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

FEDERATED STATES OF MICRONESIA COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT YYIN AND RIIKEN (YAP) AND PIIS-PANEWU AND ROMANUM (CHUUK)

(April – May 2006)

by

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

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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 Pacific Regional Coastal Fisheries Development Programme (CoFish) conducted fieldwork in four locations around the Federated States of Micronesia (FSM) from April to May 2006. Palau is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by CoFish or its associated programme PROCFish/C (Pacific Regional Oceanic and Coastal Fisheries Development Programme, coastal component)[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 the FSM covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with two teams of five programme scientists (one team working in Yap and the other in Chuuk) and several local counterparts from the Chuuk Department of Marine Resources, the Yap State Government's Department of Resources and Development and one attachment from both the Pohnpei and Kosrae fisheries department. 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 FSM, the four sites selected for the survey were Yyin and Riiken in Yap State, and Piis-Panewu and Romanum in Chuuk State. 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,

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

- presenting no major logistical problems,
- having been previously investigated, and
- presenting particular interest for the National Department of Resources and Development, the Chuuk Department of Marine Resources, and the Yap State Government's Department of Resources and Development.

Results of fieldwork at Yyin, YAP

Yyin is located on the northwest side of Yap proper centred at 9°34'N latitude and 133°08'E longitude. Yyin is about 20 minutes' drive from Colonia, the capital and administrative centre of Yap State, or 40–50 minutes by outboard-powered skiff through a channel. Yyin was chosen as a survey site because the communities are involved in coral dredging, and resources were expected to be in poor condition. Reefs in Yap are traditionally owned by families of high rank (clan system), which is the case for the selected communities. For socioeconomic surveys, the neighbouring village of Gilfith to the southwest was included in the survey.

Socioeconomics in Yyin, YAP

Fisheries are not an important sector for income generation in Yyin. Income is mainly derived from salaries and agriculture or other sources, such as small business, and retirement and other social fees. All households regularly eat fresh fish and most also eat invertebrates. The consumption of fresh fish (47 kg/person/year) and invertebrates (3 kg/person/year) is above the regional average but lower than the average across all four study sites in FSM (62.5 kg/person/year for fish and 12.4 kg/person/year for invertebrates). Canned fish consumption (25.5 kg/person/year) is higher than average. The average household expenditure level represents a moderate lifestyle that combines both traditional and cash-economy based values.

Finfish fishing is done only by males; females only fish for invertebrates. Some males fish for both finfish and invertebrates. Finfish fishers mainly target the sheltered coastal reefs and lagoon, seldom the outer reef. Invertebrate collection focuses on reef and soft-benthos habitats. Finfish fishing is characterised by the combined use of castnets, gillnets, handline and spears. Invertebrate fisheries mainly involve the use of simple tools. Some fishing is done using paddle canoes.

Finfish resources in Yyin, YAP

The status of finfish resources in Yyin at the time of surveys was very good. Yyin is not dependent on fishing for income generation and, although the community consumes a high quantity of fresh fish, the density of the population per reef habitat areas and per fishing ground does not impose a very high pressure on the overall resources. However, more impact is inflicted on the internal back-reef habitat due to the higher frequency of trips to this habitat compared to the other areas. Outer reefs displayed the highest density, size, biomass and diversity of fish, suggesting that this environment is healthy and only lightly exploited. Both the trophic composition, equally composed of herbivores and carnivores, and the average fish size and size ratio suggest that the system is still healthy. The frequent sightings of the rare and protected species, *Bolbometopon muricatum*, and of top predators (sharks) were further signs of healthy resources. Moreover, in both habitats studied, the reefs appeared very healthy and rich in live coral. The customary tenure system is still working and restricts fishing to people of a family clan. The current reef stocks appeared to be within sustainable limits for the subsistence needs of the local community.

Invertebrate resources in Yyin, YAP

There was a broad range of shallow-water reef habitats suitable for a full range of giant clams species at Yyin, although most habitats were not extensive. For this part of the Pacific, the two native giant clam species present (*Tridacna maxima* and *Hippopus hippopus*) represent a limited range of species for this large island system in the western Pacific, close to the centre of biodiversity. Surprisingly, *T. squamosa* and *T. derasa* were not noted. The overall density for *T. maxima* is low, especially inside the lagoon, and moderate-to-low on the outer-reef slope. The average density recorded for *H. hippopus* is moderate. Both species presented a full range of size classes from juveniles to large adults, suggesting that, despite the low densities, spawning and recruitment are still occurring. In general, the status of giant clams at Yyin was moderately impacted and the habitat available shallow and limited.

Local reef conditions at Yyin constitute a habitat that is limited in scale but good for juvenile and adult commercial topshells (*Trochus niloticus*). Trochus was not common on shallow-water reefs in the lagoon, but density was high within 'core' aggregations at the reef slope. In the outer slope, densities were all much greater than 500–600 shells/ha, which is the minimum threshold density recommended before commercial harvests can be considered. Most size classes were present and the high numbers of large, old shells occurring within aggregations indicate that stocks have not been comprehensively fished in previous harvests. However, the lack of juvenile and newly recruiting trochus suggests that fishery managers might need to wait a few spawning seasons before beginning commercial fishing. Survey results suggest that trochus in Yyin are, in general, well managed. The blacklip pearl oyster, *Pinctada margaritifera* was absent from Yyin.

Yyin has a limited amount of shallow, sheltered lagoon area suitable for a range of sea cucumber species. Fifteen commercial species were recorded at Yyin plus one indicator species, but the small size of the site and the lack of developed habitats were limiting factors. Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure in the past; however, some species were recorded at reasonable density, especially in protected inshore areas. There were no high-density stocks identified although, in some areas, *Actinopyga* sp. were still abundant, although few larger individuals (>12 cm) were present. Stocks of the high-value sandfish (*Holothuria scabra*) were absent, despite the suitability of the environment for this species. Another high-value species, black teatfish (*H. nobilis*) was at low density.

Recommendations for Yyin, YAP

- A monitoring system be established for finfish and selected invertebrate stocks to follow changes in these resources.

- Night spearfishing and shark feeding be controlled.

- The establishment of MPAs be considered by the Yyin community as a possible management tool, as in other areas in Yap.

- Sand mining be carefully located to avoid impacting the fishing grounds.

- Stronger management measures be applied to the small populations of giant clams, especially the larger, older clams, to ensure a viable stock of clams for subsistence use in this part of Yap.

- Before beginning a harvest of the commercial topshell (*Trochus niloticus*), fishery managers wait until a strong recruitment peak is detected, i.e. after a few spawning seasons.

- Black teatfish (*Holothuria nobilis*), a high-value species, needs to be closely managed to ensure that broodstock are protected at viable spawning densities within reserve areas, to ensure continuation of this species in the fishery.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

Results of fieldwork in Riiken, YAP

Riiken is located on the east coast of Gagil Island centred at 9°33'N latitude and 133°12'E longitude. A causeway links Gagil Island to Yap proper. Riiken is about 50 minutes drive from Colonia, the capital and urban centre of Yap State, or 20–30 minutes by outboard-powered skiff. Riiken was chosen as a survey site because the community has the only marine protected area on Yap, which was declared on its traditional fishing grounds. For socioeconomic surveys, the neighbouring village of Wanyang to the south was included.

Socioeconomics in Riiken, YAP

Fisheries are not an important sector for income generation in Riiken. Only 11% of all households obtain secondary income from fisheries. In contrast, salaries are of highest importance, complemented by income from agriculture and other sources, such as small business and retirement and other social fees. All households eat fresh fish and more than half also eat invertebrates regularly. Fresh fish consumption (44 kg/person/year) is below the average across all study sites in FSM. Although to a lesser extent, the same observation is true for invertebrate consumption (10 kg/person/year). Canned fish consumption (47 kg/person/year) is much higher than average.

People in Riiken combine traditional and cash-based economic values. Remittances do not play any role. Most finfish fishing is done by males, while females are responsible for collecting invertebrates. Finfish fishers mainly target the sheltered coastal reefs and rarely the outer reef. Finfish fishing uses various techniques, including castnets, gillnets, handlines and spears. Invertebrate fishers collect from the combined soft benthos and reeftop, and harvest lobsters and giant clams along the reef. Although a very small proportion of the invertebrate catch (mostly lobsters) is caught for sale outside the community, overall, Riiken's invertebrate fisheries are not conducted for sale. Most fishing is done without any boat transport, except for outer-reef and passage fishing, which requires paddling canoes.

Finfish resources in Riiken, YAP

The assessment indicated that the status of finfish resources in this site was good. This is due to the naturally rich condition of the reefs. The substrate was mostly coral rock, with a large amount of live coral, advantaging selected families of herbivores, such as Acanthuridae and Scaridae, which were dominant here. The frequent sightings of large predators (sharks) and rare species, such as *Bolbometopon muricatum*, were further signs of good health. Fish density was the highest in the country and biomass the second-highest; biodiversity was high compared to the average for the region. However, when analysed at the reef-habitat level, resources were very variable: in the coastal reefs and intermediate reefs, where most fishing is carried out and fisher density the highest, fish density and biomass were the lowest at this site. Therefore, effects of fishing pressure were apparent; fish sizes, numbers of fish and number of species were all smaller, suggesting that in these habitats the fishing pressure is rather high.

Invertebrate resources in Riiken, YAP

At Riiken, a full range of shallow-water reef habitats suitable for giant clams was present; however, these areas were not extensive. Only two native giant clam species were present: *Tridacna maxima* and *Hippopus hippopus*. *T. derasa* was noted but these records were derived partially from imported shells. Giant-clam densities are quite low, which gives cause for concern, since large individuals need to be at close proximity to one another (at high density) for successful reproduction. Nevertheless, the size frequency distribution showed that recruitment was still occurring, and there is hope for recovery as the full size range (from juveniles to large, reproductive adults) is present. In general, the status of giant clams at Riiken was moderately impacted by fishing.

Suitable habitat for juvenile and adult commercial topshell trochus (*Trochus niloticus*) was available, although limited in area. Trochus was not common across reefs at Riiken, but density was high within ‘core’ aggregations. High densities were also recorded in the MPA, offering good potential for the surrounding reefs. Of the five stations surveyed in the MPA and outer reef slope, four held trochus at densities >500–600 shells/ha, which is the minimum density recommended before commercial harvests can be considered. Most trochus size classes were present, indicating that previous harvests have not comprehensively fished the stock or targeted mature shells larger than the maximum size limit. Survey results suggest that trochus stocks in Riiken area are marginally impacted by fishing. The blacklip pearl oyster, *Pinctada margaritifera*, was rare at Riiken.

Riiken has suitable areas of shallow, sheltered lagoon suitable for a range of more inshore sea cucumber species. However, the lack of a more typical lagoon limits the potential for a full range of species. Fourteen species of sea cucumber were recorded at Riiken, including thirteen commercial species, which was fewer than expected, due to the small scale of the site and the relative lack of oceanic-influenced habitats. Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure in the past; however, some species were recorded at reasonable density. The high-value sandfish (*Holothuria scabra*) was still present, but not well distributed across the site, representing the last remnants of a critically important stock for future fishery considerations or future aquaculture opportunities.

Recommendations for Riiken, YAP

- Fishing pressure on lobsters be monitored and managed, as this particular resource makes up most of the reported invertebrate annual catch.

- A monitoring programme be established so the effects of the already established MPA on resource status and thus fishing potential of the local fishing ground can be followed and documented.

- Careful consideration be given in the location of sand mining in order to avoid impacting the fishing grounds.

- Management measures be introduced to ensure that aggregations of large, older giant clams are protected from fishing and therefore the sustainability of the resource can be maintained.

- High-value sea cucumber species, such as sandfish (*Holothuria scabra*) and black teatfish (*H. nobilis*), be given extra management scrutiny, to ensure that broodstock of these species remains at viable spawning densities in order to ensure continuation of the fishery.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

Results of fieldwork in Piis-Panewu, CHUUK

Chuuk is a large, semi-enclosed shallow atoll lagoon system. Both low and high islands are common with many patch reefs in the lagoon. The main influence is predominantly oceanic, although fringing, intermediate and offshore reefs are present. Piis-Panewu is located in the north of Chuuk lagoon, centred around 7°40'N latitude and 151°50'E longitude. Piis-Panewu is an hour by outboard-powered skiff from Weno, the capital and business centre of Chuuk State. Piis-Panewu is a coral atoll with two villages, Nukan and Sopotiw, and there are several passages through the reef that provide a strong ocean influence.

Socioeconomics in Piis-Panewu, CHUUK

The Piis-Panewu community has good access to a wide range of habitats, including sheltered coastal reef, lagoon, mangroves, outer reef and passages in an open-access environment. The community is completely dependent on marine resources for home consumption and for most of their cash income. The availability of motorised boats, the short, one-hour boat journey to the urban market of Weno, and the regular visits of agents to the island make it possible for the community to commercially exploit its fishery resources. The consumption of fresh fish (79 kg/person/year) and invertebrates (14.4 kg/person/year) is high. Both figures are above the average found across all study sites in FSM. By comparison, canned fish consumption is low (2.4 kg/person/year). Consumption and income patterns highlight the traditional lifestyle of the community. However, the import prices of staple food items and the transport and fuel costs increase the need to generate cash income to satisfy the relatively high costs of living. Remittances do not play an important role for many households; more households rather rely on food sent from family members in Weno.

Traditional roles show in the fact that males fish for finfish, while females collect most of the invertebrates. However, males are the main commercial fishers of invertebrates. Commercial catches of lobsters, bêche-de-mer, giant clams, trochus and octopus account for most of the annual invertebrate harvest. However, the fact that fishing targets a very few species only, that the average annual catch per fisher is very high for reeftop gleaning, and the lack of any fisheries management give reason for concern.

Overall, CPUEs are moderate (1.7–2.5 kg/hour of fishing trip) and higher at the outer reef than in sheltered coastal reef areas close to shore. Spear diving, handlining, gillnetting and deep-bottom lining are the main techniques used. Average fish sizes increase, as expected, with distance from shore. Overall, fish sizes are large, 25 cm in catches from the sheltered coastal reef and 35 cm in catches from the outer reef. However, the average size of Scaridae is 25 cm in catches from all habitats.

Finfish resources in Piis-Panewu, CHUUK

The status of finfish resources in Piis-Panewu was rather poor. Although the reefs are naturally rich, with high cover of live coral, they do not provide suitable habitat for carnivores associated with soft bottom, such as Lethrinidae and Mullidae. When analysed at the reef-habitat level, resources were rather variable. The intermediate reefs provided the richest habitat, with highest density and biomass of finfish; back-reefs were the poorest of the three habitats. The outer reefs were unusually poor for an oceanic location: the density, biomass and biodiversity of finfish were lower than the intermediate-reef values, and size and size ratio were the absolute lowest. Average size ratio was below 50% for Scaridae. Outer-reef values of all biological parameters analysed were also the lowest in the country.

Herbivores strongly dominated all reefs, including the outer reefs, with Acanthuridae and Scaridae in very high numbers and Lutjanidae almost totally absent from their typical habitats in the outer reefs, where they are most frequently fished: this is another sign of serious impact of fishing on specific target species. The dominance of herbivores, especially Acanthuridae and Scaridae, could be partially explained by the type of environment, which is mainly composed of hard bottom. In fact, the outer reefs were found to be more frequently targeted than the other habitats, an unusual case compared to the other sites in the country. Resources in the outer and back-reefs showed the first signs of high fishing pressures in terms of lower fish density, biomass, size and biodiversity compared to intermediate reefs at the site, and to similar habitats in the country.

Invertebrate resources in Piis-Panewu, CHUUK

There was a wide range of shallow-water reef habitats suitable for giant clams despite much of the protected back-reef shorelines being sandy and without much hard benthos, and most of the environment being oceanic-influenced and exposed (e.g. to recent typhoons in 2002 and 2003). For this part of the Pacific, only four species of giant clam were present: *Tridacna maxima*, *T. crocea*, *T. squamosa*, and *Hippopus hippopus*. Distribution, density and size measures indicate that all stocks are impacted by fishing, and stocks of the larger species are severely depleted.

Reefs at Piis-Panewu provide an extensive and reasonably good habitat for juvenile and adult trochus (*Trochus niloticus*), the commercial topshell. Trochus was relatively common across reefs at Piis-Panewu but density was low to moderate. Despite the current ban on commercial fishing, ongoing commercial fishing was noted, and there were anecdotal reports that trochus could be sold in Weno. Most sizes were present but no strong year class was currently visible below the commercial size class range. Overall, survey results suggested that trochus in the Piis-Panewu study area are heavily impacted by fishing and presently well below the threshold density at which commercial fishing should be contemplated. The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Piis-Panewu.

Piis-Panewu has extensive areas of shallow- and deep-water sheltered lagoon and barrier reef habitat that is suitable for sea cucumbers, although the lack of rich inshore embayments somewhat limited the range of species. Fourteen species of sea cucumber were recorded, which is fewer than expected for this location in the Pacific, but local environmental factors play a part in limiting some species. Commercial sea cucumber stocks are rare and only occur at low density. Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure. If there has been no recent fishing at this site, then it appears that species that are easily targeted (and depleted), such as the black teatfish (*Holothuria nobilis*), have not recovered from earlier fishing activities.

Recommendations for Piis-Panewu, CHUUK

- Baseline studies be undertaken to identify possible problem areas so that a fisheries management strategy that addresses major problem areas can be developed to stop and preferably reverse detrimental fisheries exploitation and, at the same time, to secure the community's livelihood.

- All communities and community members (male and female) on Piis-Panewu and other nearby islands be involved in the development of the fisheries management strategy covering both finfish and invertebrates, in order to ensure cooperation and compliance with management measures.

- State and national partners, in close cooperation with the Piis-Panewu community and all male and female fishers concerned, develop and enforce standards to control the commercial exploitation of bêche-de-mer, lobsters, trochus, giant clams and octopus as part of the fisheries management strategy.

- As a first step, the fishing of commercial species of sea cucumbers for export be strictly controlled through a moratorium until stocks recover.

- Consideration be given to establishing an MPA, where adult sea cucumbers and other species could be placed for protection in viable spawning aggregations (20–50 individuals placed within one section of their normal reef habitat – 5 m apart for sea cucumbers); however, strict enforcement would be needed to protect these potential spawning groups.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

- Spear diving, the most frequent fishing method used, be regulated, and night spearfishing banned. The use of gillnets in lagoon reefs should also be controlled.

- Careful attention be given to the location of sand mining, in order to avoid impacting fishing grounds.

Results of fieldwork in Romanum, CHUUK

Romanum is located in the north-northwest of Chuuk lagoon at 7°27'N latitude and 151°35'E longitude. Romanum is less than an hour by outboard-powered skiff from Weno, the capital and main urban centre of Chuuk State. Romanum is a small volcanic island with two villages, Winisi and Chorong. Habitat within the lagoon system generally reflects the oceanic influence. The communities at Romanum rely on the harvesting of marine resources for their own subsistence needs and as a source of income, regularly transporting their catch to Weno for marketing.

Socioeconomics in Romanum, CHUUK

The Romanum community has good access to a wide range of habitats, including sheltered coastal reef, lagoon, outer reef and passages in an open-access environment. However, the community has few if any alternatives to fishing and limited access to agricultural production. The community is highly dependent on marine resources for home consumption and for almost all cash income. The availability of motorised boats, the short journey to the urban market of Weno, and the regular visits of agents to the island make it possible for the community to commercially exploit its fishery resources. Consumption of fresh fish (81 kg/person/year) and invertebrates (18.5 kg/person/year) is high. Both figures are above the average found across all study sites in FSM. Canned fish consumption is less (12 kg/person/year).

Consumption and income patterns highlight the traditional lifestyle. However, the import prices of staple food items also require cash income to satisfy basic living costs, which are relatively high. Remittances benefit about half of the population to a limited extent only. Traditional roles show in the fact that males fish for finfish, while females collect most of the invertebrates. Female fishers are organised into smaller groups serving agents and supermarkets that order octopus and other invertebrates. Males are the main commercial fishers of bêche-de-mer, lobsters, trochus and giant clams.

Overall, CPUEs are moderate with 2–2.5 kg catch/hour of fishing trip and do not significantly change among habitats. Spear diving is the main technique used, sometimes complemented by deep-bottom lining and gillnetting. Reported average fish sizes increase, as expected, with distance from shore. Overall, reported average fish lengths are large: 25 cm in catches from the sheltered coastal reef and ~35 cm in outer-reef catches. The main families caught (i.e. Scaridae and Acanthuridae) reflect the major use of spear diving.

Results from the invertebrate fisher survey show that commercial catches of bêche-de-mer species account for most of the annual invertebrate harvest (wet weight), followed by the other commercial target species: lobsters, trochus and giant clams. However, the fact that fishing targets a very few species only, that the average annual catch per fisher is very high for reeftop gleaning, and the lack of any fisheries management give reason for concern.

Finfish resources in Romanum, CHUUK

The status of finfish resources in Romanum was found to be rather poor at the time of surveys. Similar to the reefs in Piis-Panewu, the reefs at Romanum appeared healthy and rich in live-coral cover, but had little soft bottom, which is the type of substrate associated with carnivores, such as Lethrinidae and Mullidae. However, Lutjanidae, usually associated with hard substrate, were also in low abundance or absent, probably as a result of intense fishing. Lethrinidae, Scaridae and Acanthuridae, which made up the bulk of the catches, had very low average size ratios, an indication of impact on these selected families. At the reef-habitat level, resources were very variable. Coastal reefs were particularly poor, with very small-sized fish. Fish in the intermediate and back-reefs had minimum density values and only slightly larger sizes, resulting in small values of biomass. Only outer reefs were richer, with biomass twice as high as that recorded in Piis-Panewu. Heavy fishing is carried out for subsistence as well as sale and a high density of fishers was recorded in the small fishing areas available. Signs of dynamite fishing were also recorded around Romanum. Therefore, fishing is imposing some changes in the resources: smaller sizes, smaller numbers of fish and lower number of species compared to the other sites surveyed in both Chuuk and Yap.

