'29.0412" W
TRA11	Lagoon	23°52'27.48" S	147°42'01.0188" W
TRA12	Lagoon	23°52'31.1988" S	147°38'36.6" W
TRA13	Outer reef	23°52'44.2812" S	147°42'06.4188" W
TRA14	Outer reef	23°52'48.4788" S	147°41'14.7588" W
TRA15	Coastal reef	23°53'04.3188" S	147°42'08.5212" W
TRA16	Coastal reef	23°53'31.8588" S	147°42'59.2812" W
TRA17	Coastal reef	23°53'33.9612" S	147°37'56.5788" W
TRA18	Coastal reef	23°53'34.08" S	147°37'56.5788" W
TRA19	Lagoon	23°53'51.36" S	147°40'37.38" W
TRA20	Back-reef	23°53'51.4788" S	147°40'37.4412" W
TRA21	Back-reef	23°53'56.6412" S	147°38'39.12" W
TRA22	Lagoon	23°54'03.3588" S	147°41'09.24" W
TRA23	Back-reef	23°54'05.8212" S	147°42'14.6412" W
TRA24	Back-reef	23°54'29.4588" S	147°40'34.7412" W

3.5.2 Weighted average density and biomass of all finfish species recorded in Tikehau (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus achilles*	0.0005	0.058
Acanthuridae	*Acanthurus blochii*	0.0073	3.461
Acanthuridae	*Acanthurus lineatus*	0.0001	0.035
Acanthuridae	*Acanthurus nigricans*	0.0019	0.234
Acanthuridae	*Acanthurus nigricauda*	0.0038	1.932
Acanthuridae	*Acanthurus nigroris*	0.0296	2.030
Acanthuridae	*Acanthurus olivaceus*	0.0012	0.481
Acanthuridae	*Acanthurus pyroferus*	0.0001	0.013
Acanthuridae	*Acanthurus thompsoni*	0.0006	0.025
Acanthuridae	*Acanthurus triostegus*	0.0756	4.975
Acanthuridae	*Acanthurus xanthopterus*	0.0000	0.009
Acanthuridae	*Ctenochaetus striatus*	0.0349	3.749
Acanthuridae	*Ctenochaetus strigosus*	0.0001	0.010
Acanthuridae	*Naso annulatus*	0.0066	2.600
Acanthuridae	*Naso brevirostris*	0.0000	0.013
Acanthuridae	*Naso lituratus*	0.0024	1.036

3.5.2 Weighted average density and biomass of all finfish species recorded in Tikehau (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Naso* spp.	0.0000	0.010
Acanthuridae	*Naso unicornis*	0.0004	0.127
Acanthuridae	*Naso vlamingii*	0.0008	0.539
Acanthuridae	*Zebrasoma scopas*	0.0020	0.165
Acanthuridae	*Zebrasoma veliferum*	0.0010	0.108
Balistidae	*Balistapus undulatus*	0.0051	0.833
Balistidae	*Balistoides viridescens*	0.0007	0.707
Balistidae	*Melichthys niger*	0.0235	2.623
Balistidae	*Melichthys vidua*	0.0158	1.450
Balistidae	*Odonus niger*	0.0025	0.370
Balistidae	*Pseudobalistes flavimarginatus*	0.0009	1.532
Balistidae	*Rhinecanthus aculeatus*	0.0048	1.083
Balistidae	*Rhinecanthus lunula*	0.0002	0.059
Balistidae	*Rhinecanthus rectangulus*	0.0006	0.049
Balistidae	*Sufflamen bursa*	0.0062	0.492
Carangidae	*Caranx melampygus*	0.0016	1.079
Carangidae	*Elagatis* spp.	0.0001	0.067
Carcharhinidae	*Carcharhinus melanopterus*	0.0008	14.084
Chaetodontidae	*Chaetodon auriga*	0.0050	0.388
Chaetodontidae	*Chaetodon citrinellus*	0.0039	0.124
Chaetodontidae	*Chaetodon ephippium*	0.0033	0.252
Chaetodontidae	*Chaetodon lunula*	0.0014	0.095
Chaetodontidae	*Chaetodon lunulatus*	0.0009	0.044
Chaetodontidae	*Chaetodon pelewensis*	0.0020	0.064
Chaetodontidae	*Chaetodon quadrimaculatus*	0.0034	0.144
Chaetodontidae	*Chaetodon reticulatus*	0.0010	0.063
Chaetodontidae	*Chaetodon trifascialis*	0.0008	0.023
Chaetodontidae	*Chaetodon ulietensis*	0.0034	0.136
Chaetodontidae	*Forcipiger longirostris*	0.0008	0.044
Chaetodontidae	*Heniochus chrysostomus*	0.0000	0.004
Chanidae	*Chanos chanos*	0.0004	2.511
Dasyatidae	*Dasyatis kuhlii*	0.0002	0.880
Diodontidae	*Diodon hystrix*	0.0002	0.127
Echeneidae	*Echeneis naucrates*	0.0001	0.029
Fistulariidae	*Fistularia commersonii*	0.0000	0.002
Holocentridae	*Myripristis berndti*	0.0008	0.085
Holocentridae	*Myripristis botche*	0.0000	0.002
Holocentridae	*Myripristis violacea*	0.0011	0.195
Holocentridae	*Neoniphon sammara*	0.0002	0.017
Holocentridae	*Sargocentron spiniferum*	0.0014	0.414
Labridae	*Cheilinus chlorourus*	0.0046	0.913
Labridae	*Cheilinus trilobatus*	0.0007	0.280
Labridae	*Coris aygula*	0.0007	0.226
Labridae	*Coris gaimard*	0.0002	0.024
Labridae	*Epibulus insidiator*	0.0000	0.014
Lethrinidae	*Gnathodentex aureolineatus*	0.0001	0.017

3.5.2 Weighted average density and biomass of all finfish species recorded in Tikehau (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Lethrinidae	*Lethrinus obsoletus*	0.0004	0.135
Lutjanidae	*Aphareus furca*	0.0003	0.182
Lutjanidae	*Lutjanus bohar*	0.0003	0.292
Lutjanidae	*Lutjanus fulviflamma*	0.0004	0.106
Lutjanidae	*Lutjanus fulvus*	0.0057	1.615
Lutjanidae	*Lutjanus gibbus*	0.0015	0.508
Lutjanidae	*Lutjanus monostigma*	0.0079	2.285
Mugilidae	*Crenimugil crenilabis*	0.0001	0.026
Mugilidae	*Liza vaigiensis*	0.0009	0.315
Mugilidae	*Valamugil buchanani*	0.0001	0.022
Mugilidae	*Valamugil seheli*	0.0016	0.731
Mullidae	*Mulloidichthys flavolineatus*	0.0045	1.086
Mullidae	*Parupeneus barberinus*	0.0036	1.709
Mullidae	*Parupeneus cyclostomus*	0.0001	0.012
Mullidae	*Parupeneus multifasciatus*	0.0059	0.465
Mullidae	*Parupeneus trifasciatus*	0.0001	0.017
Pomacanthidae	*Pygoplites diacanthus*	0.0000	0.005
Priacanthidae	*Priacanthus hamrur*	0.0001	0.029
Scaridae	*Calotomus carolinus*	0.0001	0.031
Scaridae	*Cetoscarus bicolor*	0.0000	0.018
Scaridae	*Chlorurus frontalis*	0.0000	0.011
Scaridae	*Chlorurus microrhinos*	0.0001	0.099
Scaridae	*Chlorurus sordidus*	0.0352	4.615
Scaridae	*Hipposcarus longiceps*	0.0010	1.008
Scaridae	*Scarus altipinnis*	0.0010	0.529
Scaridae	*Scarus flavipectoralis*	0.0000	0.008
Scaridae	*Scarus frenatus*	0.0004	0.184
Scaridae	*Scarus ghobban*	0.0031	1.721
Scaridae	*Scarus niger*	0.0000	0.019
Scaridae	*Scarus psittacus*	0.0043	0.651
Scaridae	*Scarus rivulatus*	0.0001	0.056
Scaridae	*Scarus rubroviolaceus*	0.0001	0.077
Scaridae	*Scarus schlegeli*	0.0004	0.227
Scaridae	*Scarus spinus*	0.0001	0.020
Serranidae	*Cephalopholis argus*	0.0038	1.199
Serranidae	*Cephalopholis urodeta*	0.0026	0.145
Serranidae	*Epinephelus cyanopodus*	0.0000	0.013
Serranidae	*Epinephelus fasciatus*	0.0002	0.019
Serranidae	*Epinephelus hexagonatus*	0.0003	0.014
Serranidae	*Epinephelus merra*	0.0007	0.089
Serranidae	*Epinephelus rivulatus*	0.0001	0.005
Serranidae	*Variola louti*	0.0004	0.191
Sphyraenidae	*Sphyraena barracuda*	0.0000	0.086
Sphyraenidae	*Sphyraena qenie*	0.0001	0.085
Zanclidae	*Zanclus cornutus*	0.0082	0.942
Lethrinidae	*Lethrinus olivaceus*	0.0035	2.295
Lethrinidae	*Lethrinus* spp.	0.0002	0.058
Lethrinidae	*Monotaxis grandoculis*	0.0044	0.940

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Fakarava invertebrate survey data

4.1.1 Invertebrate species recorded in different assessments in Fakarava

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		+
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Bohadschia vitiensis*	+	+		+
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria nobilis*				+
Bêche-de-mer	*Thelenota ananas*	+			
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Chama* spp.	+	+		+
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.				+
Bivalve	*Tridacna maxima*	+	+		+
Gastropod	*Chicoreus ramosus*	+	+		
Gastropod	*Conus* spp.		+		+
Gastropod	*Cypraea caputserpensis*		+		+
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea* spp.		+		
Gastropod	*Drupa* spp.		+		
Gastropod	*Lambis lambis*	+	+		
Gastropod	*Lambis truncata*	+	+		
Gastropod	*Thais* spp.		+		
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo crassus*				+
Gastropod	*Turbo setosus*				+
Octopus	*Octopus cyanea*	+			
Star	*Culcita novaeguineae*	+	+		+
Urchin	*Diadema* spp.		+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix diadema*		+		
Urchin	*Heterocentrotus mammillatus*				+

+ = presence of the species.

4.1.2 Fakarava broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	0.8	0.4	66	16.7	0.0	3	0.8	0.5	11	4.2	1.4	2
Bohadschia argus	9.9	2.3	66	32.7	4.5	20	10.0	4.5	11	15.7	6.2	7
Bohadschia vitiensis	24.4	7.8	66	107.5	24.4	15	24.8	14.5	11	68.3	30.4	4
Chama spp.	1390.0	162.9	66	1698.9	172.9	54	1387.2	343.5	11	1695.4	339.1	9
Chicoreus ramosus	0.3	0.3	66	16.7		1	0.3	0.3	11	2.8		1
Culcita novaeguineae	9.5	2.0	66	29.9	3.5	21	9.5	3.2	11	13.1	3.7	8
Holothuria atra	50.1	21.0	66	206.8	75.5	16	50.4	32.1	11	110.8	63.1	5
Lambis lambis	0.3	0.3	66	16.7		1	0.3	0.3	11	2.8		1
Lambis truncata	2.0	1.0	66	26.5	6.5	5	2.0	1.1	11	5.5	1.9	4
Octopus cyanea	0.2	0.2	66	16.1		1	0.2	0.2	11	2.6		1
Pinctada margaritifera	9.0	2.3	66	35.1	4.9	17	9.1	4.1	11	16.8	5.9	6
Thelenota ananas	0.3	0.3	66	16.7		1	0.3	0.3	11	2.8		1
Tridacna maxima	4515.8	850.0	66	4807.1	892.5	62	4490.3	1923.4	11	4490.3	1923.4	11
Trochus niloticus	55.9	18.6	66	136.7	41.2	27	55.7	34.4	11	87.6	51.3	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 Fakarava 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	7.8	5.8	96	375.0	125.0	2	7.8	7.8	16	125.0		1
Bohadschia argus	13.0	7.7	96	416.7	83.3	3	13.0	10.6	16	104.2	62.5	2
Bohadschia vitiensis	15.6	8.1	96	375.0	72.2	4	15.6	9.2	16	83.3	24.1	3
Chama spp.	5760.4	810.8	96	6912.5	920.8	80	5760.4	1519.4	16	5760.4	1519.4	16
Chicoreus ramosus	7.8	5.8	96	375.0	125.0	2	7.8	5.7	16	62.5	20.8	2
Conus spp.	7.8	5.8	96	375.0	125.0	2	7.8	7.8	16	125.0		1
Culcita novaeguineae	85.9	14.7	96	294.6	18.4	28	85.9	18.0	16	105.8	18.0	13
Cypraea caputserpensis	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Cypraea moneta	13.0	9.3	96	625.0	125.0	2	13.0	13.0	16	208.3		1
Cypraea spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Diadema spp.	26.0	9.4	96	312.5	40.9	8	26.0	16.1	16	138.9	50.1	3
Drupa spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Echinometra mathaei	65.1	22.9	96	480.8	118.3	13	65.1	32.3	16	208.3	71.0	5
Echinothrix diadema	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Holothuria atra	268.2	126.0	96	3218.8	1108.4	8	268.2	254.7	16	2145.8	1937.5	2
Lambis lambis	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Lambis truncata	54.7	18.2	96	525.0	78.6	10	54.7	23.4	16	145.8	41.3	6
Pinctada margaritifera	10.4	5.1	96	250.0	0.0	4	10.4	4.7	16	41.7	0.0	4
Thais spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Tridacna maxima	8377.6	848.9	96	8647.8	861.8	93	8377.6	1570.2	16	8377.6	1570.2	16
Trochus niloticus	1921.9	355.5	96	236.8	534.0	57	1921.9	740.1	16	2196.4	822.1	14

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 Fakarava reef-front search (RFs) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	2.3	1.7	31	35.3	11.8	2	2.4	2.4	5	11.8		1
Echinometra mathaei	53.9	10.6	31	111.4	6.3	15	55.7	24.7	5	92.8	17.6	3
Tridacna maxima	16.7	5.1	31	36.1	8.2	15	17.1	8.3	5	12.9	4.9	3
Turbo crassus	2.3	1.3	31	23.5	0.0	3	2.4	1.6	5	5.9	2.0	2
Turbo setosus	0.8	0.8	31	23.5		1	0.8	0.8	5	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 Fakarava reef-front search by walking (RFs_w) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	2.4	1.1	32	15.6	2.7	5	2.6	1.7	5	4.3	2.5	3
Cypraea caputserpensis	10.8	8.7	32	86.1	64.0	4	9.2	6.6	5	18.3	16.4	2
Heterocentrotus mammillatus	19.4	6.1	32	62.2	10.9	10	18.5	7.6	5	31.5	1.9	2
Tridacna maxima	12.8	3.4	32	27.4	5.2	15	13.0	7.1	5	6.0	2.1	4
Trochus niloticus	0.7	0.5	32	11.1	0.0	2	0.7	0.5	5	1.9	0.0	2
Turbo setosus	51.0	11.2	32	81.7	14.1	20	51.8	12.6	5	39.2	1.4	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 Fakarava 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
Bohadschia argus	20.8	12.3	24	166.7	41.7	3	20.8	14.7	4	41.7	20.8	2
Bohadschia vitiensis	10.4	7.2	24	125.0	0.0	2	10.4	10.4	4	41.7		1
Chama spp.	1338.5	320.8	24	2141.7	384.2	15	1338.5	345.7	4	1338.5	345.7	4
Conus spp.	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Culcita novaeguineae	36.5	15.9	24	175.0	30.6	5	36.5	13.1	4	48.6	6.9	3
Spondylus spp.	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Tridacna maxima	4588.5	1138.3	24	4588.5	1138.3	24	4588.5	2327.5	4	4588.5	2327.5	4
Trochus niloticus	192.7	105.3	24	578.1	278.4	8	192.7	172.5	4	385.4	322.9	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.

4.1.7 Fakarava 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
Holothuria fuscogilva	14.3	4.0	12	24.5	3.1	7	14.3	3.6	2	14.3	3.6	2
Holothuria nobilis	3.6	3.6	12	42.8		1	3.6	3.6	2	7.1		1
Thelenota anax	3.6	2.4	12	21.4	0.0	2	3.6	3.6	2	7.1		1

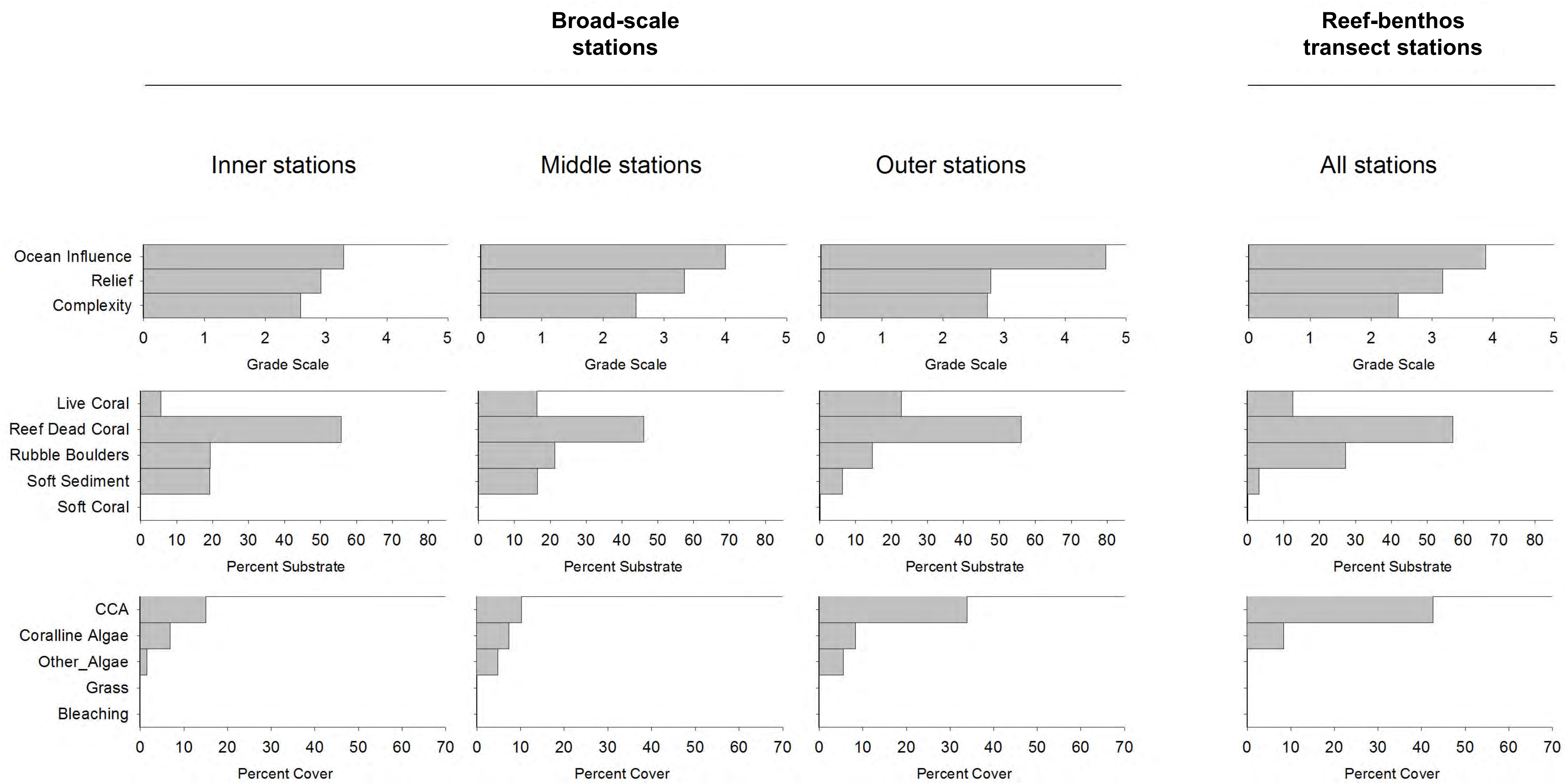
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.8 Fakarava species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna maxima	9.7	0.1	22,205
Trochus niloticus	10.2	0.1	999
Holothuria atra	18.5	0.9	303
Bohadschia vitiensis	28.9	2.9	109
Bohadschia argus	32.9	0.8	50
Pinctada margaritifera	15.9	0.4	41
Lambis truncata	28.4	1.0	29
Actinopyga mauritiana	22.3	0.7	16
Holothuria fuscogilva	38.5	1.5	8
Chicoreus ramosus	19.8	0.9	4
Conus spp.	3.9	0.9	4
Thelenota anax	47.0	3.0	2
Lambis lambis	21.5	1.5	2
Holothuria nobilis	41.5	2.5	2
Thais spp.	5.2		1
Thelenota ananas	55.0		1
Cypraea spp.	6.0		1
Drupa spp.	3.5		1
Chama spp.			8054
Turbo setosus			148
Culcita novaeguineae			78
Echinometra mathaei			66
Heterocentrotus mammillatus			63
Cypraea caputserpensis			33
Diadema spp.			10
Cypraea moneta			5
Turbo crassus			2
Echinothrix diadema			1
Octopus cyanea			1
Spondylus spp.			1