Invertebrate resources in Romanum, CHUUK

There was a wide range of shallow-water reef habitats suitable for giant clams at Romanum. However, population pressures were also evident: Chuuk state has seen large population growth; currently more than half the population of FSM live on the 15 inhabited islands. For this part of the Pacific, a limited range of only three giant clam species was present: *Tridacna maxima*, *T. squamosa*, and *Hippopus hippopus*. Distribution, density and size measures indicated that all stocks were impacted by fishing and the larger species were at critically low levels. In general, the giant clam stocks at Romanum were heavily impacted by fishing.

Local reef conditions at Romanum provide an extensive and suitable habitat for both juvenile and adult trochus (*Trochus niloticus*), the commercial topshell. Trochus was relatively common across reefs at Romanum, but the density within 'core' aggregations and across reefs in general was low to moderate. Reefs with the highest density of trochus were close to Romanum village, where they could be overseen (protected) by fishers in the local community. Most sizes were found to be present, but showed that previous harvests have comprehensively fished the stock, as aggregations were holding depleted levels of large old shells (>11 cm basal width). The lack of large older shells, which have the greatest potential to fuel future populations to support the fishery, means that recovery to the commercial threshold density level might take longer than if older shells were still present. Survey results suggest that trochus in the Romanum study area are heavily impacted by fishing and presently well below the threshold density at which commercial fishing should be contemplated. The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Romanum.

Romanum has extensive areas of shallow and deep-water sheltered lagoon and barrier reef that were suitable for a range of sea cucumber species. However, being a small island, Romanum only had limited inshore embayments of 'rich' benthos with seagrass, which somewhat limited the potential for sea cucumber species that were characteristic of such habitats. Twenty species of sea cucumber were recorded at Romanum, which is as expected for this location in the Pacific. Commercial sea cucumber stocks typically taken for commercial export were often rare or only at low density at Romanum in the current survey. Presence and density data suggest that sea cucumbers have been under significant pressure from fishing or environmental factors. If there has been no recurrent fishing at this site, then it looks as if species that are easily targeted (and depleted), like the black teatfish (*Holothuria nobilis*), have not recovered to 'healthy' levels since earlier fishing activities.

Recommendations for Romanum, CHUUK

- Baseline studies be undertaken to identify possible problem areas so that a fisheries management strategy that addresses major problem areas can be developed to stop and preferably reverse detrimental fisheries exploitation and, at the same time, to secure the community's livelihood.

- All communities and community members (male and female) on Romanum and other nearby islands be involved in the development of the fisheries management strategy covering both finfish and invertebrates, in order to ensure cooperation and compliance with management measures.

- State and national partners, in close cooperation with the Romanum community and all male and female fishers concerned, develop and enforce standards to control the commercial exploitation of bêche-de-mer, trochus, and giant clams as part of the fisheries management strategy.

- As a first step, the fishing of commercial species of sea cucumbers for export be strictly controlled through a moratorium until stocks recover.

- Consideration be given to establishing an MPA, where adult sea cucumbers and other species could be placed for protection in viable spawning aggregations (20–50 individuals placed within one section of their normal reef habitat – 5 m apart for sea cucumbers); however, strict enforcement would be needed to protect these potential spawning groups.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

- Gillnetting and spear diving be limited and night spear diving be banned; fishers should comply with these regulations.

- Careful attention be given to the location of sand mining, in order to avoid impacting fishing grounds.

RÉSUMÉ

Les agents du Projet de développement de la pêche côtière (CoFish) ont mené des travaux de terrain sur quatre sites aux États fédérés de Micronésie d'avril à mai 2006. Les États fédérés de Micronésie figurent parmi les 17 États et Territoires insulaires océaniens ayant fait l'objet d'enquêtes, échelonnées sur 5 à 6 ans, conduites par les agents du projet CoFish ou de son projet associé PROCFish/C (composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique)[3].

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

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

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

Les enquêtes conduites aux États fédérés de Micronésie s'articulaient autour de trois volets (les poissons, les invertébrés et les aspects socioéconomiques). À chaque mission, deux équipes composées de cinq scientifiques du programme (une équipe à Yap et l'autre à Chuuk) et de plusieurs homologues locaux du Service des ressources marines de Chuuk, du Département des ressources et du développement de l'État de Yap, ainsi que de deux agents détachés, l'un du Service des pêches de Pohnpei, l'autre de celui de Kosrae. Au cours des travaux de terrain, l'équipe a formé ses homologues locaux aux méthodes d'enquête et de comptage employées dans chacun des trois volets, notamment à la collecte de données et à leur saisie dans la base de données du programme.

[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 et Wallis et Futuna (PTOM). C'est pourquoi les termes CoFish et PROCFish/C sont employés indifféremment dans tous les rapports de pays.

Aux États fédérés de Micronésie, les quatre sites retenus étaient Yyin et Riiken, dans l'État de Yap, et Piis-Panewu et Romanum, dans l'État de Chuuk. Chaque site a été sélectionné selon les critères particuliers suivants :

- la pêche récifale devait y être effectivement pratiquée ;
- le site devait être représentatif du pays ;
- le système devait être relativement fermé, c'est-à dire que les habitants du site pêchaient dans des zones bien définies ;
- la taille du site devait être appropriée ;
- le site devait abriter des habitats divers ;
- il ne devait pas présenter de problèmes logistiques majeurs ;
- il devait avoir été étudié auparavant, et
- il devait présenter un intérêt particulier pour le Département des ressources et du développement, le Service des ressources marines de Chuuk et le Département des ressources et du développement de l'État de Yap.

Résultats des travaux de terrain à Yyin (Yap)

Yyin est situé sur la côte nord-ouest de l'île de Yap (9° 34′de latitude nord et 133° 08′ de longitude est). Il se trouve à environ vingt minutes de route de Colonia, capitale et centre administratif de l'État de Yap, soit 40 à 50 minutes de bateau (hors-bord) via un chenal. Ce site a été sélectionné en raison de la participation de ses habitants à l'activité d'extraction du corail : les enquêteurs s'attendaient à ce que les ressources y soient en mauvais état. Traditionnellement, les récifs de Yap appartiennent à des familles de rang élevé (système clanique) ; tel est le cas pour les communautés sélectionnées. Par ailleurs, Gilfith, village avoisinant au sud-ouest de Yyin, a été pris en compte dans l'enquête socioéconomique.

Données socioéconomiques : Yyin (Yap)

La pêche ne constitue pas une activité rémunératrice de premier plan à Yyin. Les revenus proviennent essentiellement des salaires, de l'agriculture ou d'autres sources, telles que les petites entreprises, les pensions de retraite et d'autres prestations sociales. Tous les ménages consomment régulièrement du poisson frais, la plupart également des invertébrés. La consommation de poisson frais (47 kg par personne et par an) et d'invertébrés (3 kg par personne et par an) est supérieure à la moyenne régionale, mais inférieure à celle des quatre sites d'étude des États fédérés de Micronésie (62,5 kg par personne et par an pour le poisson et 12,4 kg par personne et par an pour les invertébrés). La consommation de conserves de poisson (25,5 kg par personne et par an) est supérieure à la moyenne. Le niveau annuel de dépenses des ménages correspond à un mode de vie modeste, alliant valeurs traditionnelles et économie monétaire.

Seuls les hommes pratiquent la pêche du poisson, tandis que les femmes ciblent exclusivement les invertébrés. Certains hommes pêchent quant à eux tant du poisson que des invertébrés. Les poissons sont en grande partie capturés sur les récifs côtiers protégés, dans les eaux du lagon, et plus rarement, sur le tombant récifal externe. La collecte d'invertébrés se concentre sur les récifs et les fonds meubles. Pour la pêche du poisson, c'est l'utilisation combinée du filet maillant, de l'épervier, de la palangrotte et du fusil-harpon qui prédomine. Les invertébrés sont quant à eux collectés au moyen d'outils très simples. Il arrive que les pêcheurs recourent à des pirogues à pagaies.

Ressources en poissons : Yyin (Yap)

Lors de l'enquête à Yyin, l'état des ressources de poissons a été jugé satisfaisant. Les habitants de ce site ne sont pas tributaires de la pêche comme source de revenus et, bien qu'ils consomment une quantité élevée de poisson frais, la densité démographique par superficie d'habitat récifal et par lieu de pêche n'exerce pas une pression notable sur les ressources globales. En revanche, l'habitat de l'arrière-récif interne subit davantage le contrecoup de la fréquence des sorties, plus soutenues sur cet habitat qu'ailleurs. Les arrière-récifs présentent les valeurs les plus importantes en termes de densité, taille, biomasse et diversité des espèces, ce qui donne à penser que cet environnement est sain et soumis à une faible exploitation seulement. Tant la structure trophique, composée à parts égales d'herbivores et de carnivores, que la taille et le rapport de taille moyens des poissons indiquent que le milieu demeure en bonne santé. Le fait que *Bolbometopon muricatum*, espèce rare et protégée, et de grands prédateurs (requins) soient fréquemment observés sont d'autres signes indicateurs du bon état des ressources. De plus, sur les deux habitats étudiés, les récifs semblent être en excellent état et comporter une riche couverture de corail vivant. Le régime de propriété coutumière est toujours en place et limite la pêche aux membres d'un clan familial. D'après l'observation des stocks actuellement présents sur les récifs, l'exploitation qui y est réalisée semble garantir la pérennité des ressources disponibles à des fins de subsistance pour la communauté locale.

Ressources en invertébrés : Yyin (Yap)

À Yyin, on relève un large éventail d'habitats récifaux de faible profondeur, propices à de nombreuses espèces de bénitiers, bien que la plupart de ces habitats présentent une superficie limitée. Dans ce si vaste système insulaire du Pacifique occidental, situé à proximité du coeur de la biodiversité, il est étonnant de n'enregistrer que deux espèces endémiques de bénitier (*Tridacna maxima* et *Hippopus hippopus*). Il est également surprenant de noter qu'aucun spécimen de *T. squamosa* et de *T. derasa* n'a été observé. La densité globale de *T. maxima* est faible, notamment à l'intérieur du lagon, et moyenne à faible sur le tombant récifal externe. La densité moyenne enregistrée pour *H. hippopus* est moyenne. Ces deux espèces présentent une gamme complète de classes de taille, aussi bien des juvéniles que des adultes de grande taille, ce qui donne à penser que, malgré les faibles densités, la ponte et le recrutement n'ont jamais cessé. De manière générale, les populations de bénitiers observées à Yyin ne sont que modérément affectées, et l'habitat disponible est limité et de faible profondeur.

Les récifs de Yyin offrent un habitat à la superficie limitée mais aux conditions propices aux trocas juvéniles et adultes d'importance commerciale (*Trochus niloticus*). Il est rare d'observer des trocas au niveau des récifs de faible profondeur du lagon ; on a toutefois relevé des densités élevées au sein des principales concentrations situées sur la pente du récif. Sur la pente externe, les densités sont toutes nettement supérieures à 500-600 individus par hectare, soit le seuil de densité minimum recommandé pour qu'une exploitation commerciale puisse être envisagée. On observe la plupart des classes de taille et de nombreux coquillages âgés et de grande taille dans les concentrations, ce qui indique que les récoltes passées n'ont pas donné lieu à une exploitation intensive. Toutefois, la présence limitée de juvéniles et de jeunes adultes indique qu'il faudrait peut-être que les responsables du service des pêches patientent encore quelques saisons de reproduction avant d'autoriser la pêche commerciale. D'après les résultats de l'enquête, à Yyin, les trocas sont globalement bien gérés. Par ailleurs, l'huître perlière à lèvres noires, *Pinctada margaritifera*, n'a pas été relevée à Yyin.

À Yyin, le lagon protégé aux eaux peu profondes est limité en termes de superficie, or il s'agit d'un habitat propice à différentes espèces d'holothuries. Quinze espèces d'intérêt commercial y ont été décelées, de même qu'une espèce pouvant tenir lieu d'indicateur. Toutefois, la faible superficie du site et la présence limitée d'habitats étendus restreignent les possibilités. D'après les données relatives à la présence et à la densité, il apparaît que les holothuries ont été soumises à une pression de pêche ou à une pression environnementale importantes par le passé. Cependant, certaines espèces ont été relevées à des densités satisfaisantes, notamment dans les zones côtières protégées. Aucun stock présentant de fortes densités n'a été observé, bien que par endroits, *Actinopyga* sp. demeure abondante, malgré la faible quantité d'individus de grande taille (>12 cm). Aucun stock d'holothuries de sable (*Holothuria scabra*), espèce à forte valeur, n'a été enregistré, malgré l'environnement propice à cette espèce. Autre espèce de grande valeur, l'holothurie noire à mamelles (*H. nobilis*) est présente à de faibles densités.

Recommandations pour Yyin (Yap)

- Un système de surveillance des stocks de poissons et de certains invertébrés doit être établi, en vue de suivre l'évolution de ces ressources

- Il convient de contrôler la pêche au fusil-harpon de nuit et le nourrissage des requins.

- Comme sur d'autres sites de Yap, la création d'aires marines protégées doit être envisagée par la communauté de Yyin, en tant qu'éventuel outil de gestion.

- Il convient de limiter avec soin les zones d'extraction de sable, afin d'éviter que toute répercussion sur les lieux de pêche.

- Il faut mettre en œuvre des mesures de gestion plus strictes eu égard aux populations réduites de bénitiers, notamment pour ce qui est des spécimens âgés et de grande taille, afin de garantir la pérennité du stock en vue de son exploitation à des fins de subsistance dans cette partie de Yap.

- Avant d'envisager la collecte du troca (*Trochus niloticus*) à des fins commerciales, les responsables du service des pêches doivent d'abord observer un fort pic de recrutement, c'est-à-dire patienter quelques saisons de reproduction supplémentaires.

- Il faut contrôler de près l'exploitation de l'holothurie noire à mamelles (*Holothuria nobilis*), espèce à forte valeur marchande, si l'on veut garantir la protection des reproducteurs et conserver des densités viables de ponte à l'intérieur des réserves marines. C'est ainsi que la pérennité de cette espèce dans cette zone de pêche pourra être assurée.

- Il faut que le service des pêches suive l'évolution des activités de reconstitution des stocks et d'élevage en écloserie de l'holothurie, étant donné que ces méthodes, une fois perfectionnées, pourraient être utilisées, à l'avenir, en vue d'assurer le repeuplement de divers points du site en reproducteurs.

Résultats des travaux de terrain à Riiken (Yap)

Riiken est situé sur la côte est de l'île de Gagil (9° 33' de latitude nord et 133° 12' de longitude est). Un pont-jetée rejoint l'île de Gagil à celle de Yap. Riiken se trouve à environ 50 minutes de route de Colonia, capital et centre urbain de l'État de Yap, soit 20 à 30 minutes à l'aide d'une embarcation à moteur hors-bord. Le site de Riiken a été sélectionné parce que c'est là qu'est située la seule aire marine protégée de Yap, établie sur la zone de pêche traditionnelle. Par ailleurs, le village avoisinant de Wanyang, au sud de Riiken, a été inclus dans l'enquête socioéconomique.

Données socioéconomiques : Riiken (Yap)

La pêche ne constitue pas une activité rémunératrice de premier plan à Riiken. Elle n'est la deuxième source de revenus que de 11 pour cent des ménages seulement. En revanche, les revenus salariaux prédominent, et sont complétés par les recettes tirées de l'agriculture et d'autres sources telles que les petites entreprises, les pensions de retraite et d'autres prestations sociales. Tous les ménages consomment du poisson frais et plus de la moitié mangent régulièrement des invertébrés. La consommation de poisson frais (44 kg par personne et par an) est inférieure à la moyenne observée sur l'ensemble des sites d'étude des États fédérés de Micronésie. Le même constat s'applique, bien que dans une moindre mesure, pour la consommation d'invertébrés (10 kg par personne et par an). Les habitants recourent nettement plus souvent que la moyenne aux conserves de poisson (47 kg par personne et par an).

Les habitants de Riiken allient valeurs traditionnelles et économie monétaire. Les envois de fonds sont inexistants. Ce sont principalement les hommes qui pratiquent la pêche du poisson, tandis que les femmes se chargent de la collecte des invertébrés. Les poissons sont essentiellement capturés sur les récifs côtiers protégés et rarement sur le tombant récifal externe. Pour la pêche du poisson, le filet maillant, l'épervier, la palangrotte et le fusil-harpon sont autant de techniques employées. Les pêcheurs d'invertébrés interviennent sur les zones associant platier récifal et fonds meubles, tandis que les langoustes et les bénitiers sont récoltés le long du récif. Bien qu'une très faible proportion des prises d'invertébrés (langoustes essentiellement) soit destinée à la vente hors de la communauté, dans l'ensemble, les invertébrés sont capturés à des fins non commerciales. La plupart du temps, la pêche est réalisée sans embarcation, hormis sur le tombant récifal externe et dans les passes, où des pirogues à pagaies sont nécessaires.

Ressources en poissons : Riiken (Yap)

Il ressort des résultats obtenus qu'à l'époque de l'évaluation, l'état des ressources en poissons de ce site est bon, ce qui peut notamment s'expliquer par la richesse des récifs. Le substrat se compose essentiellement de blocs de corail et affiche une forte proportion de coraux vivants, ce qui profite à certaines familles précises d'herbivores, comme les acanthuridés et les scaridés, lesquels sont prédominants sur ce site. Le fait que de grands prédateurs (requins) et des espèces rares, telles que *Bolbometopon muricatum*, soient fréquemment observés sont d'autres signes indicateurs du bon état des ressources. La densité de poissons est la plus importante du pays et la biomasse la deuxième plus forte. De plus, on note une importante biodiversité par rapport à la moyenne régionale. Toutefois, analysées à l'échelle de l'habitat récifal, les ressources varient fortement : sur les récifs côtiers et intermédiaires, principales destinations des sorties de pêche et sites présentant les densités de pêcheurs les plus élevées, les densités de poissons et la biomasse sont les plus faibles du site. Par conséquent, les effets de la pression de pêche se font ressentir : les poissons sont plus petits, moins diversifiés et présents en moins grand nombre, ce qui indique que sur ces habitats, la pression de pêche est assez forte.

Ressources en invertébrés : Riiken (Yap)

À Riiken, on observe un large choix d'habitats récifaux peu profonds, propices aux bénitiers. Toutefois, ces zones présentent une superficie limitée. Seules deux espèces endémiques de bénitiers sont présentes : *Tridacna maxima* et *Hippopus hippopus*. *T. derasa* a été relevée, mais il s'agit en partie de coquillages importés. Les densités de bénitiers sont relativement faibles, ce qui constitue une source d'inquiétude, étant donné que pour assurer la reproduction, il faut que des individus de grande taille se trouvent à proximité les uns des autres (à de fortes densités). Néanmoins, d'après la répartition des fréquences de taille, le recrutement continue de se produire, et une amélioration de la situation est espérée en raison de la présence de toute la gamme de tailles (individus juvéniles comme adultes de grande taille en âge de se reproduire). Dans l'ensemble, à Riiken, les bénitiers sont modérément affectés par les activités de pêche.

On relève un habitat propice aux trocas juvéniles et adultes de valeur commerciale (*Trochus niloticus*), bien que d'une superficie limitée. Le troca n'est pas commun sur les récifs de Riiken, mais à l'intérieur des principales concentrations, on enregistre des densités élevées. De fortes densités ont également été relevées au sein de l'aire marine protégée, ce qui augure bien pour les récifs environnants. Sur les cinq stations étudiées dans l'aire marine protégée et sur le tombant récifal externe, quatre comportent des trocas à des densités supérieures à 500-600 coquillages par hectare, ce qui correspond à la densité minimale recommandée avant qu'une pêche commerciale puisse être envisagée. La plupart des classes de trocas sont présentes, signe que les récoltes passées n'ont pas entièrement épuisé les stocks ou qu'elles ciblaient des individus matures présentant une taille supérieure à la limite de taille maximale. D'après les résultats de l'enquête, les stocks de trocas dans la zone de Riiken ne sont que faiblement affectés par la pêche. Par ailleurs, l'huître perlière à lèvres noires (*Pinctada margaritifera*) est rare à Riiken.

Riiken dispose de zones lagonaires protégées et peu profondes qui conviennent à diverses espèces d'holothuries que l'on trouve à proximité du rivage. Toutefois, en l'absence d'un lagon plus classique, l'ensemble des espèces ne peuvent être représentées. Quatorze espèces d'holothuries ont été enregistrées à Riiken, dont treize d'importance commerciale, un nombre inférieur à ce qui était prévu, en raison de l'échelle limitée du site et de la relative absence d'habitats soumis à l'influence océanique. Les données relatives à la présence et à la densité donnent à penser que par le passé, les holothuries ont été soumises à une importante pression de pêche ou pression environnementale. Cependant, certaines espèces sont présentes à des densités raisonnables. Espèce de forte valeur, l'holothurie de sable (*Holothuria scabra*) est toujours présente, tout en n'étant que peu répandue sur le site : il s'agit là des derniers vestiges d'un stock déterminant pour l'avenir de la pêche de cette espèce ou pour son éventuelle aquaculture.

Recommandations pour Riiken (Yap)

- Il convient de surveiller la pression de pêche exercée sur les langoustes, étant donné que celles-ci comptent pour une grande partie des captures annuelles déclarées d'invertébrés.

- Un programme de suivi doit être établi afin que les effets sur l'état des ressources de l'aire marine d'ores et déjà créée, de même que les perspectives de développement de la pêche sur la zone locale, puissent être vérifiés et enregistrés.

- Une attention particulière doit être portée au choix des zones d'extraction de sable, afin d'éviter toute répercussion sur les lieux de pêche.

- Des mesures de gestion doivent être introduites afin de protéger de la pêche les concentrations de bénitiers plus âgés et de grande taille et, par conséquent, de garantir la pérennité des ressources.