SE = standard error; n = number.

4.1.9 Habitat descriptors for independent assessment – Fakarava



4.2 Maatea invertebrate survey data

4.2.1 Invertebrate species recorded in different assessments in Maatea

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		+
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Bohadschia vitiensis*	+	+		
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria fuscogilva*	+	+		+
Bêche-de-mer	*Holothuria leucospilota*	+			
Bêche-de-mer	*Thelenota ananas*	+	+		
Bivalve	*Chama* spp.	+	+		
Bivalve	*Pinctada margaritifera*				+
Bivalve	*Spondylus* spp.	+	+		+
Bivalve	*Tridacna maxima*	+	+		+
Cnidarians	*Stichodactyla* spp.	+	+		+
Gastropod	*Astralium* spp.		+		
Gastropod	*Cassis cornuta*				+
Gastropod	*Conus miles*		+		
Gastropod	*Conus* spp.	+	+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea arabica*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea obvelata*		+		
Gastropod	*Cypraea tigris*	+	+		
Gastropod	*Lambis truncata*	+	+		+
Gastropod	*Strombus* spp.		+		
Gastropod	*Thais* spp.		+		+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo marmoratus*	+	+		+
Gastropod	*Turbo setosus*		+		
Octopus	*Octopus* spp.	+	+		+
Star	*Acanthaster planci*	+	+		
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia laevigata*		+		
Urchin	*Diadema* spp.	+	+		
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix calamaris*	+	+		+
Urchin	*Echinothrix diadema*	+	+		+
Urchin	*Echinothrix* spp.				+
Urchin	*Tripneustes gratilla*	+	+		

+ = presence of the species.

4.2.2 Maatea 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	0.9	0.6	73	22.2	5.6	3	0.9	0.5	12	3.6	1.0	3
Actinopyga mauritiana	3.0	1.5	73	43.3	11.3	5	3.0	2.1	12	18.1	4.2	2
Bohadschia argus	79.7	16.2	73	109.7	21.0	53	80.2	35.3	12	80.2	35.3	12
Bohadschia vitiensis	0.5	0.3	73	16.7	0.0	2	0.5	0.5	12	5.6		1
Chama spp.	24.0	5.8	73	58.3	11.6	30	23.6	10.8	12	28.3	12.6	10
Conus spp.	1.6	0.7	73	19.4	2.8	6	1.6	0.6	12	3.8	0.7	5
Culcita novaeguineae	2.5	0.8	73	18.3	1.7	10	2.5	1.2	12	5.0	1.8	6
Cypraea tigris	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Diadema spp.	4619.2	1004.8	73	6744.0	1368.7	50	4672.7	2401.9	12	5607.2	2807.0	10
Echinometra mathaei	461.4	37.8	73	543.2	35.5	62	459.5	71.0	12	459.5	71.0	12
Echinothrix calamaris	39.5	8.0	73	72.1	12.6	40	38.5	10.9	12	42.0	11.3	11
Echinothrix diadema	30.6	5.3	73	65.7	7.7	34	30.4	8.6	12	40.5	9.1	9
Holothuria atra	345.0	235.1	73	2098.5	1366.2	12	349.8	285.8	12	1399.0	1031.0	3
Holothuria fuscogilva	0.7	0.4	73	16.7	0.0	3	0.7	0.3	12	2.6	0.1	3
Holothuria leucospilota	0.2	0.2	73	17.9		1	0.2	0.2	12	3.0		1
Lambis truncata	3.7	2.3	73	44.4	24.6	6	3.7	2.3	12	8.8	4.9	5
Octopus spp.	0.5	0.3	73	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Spondylus spp.	1.1	0.5	73	16.7	0.0	5	1.2	0.5	12	3.5	0.7	4
Stichodactyla sp.	8.2	4.2	73	66.7	27.8	9	8.3	5.6	12	14.2	9.2	7
Thelenota ananas	1.6	0.7	73	19.4	2.8	6	1.6	0.8	12	4.7	1.3	4
Tridacna maxima	274.9	37.9	73	329.0	42.0	61	269.4	64.6	12	293.9	65.5	11
Tripneustes gratilla	0.9	0.4	73	16.7	0.0	4	0.9	0.4	12	2.8	0.0	4
Trochus niloticus	75.8	26.0	73	149.6	48.6	37	76.8	32.0	12	76.8	32.0	12
Turbo marmoratus	4.1	1.7	73	37.5	10.3	8	4.1	3.0	12	12.4	8.0	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.

4.2.3 Maatea 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	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Actinopyga mauritiana	37.3	12.6	114	425.0	65.1	10	37.3	21.1	19	141.7	62.6	5
Astralium spp.	13.2	6.9	114	375.0	72.2	4	13.2	6.4	19	62.5	12.0	4
Bohadschia argus	61.4	17.8	114	411.8	77.1	17	61.4	26.3	19	129.6	46.8	9
Bohadschia vitiensis	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Chama spp.	125.0	52.6	114	838.2	306.1	17	125.0	57.9	19	263.9	106.5	9
Conus miles	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Conus spp.	24.1	8.8	114	305.6	55.6	9	24.1	10.2	19	76.4	19.9	6
Culcita novaeguineae	11.0	4.8	114	250.0	0.0	5	11.0	5.4	19	52.1	10.4	4
Cypraea annulus	11.0	5.7	114	312.5	62.5	4	11.0	7.0	19	69.4	27.8	3
Cypraea arabica	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Cypraea caputserpensis	21.9	7.3	114	277.8	27.8	9	21.9	10.3	19	83.3	22.8	5
Cypraea moneta	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Cypraea obvelata	6.6	3.8	114	250.0	0.0	3	6.6	3.6	19	41.7	0.0	3
Cypraea tigris	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Diadema spp.	4050.4	695.1	114	6891.8	1054.0	67	4050.4	1557.4	19	5497.0	1986.5	14
Echinometra mathaei	5938.6	545.1	114	6979.4	579.1	97	5938.6	963.4	19	5938.6	963.4	19
Echinothrix calamaris	326.8	44.3	114	716.3	63.7	52	326.8	87.9	19	477.6	104.5	13
Echinothrix diadema	609.6	108.0	114	1085.9	170.5	64	609.6	198.9	19	609.6	198.9	19
Holothuria atra	366.2	181.0	114	3795.5	1592.5	11	366.2	287.5	19	1739.6	1249.0	4
Holothuria fuscogilva	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Lambis truncata	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Linckia laevigata	8.8	4.3	114	250.0	0.0	4	8.8	6.0	19	83.3	0.0	2
Octopus spp.	11.0	4.8	114	250.0	0.0	5	11.0	5.4	19	52.1	10.4	4
Spondylus spp.	32.9	11.5	114	375.0	67.2	10	32.9	12.2	19	78.1	20.0	8
Stichodactyla spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Strombus spp.	2.2	2.2	114	250.0		1	2.2	2.2	19	41.7		1
Thais spp.	8.8	5.3	114	333.3	83.3	3	8.8	5.1	19	55.6	13.9	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.

4.2.3 Maatea 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
Thelenota ananas	4.4	3.1	114	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Tridacna maxima	1491.2	166.8	114	1931.8	192.4	88	1491.2	303.5	19	1666.7	312.3	17
Tripneustes gratilla	19.7	9.9	114	375.0	125.0	6	19.7	10.7	19	93.8	31.3	4
Trochus niloticus	2210.5	522.2	114	3761.2	840.3	67	2210.5	1161.2	19	2625.0	1359.8	16
Turbo marmoratus	78.9	20.3	114	500.0	70.0	18	78.9	37.4	19	250.0	86.1	6
Turbo setosus	17.5	9.7	114	400.0	150.0	5	17.5	9.7	19	83.3	29.5	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.

4.2.4 Maatea 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	7.3	3.3	42	51.0	12.8	6	7.3	6.0	7	17.0	13.1	3
Echinometra mathaei	11.2	11.2	42	470.6		1	11.2	11.2	7	78.4		1
Echinothrix diadema	11.8	4.3	42	49.4	12.4	10	11.8	6.4	7	16.5	8.2	5
Octopus spp.	1.1	1.1	42	47.1		1	1.1	1.1	7	7.8		1
Stichodactyla spp.	1.7	1.2	42	35.3	11.8	2	1.7	1.2	7	5.9	2.0	2
Thais spp.	0.6	0.6	42	23.5		1	0.6	0.6	7	3.9		1
Tridacna maxima	2.8	1.2	42	23.5	0.0	5	2.8	1.4	7	6.5	1.3	3
Trochus niloticus	210.1	80.8	42	441.2	155.6	20	210.1	191.3	7	294.1	265.9	5
Turbo marmoratus	29.1	6.7	42	58.3	10.0	21	29.1	8.0	7	29.1	8.0	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.

4.2.5 Maatea 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	13.9	8.3	36	166.7	41.7	3	13.9	10.3	6	41.7	20.8	2
Echinothrix spp.	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Tridacna maxima	13.9	10.9	36	250.0	125.0	2	13.9	10.3	6	41.7	20.8	2
Trochus niloticus	1371.5	487.0	36	2244.3	744.0	22	1371.5	811.7	6	1371.5	811.7	6
Turbo marmoratus	104.2	28.8	36	250.0	48.8	15	104.2	29.9	6	104.2	29.9	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.

4.2.6 Maatea sea cucumber day search (Ds) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	5.7	2.0	30	24.5	3.1	7	5.7	4.2	5	14.3	7.1	2
Cassis cornuta	0.7	0.7	30	21.4		1	0.7	0.7	5	3.6		1
Culcita novaeguineae	0.7	0.7	30	21.4		1	0.7	0.7	5	3.6		1
Echinothrix calamaris	0.7	0.7	30	21.4		1	0.7	0.7	5	3.6		1
Echinothrix spp.	0.7	0.7	30	21.4		1	0.7	0.7	5	3.6		1
Holothuria fuscogilva	12.8	6.9	30	96.4	26.9	4	12.8	12.8	5	64.2		1
Lambis truncata	2.9	1.4	30	21.4	0.0	4	2.9	1.3	5	4.8	1.2	3
Pinctada margaritifera	0.7	0.7	30	21.4		1	0.7	0.7	5	3.6		1
Spondylus spp.	27.1	25.0	30	271.2	239.2	3	27.1	27.1	5	135.6		1
Stichodactyla spp.	22.1	21.4	30	331.9	310.5	2	22.1	22.1	5	110.6		1
Trochus niloticus	25.0	25.0	30	749.5		1	25.0	25.0	5	124.9		1
Turbo marmoratus	2.1	1.6	30	32.1	10.7	2	2.1	2.1	5	10.7		1

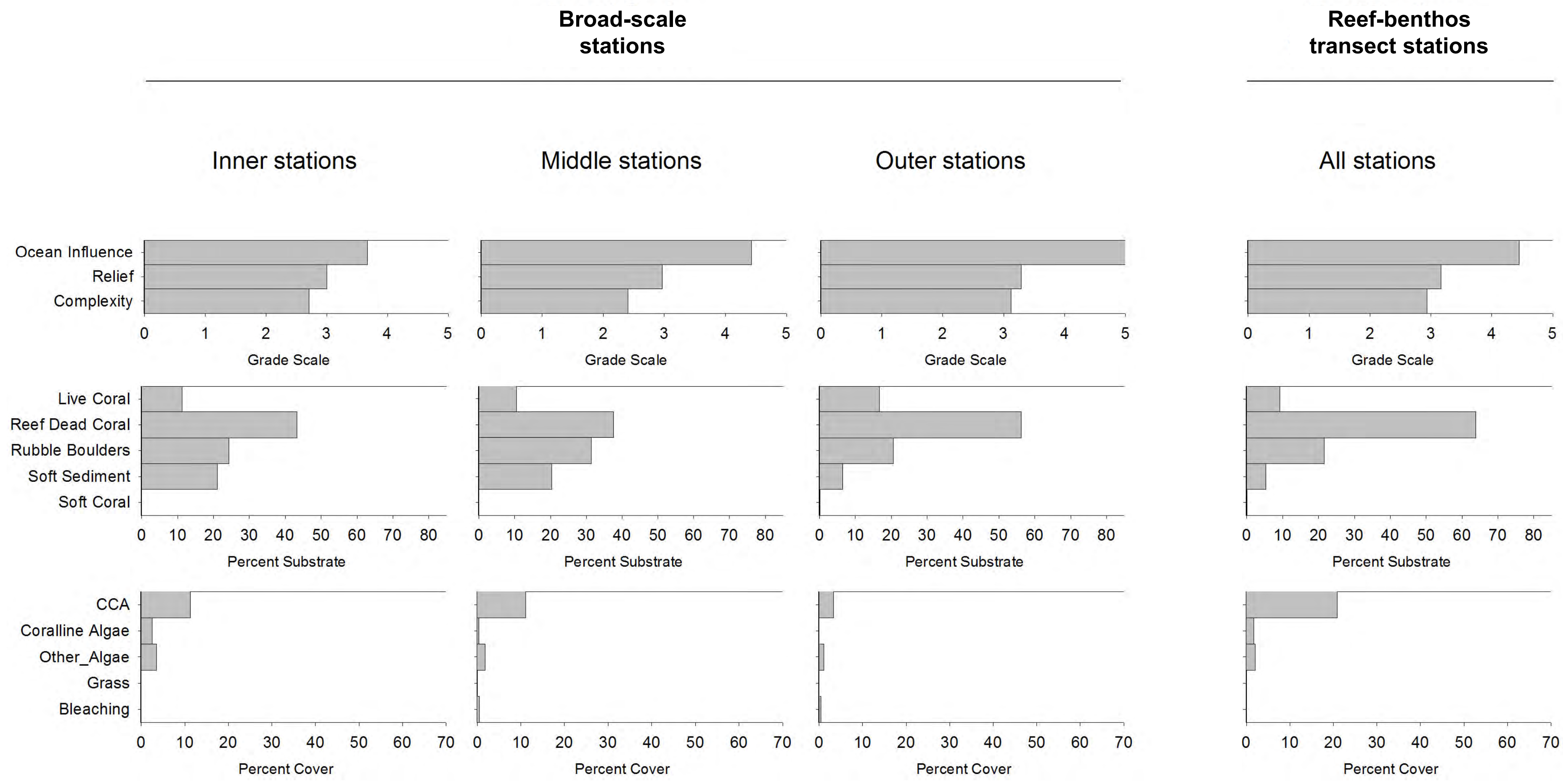
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.7 Maatea species size review – all survey methods

Species	Mean length (cm)	SE	n
Echinometra mathaei	3.0	0.0	4746
Trochus niloticus	9.6	0.1	2144
Tridacna maxima	9.6	0.1	1893
Bohadschia argus	30.1	0.7	382
Turbo marmoratus	14.6	0.4	139
Spondylus spp.	4.0	0.0	58
Actinopyga mauritiana	19.0	1.0	47
Holothuria fuscogilva	39.2	1.0	22
Lambis truncata	29.7	0.8	21
Conus spp.	5.7	0.8	18
Thelenota ananas	47.2	3.0	9
Turbo setosus	6.1	0.7	8
Astralium spp.	3.5	0.1	6
Thais spp.	5.6	0.3	5
Holothuria atra	20.0	0.0	1668
Cypraea tigris	8.4	0.0	2
Cassis cornuta	20.4	0.0	1
Strombus spp.	9.0	0.0	1
Conus miles	4.5	0.0	1
Diadema spp.			22,079
Echinothrix diadema			433
Echinothrix calamaris			323
Chama spp.			162
Stichodactyla spp.			71
Culcita novaeguineae			17
Tripneustes gratilla			13
Cypraea caputserpensis			10
Octopus spp.			9
Acanthaster planci			6
Cypraea annulus			5
Linckia laevigata			4
Bohadschia vitiensis			3
Cypraea obvelata			3
Cypraea moneta			2
Echinothrix spp.			2
Holothuria leucospilota			1
Pinctada margaritifera			1
Cypraea arabica			1

SE = standard error; n = number.