- Il convient de surveiller de près l'état des stocks des holothuries de grande valeur, comme l'holothurie de sable (*Holothuria scabra*) et l'holothurie noire à mamelles (*H. nobilis*), afin de s'assurer que les densités de reproducteurs demeurent suffisamment élevées pour garantir la ponte et pour que la pêche se poursuive.

- Il faut que le service des pêches suive l'évolution des activités de reconstitution des stocks et d'élevage en écloserie de l'holothurie, étant donné que ces méthodes, une fois perfectionnées, pourraient être utilisées, à l'avenir, en vue de repeupler divers points du site en reproducteurs.

Résultats des travaux de terrain à Piis-Panewu (Chuuk)

Chuuk est un grand système lagonaire (atoll) semi-fermé aux eaux peu profondes. Tant les îles basses que celles hautes sont communes et on observe de nombreux récifs au sein du lagon. C'est l'influence océanique qui prédomine, malgré la présence de récifs frangeants, intermédiaires et au large. Piis-Panewu se trouve au nord du lagon de Chuuk (environ 7° 40' de latitude nord et 151° 50' de longitude est), à une heure de bateau (hors-bord) de Weno, capitale et centre économique de l'État de Chuuk. Il s'agit d'un atoll corallien doté de deux villages, Nukan et Sopotiw, de même que de plusieurs passes à l'origine de la forte influence océanique.

Données socioéconomiques : Piis-Panewu (Chuuk)

La communauté de Piis-Panewu a facilement accès à des habitats très diversifiés, notamment un récif côtier protégé, un lagon, des mangroves, un tombant récifal externe et des passes dans un environnement libre d'accès. Elle est totalement tributaire des ressources marines, dont elle tire nourriture et la majeure partie de ses revenus monétaires. La présence d'embarcations à moteur, la rapidité du trajet (1 heure de bateau) jusqu'au marché de Weno et les fréquentes visites de revendeurs sur l'île permettent à la communauté de pratiquer l'exploitation commerciale de ses ressources halieutiques. La consommation de poisson frais (79 kg par personne et par an) et d'invertébrés (14,4 kg par personne et par an) est élevée. Ces deux chiffres sont supérieurs à la moyenne enregistrée sur l'ensemble des sites d'étude des États fédérés de Micronésie. À titre de comparaison, la consommation de conserves de poissons est faible (2,4 kg par personne et par an). Les observations relatives à la consommation et aux revenus sont révélatrices du mode de vie traditionnel de la communauté. Toutefois, les prix à l'importation des denrées vivrières de base et le coût du transport et de l'essence renforcent la nécessité de gagner de l'argent, afin de faire face au coût de la vie relativement élevé. Les envois de fonds ne jouent qu'un rôle mineur pour de nombreux ménages ; la plupart d'entre eux dépendent davantage de la nourriture envoyée par des membres de la famille installés à Weno.

Les rôles traditionnels se retrouvent dans le fait que les hommes se chargent de la pêche du poisson, tandis que les femmes collectent la plupart des invertébrés. Toutefois, pour ce qui est de la pêche des invertébrés à des fins commerciales, ce sont les hommes qui sont les principaux acteurs. Les prises de langoustes, holothuries, bénitiers, trocas et poulpes destinées à la vente représentent la plupart des captures annuelles d'invertébrés. Cependant, le fait que les pêcheurs ne ciblent qu'un nombre très réduit d'espèces et que les prises annuelles moyennes par pêcheur sont très élevées pour la collecte sur le platier récifal, de même que l'absence de mesures de gestion des pêches donnent lieu de s'inquiéter.

Les PUE sont globalement moyennes (1,7-2,5 kg par heure de sortie de pêche) et supérieures sur le tombant récifal externe que sur les récifs côtiers protégés proches du rivage. Le fusil-harpon, la palangrotte, le filet maillant et la pêche profonde à la palangre constituent les principales techniques utilisées. Il n'est guère étonnant de noter que plus l'on s'éloigne des côtes, plus la taille moyenne des poissons augmente. Les poissons sont généralement grands : 25 cm sur le récif côtier protégé et 35 cm sur le tombant récifal externe. Toutefois, quel que soit l'habitat, la taille moyenne des scaridés est de 25 cm.

Ressources en poissons : Piis-Panewu (Chuuk)

À Piis-Panewu, les ressources en poissons sont en relativement mauvais état. Bien que les récifs soient naturellement riches et présentent une forte couverture de corail vivant, ils n'offrent pas d'habitat propice aux carnivores associés aux fonds meubles, comme les lethrinidés et les mullidés. Analysées à l'échelle de l'habitat récifal, les ressources présentent des états variés. C'est sur les récifs intermédiaires que l'on observe la plus grande richesse : la densité et la biomasse de poissons y sont les plus fortes. En revanche, l'arrière-récif constitue le plus pauvre des trois habitats. Le tombant récifal externe est inhabituellement pauvre pour un site exposé à l'océan : la densité, la biomasse et la biodiversité des poissons y sont inférieures à celles du récif intermédiaire, tandis que la taille et le rapport de taille sont les plus faibles, et de loin. Le rapport de taille moyen est inférieur à 50 pour cent pour les scaridés. Les valeurs relevées sur le tombant récifal externe pour tous les paramètres biologiques analysés sont également les plus faibles du pays.

Les herbivores prédominent sur tous les types de récifs, y compris sur le tombant récifal externe : les acanthuridés et les scaridés sont très nombreux, tandis que les lutjanidés sont quasiment absents de leur habitat de prédilection, sur le tombant récifal externe, là où ils sont le plus souvent pêchés. Il s'agit là d'un autre signe indicateur des graves répercussions de la pêche sur certaines espèces ciblées. La prédominance des herbivores, en particulier des acanthuridés et des scaridés, pourrait en partie s'expliquer par le type d'environnement, principalement composé de fonds durs. En effet, il semble que le tombant récifal externe soit un habitat plus fréquemment visé que les autres, constat inhabituel par rapport aux autres sites du pays. Les ressources présentes sur le tombant récifal externe et l'arrière-récif présentent les premiers signes d'une forte pression de pêche : la densité de poissons, la biomasse, la taille et la biodiversité y sont moins importantes que sur les récifs intermédiaires du site et que sur les habitats similaires du pays.

Ressources en invertébrés : Piis-Panewu (Chuuk)

On relève une large gamme d'habitats récifaux de faible profondeur convenant aux bénitiers, alors même qu'une grande partie des zones côtières protégées par les arrière-récifs sont sablonneuses et dotées de peu de fonds durs. La majeure partie du site est exposée et soumise à l'influence océanique (cf. les récents cyclones en 2002 et 2003). Il est étonnant de noter que seules quatre espèces de bénitiers sont présentes dans cette partie du Pacifique : *Tridacna maxima*, *T. crocea*, *T. squamosa* et *Hippopus hippopus*. D'après les mesures de répartition, de densité et de taille, on observe que tous les stocks sont affectés par la pêche, et que les stocks des espèces de grande taille sont en voie d'épuisement.

Les récifs de Piis-Panewu offrent un habitat étendu et en relativement bon état aux trocas juvéniles et adultes (*Trochus niloticus*), espèce de valeur commerciale. Les trocas sont assez courants sur les récifs de Piis-Panewu, à une densité toutefois faible à moyenne. Bien qu'interdite, la pêche commerciale continue d'être pratiquée, et d'après des rapports issus d'observations sur le terrain, des trocas seraient vendus à Weno. La plupart des tailles sont présentes et aucune classe d'âge n'est fortement représentée en dessous de la fourchette de tailles commercialisables. Dans l'ensemble, les résultats de l'enquête donnent à penser que, dans la zone de Piis-Panewu, une très forte pression de pêche est exercée sur le troca et qu'à l'heure actuelle, sa densité est nettement inférieure au seuil à partir duquel la récolte à des fins commerciales peut être envisagée. Par ailleurs, l'huître perlière à lèvres noires (*Pinctada margaritifera*) est relativement peu répandue à Piis-Panewu.

Piis-Panewu dispose de vastes récifs-barrières et zones lagonaires protégées aux eaux profondes et peu profondes, habitats propices à l'holothurie. Toutefois, l'absence de baies côtières riches limite quelque peu la diversité des espèces. Quatorze espèces d'holothuries ont été enregistrées, un nombre inférieur à celui escompté pour un tel site du Pacifique. Les facteurs environnementaux locaux jouent en effet un rôle en limitant la présence de certaines espèces. Les stocks d'holothuries d'importance commerciale sont rares et présentent uniquement de faibles densités. D'après les données relatives à la présence et à la densité, il semble que les holothuries aient été soumises à une importante pression de pêche ou pression environnementale. Même si aucune pêche n'a été menée sur ce site, il semble néanmoins que les populations des espèces les plus ciblées (et aussi les plus susceptibles de s'éteindre), comme l'holothurie noire à mamelles (*Holothuria nobilis*), ne se soient toujours pas reconstituées depuis les dernières activités de pêche.

Recommandations pour Piis-Panewu (Chuuk)

- Il convient d'entreprendre des études de référence en vue de déterminer les éventuels domaines problématiques, de sorte à élaborer une stratégie de gestion des pêches visant à résoudre les principaux problèmes. L'objectif est de faire cesser l'exploitation abusive des ressources et, dans l'idéal, de modifier la situation, tout en garantissant des moyens de subsistance pour la communauté.

- Si l'on veut s'assurer de leur coopération et du respect des mesures de gestion, l'ensemble des communautés et des habitants et habitantes de Piis-Panewu et d'autres îles avoisinantes doivent participer à l'élaboration d'une stratégie de gestion des pêches portant aussi bien sur les poissons que sur les invertébrés.

- Les pouvoirs publics et les partenaires nationaux, en étroite collaboration avec la communauté de Piis-Panewu et l'ensemble des femmes et des hommes concernés, doivent élaborer et faire respecter certaines normes en vue de contrôler l'exploitation commerciale de l'holothurie, de la langouste, du troca, du bénitier et du poulpe, dans le cadre de la stratégie de gestion des pêches.

- La première étape sera de procéder, à l'aide d'un moratoire, au strict contrôle de l'exportation des espèces d'holothuries d'importance commerciale, jusqu'à ce que les stocks se reconstituent.

- Il faut examiner la possibilité de créer une aire marine protégée, où les holothuries adultes et d'autres espèces pourraient être déposées et protégées, à des concentrations de reproducteurs viables (20-50 individus déposés sur une partie de leur habitat récifal habituel, à 5 mètres les uns des autres). Toutefois, la protection de ces groupes de reproducteurs potentiels nécessitera alors le respect absolu des règles imposées.

- Il faut que le service des pêches suive l'évolution des activités de reconstitution des stocks et d'élevage en écloserie de l'holothurie, étant donné que ces méthodes, une fois perfectionnées, pourraient être utilisées, à l'avenir, en vue de repeupler divers points du site en reproducteurs.

- L'utilisation du fusil-harpon, engin le plus souvent employé, doit être réglementée, et ce type de pêche doit être interdit de nuit. Il convient également de contrôler le recours au filet maillant au niveau des récifs du lagon.

- Une attention particulière doit être portée au choix des zones d'extraction de sable, afin d'éviter toute répercussion sur les lieux de pêche.

Résultats des travaux de terrain à Romanum (Chuuk)

Romanum est située dans la partie nord/nord-ouest du lagon de Chuuk (7° 27' de latitude nord et 151°35' de longitude est), à moins d'une heure de bateau (hors-bord) de Weno, capitale et principal centre urbain de l'État de Chuuk. Romanum est une petite île volcanique dotée de deux villages, Winisi et Chorong. Les habitats présents au sein du système lagonaire sont en grande partie le reflet de l'influence océanique. Les communautés de Romanum sont tributaires de la récolte de ressources halieutiques, tant pour leur subsistance que pour la génération de revenus. Les prises sont en effet régulièrement transportées jusqu'à Weno, où elles sont vendues.

Données socioéconomiques : Romanum (Chuuk)

La communauté de Romanum a facilement accès à des habitats très diversifiés, notamment un récif côtier protégé, un lagon, un tombant récifal externe et des passes dans un environnement libre d'accès. Toutefois, elle ne dispose que de peu, voire pas du tout, d'options alternatives à la pêche et, dans une moindre mesure, à l'agriculture. La communauté est fortement tributaire des ressources marines, dont elle tire nourriture et la plupart de ses revenus monétaires. La présence d'embarcations à moteur, la rapidité du trajet jusqu'au marché de Weno et les fréquentes visites de revendeurs sur l'île permettent à la communauté de pratiquer l'exploitation commerciale de ses ressources halieutiques. La consommation de poisson frais (81 kg par personne et par an) et d'invertébrés (18,5 kg par personne et par an) est élevée. Ces deux chiffres sont supérieurs à la moyenne de l'ensemble des sites d'étude aux États fédérés de Micronésie. La consommation de conserves de poissons est moindre (12 kg par personne et par an).

Les observations relatives à la consommation et aux revenus sont révélatrices du mode de vie traditionnel de la communauté. Toutefois, les prix à l'importation des denrées vivrières de base nécessitent des revenus afin de faire face aux dépenses quotidiennes, dont le coût est relativement élevé. Près de la moitié de la population bénéficie, dans une certaine mesure seulement, d'envois de fonds. Les rôles traditionnels se retrouvent dans le fait que les hommes se chargent de la pêche du poisson, tandis que les femmes collectent la plupart des invertébrés. Les femmes sont organisées en petits groupes chargés du négoce du poulpe et d'autres invertébrés avec les revendeurs et les supermarchés. Pour ce qui est de l'exploitation commerciale de l'holothurie, de la langouste, du troca et du bénitier, ce sont les hommes qui sont les principaux acteurs.

Les PUE sont globalement moyennes (2-2,5 kg par heure de sortie de pêche) et ne varient pas sensiblement d'un habitat à l'autre. Le fusil-harpon, principale technique employée, est parfois accompagné de la pêche profonde à la palangre et du filet maillant. Il n'est guère étonnant de noter que plus l'on s'éloigne des côtes, plus la taille moyenne des poissons augmente. Les poissons sont généralement grands : 25 cm sur le récif côtier protégé et environ 35 cm sur le tombant récifal externe. Les principales familles attrapées (scaridés et acanthuridés) sont le reflet du recours massif au fusil-harpon.

D'après les résultats obtenus lors de l'enquête sur les invertébrés, on note que les prises d'espèces d'holothuries d'importance commerciale représentent la majeure partie de la récolte annuelle d'invertébrés (poids humide), suivies d'autres espèces commercialisables ciblées : langoustes, trocas et bénitiers. Toutefois, le fait que les pêcheurs ne ciblent que quelques espèces précises et que les prises annuelles moyennes par pêcheur sont très élevées pour le ramassage sur le platier récifal, de même que l'absence de mesures de gestion de la pêche suscitent des inquiétudes.

Ressources en poissons : Romanum (Chuuk)

À Romanum, au moment de l'enquête, les ressources en poissons sont en relativement mauvais état. Comparables aux récifs de Piis-Panewu, ceux de Romanum semblent être en bonne santé et présenter une forte couverture de corail vivant. Toutefois, on relève peu de fonds meubles, type de substrat propice aux carnivores, comme les lethrinidés et les mullidés. Cependant, les lutjanidés, famille généralement associée aux fonds durs, sont eux aussi présents en faible abondance, voire absents : la pêche intensive est certainement à l'origine de cette situation. Les lethrinidés, les scaridés et les acanthuridés, qui représentent la majeure partie des prises, affichent de très faibles rapports moyens de taille, signe que ces familles précises sont affectées. Analysées à l'échelle de l'habitat récifal, les ressources présentent des états variés. Les récifs côtiers sont particulièrement pauvres et les poissons y sont très petits. Sur les récifs intermédiaires et les arrière-récifs, on relève des densités de poissons minimales et des tailles à peine plus grandes, ce qui découle sur une biomasse faible. Seuls les tombants récifaux externes apparaissent plus riches : la biomasse y est deux fois plus élevée que celle enregistrée à Piis-Panewu. D'importantes activités de pêche sont conduites à des fins de subsistance mais aussi de commercialisation. De plus, dans les petites zones de pêche disponibles, on note une densité de pêcheurs élevée. Aux environs de Romanum, on a également observé des traces de pêche à la dynamite. Par conséquent, la pêche se répercute fortement sur les ressources : on relève des tailles plus petites, des quantités réduites et une moindre diversité des espèces par rapport aux autres sites étudiés tant à Chuuk qu'à Yap.

Ressources en invertébrés : Romanum (Chuuk)

À Romanum, on relève une large gamme d'habitats récifaux de faible profondeur convenant aux bénitiers. Toutefois, la pression démographique est également indéniable : la population de l'État de Chuuk a fortement augmenté et, aujourd'hui, plus de la moitié des habitants des États fédérés de Micronésie y vivent, répartis sur les quinze îles habitées. Il est étonnant de noter que seules trois espèces de bénitiers sont présentes dans cette partie du Pacifique : *Tridacna maxima*, *T. squamosa* et *Hippopus hippopus*. D'après les mesures de répartition, de densité et de taille, on observe que tous les stocks sont affectés par la pêche, et que les stocks des espèces de grande taille ont atteint un stade critique. Dans l'ensemble, à Romanum, les stocks de bénitiers sont extrêmement affectés par la pêche.

À Romanum, les récifs offrent un habitat étendu et propice aux trocas juvéniles comme adultes (*Trochus niloticus*), espèce d'importance commerciale. Le troca est assez répandu sur les récifs, mais à l'intérieur des principales concentrations et sur les récifs en général, on enregistre des densités faibles à moyennes. C'est à proximité du village de Romanum que l'on observe les plus fortes densités de trocas, là où les pêcheurs de la communauté locale sont en mesure de surveiller (protéger) ceux-ci. La plupart des tailles y sont présentes, mais on peut noter que les récoltes précédentes ont donné lieu à une exploitation intensive des stocks. En effet, les concentrations ne comportent plus d'individus de grande taille (>11 cm de largeur à la base). L'absence de coquillages âgés et de grande taille, c'est-à-dire ceux les plus susceptibles de participer au renouvellement des populations et, ainsi, de rendre possible la poursuite de la pêche, signifie qu'il faudra peut-être davantage de temps, qu'en présence d'individus plus âgés, avant que la densité minimale à partir de laquelle peut être envisagée la pêche commerciale ne soit atteinte. D'après les résultats de l'enquête, il semble que sur la zone d'étude de Romanum, le troca soit fortement affecté par la pêche et, qu'à l'heure actuelle, la densité soit nettement inférieure au seuil à partir duquel peut être envisagée la pêche commerciale. Par ailleurs, l'huître perlière à lèvres noires (*Pinctada margaritifera*) est relativement peu répandue à Romanum.

Romanum dispose de vastes récifs-barrières et zones lagonaires protégées aux eaux profondes et peu profondes, habitats propices à diverses espèces d'holothuries. Cependant, étant donné que Romanum est une île de petite taille, le nombre de baies côtières présentant des fonds « riches » dotés d'herbiers est limité, ce qui restreint dans une certaine mesure la possibilité d'observer des holothuries que l'on trouve habituellement dans de tels habitats. À Romanum, vingt espèces d'holothuries ont été observée, constat normal dans cette partie du Pacifique. En revanche, d'après les résultats de la présente enquête, les stocks d'holothuries d'importance commerciale, généralement exportées, sont souvent rares ou présents à de faibles densités seulement. D'après les données relatives à la présence et à la densité, il semble que les holothuries aient été soumises à une forte pression de pêche et à une pression exercée par des facteurs environnementaux. Aucune activité de pêche n'a été régulièrement réalisée sur ce site ; cependant, il semble que les populations des espèces les plus ciblées (et susceptibles de s'éteindre), comme l'holothurie noire à mamelles (*Holothuria nobilis*), n'aient toujours pas regagné de niveaux « sains » depuis les dernières activités de pêche.

Recommandations pour Romanum (Chuuk)

- Il convient d'entreprendre des études de référence en vue de déterminer les éventuels domaines problématiques, de sorte à élaborer une stratégie de gestion des pêches visant à résoudre les principaux problèmes. L'objectif est de faire cesser l'exploitation abusive des ressources et, dans l'idéal, de modifier la situation, tout en garantissant des moyens de subsistance pour la communauté.

- Si l'on veut s'assurer de leur coopération et du respect des mesures de gestion, l'ensemble des communautés et des habitants et habitantes de Piis-Panewu et d'autres îles avoisinantes doivent participer à l'élaboration d'une stratégie de gestion des pêches portant aussi bien sur les poissons que sur les invertébrés.

- Les pouvoirs publics et les partenaires nationaux, en étroite collaboration avec la communauté de Romanum et l'ensemble des femmes et des hommes concernés, doivent élaborer et faire respecter certaines normes en vue de contrôler l'exploitation commerciale de l'holothurie, du troca et du bénitier, dans le cadre de la stratégie de gestion des pêches.

- La première étape sera de procéder, à l'aide d'un moratoire, au strict contrôle de l'exportation des espèces d'holothuries d'importance commerciale, jusqu'à ce que les stocks se reconstituent.

- Il faut examiner la possibilité de créer une aire marine protégée, où les holothuries adultes et d'autres espèces pourraient être déposées et protégées, à des concentrations de reproducteurs viables (20-50 individus déposés sur une partie de leur habitat récifal habituel, à 5 mètres les uns des autres). Toutefois, la protection de ces groupes de reproducteurs potentiels nécessitera alors le respect absolu des règles imposées.

- Il faut que le service des pêches suive l'évolution des activités de reconstitution des stocks et d'élevage en écloserie de l'holothurie, étant donné que ces méthodes, une fois perfectionnées, pourraient être utilisées, à l'avenir, en vue de reformer des populations de reproducteurs en divers points du site.

- L'utilisation du filet maillant et du fusil-harpon doit être limitée et la pêche de nuit au fusil-harpon interdite. Il est indispensable que les pêcheurs respectent ces mesures.

- Une attention particulière doit être portée au choix des zones d'extraction de sable, afin d'éviter toute répercussion sur les lieux de pêche.