4.2.8 Habitat descriptors for independent assessment – Maatea



4.3 Mataiea invertebrate survey data

4.3.1 Invertebrate species recorded in different assessments in Mataiea

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Bohadschia similis*				+
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria nobilis*				+
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*	+	+		+
Cnidarians	*Stichodactyla* spp.				+
Gastropod	*Astralium* spp.		+		+
Gastropod	*Conus nimbosus*		+		
Gastropod	*Conus* spp.	+	+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea erosa*		+		
Gastropod	*Cypraea isabella*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea obvelata*		+		
Gastropod	*Cypraea* spp.		+		
Gastropod	*Cypraea tigris*	+			
Gastropod	*Drupa* spp.		+		
Gastropod	*Drupella* spp.		+		
Gastropod	*Lambis* spp.		+		+
Gastropod	*Lambis truncata*	+			
Gastropod	*Terebra* spp.		+		
Gastropod	*Thais aculeata*		+		
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo marmoratus*	+	+		+
Gastropod	*Turbo setosus*		+		
Gastropod	*Vasum ceramicum*		+		+
Octopus	*Octopus cyanea*	+	+		
Star	*Acanthaster planci*	+			
Star	*Culcita novaeguineae*	+	+		+
Urchin	*Diadema* spp.	+	+		+
Urchin	*Echinometra mathaei*	+	+		
Urchin	*Echinothrix calamaris*	+	+		
Urchin	*Echinothrix diadema*	+	+		
Urchin	*Tripneustes gratilla*	+			

+ = presence of the species.

4.3.2 Mataiea 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	78	16.7		1	0.2	0.2	13	2.7		1
Actinopyga mauritiana	1.1	0.6	78	20.8	4.2	4	1.1	0.7	13	4.6	1.9	3
Bohadschia argus	68.8	10.2	78	105.2	13.0	51	69.2	18.1	13	74.9	18.7	12
Chama spp.	41.7	17.9	78	541.7	98.6	6	41.8	41.8	13	543.5		1
Conus spp.	2.0	0.8	78	22.2	4.2	7	2.1	0.8	13	4.5	0.9	6
Culcita novaeguineae	14.4	2.2	78	28.1	3.0	40	14.4	3.8	13	18.7	4.1	10
Cypraea tigris	0.4	0.3	78	16.7	0.0	2	0.4	0.3	13	2.8	0.0	2
Diadema spp.	282.1	217.1	78	1294.3	979.0	17	280.9	215.7	13	730.3	530.0	5
Echinometra mathaei	31.4	11.8	78	306.0	54.4	8	31.5	17.4	13	81.9	36.5	5
Echinothrix calamaris	3.4	3.0	78	133.9	100.5	2	3.6	3.1	13	23.2	17.6	2
Echinothrix diadema	104.4	31.2	78	407.3	94.4	20	104.4	61.6	13	226.1	119.2	6
Holothuria atra	126.3	79.2	78	703.6	419.4	14	124.4	83.4	13	269.6	168.5	6
Lambis truncata	4.9	2.7	78	47.7	22.4	8	4.9	3.0	13	15.9	7.7	4
Octopus cyanea	0.2	0.2	78	14.7		1	0.2	0.2	13	2.7		1
Pinctada margaritifera	0.2	0.2	78	16.7		1	0.2	0.2	13	2.7		1
Synapta spp.	0.4	0.3	78	15.7	1.0	2	0.4	0.3	13	2.7	0.0	2
Thelenota ananas	2.7	1.2	78	26.8	8.4	8	2.7	1.3	13	5.9	2.2	6
Tridacna maxima	31.6	9.1	78	64.8	17.3	38	30.9	15.9	13	36.5	18.3	11
Tripneustes gratilla	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Trochus niloticus	159.1	40.0	78	302.6	69.1	41	159.4	52.1	13	207.2	60.0	10
Turbo marmoratus	0.8	0.4	78	16.1	0.6	4	0.8	0.4	13	2.7	0.0	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.

4.3.3 Mataiea 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	362.2	170.9	78	3531.3	1237.8	8	362.2	351.9	13	2354.2	2229.2	2
Astralium spp.	19.2	8.9	78	300.0	50.0	5	19.2	9.0	13	62.5	12.0	4
Bohadschia argus	147.4	29.4	78	425.9	53.1	27	147.4	41.0	13	174.2	43.8	11
Chama spp.	9.6	5.5	78	250.0	0.0	3	9.6	5.1	13	41.7	0.0	3
Conus nimbosus	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Conus spp.	64.1	34.3	78	833.3	327.0	6	64.1	54.1	13	277.8	215.6	3
Culcita novaeguineae	44.9	13.5	78	318.2	35.2	11	44.9	20.3	13	116.7	33.3	5
Cypraea annulus	12.8	10.1	78	500.0	250.0	2	12.8	9.9	13	83.3	41.7	2
Cypraea caputserpensis	115.4	81.4	78	1285.7	835.3	7	115.4	81.3	13	375.0	231.4	4
Cypraea erosa	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Cypraea isabella	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea moneta	41.7	16.7	78	541.7	41.7	6	41.7	35.3	13	270.8	187.5	2
Cypraea obvelata	35.3	19.7	78	687.5	213.5	4	35.3	26.6	13	229.2	104.2	2
Cypraea spp.	9.6	9.6	78	750.0		1	9.6	9.6	13	125.0		1
Diadema spp.	6214.7	978.4	78	7574.2	1123.7	64	6214.7	2251.2	13	6732.6	2381.6	12
Drupa spp.	12.8	9.0	78	500.0	0.0	2	12.8	12.8	13	166.7		1
Drupella spp.	583.3	277.1	78	6500.0	2137.4	7	583.3	445.8	13	1895.8	1324.4	4
Echinometra mathaei	4115.4	902.9	78	5350.0	1127.5	60	4115.4	1920.5	13	4458.3	2054.2	12
Echinothrix calamaris	179.5	60.3	78	666.7	189.2	21	179.5	77.3	13	259.3	101.8	9
Echinothrix diadema	246.8	102.8	78	1069.4	394.4	18	246.8	132.0	13	401.0	199.2	8
Holothuria atra	16.0	10.5	78	416.7	166.7	3	16.0	13.0	13	104.2	62.5	2
Lambis spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Octopus cyanea	9.6	5.5	78	250.0	0.0	3	9.6	6.9	13	62.5	20.8	2
Spondylus spp.	32.1	29.0	78	1250.0	1000.0	2	32.1	28.8	13	208.3	166.7	2
Terebra spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Thais aculeata	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Tridacna maxima	1506.4	231.2	78	2175.9	291.0	54	1506.4	526.0	13	1780.3	586.1	11
Trochus niloticus	1727.6	458.0	78	4210.9	965.7	32	1727.6	1064.1	13	2245.8	1354.0	10

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 Mataiea 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
Turbo marmoratus	80.1	39.4	78	1041.7	331.8	6	80.1	80.1	13	1041.7		1
Turbo setosus	22.4	19.5	78	875.0	625.0	2	22.4	19.2	13	145.8	104.2	2
Vasum ceramicum	12.8	7.8	78	333.3	83.3	3	12.8	9.9	13	83.3	41.7	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.

4.3.4 Mataiea 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
Tridacna maxima	7.6	5.1	12	45.5	0.0	2	7.6	7.6	2	15.2		1
Trochus niloticus	41.7	31.4	12	250.0	113.6	2	41.7	41.7	2	83.3		1
Turbo marmoratus	3.8	3.8	12	45.5		1	3.8	3.8	2	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.

4.3.5 Mataiea 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
Astralium spp.	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Bohadschia argus	41.7	15.1	30	178.6	25.3	7	41.7	27.2	5	69.4	38.7	3
Culcita novaeguineae	8.3	5.8	30	125.0	0.0	2	8.3	8.3	5	41.7		1
Diadema spp.	675.0	454.4	30	5062.5	2751.2	4	675.0	442.6	5	1687.5	500.0	2
Lambis spp.	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Stichodactyla sp.	12.5	9.2	30	187.5	62.5	2	12.5	12.5	5	62.5		1
Thelenota ananas	12.5	7.0	30	125.0	0.0	3	12.5	8.3	5	31.3	10.4	2
Tridacna maxima	12.5	7.0	30	125.0	0.0	3	12.5	8.3	5	31.3	10.4	2
Trochus niloticus	733.3	164.7	30	916.7	188.2	24	733.3	254.9	5	733.3	254.9	5
Turbo marmoratus	16.7	13.0	30	250.0	125.0	2	16.7	16.7	5	83.3		1
Vasum ceramicum	4.2	4.2	30	125.0		1	4.2	4.2	5	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.

4.3.6 Mataiea 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	53.3	18.6	12	91.4	22.4	7.0	53.3	26.7	2	53.3	26.7	2
Bohadschia similis	431.1	132.0	12	574.8	147.1	9.0	431.1	315.6	2	431.1	315.6	2
Stichopus horrens	4.4	4.4	12	53.3		1.0	4.4	4.4	2	8.9		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.

4.3.7 Mataiea sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	2.4	2.4	18	42.8		1	2.4	2.4	3	7.1		1
Holothuria fuscogilva	15.5	4.5	18	30.9	5.2	9	15.5	8.3	3	23.2	5.4	2
Holothuria nobilis	1.2	1.2	18	21.4		1	1.2	1.2	3	3.6		1
Thelenota ananas	8.3	5.2	18	50.0	18.9	3	8.3	8.3	3	25.0		1

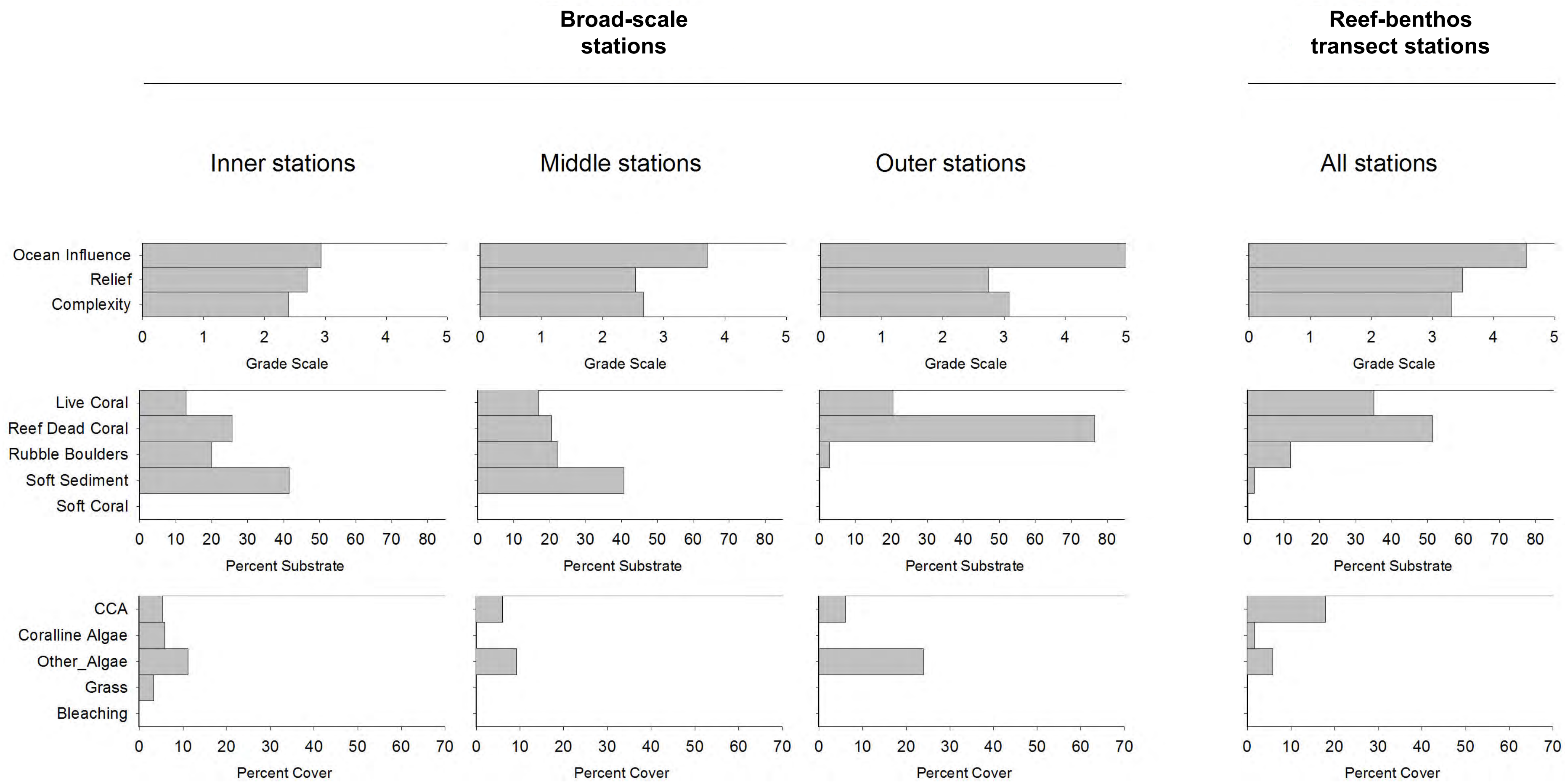
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.8 Mataiea species size review – all survey methods

Species	Mean length (cm)	SE	n
Trochus niloticus	9.7	0.1	1483
Tridacna maxima	8.2	0.2	626
Holothuria atra	16.8	1.7	596
Bohadschia argus	27.9	0.3	398
Chama spp.	9.5	0.0	203
Actinopyga mauritiana	19.1	0.6	118
Turbo marmoratus	11.7	0.6	34
Conus spp.	10.6	0.4	30
Thelenota ananas	44.6	2.2	23
Lambis truncata	29.0	1.2	23
Holothuria fuscogilva	34.5	1.2	13
Astralium spp.	3.1	0.1	7
Turbo setosus	2.1	0.0	7
Vasum ceramicum	8.0	0.8	5
Cypraea erosa	2.7	0.2	2
Lambis spp.	16.3	3.8	2
Conus nimbosus	3.9	0.3	2
Holothuria nobilis	30.0		1
Pinctada margaritifera	12.0		1
Thais aculeata	5.6		1
Diadema spp.			3423
Echinometra mathaei			1434
Echinothrix diadema			574
Drupella spp.			182
Bohadschia similis			91
Culcita novaeguineae			84
Echinothrix calamaris			73
Cypraea caputserpensis			36
Cypraea moneta			13
Cypraea obvelata			11
Spondylus spp.			10
Drupa spp.			4
Cypraea annulus			4
Octopus cyanea			4
Stichodactyla spp.			3
Cypraea spp.			3
Synapta spp.			2
Cypraea tigris			2
Stichopus horrens			2
Terebra spp.			1
Cypraea isabella			1
Tripneustes gratilla			1
Acanthaster planci			1

SE = standard error; n = number.

4.3.9 Habitat descriptors for independent assessment – Mataiea



4.4 Raivavae invertebrate survey data

4.4.1 Invertebrate species recorded in different assessments in Raivavae

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 hilla*				+
Bêche-de-mer	*Holothuria leucospilota*		+		
Bêche-de-mer	*Holothuria nobilis*		+		
Bêche-de-mer	*Synapta* spp.	+	+		
Bivalve	*Atrina* spp.	+			
Bivalve	*Chama* spp.	+	+		
Bivalve	*Pinctada margaritifera*	+			
Bivalve	*Tridacna maxima*	+	+		+
Cnidarians	*Stichodactyla* spp.	+			
Crustacean	*Panulirus* spp.	+			+
Gastropod	*Astralium* spp.		+		+
Gastropod	*Cerithium* spp.		+		
Gastropod	*Charonia tritonis*	+			
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus* spp.	+	+		
Gastropod	*Cymatium* spp.		+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Drupa* spp.		+		
Gastropod	*Lambis truncata*	+	+		
Gastropod	*Turbo setosus*	+	+		+
Gastropod	*Turbo* spp.				+
Star	*Linckia laevigata*	+			
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix diadema*		+		
Urchin	*Echinothrix* spp.		+		
Urchin	*Tripneustes gratilla*	+	+		+

+ = presence of the species.

4.4.2 Raivavae broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	6.2	2.6	72	49.5	14.3	9	6.1	3.3	12	24.4	4.1	3
Atrina spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Bohadschia argus	0.7	0.4	72	16.7	0.0	3	0.7	0.5	12	4.2	1.4	2
Chama spp.	224.1	96.0	72	474.5	196.0	34	224.0	134.1	12	298.7	173.8	9
Charonia tritonis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus spp.	0.9	0.5	72	16.7	0.0	4	0.9	0.4	12	2.8	0.0	4
Echinometra mathaei	255.9	55.7	72	472.5	89.4	39	255.6	126.1	12	438.2	191.4	7
Holothuria atra	6097.3	1249.6	72	8129.7	1574.0	54	6089.5	2980.0	12	6643.1	3207.6	11
Lambis truncata	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Linckia laevigata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Panulirus spp.	0.2	0.2	72	15.8		1	0.2	0.2	12	2.5		1
Pinctada margaritifera	1.9	0.7	72	19.0	2.4	7	1.9	0.9	12	5.6	1.6	4
Stichodactyla spp.	0.4	0.3	72	16.0	0.7	2	0.4	0.3	12	2.7	0.1	2
Synapta spp.	0.2	0.2	72	15.5		1	0.2	0.2	12	2.5		1
Tridacna maxima	1607.1	273.4	72	1753.2	291.8	66	1606.7	551.1	12	1606.7	551.1	12
Tripneustes gratilla	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Turbo setosus	0.2	0.2	72	15.4		1	0.2	0.2	12	2.6		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.

4.4.3 Raivavae 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	13.9	8.4	72	333.3	83.3	3	13.9	10.7	12	83.3	41.7	2
Astralium spp.	13.9	8.4	72	333.3	83.3	3	13.9	7.8	12	55.6	13.9	3
Bohadschia argus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cerithium spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Chama spp.	59.0	21.3	72	386.4	91.5	11	59.0	24.8	12	118.1	36.4	6
Conus flavidus	6.9	4.9	72	250.0	0.0	2	6.9	6.9	12	83.3		1
Conus spp.	10.4	7.7	72	375.0	125.0	2	10.4	7.5	12	62.5	20.8	2
Cymatium spp.	10.4	7.7	72	375.0	125.0	2	10.4	7.5	12	62.5	20.8	2
Cypraea annulus	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Drupa spp.	125.0	42.5	72	900.0	159.0	10	125.0	97.0	12	500.0	336.8	3
Echinometra mathaei	1875.0	212.7	72	2213.1	225.2	61	1875.0	499.9	12	2045.5	514.8	11
Echinothrix diadema	756.9	189.1	72	2270.8	426.1	24	756.9	392.5	12	1297.6	606.0	7
Echinothrix spp.	72.9	69.5	72	2625.0	2375.0	2	72.9	69.2	12	437.5	395.8	2
Holothuria atra	2729.2	601.1	72	3778.8	786.6	52	2729.2	1309.7	12	3275.0	1522.3	10
Holothuria leucospilota	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Holothuria nobilis	10.4	5.9	72	250.0	0.0	3	10.4	5.4	12	41.7	0.0	3
Lambis truncata	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Synapta spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Tridacna maxima	15,996.5	1289.8	72	16,221.8	1288.0	71	15,996.5	3072.7	12	15,996.5	3072.7	12
Tripneustes gratilla	163.2	58.1	72	618.4	186.7	19	163.2	77.2	12	326.4	124.7	6
Turbo setosus	3.5	3.5	72	250.0		1	3.5	3.5	12	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.