ACRONYMS AND ABBREVIATIONS

ACP	African, Caribbean and Pacific Group of States
ADB	Asian Development Bank
AIMS	Australian Institute of Marine Science
AUD	Australian dollar(s)
AusAID	Australian Agency for International Development
BdM	bêche-de-mer (or sea cucumber)
CCS	Chuuk Conservation Society
CDMR	Chuuk Department of Marine Resources
CMT	customary marine tenure
CoFish	Pacific Regional Coastal Fisheries Development Programme
COTS	crown of thorns starfish
CPUE	catch per unit effort
CSP	Conservation Society of Pohnpei
DEA	Department of Economic Affairs
DMR	Department of Marine Resources
Ds	day search
D-UVC	distance-sampling underwater visual census
EDF	European Development Fund
EEZ	exclusive economic zone
EU/EC	European Union/European Commission
FAD	fish aggregating device
FAO	Food and Agricultural Organization (UN)
FFA	Forum Fisheries Agency
FL	fork length
FSM	Federated States of Micronesia
GDP	gross domestic product
GIS	geographic information systems
GPS	global positioning system
GRT	gross registered tonnage
ha	hectare
HH	household
MCRMP	Millennium Coral Reef Mapping Project
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MMA	Micronesian Maritime Authority
MMDC	Micronesian Mariculture Demonstration Centre
MOP	mother-of-pearl
MOPt	mother-of-pearl transect
MPA	marine protected area
MRM	marine resource management

MSA	medium-scale approach
MSY	maximum sustainable yield
NAC	National Aquaculture Centre
NASA	National Aeronautics and Space Administration (USA)
NBSAP	National Biodiversity Strategy and Action Plan
NCA	nongeniculate coralline algae
NFC	National Fisheries Corporation
NMRD	National Marine Resources Division
NORMA	National Oceanic Resource Management Authority
Ns	night search
OCT	Overseas Countries and Territories
OFCF	Overseas Fisheries Cooperation Foundation
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
REA	rapid ecological assessment
RFID	Reef Fisheries Integrated Database
RFs	reef-front search
RFs_w	reef-front search by walking
SBq	soft-benthos quadrat
SCUBA	self-contained underwater breathing apparatus
SE	standard error
SOPAC	Pacific Islands Applied Geoscience Commission
SPAGS	Spawning and Aggregation Sites
SPC	Secretariat of the Pacific Community
TNC	The Nature Conservancy
TTPI	Trust Territory of the Pacific Islands
USD	United States dollar(s)
WCPO	western and central Pacific Ocean
WHO	World Health Organization
YAPCAP	Yap Community Action Programme

1. INTRODUCTION AND BACKGROUND

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

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

1.1 The PROCFish and CoFish programmes

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

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

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

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

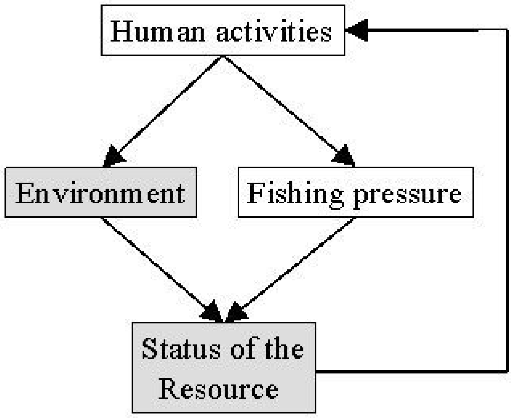

Figure 1.1: Synopsis of the CoFish multidisciplinary approach.
CoFish conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the basis for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

Expected outputs of the project include:

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

1.2 PROCFish/C and CoFish methodologies

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

1.2.1 Socioeconomic assessment

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

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

Socioeconomic assessments also relied on additional complementary data, including:

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

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

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

1.2.2 Finfish resource assessment

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

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

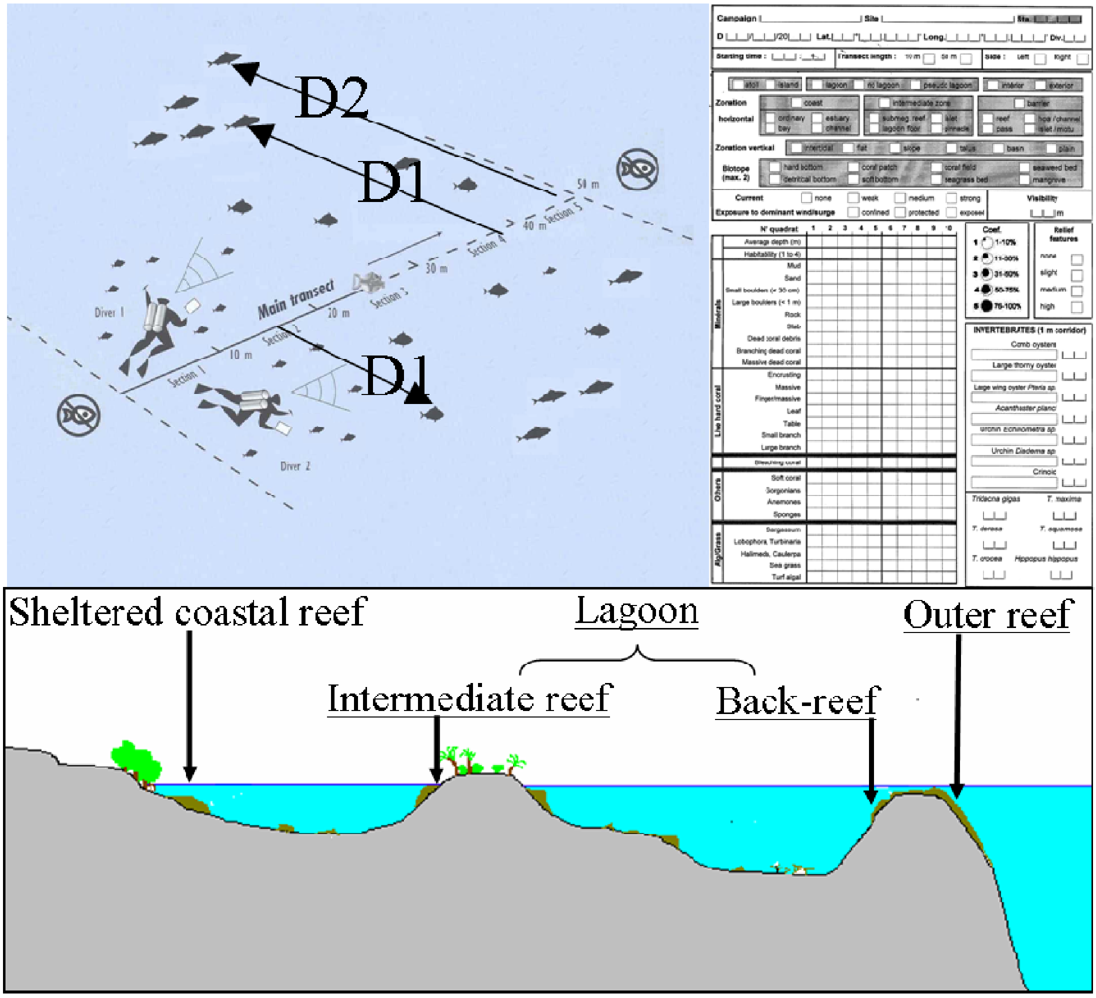

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

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

1.2.3 Invertebrate resource assessment

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

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

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

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

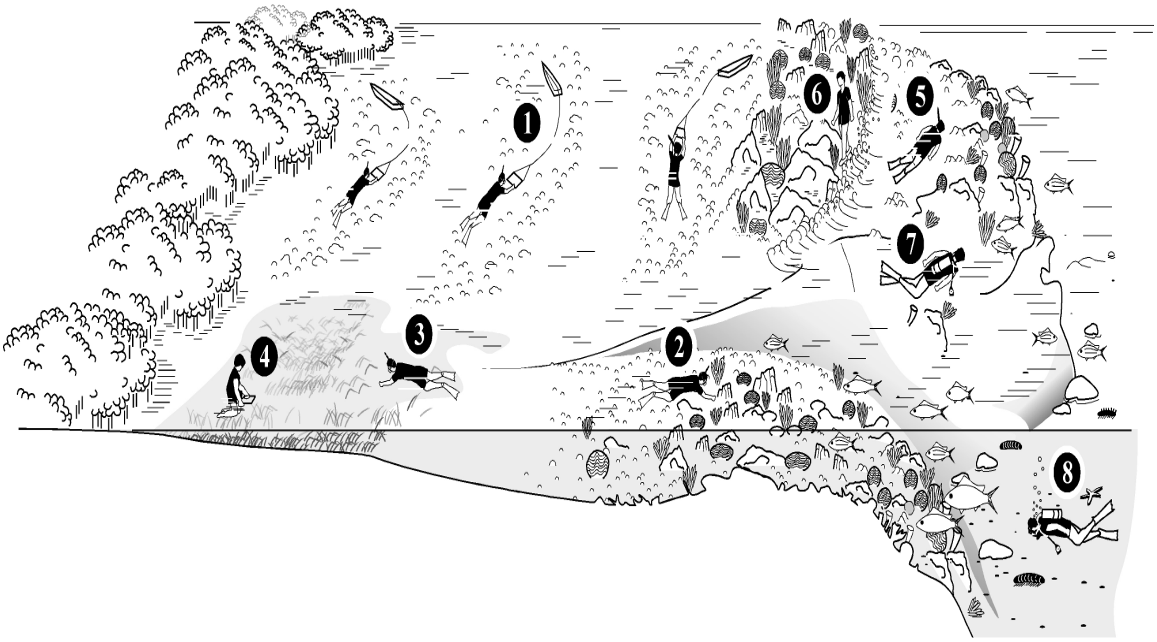

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal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

1.3.1 General

The Federated States of Micronesia (FSM) lie in the North Pacific Ocean, extending 1600 km from north to south, between 1° and 14°N latitude, and 3300 km from east to west, between 135° and 166°E longitude. They are located north of Papua New Guinea and south of Guam (Figure 1.4). FSM is divided into four states, which are from west to east: Yap, Chuuk (called Truk until 1990), Pohnpei (called Ponape until 1984) and Kosrae (formerly called Kusaie). The total landmass of FSM is 701 km², with a declared Exclusive Economic Zone (EEZ) of more than 2.9 million km² and 1000 km of lagoons (Gillett 2002a; Chapman 2004). The country comprises 607 islands. While major islands are high mountainous islands of volcanic origin, most of the islands are uninhabited small coral atolls (FSM Government 2002a; Turner 2007). Land elevation ranges from sea level to 791 m. FSM's climate is tropical and heavily influenced by the northeast trade winds. Strong trade winds prevail from December through April, with periods of weaker winds and doldrums occurring from May to November. Rainfall is high, varying from 3000 mm on drier islands to over 10,000 mm per annum on Pohnpei (Lindsay 2003; Turner 2007).

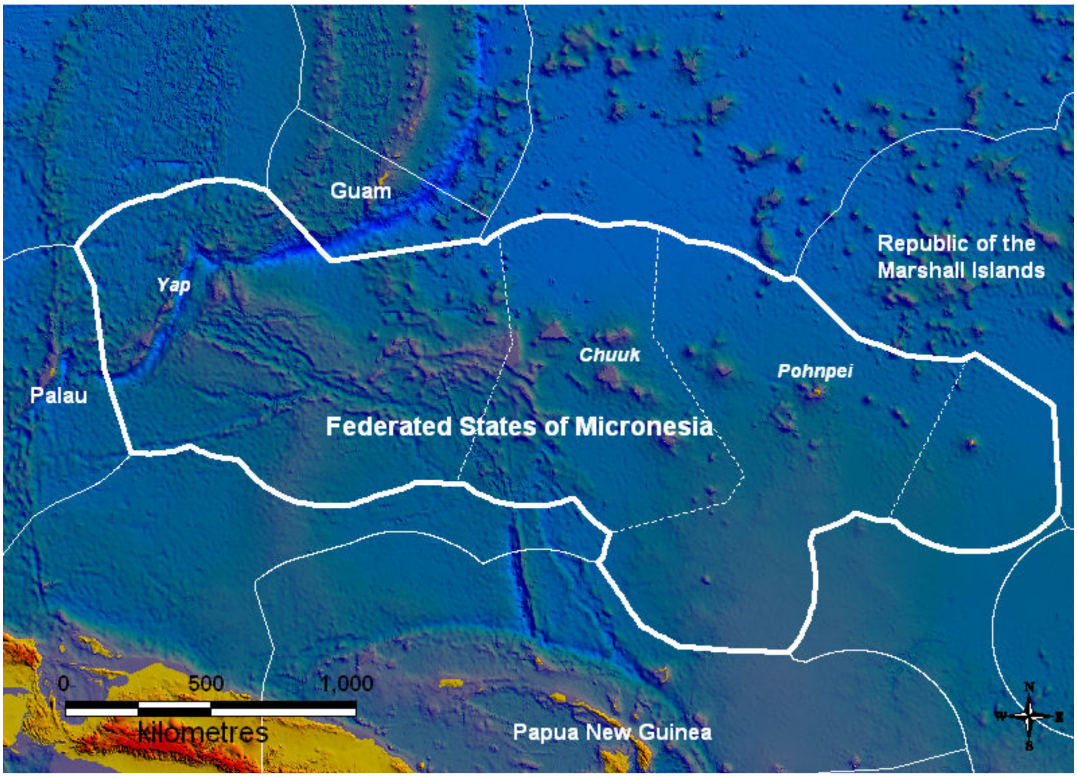

Figure 1.4: Map of FSM.

Yap State, in the west of FSM, consists of Yap proper, which includes the four volcanic islands of Rumung, Maap, Gagil-Tamil and Yap, 15 outer islands and an archipelago of 11 atolls to the north and east. These atolls and islands are spread over about 40% of FSM's sea area. The land area of Yap is 121.2 km² (Smith 1992; SOPAC 1998).

Chuuk State consists of Chuuk lagoon and four outer island groups: the Hall Islands, Namonuito Atoll (Namonweito), the Western Islands and Mortlock Islands. Chuuk lagoon is a complex group of islands that includes 14 volcanic islands and 84 flat islets surrounded by a coral ring, forming a 2100 km² lagoon. The land area of Chuuk is 118 km² (SOPAC 1998).

Pohnpei State consists of Pohnpei Proper, a large volcanic island and six outer island atolls: Sapwuahfik (Ngatik), Nukuor, Kapingamarangi, Mwoakilloa (Mokil), Pingelap, and Oroluk. Pohnpei Island has a land surface of 345.4 km² and a 770 km² lagoon. Pohnpei Proper has a narrow littoral zone where most people live, mangrove fringes around most of the island, a large lagoon and a circumferential barrier reef (Smith 1992; SOPAC 1998).

Kosrae State is the eastern most state and consists of one volcanic island formation (of five very closely situated islands). It has a land surface area of 109.6 km² and no lagoons. The state is largely mountainous; the interior is densely forested and only the coastal areas are inhabited (Smith 1992).

The total population of FSM at the 2000 national census was 107,008. Annual population growth rate in 2000 was estimated to be 0.3% per annum. Approximately half of the population is below the age of 18 years. About 18% of the population lives in the outer islands. The population per state in 2000 was 11,241 in Yap, 53,595 in Chuuk, 34,486 in Pohnpei and 7686 in Kosrae. Population density varies from 69 residents per km² in Kosrae to 422 residents per km² in Chuuk (FSM Government 2002a).

FSM is a young independent nation. It was a United Nations Trust Territory of the Pacific Islands (TTPI) administered by the United States of America until the two nations signed a Compact of Free Association in 1986, leading to the termination of the trusteeship by the United Nations in 1991. The Compact treaty established a special relationship with America and provides economic support to the FSM. In 2002, the funding provisions under the original Compact were being renegotiated between the two countries to determine their future relationship (UNDP 2002). The FSM has three levels of government: National, State and Municipal. In addition, traditional governance continues to play a major role in daily life (Anon. 1987).

The economy of FSM is small and largely dependent on aid provided through the Compact (SPREP 1993). The majority of activities are government services, wholesale and retail, and subsistence farming and fishing. Imports in 2002 totalled USD 104.3 million: 42.2% from the USA (excluding Guam); 20.2% from Guam; and 10.6% from Japan. Exports worth USD 14.4 million were to USA (excluding Guam) 29%; Japan 18.7%; and Guam 7.9%. The main imports are foodstuffs and beverages, manufactured goods, machinery, and equipment. The main exports are copra, bananas, black pepper, fish, and garments (Turner 2007).

1.3.2 The fisheries sector

FSM fisheries comprise the offshore fishery for tuna and other pelagic species, the small-scale tuna fishery around fish aggregating devices (FADs), the deep-water snapper fishery, and reef fisheries for a range of fish and invertebrate species. In addition, FSM has a diverse range of aquaculture and mariculture projects.

When looking at the nearshore resources, the two main fisheries in FSM are the deep-water snapper fishery and the tuna fishery. Most nearshore fishery development has occurred in the tuna fishery, and the FSM Government, with ADB assistance, has finalised a National Tuna Management Plan for the country (FSM Government 2002b).

Offshore tuna fishery

The EEZ of FSM contains substantial tuna stocks, which are fished primarily by foreign longline, purse-seine and pole-and-line vessels under access agreements (Anon. 1988, Anon. 1994, Anon. 2005). Tuna fishing first began in the waters around FSM in the 1930s, when Japanese pole-and-line vessels were based in the region. This fishery declined during World War II, resuming after the war with distant-water vessels that were based in Japan (SPC 1984). As commercial interest in the tuna fishery, especially for skipjack tuna (*Katsuwonus pelamis*) expanded, SPC's Skipjack Survey and Assessment Programme conducted tagging surveys in the waters around FSM in 1978 (Kearney *et al.* 1979), 1979 (Kearney and Hallier 1980), and 1980 (SPC 1984).

The Micronesian Maritime Authority (MMA) was established in 1979 to license foreign fishing vessels wishing to fish in the FSM EEZ. In 1981 the MMA assessed that 22,000 mt of tuna were taken by foreign longliners, plus another 55,000 mt of surface tuna caught by foreign purse seiners and pole-and-liners (Anon. 1983). The early 1980s also saw investment by the state governments in tuna fishing operations, with Chuuk State operating three pole-and-line vessels with Micronesian crews in 1981, landing 105 mt of skipjack and other tuna, some of which were exported to Hawaii for canning (Anon. 1983).

1: Introduction and background

The National Fisheries Corporation (NFC) was established in 1987. NFC is the commercial arm of the government and was designed to develop domestic commercial fishing and fish processing for exports, enter into joint ventures, participate in commercial fishing projects, and invest in the expansion and improvement of the FSM fishing industry (Anon. 1987, Anon. 1991). In 1991, modern tuna longline shore facilities were under construction in Chuuk and Yap States, to be operated by Chuuk Fresh Tuna Inc. and Yap Fresh Tuna. A tuna processing facility was also under construction in Pohnpei in 1991 (Anon. 1991). Different joint venture and transhipment operations were also underway in 1991 from Yap, Chuuk, and Pohnpei States (Anon. 1991).

NFC commenced local tuna longlining operations in 1992, operating four small longline vessels. This expanded to NFC managing a fleet of 11 longline vessels by 1995 (Beverly and Chapman 1997). In 1995, SPC was requested to provide technical assistance with the operation of several longline vessels that were not catching well. This assistance was provided in 1996, although little fishing was undertaken due to vessel breakdowns (Beverly and Chapman 1997). Also at this time the NFC was operating two aircraft to fly their fresh tuna from Yap, Chuuk and Pohnpei to export markets in Japan and Hawaii.

Purse-seine fishing is permitted in FSM by vessels registered in Japan, Taiwan, China, Republic of Korea, USA, and Vanuatu, in addition to four locally owned seiners. Longline fishing is carried out by Japanese, Chinese, and Taiwanese vessels together with locally owned vessels. Pole-and-line tuna fishing is exclusively by Japanese vessels (Gillett 2002a). According to Gillett (2002a), during the years 1991–1999, an estimated 1250,300 mt of tuna were caught in the FSM EEZ. Of this amount, 86.3% was caught by purse seine, 8.8% by longline, and 4.8% by pole and line. In 1999 about 130,000 mt of tuna were taken in the FSM EEZ, of which only about 2% was captured by locally based vessels (Gillett 2002a). By 2002, the domestic fleet consisted of 18 vessels working mainly from Chuuk, Pohnpei, and Yap; these fished 1190 days for a catch of only 259 mt (Park 2003).

Catch and effort has fluctuated with total catches of target tuna species ranging from about 75,000 mt to over 200,000 mt during the last decade. The 2004 annual catch of tuna within the FSM EEZ by all gear types has markedly risen and fallen within the previous 10 years: three years of decline, followed by a one-year steep increase (Anon. 2005). By 2006, catch rates were increasing in the FSM EEZ with logsheets estimating 129,577 mt. The three gear types producing the total catch of the target tuna catch were: purse seine 122,214 mt; longline 6004 mt; and pole and line 1359 mt. The total EEZ catch increased 12% over the previous year's total EEZ catch from all fleets within both the purse-seine and longline fisheries (Anon. 2007). The catch from domestic longline vessels, though, is mainly taken from the EEZ of Marshall Islands, where these vessels mainly operate, and in 2006 the reported catch was 482 mt (Anon. 2007).

The management of the tuna fishery in the FSM EEZ is currently the responsibility of the National Oceanic Resource Management Authority (NORMA), which replaced the Micronesian Maritime Authority (MMA) in the early 2000s. The Authority works under *Title 24 – Fisheries Act 2002*, which establishes a comprehensive framework for tuna fisheries management within waters 12 to 200 nm offshore (Chapman 2004). The control of tuna fishing in state waters (from high-water mark to 12 nm offshore) comes under the various state fishery zone acts (Smith 1992, Chapman 2004), and for foreign vessels is coordinated by NORMA.

Small-scale tuna fishery including fishing around FADs

In FSM, traditional fishing techniques to catch tunas included trolling, pole-and-line fishing with pearl-shell lures, and mid-water handlining. These activities were undertaken from both sailing canoes and paddling canoes (Chapman 2004, SPC 1984). Practically all traditional techniques have accepted modern materials for use at the present time, such as nylon lines and nets, metal hooks, and electric torches. The majority of Micronesians still depend upon a subsistence lifestyle. Commercial fishing, however, is greatly expanding, with trolling, mid-water handlining, and other fishing methods associated with fishing for tuna around FADs (Gawel 1988).

The use of FADs for nearshore fishing activities is fairly new in the FSM, and commenced in 1984 in both Pohnpei and Yap States. Off Pohnpei, the Pacific Tuna Development Foundation deployed around 10 FADs; however, most were lost within a couple of months of deployment (Beverly 2001b). Yap's FAD programme also started in 1984, when SPC was requested to provide technical assistance with the rigging and deployment of FADs, which was part of a project being implemented by the Yap Community Action Programme (YAPCAP), which funded the materials for the project (Chapman and Cusack 1997, Chapman 1988). Four FADs were rigged and deployed in 1984 and another two in 1985 (Chapman 1988). Prior to the introduction of FADs, the trolling activities of male fishers were confined to the reef or to an occasional school of tuna near the coast. Since the FADs were deployed, male fishers spend most of their time trolling around them, particularly when bad weather prevents bottom fishing. A survey of trolling around the FADs recorded a catch rate of 8.4 kg/line hour, a much better return than the reef and open-water trolling results (Chapman and Cusack 1997).

In 1987, Kosrae had two FADs installed; however, there are no records of their success (Moana and Cusack 1997). Also in the late 1980s, around 100 FADs were deployed around Pohnpei State by the Philippine purse-seine company, Mar Fishing Company, to support purse-seining operations, mainly around Kapingamarangi Atoll. However, most of the FADs had a short lifespan and the project was assessed as being unsuccessful (Beverly 2001b).

In support of small-scale tuna fishery development, the Government of Japan in the late 1980s provided the Fisheries Department in Kosrae State with 75 x 7.5 m fibreglass catamarans (Chapman 2004). The US implemented a similar project in the late 1980s in Chuuk, with small-scale tuna fishing vessels leased or given to private individuals or to municipalities (Chapman 2004).

The SPC was again asked to provide technical assistance with rigging and deploying nearshore FADs in 2000 in three states: Yap, Kosrae and Pohnpei, and to train local fisheries officers in these methods. In Yap, staff were trained in FAD site surveys, with three locations surveyed and contour maps produced, although no FADs were rigged or deployed (Beverly 2000). In Kosrae, two trips were undertaken, the first to conduct site surveys and rig and deploy two FADs. The second was to provide training to fisheries staff and local fishers in mid-water handlining methods and the use of vertical longlines in association with the FADs, plus the deploying of a third FAD (Beverley 2001a). In Pohnpei, three sites were surveyed with one FAD deployed and local staff trained in the different methodologies (Beverly 2001b).

In the 2000s, little progress with small-scale tuna fishery development has occured. In 2003, there were around 50–100 part-time fishers trolling for tuna from outboard-powered skiffs at both Pohnpei and Chuuk, although there are no FADs to fish around. In Yap and Kosrae there were around 25–50 small-scale, part-time tuna fishers, and again no FADs for them to work around (Chapman 2004).

Sport or game fishing is another component of the FSM tuna industry. In Pohnpei there are several charter vessels, as well as local male fishers who are also willing to take paying passengers on trips. The Pohnpei Game Fishing Club holds several tournaments per year. In the late 1990s and early 2000s there were about 100 game-fishing vessels throughout the four states. Today several charter boats are available in FSM, mainly linked to hotels. Pohnpei Game Fishing Club holds at least one tournament each month with around 20 vessels competing (Saunders 1988, Paulo 1989, Whitelaw 2001).

Deep-water snapper

The deep-water resources of FSM are dominated by the Lutjanidae (snappers), of which the subfamily Etelinae (deep-water snappers) predominate (Smith 1992). SPC conducted fishing trials and training in fishing methods to catch deep-water snappers in Yap (1978/1979), Kosrae (1979) and Chuuk (1980). The first trial and training course were undertaken in Yap, with fishing conducted around Yap (catch rate of 4.6 kg/reel-hour) and at two outer islands: Ulithi (catch rate of 14.4 kg/reel-hour) and Ngulu (catch rate of 13.2 kg/reel-hour) (Mead and Crossland 1980). Mead and Crossland (1979) recorded a catch rate of 9.6 kg/reel-hour for Kosrae, with large-sized fish compared to other places in the Pacific and very few sharks. Fishing trials in Chuuk in 1980 produced a catch rate of 5.9 kg/reel-hour (4.1 kg/reel-hour if sharks were excluded), although very few deep-water snappers of the genera *Pristipomoides* or *Etelis* were caught (Taumaia and Crossland 1980).

From 1983 to 1986, deep-water snapper fishing trials were undertaken by a private operator who fished around Pohnpei as well as Ant and Pakin Atolls. McCoy (1988) recorded catch rates of between 3.9 and 5.5 kg/reel-hour for these fishing trials over the four-year period. Further fishing trials and training were undertaken by SPC for deep-water snappers in Yap (1984/1985), Kosrae (1987), and Chuuk (1988). Chapman and Cusack (1997) recorded catch rates of 4.4 kg/reel-hour for deep-water snapper fishing around Yap, and 8.3 kg/reel-hour at Ulithi during 1984 and 1985. The trials in Kosrae in 1987 did not yield the same high catch rates recorded in 1979, and were about one-third of this at 3.1 kg/reel-hour (Moana and Cusack 1997). The catch rate for Chuuk in 1988 (3.8 kg/reel-hour) was comparable to that attained in 1980 (4.1 kg/reel-hour), although a slightly higher catch rate was recorded at the outer island of Ruo (5.2 kg/reel-hour) during a training trip to this location (Chapman 1999).

From 1989 to 1991, the National Fisheries Corporation (NFC) and the Overseas Fisheries Cooperation Foundation (OFCF) of Japan conducted surveys of seamounts from Yap to Chuuk State for deep-water snappers using bottom longlines (trotlines) and drop lines. Catches varied from location to location, with a total catch of 21,243 fish weighing 39,260 kg being landed during the survey period (Diplock and Dalzell 1991, Hood 1991, OFCF 1992). Given the different methods used, it was not possible to come up with a catch rate.

Dalzell and Preston (1992) undertook an assessment of the deep-water snapper catch and effort data for FSM from the available data at that time. This was done for each of the four states. For Kosrae State, the potential yield was estimated at 3.7–11.0 mt/year; for Yap State

53–159 mt/year; for Chuuk State 56.8–170.3 mt/year; and for Pohnpei State 31.5–94.4 mt/year. Based on this work, the estimated potential yield of deep-water species from the whole of the FSM probably lies between 145 and 434.7 mt/year (Dalzell and Preston 1992).

The deep-water snapper fishery in FSM continues in the 2000s as an *ad hoc* fishery, with no fishers targeting these species on a regular basis. In 2003 there were ice plants present in rural fishing centres (2 in Yap, 3 in Chuuk, and 1 in Pohnpei); however, fishers still did not target these species. The fishery is mainly for subsistence and artisanal fishers, with catches sold locally but not exported (Chapman 2004). There is also no development and/or management plan in place for the deep-water snapper fishery in FSM, and there are no immediate plans to develop one (Smith 1992, Chapman 2004). The control of deep-water fisheries would come under each state's fishery zone act within state waters, and under the FSM Marine Resources legislation (FSM Code, Title 24).

Deep-water shrimps

The caridean shrimp species present are *Heterocarpus laevigatus* (smooth nylon shrimp) and *H. ensifer* (armed nylon shrimp). Other species are also present, but are of minimal significance commercially. Small numbers of these caridean shrimp were found during preliminary surveys of Yap and Kosrae (Saunders 1987, 1988). There is no information available on the status of deep-water shrimp stocks in FSM. Saunders (1987) stresses the need for regular shrimp stock surveys and an ongoing monitoring programme for Yap (Smith 1992).

Aquaculture and mariculture

Historically the islands that today make up FSM practised only limited types of aquaculture. Traditionally, several species of marine organisms (giant clams, milkfish, rabbit fish, mullet) were held captive (and in some cases fed); they were used for special occasions, or provided a reserve food supply in times of poor weather. These practices are still in use today in the more remote communities and atolls. Most aquaculture programmes undertaken within FSM have been marine-based; very limited brackish and freshwater aquaculture programmes have been undertaken, focusing solely on milkfish and aquarium fish (Lindsay 2003).

Yap State aquaculture activities

There has been no aquaculture activity recorded in Yap before the mid-1970s, when a pond was constructed by the Rull municipality, and later found to be unsuitable by experts from the Philippines. Following this, a small pond was constructed in 1977 for milkfish and prawn culture experiments. In 1981, an aquaculture feasibility study was done on Yap by a group of experts from the Philippines, with some potential sites identified (Uwate *et al.* 1984).

Giant clams

Over the last decade Yap has received over 80,000 giant clams (*Tridacna derasa* and *Hippopus hippopus*) designed to restock its reefs. Both the main island and Yap's outer atolls have received clams from the Micronesian Mariculture Demonstration Centre (MMDC) but very few of these have survived because of storms and maintenance problems. There are several government-owned, ocean-nursery giant clam grow-out farms and several semiprivate, small-scale giant clam grow-out farms located both within the main island of Yap proper and the outer atolls. Private involvement to date has been limited to several small-scale, ocean-nursery giant clam grow-out farms that have not yet reached commercial fruition. Five small-scale, private clam farms have been jointly commissioned by the state government and National Aquaculture Centre (NAC) in Kosrae, to attempt to develop commercial clam farming in Yap (Lindsay 1993, 2003).

In the early 1990s, Yap had a Protection of Clams law, which set harvest seasons and size limits, and banned the sale of clam meat. The state is unable to declare sanctuary areas, due to the nature of the traditional reef-ownership system (Smith 1992).

Trochus

Trochus niloticus is a native marine species of Yap and is considered to be one of the most valuable marine species present in the state. It is harvested annually when a suitable stock size allows for marketing and consumption of the meat. However, trochus was introduced to Ulithi and Ngulu (outer islands of Yap) by the Japanese between 1930 and 1940 (McGowan 1958). Trochus stock assessment is usually conducted at least three months before the harvesting season opens (Fanafal 1997).

Sponges

An experiential sponge demonstration farm was developed on the outer island of Ulithi in 1995. The farm is still in existence and maintained by the island's community. Limited numbers of sponges have been sold to the domestic tourism market (Lindsay 2003).

Other species

During the 1980s and 1990s, several small-scale, government-sponsored demonstration projects were initiated in Yap to culture a variety of marine organisms (Nelson 1987, Lindsay 2003). These have included rabbit fish, giant freshwater prawns (*Macrobrachium* spp.) and seaweed. All projects have been very small-scale, and none have led to any further activities (Lindsay 2003).

Chuuk State aquaculture activities

Limited Japanese activity on aquaculture was recorded pre-World War II, then nothing is recorded until an assessment and recommendations were made regarding oyster culture in 1972 (Uwate *et al.* 1984).

Giant clams

Chuuk has also received thousands of clams (*Tridacna derasa* and *Hippopus hippopus*) for reseeding purposes from the NAC. Five small-scale private clam farms have been jointly commissioned by the state government and NAC to attempt to develop commercial clam farming in Chuuk. These farms have each been provided with 2000 one-year old *T. derasa* clams (Lindsay 2003).

Trochus

Trochus was introduced to Chuuk lagoon by Japanese workers before World War II. The Chuuk State Department of Marine Resources employs local conservation officers who are responsible for managing marine resources. The conservation officers survey trochus stocks annually and recommend the date of the harvest season (Gawel 1997). Chuuk had nine sanctuary areas during the 1980s, at least one of which was retained during the 1986 harvest (Smith 1992).

Sponges

A survey of sponge stocks was carried out in the late 1980s to assess the suitability of sites and the availability of the desired sponge varieties (Anon. 1990). An experiential sponge demonstration farm was developed in 1997 on the island of Tonoas in Chuuk lagoon. The farm is still in existence and maintained by the island's community. Small numbers of sponges have been sold on the domestic market (Lindsay 2003).

Other species

Over the past decade several small-scale government-sponsored demonstration projects have been initiated in Chuuk to culture a variety of marine organisms. According to Lindsay (2003), these have included rabbit fish and seaweed. There have been several fish cages deployed within the state for the purpose of holding marine fish destined for the live fish trade. These small-scale operations were short-lived and are no longer operating (Lindsay 2003).

Pohnpei State aquaculture activities

Pre-World War II, the Japanese attempted pearl, sponge and turtle culture projects in Pohnpei. However, it was not until the early 1970s that aquaculture-related activities picked up, with demonstration ponds constructed at Sokehs. These were plagued with problems and fell into disuse by 1975. In the early 1980s, experimental culture of the algae *Eucheuma* was undertaken, and in 1983 a private seaweed project was initiated (Uwate *et al.* 1984).

Giant clams

Like all four states, Pohnpei state participates in NAC's integrated aquaculture programme and has received both giant clams and technical training from this programme. Since 1989, the Lenger Island hatchery has been culturing clams and trochus sporadically. Clams have been produced for reef-restocking programmes and community-based commercial farming. The hatchery has produced over a quarter of a million six-month old clams since its inception and has reseeded 30% of these. Four species of giant clams can be produced at this facility: *Tridacna maxima*, *T. derasa*, *T. squamosa* and *Hippopus hippopus*. All species except *T. derasa* originate from native stocks; *T. derasa* have been imported from Palau and Kosrae (Lindsay 2003).

Trochus

Trochus (*Trochus niloticus*) were introduced to Pohnpei Island in 1939. Adult trochus were introduced into Pohnpei and several outer atolls in the 1950s. Original populations of this animal have survived and have contributed sporadically to the domestic incomes of Pohnpei through the sale of shell for the button industry. The Pohnpei state government has operated a trochus reseeding programme. These animals have been cultured at the Lenger Island hatchery and have reseeded the reefs of Pohnpei. Currently the state is not culturing trochus. Very high mortalities have been experienced from reseeded animals. Adult stocks from different sections of the reefs and several outer islands have been translocated in an effort to increase natural population stocks of trochus around the island of Pohnpei. Several trochus sanctuaries have been created, and related enforcement legislation enacted (David and Curren 1997, Lindsay 2003).

Pohnpei currently has trochus sanctuary areas within which harvesting is not permitted. Like the other states, Pohnpei has its own legislation concerning trochus harvesting that covers when harvesting can occur, duration of harvest period, size of trochus harvested, those permitted to harvest, and restrictions on harvest techniques. These guidelines are also covered by the FSM Code (Smith 1992, Lindsay 2003).

Pearl oysters

Pearl oysters (*Pinctada margaritifera*) have been cultured in Pohnpei since 1994 on the outer atoll of Nukuoro. The farm is community-based (owned and operated by the municipal council) and has received funding support since its inception. It relies on the collection of wild spat (through the deployment of spat collectors). The farm has received technical assistance since its inception, and has produced three small batches of black pearls (Lindsay 2003).

Sponges

Surveys were carried out in 1988 and 1989 of the Pohnpei reef system for commercial sponges. Only one species of commercial sponge, *Sponaia officinalis*, was observed during the survey period (Croft 1989). In 1995 an economic feasibility study of small-scale sponge farming in Pohnpei was carried out. The survey results showed that, although a sponge farm would be profitable, it would not support a family as a main source of income (Adams *et al.* 1995). Regardless of this finding, numerous small-scale demonstration and community-based farms have been developed within Pohnpei as well as the other three states (Stevely *et al.* 1994, Lindsay 2003).

The only legislation regarding sponges is in FSM Code (Title 23, section 106), which was taken from the Trust Territory Code and has yet to be updated. This law requires permission from the Commissioner for anyone wishing to harvest sponges that have been artificially planted or cultivated (Smith 1992, Lindsay 2003).

Other species

Over the past decade numerous small-scale demonstration projects have been initiated in Pohnpei on a wide range of marine and freshwater organisms. Funded by the government and educational institutions, these include programmes that focused on cultivation techniques for seaweed, hard and soft corals and rabbit fish. All were designed to provide income for local communities (and in some cases the private sector). Unfortunately, none of these programmes have resulted in a profitable economic business. Most programmes operated between one and two years and were small in scale (Smith 1992, Lindsay 2003).

Kosrae State aquaculture activities

It is believed that traditional fish culture was practised in Lelu, with a few natural ponds modified to retain fish. In 1976 an experimental pond was constructed; however, the fish used to stock the pond all died within a few days. Other attempts at stocking this pond were tried unsuccessfully and by 1981 the pond was no longer operational (Uwate *et al.* 1984).

FSM decided in the late 1980s to establish the National Aquaculture Centre (NAC) in Kosrae, and this centre was operational in 1991 (Anon. 1991, Peavey and Riley 1994).

Giant clams

Giant clams are the primary organisms cultured in Kosrae for aquaculture. NAC has produced giant clams since 1991 for the dual purpose of restocking depleted reefs and developing commercial clam farming within FSM (Peavey and Riley 1994). The NAC facility has produced well over one million yearling clams since its inception and has reseeded several hundred thousand juvenile clams to the reefs of Kosrae and the other states. Four species of giant clams can be produced at this facility: *Tridacna maxima*, *T. derasa*, *T. gigas* and *Hippopus hippopus*. The three latter species are all derived from imported stocks, although they are native to the region. The majority of clams currently cultivated at the NAC facility are *T. derasa*. Giant clam restocking programmes have been successful in Kosrae State (Lindsay 2003).

Under Kosrae State Code Section 13.523 a sanctuary area is declared adjacent to the NAC for the purpose of protecting giant clams and promoting the expansion of the giant clam population in the state (Smith 1992).

Trochus

In Kosrae, 500 trochus (*Trochus niloticus*) were introduced from Pohnpei in 1959, and the first harvest was in 1984 (DFMR 1996). Following five harvests in 1984, 1985, 1986, 1988 and 1990, declining stock populations led to a harvest moratorium (Molina *et al.* 1997). In 1993, a stock survey showed that the numbers were not sufficient for a harvest. These results led to an extension of the moratorium to 1995 (Tsutsui and Sigrah 1994, Ikeguchi and Sigrah 1996). During the 1990s, the Kosrae State Fisheries Division has operated a trochus reseeding programme. These animals are cultured at the NAC facility to reseed the reefs of Kosrae. The programme ceased culturing trochus in 1999 and has focused on recruitment and survival of the original released trochus (Lindsay 2003).

Kosrae has several trochus sanctuaries. The stocks from the sanctuary areas are transplanted and used to replenish other areas. Kosrae has its own legislation concerning trochus (Smith 1992).

Green snails

The green snail (*Turbo marmoratus*) was introduced to Kosrae in 1999 from cultured stocks from Tonga. The goal was to provide a source of protein and, more importantly, a source of income from the sale of the shell. In total, 300 individuals were introduced and held in quarantine at NAC before the majority of individuals were released onto the reefs of Kosrae. The Kosrae Fisheries Development Section is monitoring the growth and survival of remaining stocks and several attempts to culture hatchery-kept stocks have been undertaken (Lindsay 2003).

Other species

Over the past decade several small-scale, government-sponsored demonstration projects have been initiated in Kosrae to culture a variety of marine organisms. These include seaweed, hard and soft corals and rabbit fish. All projects have been on a very small scale, and none have led to any further activities in the public or private sectors (Lindsay 2003).

Reef and reef fisheries (finfish and invertebrates)

Coral reef biodiversity and complexity is high within FSM and this diversity diminishes notably from west to east within the region. Using stony corals as an example, approximately 350 species are recorded in Yap, 300 from Chuuk, 200 from Pohnpei and 150 from Kosrae. All major types of coral reefs are found within the FSM, including barrier reefs, fringing reefs, atolls and submerged reefs. Common reef habitats in the FSM include lagoon reefs (pinnacle, patch), passes, channels, shallow reef flats, terraces, submerged reefs, slopes, reef holes, embayments, quasi estuaries, seagrass beds, mangroves, mud flats and sand flats (Lindsay and Edward 2000).

FSM depends heavily on its coral reefs for food and revenue derived from fish sales to local markets, diving and other tourism activities in marine areas. The threats to coral reef ecosystems include the overharvest of fishery resources and impacts from land-based activities, global threats associated with climate change, warming temperatures and ocean acidification. In the past 10 years, FSM has made significant commitments at many levels to try and reverse this trend. Communities have sought assistance from local conservation NGOs and government agencies to blend traditional management practices, science, and new technologies to begin the process of building an ecologically connected, resilient system of protected areas (George *et al.* 2008).

Reef fisheries

Due to the various methods used to estimate inshore fish (especially reef fish) production figures, and the uncertainties associated with the data collection, an estimate of inshore fish production for the whole of FSM is not possible. No reports on stock assessments of individual species or families of inshore fish in FSM could be located in the 1980s and early 1990s (Smith 1992). Smith and Dalzell (1991) conducted four stock depletion experiments at Woleai Atoll (Yap State), using a traditional leaf-sweep method and group spearfishing, to estimate the 'fishable' biomass of the back-reef areas. The estimates ranged from 5.6 to 25.5 mt/km^2 or 46,300 to 177,500 fish/km^2. For the purposes of calculating an overall fishable biomass estimate for the back-reefs of Woleai the means of the four fishing experiments were used to estimate average densities of 12.6 mt/km^2 or 94,000 fish/km^2. The back-reefs of Woleai lagoon cover an area of about 5 km^2, which gives an estimate of a total fishable biomass of 60 mt or 470,000 fish. Woleai Atoll is subject to subsistence fishing only.