4.4.4 Raivavae 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	145.1	43.9	24	204.8	56.2	17	145.1	106.8	4	193.5	134.7	3
Echinometra mathaei	500.0	198.4	24	2000.0	352.9	6	500.0	500.0	4	2000.0		1
Holothuria atra	182.4	60.0	24	257.4	78.1	17	182.4	149.1	4	182.4	149.1	4
Panulirus spp.	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Tridacna maxima	303.9	57.7	24	303.9	57.7	24	303.9	109.6	4	303.9	109.6	4
Turbo spp.	2.0	1.4	24	23.5	0.0	2	2.0	2.0	4	7.8		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.

4.4.5 Raivavae 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	63.0	24.3	12	63.0	24.3	12	63.0	42.6	2	63.0	42.6	2
Holothuria atra	555.6	76.5	12	555.6	76.5	12	555.6	77.8	2	555.6	77.8	2
Tridacna maxima	1025.9	193.7	12	1025.9	193.7	12	1025.9	68.5	2	1025.9	68.5	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.

4.4.6 Raivavae 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	416.7	109.1	24	476.2	119.3	21	416.7	255.5	4	416.7	255.5	4
Astralium spp.	3.8	2.6	24	45.5	0.0	2	3.8	3.8	4	15.2		1
Echinometra mathaei	36.0	7.2	24	61.7	6.0	14	36.0	3.6	4	36.0	3.6	4
Holothuria atra	458.3	157.7	24	478.3	163.4	23	458.3	219.8	4	458.3	219.8	4
Panulirus spp.	3.8	2.6	24	45.5	0.0	2	3.8	2.2	4	7.6	0.0	2
Tridacna maxima	111.7	39.9	24	191.6	60.5	14	111.7	79.5	4	111.7	79.5	4
Turbo setosus	3.8	2.6	24	45.5	0.0	2	3.8	2.2	4	7.6	0.0	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.

4.4.7 Raivavae 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
Echinometra mathaei	26.7	12.3	12	80.0	15.4	4	26.7	26.7	2	53.3		1
Holothuria atra	160.0	50.0	12	192.0	54.6	10	160.0	0.0	2	160.0	0.0	2
Holothuria hilla	13.3	7.0	12	53.3	0.0	3	13.3	13.3	2	26.7		1
Tridacna maxima	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Tripneustes gratilla	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1

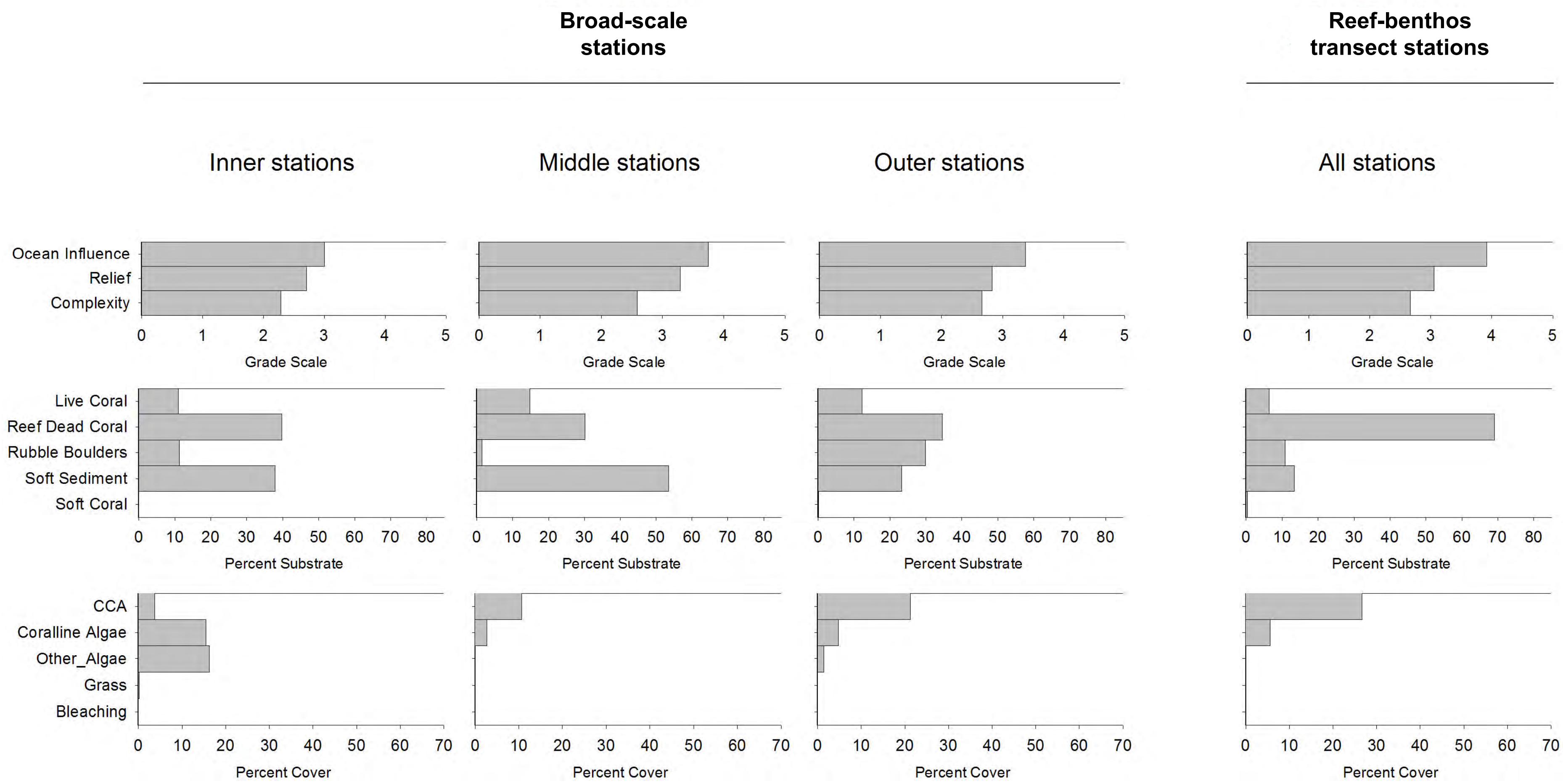
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.8 Raivavae species size review – all survey methods

Species	Mean length (cm)	SE	n
Holothuria atra	20.2	0.0	29,175
Tridacna maxima	15.0	0.1	13,082
Actinopyga mauritiana	22.0	0.0	467
Tripneustes gratilla	9.5	0.2	49
Pinctada margaritifera	15.8	2.1	8
Conus spp.	6.8	1.6	7
Astralium spp.	4.0	0.1	6
Bohadschia argus	33.5	2.2	4
Panulirus spp.	16.3	3.8	4
Lambis truncata	31.3	1.9	4
Turbo setosus	8.0	0.0	4
Cymatium spp.	6.2	0.2	3
Holothuria nobilis	28.7	1.8	3
Conus flavidus	3.8	0.8	2
Holothuria leucospilota	16.5	0.5	2
Charonia tritonis	27.0	0.0	1
Cerithium spp.	6.8	0.0	1
Echinometra mathaei			2189
Chama spp.			985
Echinothrix diadema			218
Drupa spp.			36
Echinothrix spp.			21
Stichodactyla spp.			2
Synapta spp.			2
Cypraea annulus			2
Turbo spp.			2
Atrina spp.			2
Linckia laevigata			1

SE = standard error; n = number.

4.4.9 Habitat descriptors for independent assessment – Raivavae



4.5 Tikehau invertebrate survey data

4.5.1 Invertebrate species recorded in different assessments in Tikehau

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		+
Bêche-de-mer	*Bohadschia argus*	+			
Bêche-de-mer	*Bohadschia vitiensis*	+	+		
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Thelenota ananas*	+			+
Bivalve	*Arca* spp.		+		
Bivalve	*Chama* spp.	+	+		+
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.	+			
Bivalve	*Tridacna maxima*	+	+		+
Gastropod	*Astralium* spp.		+		
Gastropod	*Chicoreus ramosus*	+			
Gastropod	*Conus* spp.	+	+		
Gastropod	*Cypraea annulus*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea* spp.		+		
Gastropod	*Lambis truncata*	+	+		
Gastropod	*Thais* spp.	+			
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo setosus*				+
Octopus	*Octopus cyanea*		+		
Star	*Culcita novaeguineae*	+	+		
Urchin	*Diadema* spp.		+		
Urchin	*Echinometra mathaei*	+	+		
Urchin	*Tripneustes gratilla*	+			

+ = presence of the species.