The control of inshore fish resources lies with the individual states. Smith (1992) notes that all states have legislation prohibiting the use of explosives, poisons, chemicals or other substances that kill fish or marine life. Kosrae prohibits procuring fish or other marine life from midnight Saturday to midnight Sunday. Pohnpei State has specific legislation concerning bumphead parrotfish (*Bolbometopon muricatum*) and groupers (Serranidae).

Gillett (2002) cites that a 1995 report on subsistence fishing in Pohnpei alone estimated a total catch of around 1710 to 1850 mt/year by subsistence fishers, and the total fish consumption in Pohnpei was estimated at around 3000 mt/year. Gillett (2002) also reports that fish consumption rates in FSM across the whole country in the 1990s have ranged from 72 to 114 kg/person/year. Estimates by the Asian Development Bank in the late 1990s put the value of the subsistence catch in FSM at around USD 10 million and that of the coastal commercial fishery at around USD 14.5 million (Gillett 2002).

Trochus

Trochus is the greatest cash-value inshore resource in FSM. It was introduced to various locations within FSM by the Japanese before 1940 (Gillett 2002, Smith 1992). Catch statistics are available from 1915 for Yap. Sporadic commercial harvests occurred in the 1980s from Yap, Ulithi, Chuuk lagoon, Pohnpei and Kosrae (Smith 1992), with average annual exports of shell being around 18 mt from Yap, 11.5 mt from Chuuk, and 90 mt from Pohnpei (Anon. 1983). During the 1980s and 1990s, there were three attempts to establish button factories, all on Pohnpei; however, these all failed due to inconsistent supply of the shell and relatively high labour costs (Gillett 2002). Management of the trochus resource is under the jurisdiction of each state.

Bêche-de-mer

Surveys conducted in Yap's outer islands (Moore 1986a, 1986b, Moore *et al.* 1986) indicated that *Thelenota ananas* followed by *Holothuria nobilis* were the most abundant of the commercially valuable sea cucumber species. A brief survey of Mwoakilloa and Pingelap atolls in Pohnpei State reported that *H. atra* was the most abundant species at both atolls, followed by *Actinopyga mauritiana* at Pingelap (David 1991). No stock estimates were provided. No detailed stock assessments could be located for Chuuk or Pohnpei. A survey was conducted in Chuuk lagoon by the University of Guam Marine Laboratory and the Chuuk Department of Marine Resources (CDMR), but no report could be located. There are no legislation or policies at either the national or state level concerning sea cucumber exploitation in the 1980s and early 1990s (Smith 1992).

In 2000, following concerns regarding the sustainability of commercial sea cucumber harvesting expressed by the Kosrae State Government, municipalities and individuals, a moratorium was decreed on harvesting. The Government of Kosrae accepted and cancelled all permits, which effectively stopped legal commercial harvesting. Visual resource survey methods were used to evaluate current standing stock populations of two commercially harvested sea cucumbers, the surf redfish *Actinopyga mauritiana* and greenfish *Stichopus chloronotus* in Kosrae. Sixteen species of sea cucumbers were located and recorded during the evaluation. Stock populations of all potential commercial sea cucumber species inhabiting the reef flats of Kosrae were low to very low, including the two harvested species. The density per square metre of these individuals varied among site locations; however, all sites recorded very low stock densities when compared to the previous study undertaken in the 1990s (Edward 1997). A total ban on the commercial exploitation of all species of marine sea cucumbers was recommended until management measures were in place to ensure sustainable harvesting of stock (Lindsay and Abraham 2004).

Sea turtles

The sea turtle species present in FSM are: *Chelonia mydas* (green turtle), *Eretmochelys imbricata* (hawksbill turtle), *Lepidochelys olivacea* (olive ridley turtle) and *Dermochelys coriacea* (leatherback turtle). Green and hawksbill turtles are distributed throughout FSM, with green turtles being the most abundant. Green turtles have been recorded nesting in all states. Hawksbill turtles nest on a number of islands in Chuuk lagoon. Leatherback turtles have been recorded from Yap and Chuuk States. They inhabit open waters and are very rare in FSM. Olive ridley turtles are rarely sighted in FSM waters, but there have been a number of confirmed reports from around Satawal Island in Yap State (Smith 1992).

Smith (1992) noted that Yap State's Outer Island Turtle Project was currently into its third year. Both Yap and Pohnpei States have turtle projects underway and/or proposed. In Pohnpei a survey was undertaken in 1999 to determine the status of sea turtles. The green turtle and the hawksbill are the two most common turtles in Pohnpei. The leatherback has been recorded from time to time outside the reef. Pohnpei law states that no hawksbill turtles or sea turtles shall be taken or intentionally killed while on shore, nor shall their eggs be taken. There are minimum size limits, closed seasons, and a ban on the sale of turtles. However, in a small, close-knit community it can be difficult to enforce fines, confiscate gear, or imprison violators. Public support for conservation measures is sought through education and awareness programmes (Buden and Edward 2001).

Lobsters

The two species of rock lobster with commercial value in FSM are *Panulirus penicillatus* and *P. versicolor.* A less abundant species of low commercial value, *P. longipes femoristriga,* is also present. The ornate lobster, *P. ornatus,* may also be present but in very low numbers. The slipper lobster, possibly *Scyllarides neocaledonicus,* occurs in low numbers. All species are distributed throughout FSM. In 1985, Micronesian Maritime Authority (MMA) authorised a survey of commercial lobster species on the submerged reefs between Chuuk and Yap. After a 20-day trip no lobsters were caught (MMA 1990). In 1992 there was no information available on the status of the spiny lobster stocks for any states in FSM. In addition, there was no evidence to suggest that they were being over-harvested (Smith 1992).

1.3.3 Fisheries research activities

Marine research has been undertaken with the assistance of external governments and institutions. The national Fisheries Section of the National Government Department of Economic Affairs (DEA) undertakes fisheries and aquaculture research. A summary of the research to date includes: monitoring, stock assessment of specific resources, and development-oriented research to identify new grounds or techniques with commercial fishing or aquaculture potential (clam farming or wool sponge aquaculture), bait fishing, depletion experiments, grouper spawning aggregations, turtle tagging and assessment, trochus reseeding, stock assessment of bêche-de-mer, pearl shells, spiny lobster, recording of traditional fishing knowledge, investigations of inshore plankton, fish poisoning studies, and tuna fishing (Gawel 1988, Adams *et al.* 1995, Dalzell and Smith 1995, Gillett 2002).

A number of household surveys have been conducted. In 1986, a household survey of agriculture and marine resources consumption was carried out in Yap proper by the Yap State Department of Resources and Development. It was initiated to obtain baseline information on livestock, key agricultural resources, boats, ponds and household consumption (YDRD 1986).

Coastal resource atlases have been prepared for FSM. In 1988, a Yap coastal resource atlas was prepared by the University of Hawaii Sea Grant extension services. The atlas provides maps of the Yap atolls and pinpoints the locations of pelagic fish, reef fish, and invertebrates (Manoa Map Works 1988). In the early 1990s, a coastal resources atlas and inventory of the entire Chuuk lagoon was done. This completed the last of the major island groups and the next phase will cover the outer islands of the entire FSM (Anon. 1994).

Detailed coral reef maps have been produced by the United States Coral Reef Task Force. Mapping determines the location and extent of benthic habitats, assesses the health of benthic communities (such as coral), and monitors the ability to detect and measure changes over time in benthic habitat communities. The maps have a number of components, including development of digital shorelines, high-resolution bathymetry, habitat classification systems, and digital habitat maps. Other information is incorporated into the maps including historic data. The maps will be developed and distributed in geographic information systems (GIS) creating a tool that can be used by researchers and managers to study and evaluate the condition of the ecosystem (U.S. Coral Reef Task Force 1999).

Gender and fisheries research is a potentially rich field because of its relative novelty and the great diversity of issues and situations. The sector has strong gender divisions of labour, with limited female access to the means of production in fisheries and aquaculture because of cultural taboos and practices (Choo *et al.* 2008). In 2000 and 2001, at the request of the FSM government, baseline surveys were conducted in Yap, Pohnpei, Chuuk, and Kosrae, assessing the role of females in the fisheries sector, opportunities and constraints to their development, and areas for assistance. (Lambeth 2000, Lambeth and Santiago 2001a, 2001b, Lambeth and Abraham 2001). As a follow up to the studies, SPC provided training to female representatives from the four states. In response to their requests, training was provided in seafood quality and handling, seafood processing methods, small-scale fish marketing, and the conservation of marine resources.

1.3.4 Fisheries management

The management of specific resources is dealt with under earlier headings. However, it may be worth summarising the institutional and legislative tools for management. The importance of using a management style that incorporates tradition and custom is important in FSM, as can be seen in the case studies provided of Yap and Pohnpei. Although individual states are able to operate fairly independently in marine resource matters, they also contribute to national management plans (NFS 1997). The FSM National Biodiversity Action Plan was achieved through the input of state representatives, who then created their own individual plans highlighting island-specific environmental, economic, and socio-cultural features.

There are several government and semi-government agencies involved with marine resources exploitation and management at the national as well as state levels. For tuna, the National Oceanic Resources Management Authority (NORMA) has jurisdiction from 12 to 200 nm offshore. The National Marine Resources Division (NMRD) of the Department of Resources and Development, is responsible for providing the national and state governments with technical information, coordinating training, advisory services and support for development and management activities in marine resources including fisheries, aquaculture and coastal resource management, from low-water mark to 12 nm offshore. NMRD administers the National Aquaculture Centre, based in Kosrae. Other agencies involved with marine resources exploitation and management include the Micronesian Maritime Authority, Division of Marine Surveillance, National Fisheries Corporation, Kosrae Marine Resources Division, Pohnpei Marine Resources Division, Economic Development Authority, Chuuk Department of Marine Resources, Yap Marine Resources Management Division and Yap Fishing Authority. The states, for all intents and purposes, operate independently in fisheries matters (Smith 1992, NFS 1997, Gillett 2002, Chapman 2004).

At the national level, marine resources are addressed in the Code of the Federated States of Micronesia. *Marine Species Preservation* (*Title 23*) restricts the use of certain collection methods (explosives, poisons, and chemicals) and provides guidelines on the harvest of key marine species (e.g. sponges, trochus and pearl oysters). The *Endangered Species Act* (*Title 23*) establishes policy relating to the preservation of endangered species. *Marine Resources* (*Title 24*) extends the fishery jurisdiction of Micronesia out two hundred miles from its shores. The purpose of the title is to '...promote economic development and to manage and conserve Micronesia's vital sea resources'. The Micronesian Maritime Authority (MMA) is established by Chapter 3 of this Title, to adopt regulations for the conservation, management, and exploitation of all living resources in the extended fishery zone of FSM. State Entities for Development of Marine Resources (Title 24) authorises each state government to '...establish by law an entity to promote, develop, and support commercial utilization of living marine resources within its jurisdiction...' (Uwate 1987).

Yap has a complex marine and fisheries management structure. The Government of Yap has the three branches of the executive, legislative and judicial but also has the customary branch. Any resource management involving the use of inshore marine resources must be accepted and approved by the Council of Chiefs. On Ulithi atoll ownership of the reef and lagoon areas belongs to the highest ranking clan. On Woleai atoll the reef and lagoon is divided up and controlled by the ranking clan in each island or village. On Satawal one chief is chief of the sea and has the right to control the use of marine resources and fishing methods. One advantage that the traditional system has over the legislative system is that the latter is usually too rigid and slow to respond to changing circumstances (Tafileichig and Inoue 2001).

In Pohnpei, the Conservation Society of Pohnpei (CSP) marine programme combines elements of traditional marine resource management with modern science to empower local communities to protect Pohnpei's marine biodiversity. Currently, the programme's main focuses are marine protected area (MPA) establishment and management; spawning and aggregation sites protection (SPAGS); fish, coral, and sediment monitoring; and income generating activities for MPA communities. CSP currently works in close collaboration with local communities and the municipal and state governments in five of the 11 MPAs. CSP has been studying grouper spawning and aggregation sites to determine when grouper populations require special protection. The programme has been monitoring the current state of Pohnpei's fish populations, coral reef, and sediment build-up in order to keep track of any positive or negative changes over time. The final focus area for the CSP is helping to establish and support the Lenger Island community in sponge farming (CSP n.d., Rhodes *et al.* 2005).

The Federated States of Micronesia developed their National Biodiversity Strategy and Action Plan (NBSAP) through a series of multi-sectoral meetings and discussions throughout the nation over a period of 14 months. In addition to introductory sections on biodiversity, threats and constraints, vision, principles and strategy, the NBSAP contains 11 themes, numerous objectives and a great many proposed actions. It was completed in 2002 and subsequently presented to the Conference of Parties of the Convention on Biological Diversity. The NBSAP is an umbrella document for biodiversity activities in the FSM. Individual Biological Strategy Action Plans for States were completed in 2004 (Gaan and Chieng 2004, Nakayama 2004).

1.4 Selection of sites in the Federated States of Micronesia

Four CoFish sites were selected in the Federated States of Micronesia, two at Chuuk (Piis-Panewu and Romanum) and two on Yap (Yyin and Riiken) (Figure 1.5). These sites were selected as they shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country (in this case two of the states), 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 (not in the case of Chuuk), and presented particular interest for the National Department of Resources and Development, the Chuuk Department of Marine Resources, and the Yap State Government's Department of Resources and Development.

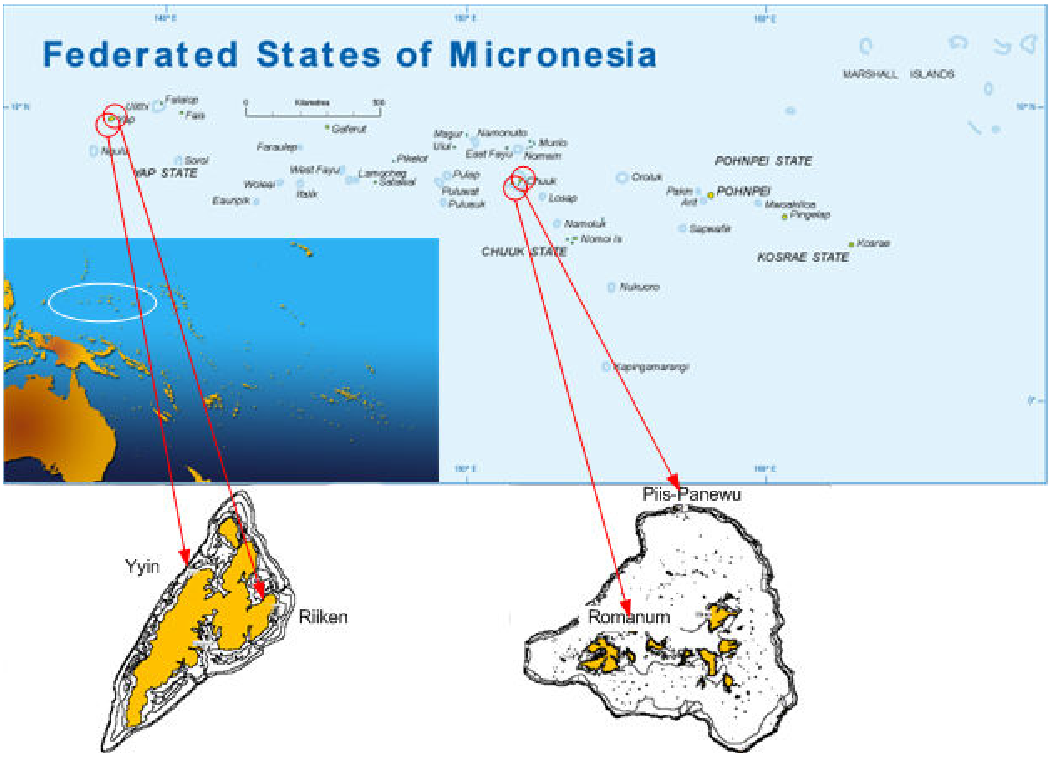

Figure 1.5: Map of the four CoFish sites selected in FSM.

[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 YYIN, YAP

2.1 Site characteristics

Yyin is located on the northwest side of Yap proper centred at 9°3'N latitude and 133°08'E longitude (Figure 2.1). Yyin is about 20 minutes' drive from Colonia, the capital and administrative centre of Yap State, or 40–50 minutes by outboard-powered skiff through a channel. Yyin was chosen as a survey site because the communities there are involved in coral dredging, and resources were expected to be in poor condition. Reefs in Yap are traditionally owned by families of high rank (cast system), which is the case for the selected communities. Families of lower rank live inland and must ask permission from reef owners before fishing on their reefs and in return give part of their catch to the owners. For the socioeconomic surveys, the neighbouring village of Gilfith to the southwest was included in the survey.

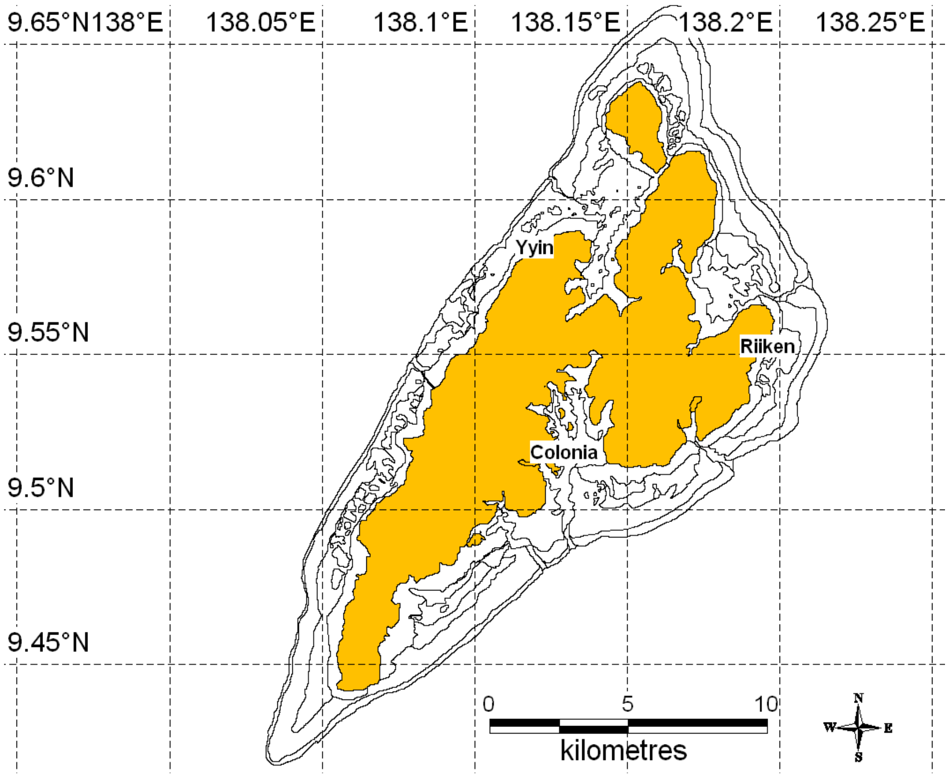

Figure 2.1: Map of Yyin, YAP.

2.2 Socioeconomic surveys: Yyin, YAP

Socioeconomic fieldwork was carried out in the Yyin and Gilfith communities (in the following referred to as 'Yyin') located on the west coast of Yap in April – May 2006. The survey covered a total of 13 households (7 in Gilfith; 6 in Yyin) including 99 people. Thus, the survey represents about 87% of the community's households (15) and 68% of the total population (146).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 12 individual interviews of finfish fishers (males only) and six invertebrate fishers (4 males, 2 females) were conducted. These fishers belonged to one of the 13 households surveyed. Sometimes, the same person was interviewed for both finfish and invertebrate fishing.

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

Our survey results (Table 2.1) suggest an average of two fishers per household. If we apply this average to the total number of households, we arrive at a total of 34 fishers in Yyin. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 14 finfish fishers (males only), a total of 8 invertebrate fishers (females only) and 12 fishers (males) who fish for both finfish and invertebrates.

About 77% of all households in Yyin own a boat; most (90%) are non-motorised and 10% are motorised.

Ranked income sources (Figure 2.2) suggest that fisheries are not as important as salaries for income generation. None of the households indicated that fisheries are their first source of income, and only 8% quoted fisheries as a secondary income source. Salaries provide 62% of all households with first income, and another 23% gain their cash income either from agricultural produce (betel nut, root crops) or from other sources, including business, and social fees. Agriculture also provides secondary income for 38% of all households interviewed, and salaries provide secondary income for 15% of households.

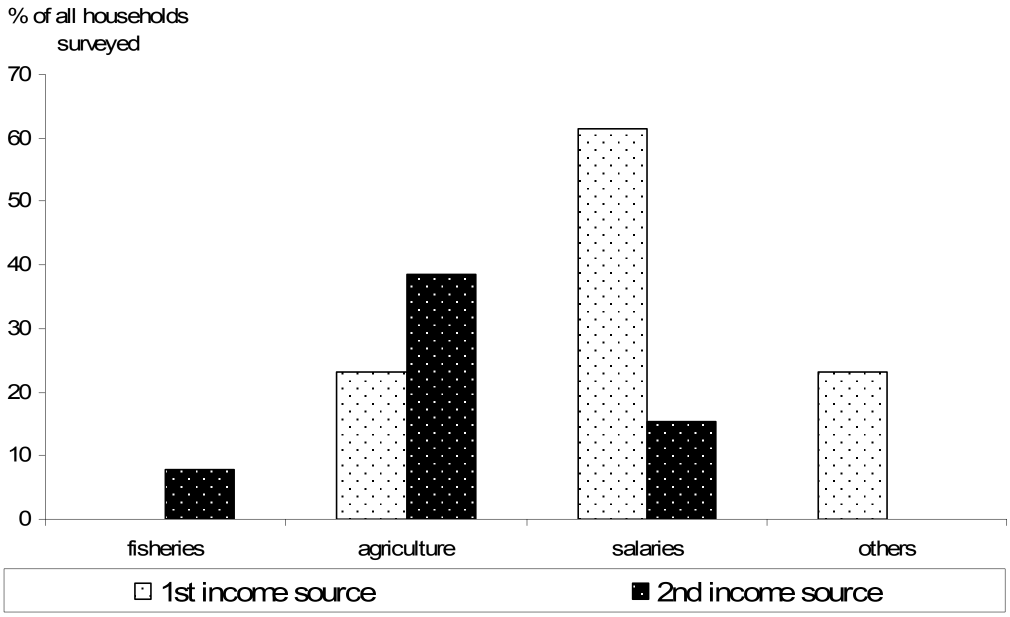

Figure 2.2: Ranked sources of income (%) in Yyin.
Total number of households = 13 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

The importance of fisheries, however, shows in the fact that all households eat fresh fish and about 70% also eat invertebrates. The fish that is eaten is caught by a member of the household (100%), sometimes bought (31%) and often received as a gift (54%). The proportion of invertebrates caught by a member of the household where consumed is lower

(69%). However, invertebrates are not bought or exchanged as gifts among Yyin community members. These results suggest that the finfish marketed may be sold, at least to some extent, within the Yyin community, but the sale of invertebrates always targets an outside market.

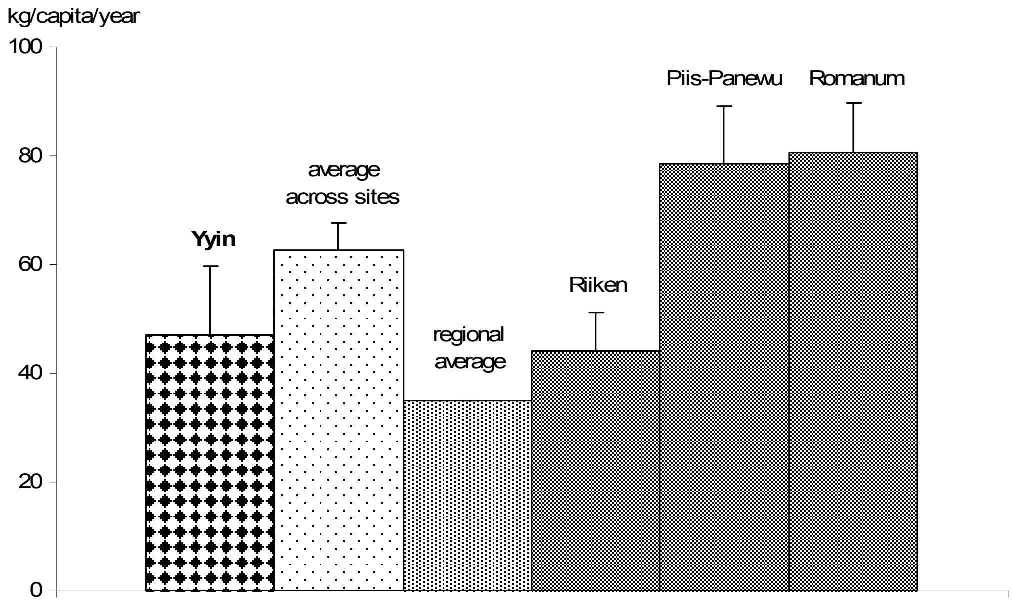

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Yyin (n = 13) compared to the average across sites and the regional average (FAO 2008) and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

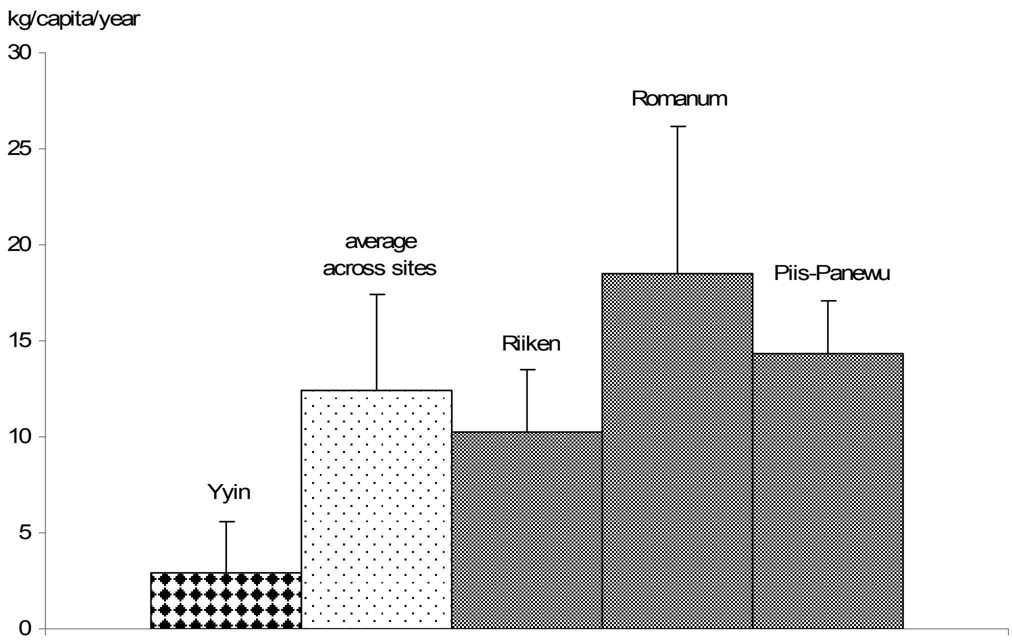

Figure 2.4: Per capita consumption (kg/year) of invertebrates (meat only) in Yyin (n = 13) compared to the average across sites and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Fresh-fish consumption in Yyin (~47 ±12.8 kg/person/year) is above the regional average (FAO 2008; Figure 2.3), but below the average across all sites studied in the FSM. The consumption of invertebrates (meat only) is 5 kg/person/year (Figure 2.4), which is significantly lower than finfish consumption and the lowest compared to the other study sites in FSM. Canned-fish consumption is surprisingly high (~26 ±5.68 kg/person/year) (Table 2.1).

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

Survey coverage	Site (n = 13 HH)	Average across sites (n = 83 HH)
Demography		
HH involved in reef fisheries (%)	100.0	96.4
Number of fishers per HH	2.00 (±0.36)	3.17 (±0.32)
Male finfish fishers per HH (%)	42.3	44.1
Female finfish fishers per HH (%)	0.0	1.1
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	23.1	27.0
Male finfish and invertebrate fishers per HH (%)	34.6	24.0
Female finfish and invertebrate fishers per HH (%)	0.0	3.4
Income		
HH with fisheries as 1st income (%)	0.0	48.2
HH with fisheries as 2nd income (%)	7.7	4.8
HH with agriculture as 1st income (%)	23.1	8.4
HH with agriculture as 2nd income (%)	38.5	20.5
HH with salary as 1st income (%)	61.5	34.9
HH with salary as 2nd income (%)	15.4	4.8
HH with other sources as 1st income (%)	23.1	9.6
HH with other sources as 2nd income (%)	0.0	10.8
Expenditure (USD/year/HH)	3969.23 (±755.10)	3751.42 (±249.95)
Remittance (USD/year/HH) [(1)]		1095.71 (±256.43)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	46.92 (±12.82)	62.54 (±5.01)
Frequency fresh fish consumed (times/week)	2.77 (±0.47)	3.67 (±0.21)
Quantity fresh invertebrate consumed (kg/capita/year)	2.94 (±2.65)	12.40 (±5.01)
Frequency fresh invertebrate consumed (times/week)	0.28 (±0.13)	1.08 (±0.13)
Quantity canned fish consumed (kg/capita/year)	25.48 (±5.68)	23.87 (±3.14)
Frequency canned fish consumed (times/week)	3.09 (±0.66)	2.68 (±0.23)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	69.2	74.7
HH eat canned fish (%)	92.3	91.6
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	30.8	0.0
HH eat fresh fish they are given (%)	53.8	38.9
HH eat fresh invertebrates they catch (%)	69.2	100.0
HH eat fresh invertebrates they buy (%)	0.0	0.0
HH eat fresh invertebrates they are given (%)	0.0	33.3

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

Comparison of results from all FSM sites studied (Table 2.1) shows that the people of Yyin are less dependent on fisheries for income generation, and people also eat less fresh fish and invertebrates and do so less frequently. However, people in Yyin eat canned fish in greater amounts and more frequently than the average in FSM. There is no major difference between Yyin and the study site average in the average household expenditure level. No households in Yyin receive remittances.

2.2.2 Fishing strategies and gear: Yyin

Degree of specialisation in fishing

Fishing in Yyin is performed by both gender groups (Figure 2.5). However, 42% of all fishers target exclusively finfish and these fishers are males only. Female fishers only target invertebrates (23%) and no males exclusively harvest invertebrates. However, 35% of all male fishers target invertebrates in combination with finfish.

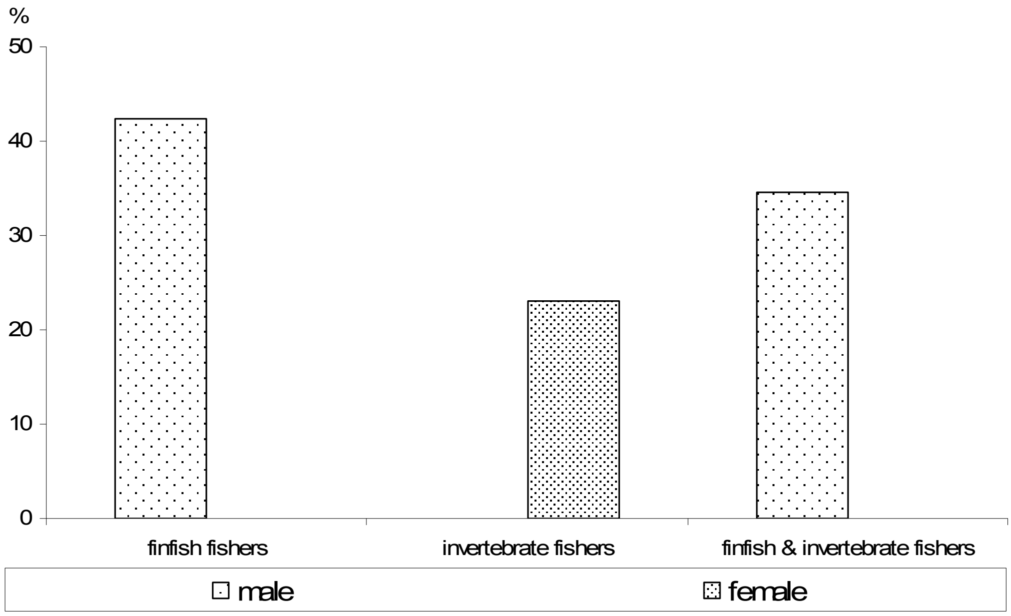

Figure 2.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Yyin.
All fishers = 100%.

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 Yyin

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	25.0	0.0
	Sheltered coastal reef & lagoon	66.7	0.0
	Sheltered coastal reef & outer reef	8.3	0.0
Invertebrates	Other	50.0	0.0
	Reeftop	50.0	0.0
	Soft benthos (seagrass)	0.0	50.0
	Soft benthos (seagrass & sandy intertidal areas)	25.0	50.0

'Other' refers to the giant clam fishery.
Finfish fisher interviews, males: n = 12; females: n = 0. Invertebrate fisher interviews, males: n = 4; females, n = 2.

Fishing patterns and strategies

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

Our survey sample suggests that fishers in Yyin can choose among the sheltered coastal reef, lagoon and outer reef for their fishing activities. Most (67%) male fishers combine sheltered coastal reef and lagoon in one fishing trip. A quarter of all male fishers exclusively target the sheltered coastal reef and the smallest number (8%) combine the sheltered coastal and outer reef in one fishing trip.

By comparison, invertebrate fisheries are less diverse and, data suggest, less important than finfish fisheries. Half the male invertebrate fishers either target the reeftop or dive for giant clams and/or lobsters. All the female invertebrate fishers mainly target the soft benthos. Half of the female fishers collect in seagrass habitats and the other half also target the intertidal, sandy areas. Only 25% of the male invertebrate fishers collect shells in the combined intertidal and seagrass areas (Figure 2.6). The fact that only male fishers dive for lobsters and giant clams confirms the generally observed gender separation, i.e. females in the Pacific Islands hardly ever dive for invertebrates or other seafood but rather engage in gleaning fisheries (Figure 2.7).

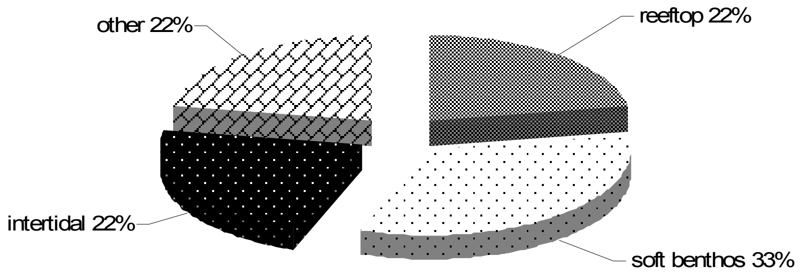

Figure 2.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Yyin.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the giant clam fishery.

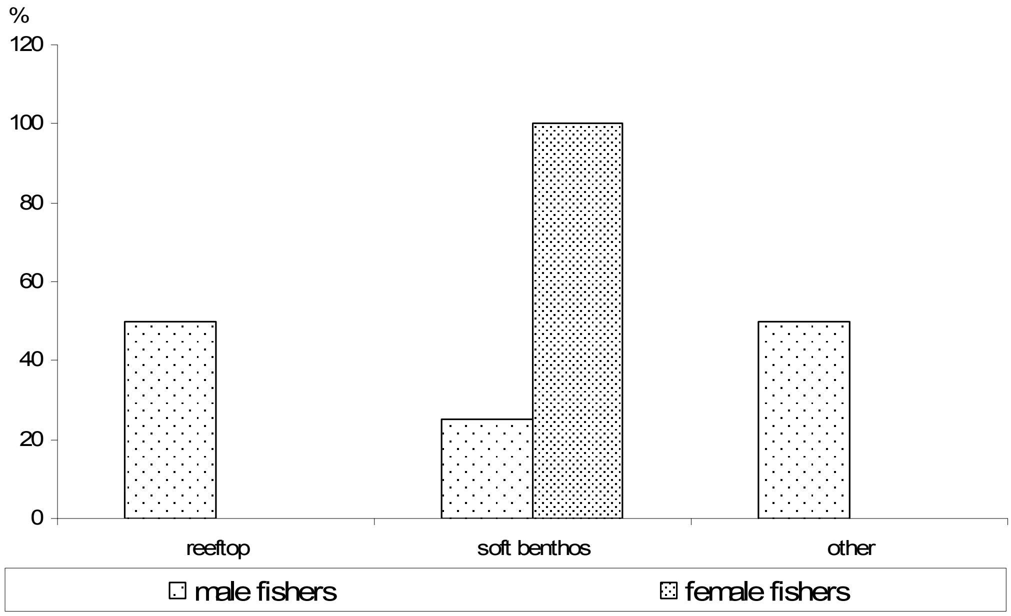

Figure 2.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Yyin.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 4 for males, n = 2 for females; 'other' refers to the giant clam fishery.

Gear

Figure 2.8 shows that fishing strategies vary considerably among habitats targeted. Fishers targeting the sheltered coastal reef mainly use gillnets and/or spear dive in the same trip, while fishers who combine the sheltered coastal and outer reef during one fishing trip use only casting rods. The most diverse and unspecified fishing is performed by fishers who visit both the sheltered coastal reef and the lagoon in one trip. While most use either gillnets or spear diving, others also use castnets and handlines, or only go spear diving. While trips to the outer reef require boat transport, 75% of fishing trips to the sheltered coastal reef and lagoon combined use boat transport and 67% of trips to the sheltered coastal reef alone use a canoe.

Gleaning and free-diving for invertebrates is done using very simple tools only. Lobsters and giant clams are picked up by hand, perhaps using a screwdriver or rod to prise loose giant clams. Diving does not involve any gear other than mask, snorkel and, possibly, fins. Diving for lobster and giant clams is the only invertebrate fishery that always requires paddle canoes (non-motorised). All other invertebrates are collected while walking.

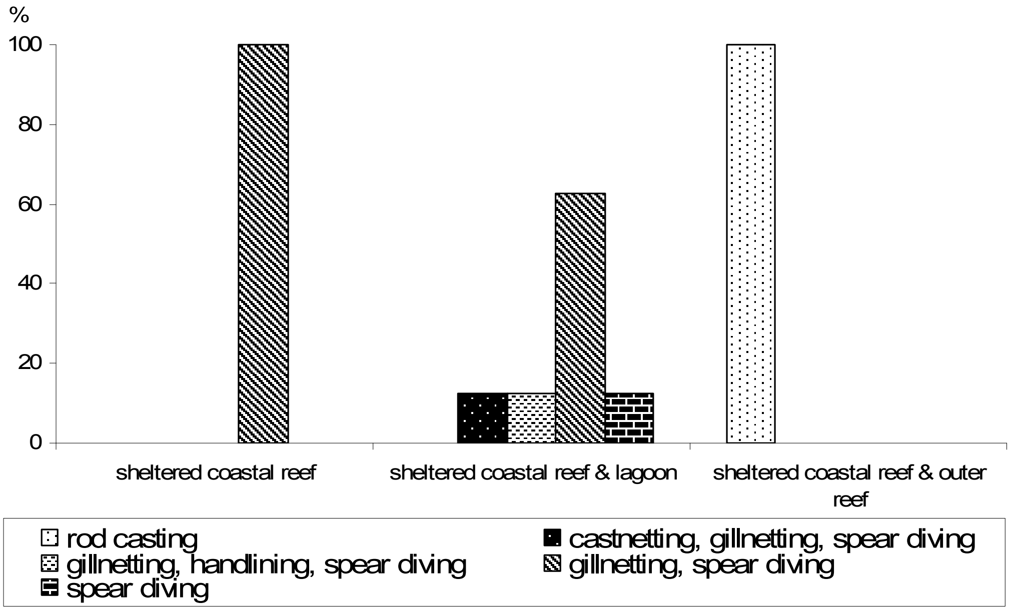

Figure 2.8: Fishing methods commonly used in different habitat types in Yyin.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 2.3 the most frequent fishing trips are those to the fishing grounds closest to shore. Accordingly, fishers targeting the sheltered coastal reef or the combined sheltered coastal reef and lagoon go usually 1.5 times/week; fishing the combined sheltered coastal and outer reef is done very rarely. Trip duration does not vary much; on average, a fishing trip takes three hours regardless of which habitat is targeted. Invertebrates are fished much less often than finfish, i.e., about once a month or even less often. Collection or dive trips take 2–4.5 hours. Female fishers tend to spend less time on invertebrate collection trips than do males.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.50 (±0.50)		3.33 (±0.44)	
	Sheltered coastal reef & lagoon	1.76 (±0.42)	0	3.31 (±0.39)	0
	Sheltered coastal reef & outer reef	0.04 (n/a)	0	3.00 (n/a)	0
Invertebrates	Other	0.06 (±0.02)	0	3.50 (±0.00)	0
	Reeftop	0.23 (±0.00)	0	2.75 (±1.75)	0
	Soft benthos	0	0.04 (n/a)	0	2.00 (n/a)
	Soft benthos & intertidal	0.23 (n/a)	0.08 (n/a)	4.50 (n/a)	2.00 (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 = 12; females: n = 0. Invertebrate fisher interviews, males: n = 4; females: n = 2.

Finfish is usually caught according to the tide; hence, fishers go out either at day or night, with a slight preference for night fishing if spear diving is involved. Invertebrates are mostly collected during the day. However, collection from seagrass areas is done at night.

Most finfish and invertebrate fishers reported fishing year-round; however, 25% of the fishers who target sheltered coastal reef and lagoon areas in one fishing trip stop fishing during one-quarter of the year.

2.2.3 Catch composition and volume – finfish: Yyin

Catches from the sheltered coastal reef include a variety of different fish species and species groups, the main ones being: *Scarus* spp., *Ctenochaetus striatus*, *Chlorurus* spp. and *Gerres erythrurum*, each representing 11–12% of the total annual reported catch. Catches from the combined fishing of the sheltered coastal reef and lagoon areas are dominated by *Caranx melampygus*, *Naso unicornis*, *Chlorurus* spp. and *Siganus lineatus* each contributing 10–13% of the total reported catch. Catches from the combined fishing of the sheltered coastal and outer reef areas did not reveal high species diversity, only comprising *Caranx melampygus*, *Caranx* spp. and *Sphyraena* spp. (Detailed data are provided in Appendix 2.1.1.).

Our survey sample of finfish fishers interviewed represents about 38% of the projected total number of finfish fishers in Yyin. However, the survey included both commercial and subsistence fishers. Hence, we have extrapolated our results to estimate the total annual fishing pressure imposed by the people of Yyin on their fishing ground. This estimate does not include any possible impact illegally imposed by external fishers.

As shown in Figure 2.9, over half of the impact is due to commercial reef fishing; catches that are sold outside the Yyin community account for 55–56% of the total annual estimated catch, or ~9.6 t/year. Subsistence need determines about 44–45% of the total catch, corresponding to a total consumption of ~7.6 t/year. Finfish is caught only by males; female fishers only collect invertebrates. Highest pressure is imposed on the sheltered coastal reef and the combined sheltered reef and lagoon. Fishing impact on the outer-reef resources is minor (0.1 % of the total annual catch).