4.5.2 Tikehau broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	1.7	1.2	78	66.7	0.0	2	1.7	1.2	13	11.1	0.0	2
Bohadschia argus	3.6	1.0	78	21.8	2.2	13	3.6	1.2	13	7.8	0.8	6
Bohadschia vitiensis	22.4	6.1	78	87.5	16.7	20	22.4	9.5	13	58.1	13.6	5
Chama spp.	212.5	31.2	78	312.7	38.9	53	211.3	52.7	13	305.3	49.4	9
Chicoreus ramosus	0.4	0.3	78	16.7	0.0	2	0.4	0.3	13	2.7	0.0	2
Conus spp.	0.6	0.4	78	16.7	0.0	3	0.6	0.5	13	4.1	1.4	2
Culcita novaeguineae	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Echinometra mathaei	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Holothuria atra	17.3	8.5	78	168.5	63.5	8	17.4	16.0	13	75.3	67.0	3
Lambis truncata	1.1	1.1	78	83.3		1	1.1	1.1	13	13.9		1
Pinctada margaritifera	1.5	0.5	78	16.7	0.0	7	1.5	0.5	13	3.2	0.5	6
Spondylus spp.	0.2	0.2	78	16.7		1	0.2	0.2	13	2.7		1
Thais spp.	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Thelenota ananas	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Tridacna maxima	572.6	79.3	78	620.3	83.5	72	571.4	155.7	13	571.4	155.7	13
Tripneustes gratilla	0.2	0.2	78	16.7		1	0.2	0.2	13	2.8		1
Trochus niloticus	15.0	6.8	78	106.1	39.1	11	15.0	7.5	13	38.9	14.3	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.

4.5.3 Tikehau 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	38.5	16.5	78	428.6	105.1	7	38.5	27.7	13	250.0	83.3	2
Arca spp.	839.7	184.1	78	1926.5	343.6	34	839.7	247.2	13	1091.7	274.6	10
Astralium spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Bohadschia vitiensis	16.0	7.0	78	250.0	0.0	5	16.0	7.5	13	52.1	10.4	4
Chama spp.	1887.8	248.4	78	2887.3	296.0	51	1887.8	523.0	13	2454.2	565.5	10
Conus spp.	6.4	4.5	78	250.0	0.0	2	6.4	6.4	13	83.3		1
Cypraea annulus	9.6	7.1	78	375.0	125.0	2	9.6	9.6	13	125.0		1
Cypraea caputserpensis	32.1	16.7	78	625.0	125.0	4	32.1	20.1	13	138.9	55.6	3
Cypraea moneta	28.8	18.2	78	750.0	250.0	3	28.8	28.8	13	375.0		1
Cypraea spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Diadema spp.	35.3	10.9	78	275.0	25.0	10	35.3	17.6	13	91.7	33.3	5
Echinometra mathaei	189.1	41.9	78	702.4	83.8	21	189.1	85.5	13	409.7	141.3	6
Holothuria atra	28.8	14.4	78	450.0	122.5	5	28.8	19.7	13	187.5	20.8	2
Lambis truncata	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Octopus cyanea	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Pinctada margaritifera	16.0	7.0	78	250.0	0.0	5	16.0	7.5	13	52.1	10.4	4
Tridacna maxima	3003.2	381.7	78	3718.3	425.6	63	3003.2	889.4	13	3253.5	927.8	12
Trochus niloticus	1253.2	255.9	78	2715.3	445.7	36	1253.2	572.3	13	1810.2	763.9	9

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.5.4 Tikehau 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	30.1	8.8	24	55.6	12.4	13	30.1	18.9	4	40.1	22.6	3
Tridacna maxima	43.5	34.5	24	116.0	90.0	9	43.5	38.0	4	58.0	49.7	3
Turbo setosus	125.9	45.5	24	251.9	76.0	12	125.9	120.4	4	167.9	159.6	3
Heterocentrotus mammillatus	*											

* Not counted but extremely common on crest; mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.5.5 Tikehau 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
Chama spp.	34.1	26.3	12	136.4	90.9	3	34.1	34.1	2	68.2		1
Tridacna maxima	22.7	8.8	12	54.5	9.1	5	22.7	7.6	2	22.7	7.6	2
Trochus niloticus	7.6	5.1	12	45.5	0.0	2	7.6	7.6	2	15.2		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.

4.5.6 Tikehau 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
Arca spp.	20.8	20.8	12	250.0		1	20.8	20.8	2	41.7		1
Chama spp.	1114.6	299.3	12	1337.5	313.5	10	1114.6	552.1	2	1114.6	552.1	2
Culcita novaeguineae	20.8	14.0	12	125.0	0.0	2	20.8	20.8	2	41.7		1
Trochus niloticus	343.8	116.3	12	458.3	135.0	9	343.8	52.1	2	343.8	52.1	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.

4.5.7 Tikehau 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
None found			12			12			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.

4.5.8 Tikehau 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
Thelenota ananas	5.4	2.8	12	21.4	0.0	3	5.4	5.4	2	10.7		1

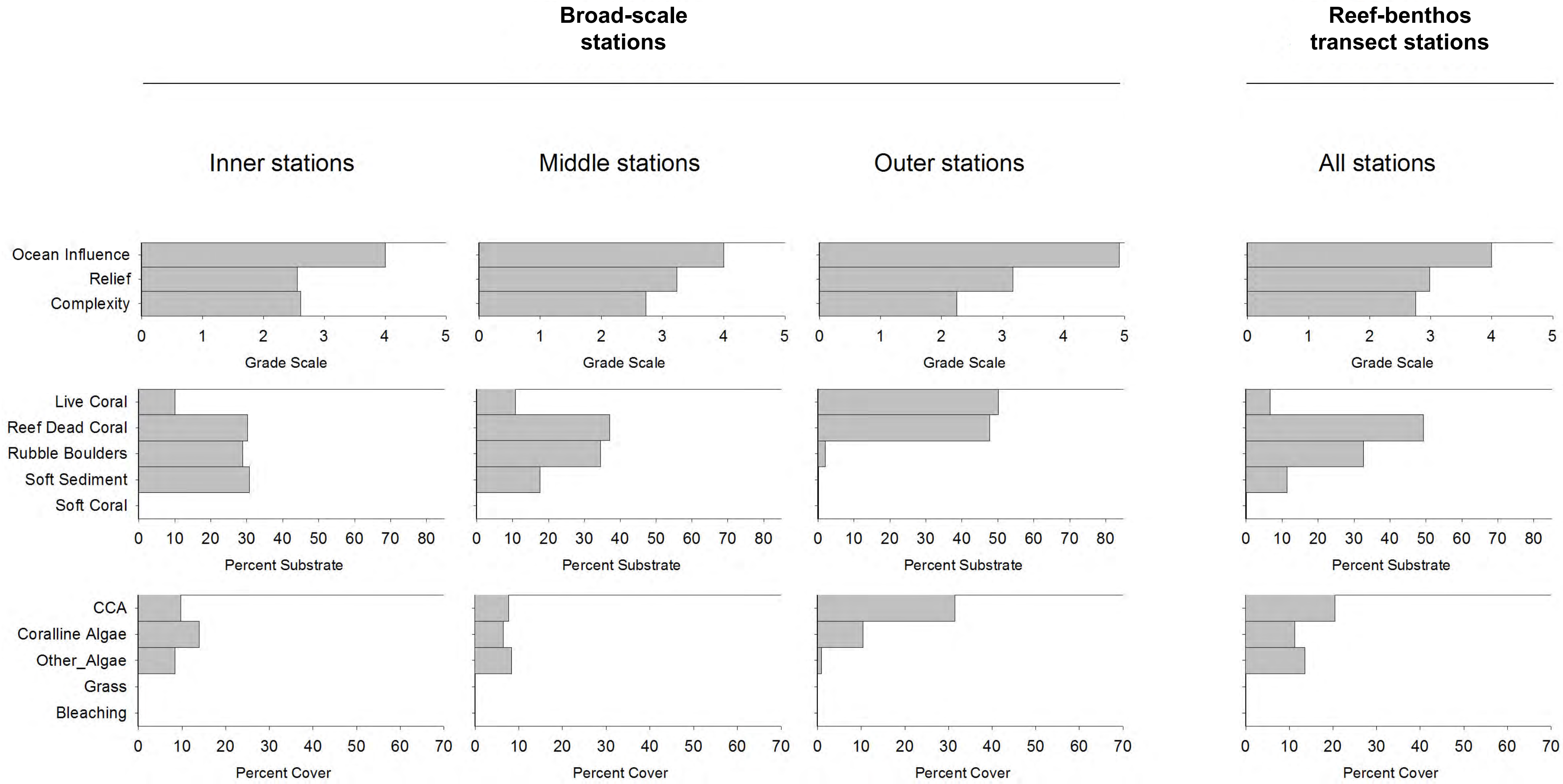
Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.5.9 Tikehau species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna maxima	11.5	0.1	3581
Trochus niloticus	10.4	0.1	496
Turbo setosus	6.0	0.1	272
Bohadschia vitiensis	36.7	0.6	101
Holothuria atra	20.8	1.0	92
Actinopyga mauritiana	17.7	0.6	85
Bohadschia argus	38.5	0.7	17
Pinctada margaritifera	12.7	0.7	11
Lambis truncata	21.8	0.9	6
Conus spp.	11.0	0.0	5
Thelenota ananas	45.0	4.1	4
Chicoreus ramosus	25.0	0.0	2
Astralium spp.	2.0	0.0	1
Cypraea spp.	4.8	0.0	1
Thais spp.	9.0	0.0	1
Chama spp.			1703
Arca spp.			264
Echinometra mathaei			60
Diadema spp.			11
Cypraea caputserpensis			10
Cypraea moneta			9
Cypraea annulus			3
Culcita novaeguineae			3
Spondylus spp.			1
Octopus cyanea			1
Tripneustes gratilla			1

SE = standard error; n = number.

4.5.10 Habitat descriptors for independent assessment – Tikehau



APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – FRENCH POLYNESIA

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
French Polynesia

(January 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 French Polynesia 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 Wallis and Futuna and data availability (satellite images and Geographical Information Systems mapped products), please contact:

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98848 New Caledonia;
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Reference: Andréfouët S, and 6 authors (2005), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th ICRS, Okinawa 2004, Japan: pp. 1732-1745.