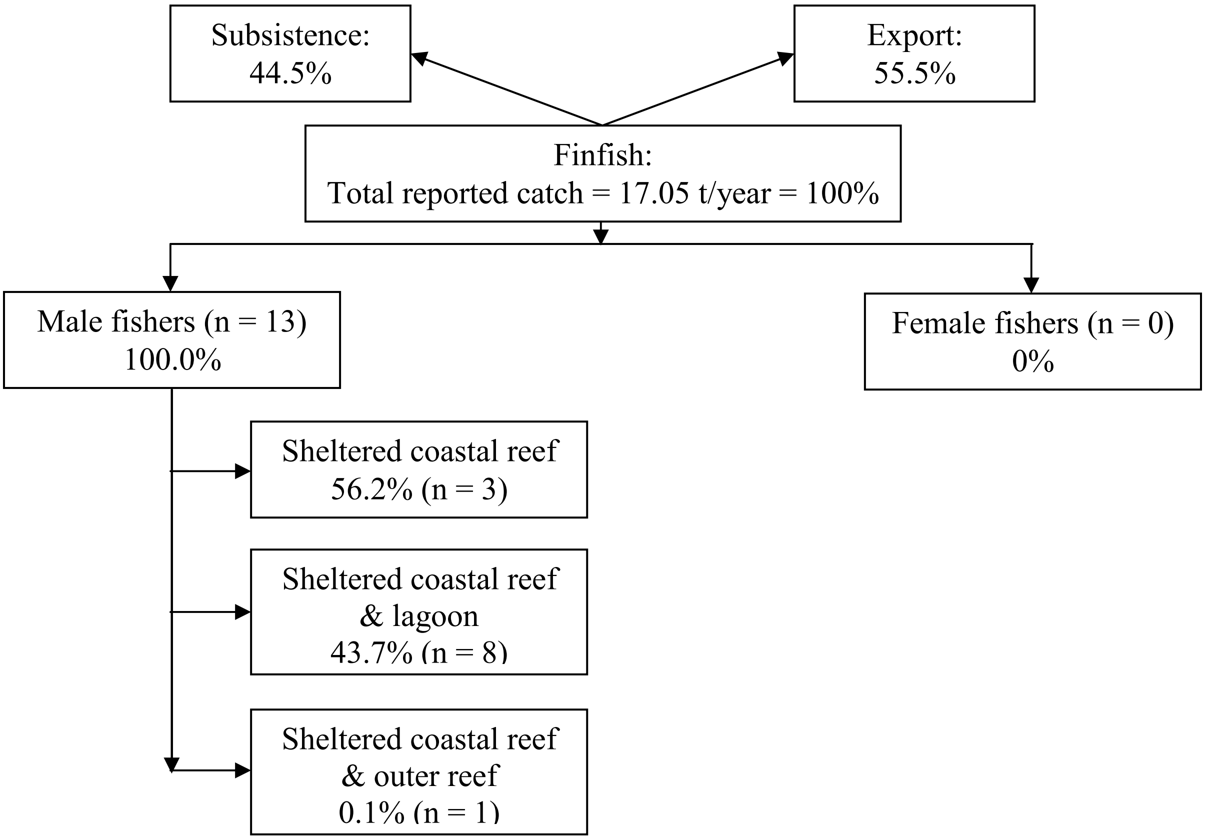

Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Yyin.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The high impact on the combined sheltered coastal reef and lagoon is a function of the number of fishers targeting these areas as well as the average annual catch rate. As shown in Figure 2.10, annual catches can reach up to almost 1500 kg/fisher/year in the sheltered coastal reef. Annual catches drop considerably if sheltered coastal reef and lagoon are jointly fished, and the annual catch reported for the combined fishing of sheltered coastal and outer reef is negligible. However, these results, together with the comparison with the other two habitats fished suffer from the small number of outer-reef fishers sampled.

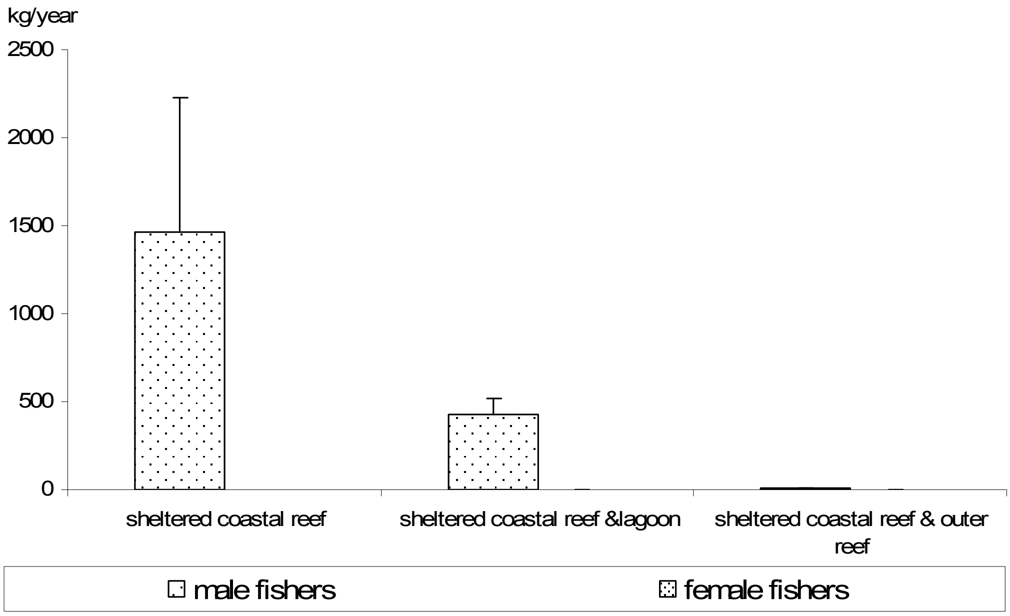

Figure 2.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Yyin.
Bars represent standard error (+SE).

This trend also shows when comparing the CPUEs calculated for the different habitats fished. Highest CPUEs are achieved by sheltered coastal reef fishing; CPUEs for the combined fishing of either sheltered coastal reef and lagoon or sheltered coastal and outer reef are considerably lower.

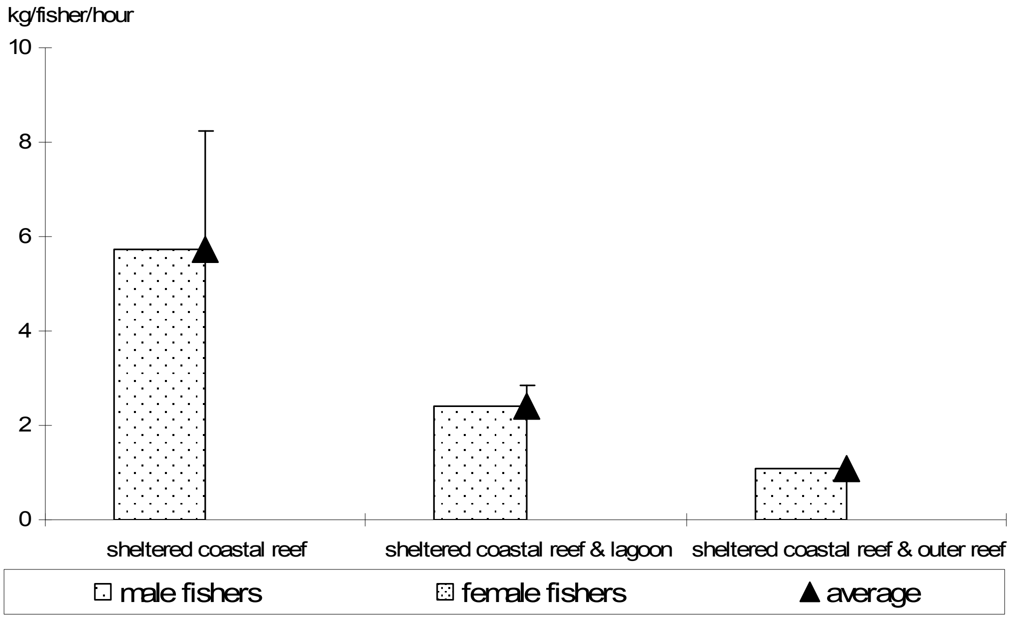

Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Yyin.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data show that most catch from the sheltered coastal reef is intended for sale outside the Yyin community, while catches from the sheltered coastal reef and lagoon combined and sheltered coastal and outer reef combined mainly serve subsistence purposes and social obligations (Figure 3.12).

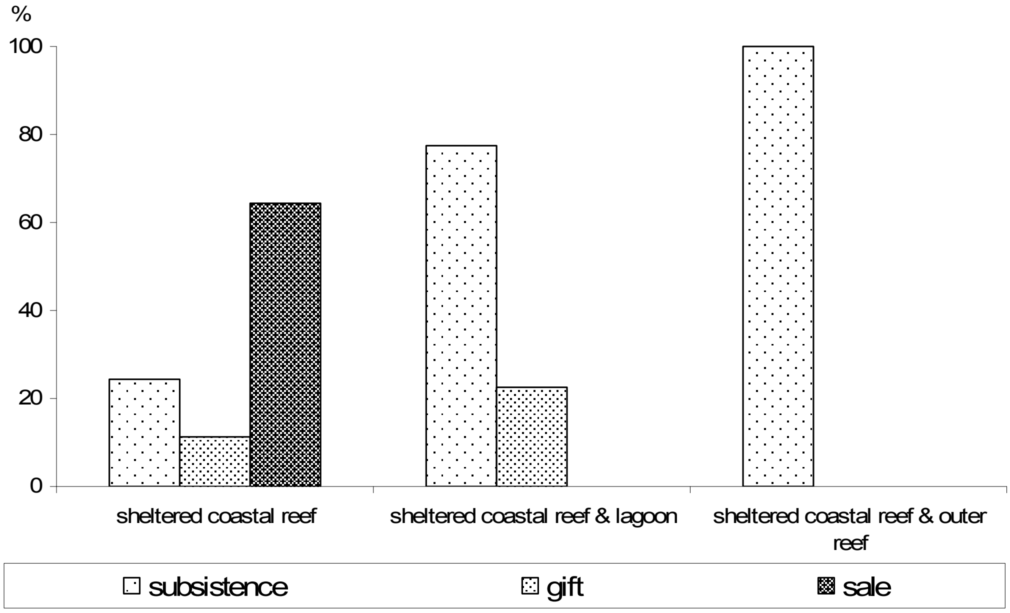

Figure 2.12: The use of finish catches for subsistence, gift and sale, by habitat in Yyin.
Proportions are expressed in % of the total number of trips per habitat.

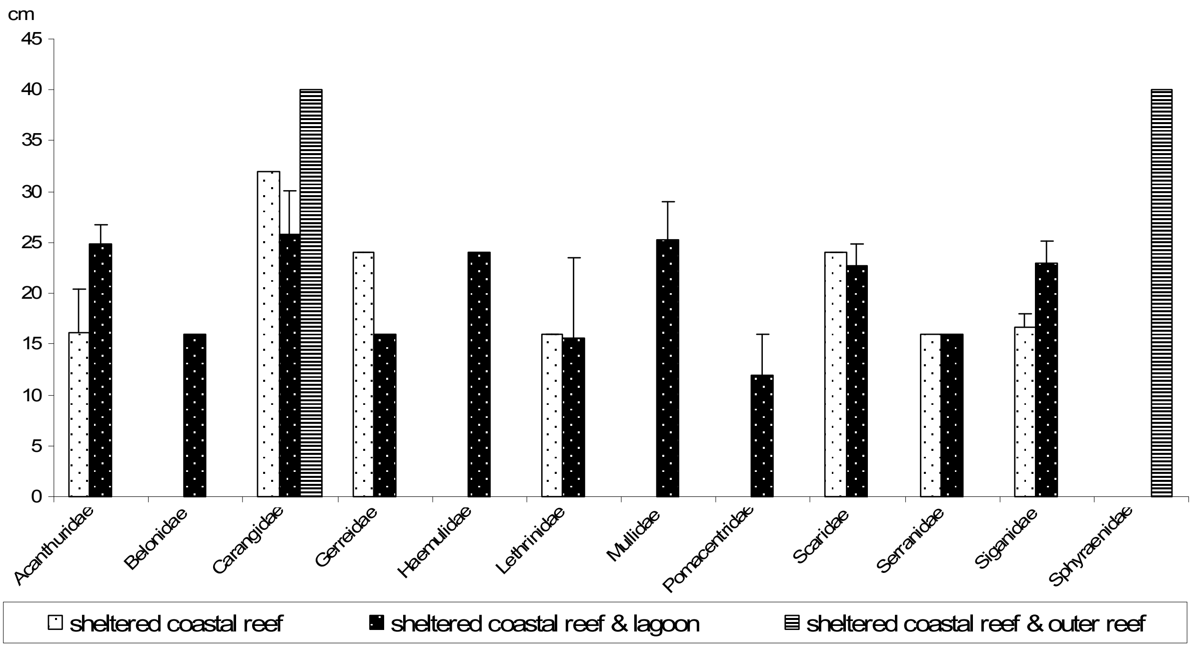

Figure 2.13: Average sizes (cm fork length) of fish caught by family and habitat in Yyin.
Bars represent standard error (+SE).

The average sizes of Acanthuridae and Siganidae reported in catches from the combined fishing of sheltered coastal reef and lagoon are larger than those in the sheltered coastal reef, but the reverse is true for Carangidae and Gerreidae. Average fish sizes reported for the two major species groups: Carangidae and Sphyraenidae are large in catches from the outer reef. In general, average fish sizes are relatively small (15–25 cm).

Some parameters selected to assess the current fishing pressure on Yyin's living reef resources are shown in Table 2.4. The comparison of habitat surfaces that are included in the Yyin fishing ground shows that the combined sheltered coastal reef (or reef flat) and lagoon is the largest area. The difference between the total available reef area and the total fishing ground area is not substantial. Overall fisher density is low, 5–6 fishers/km^2. Highest reported annual catches in sheltered coastal reef or on the reef flats correspond to a fisher density of 6 /km^2. Overall, population density is moderate 24–25 people/km² of supporting reef or total fishing ground area. Considering that about half of all fishing pressure is imposed by subsistence needs, the current annual fishing pressure of 1 t/km² is important. In summary, while overall fisher density is low, fishing pressure imposed due to the current subsistence needs alone is moderate taking into account the limited reef and total fishing ground area.

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

Parameters	Habitat				
	Sheltered coastal reef	**Sheltered coastal reef & lagoon (4)**	**Sheltered coastal reef & outer reef**	**Total reef**	**Total fishing ground (4)**
Fishing ground area (km^2)	1.08	4.66	0.78	5.12	5.44
Density of fishers (number of fishers/km^2 fishing ground) (1)	6	5	n/a	5	5
Population density (people/km^2) (2)				25	24
Average annual finfish catch (kg/fisher/year) (3)	1466.58 (±759.05)	427.28 (±88.93)	5.44 (n/a)		
Total fishing pressure of subsistence catches (t/km^2)				1	1

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers (= 26) is extrapolated from household surveys; (2) total population = 130; total subsistence demand = 5.92 t/year; (3) catch figures are based on recorded data from survey respondents only; (4) total lagoon area = 3.58 km^2.

2.2.4 Catch composition and volume – invertebrates: Yyin

Calculations of the recorded annual catch rates per species groups are shown in Figure 2.14. The major impact by wet weight is mainly due to giant clams, *Hippopus hippopus* (*fasu*) and *Tridacna maxima* (*tow*). By comparison, catches reported for *Nerita albica* (*mire*) and *Anadara* spp. (*goy*) are of minor, if not insignificant importance. Figure 2.14 also shows that the range of exploited species that were recorded is low (Detailed data are provided in Appendices 2.1.2 and 2.1.3.).

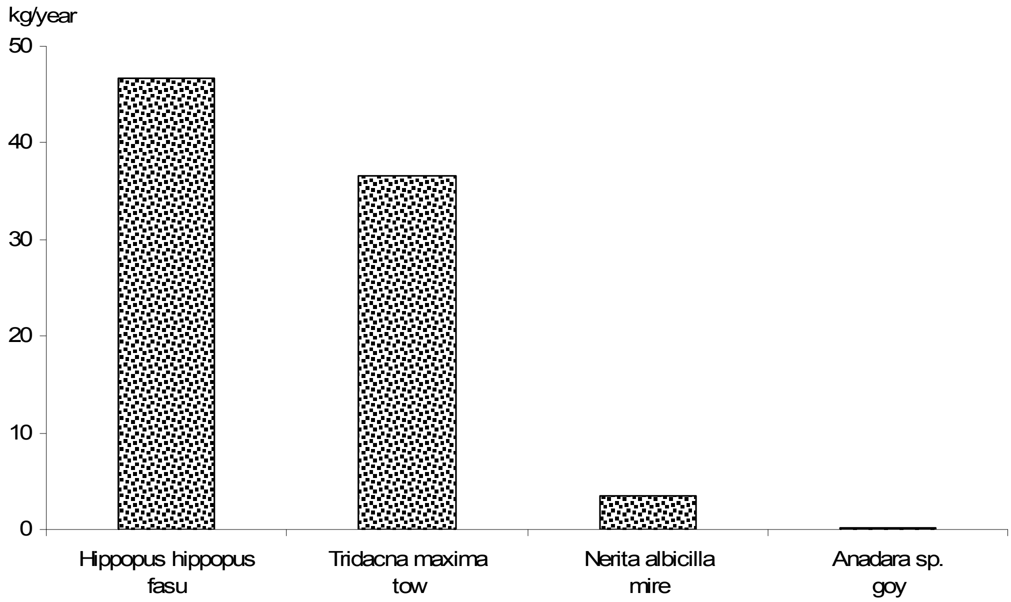

Figure 2.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Yyin.

As stated above, invertebrate fisheries are limited and are not of great importance in Yyin. Accordingly, the limited biodiversity reported for catches is not surprising. Species captured in soft-benthos catches were mainly characterised by 1–2 vernacular names (*mire* and *goy*) and the giant clams targeted in reeftop and other dive fisheries by two vernacular names (*fasu* and *tow*) (Figure 2.15).

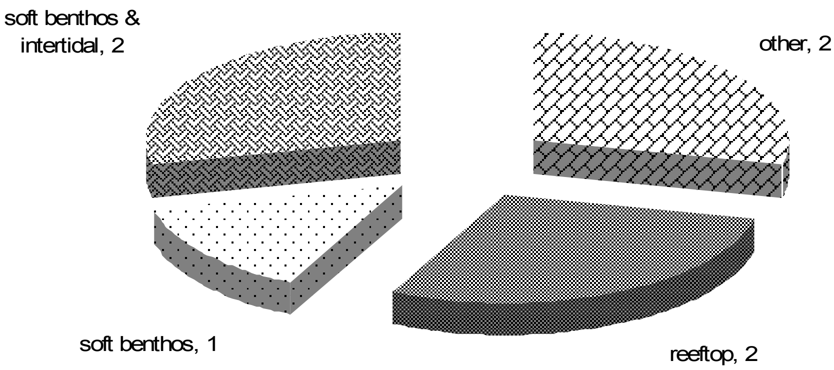

Figure 2.15: Number of vernacular names recorded for each invertebrate fishery in Yyin.
'Other' refers to the giant clam fishery.

Figure 2.16 shows that average annual catches by wet weight are low. Highest catch rates, however, were reported for reeftop gleaning, with ~38 kg/fisher/year, while catch rates from soft-benthos (*Nerita polita* and *Anadara* spp.) and reeftop or 'other' dive fisheries (giant clams) were extremely low (≥5 kg/fisher/year) and similarly low for female invertebrate fishers who mainly target the soft benthos (>5 kg/fisher/year).

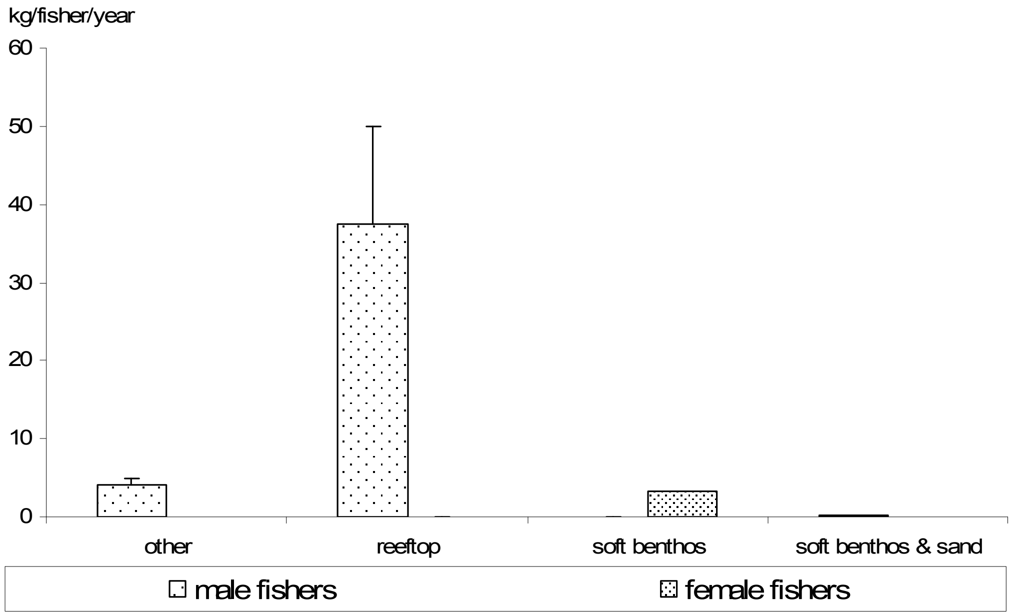

Figure 2.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Yyin.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers that target each habitat (n = 4 for males, n = 2 for females). Bars represent standard error (+SE).

In contrast to finfish fisheries, invertebrate fisheries are pursued only for subsistence purposes (Figure 2.17). Therefore, all current fishing impact on invertebrate resources is determined only by the subsistence needs of the Yyin community.

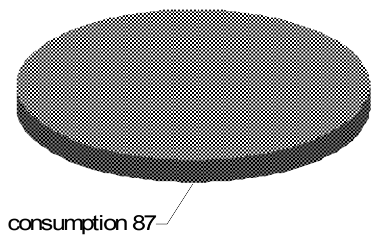

Figure 2.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Yyin.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) amounts to 0.09 t/year (Figure 2.18). Catches from the reeftop (giant clams) are prominent, representing ~86% of the total reported annual catch. Giant clams collected by divers and shells harvested by female fishers from soft benthos determine the remaining catch.

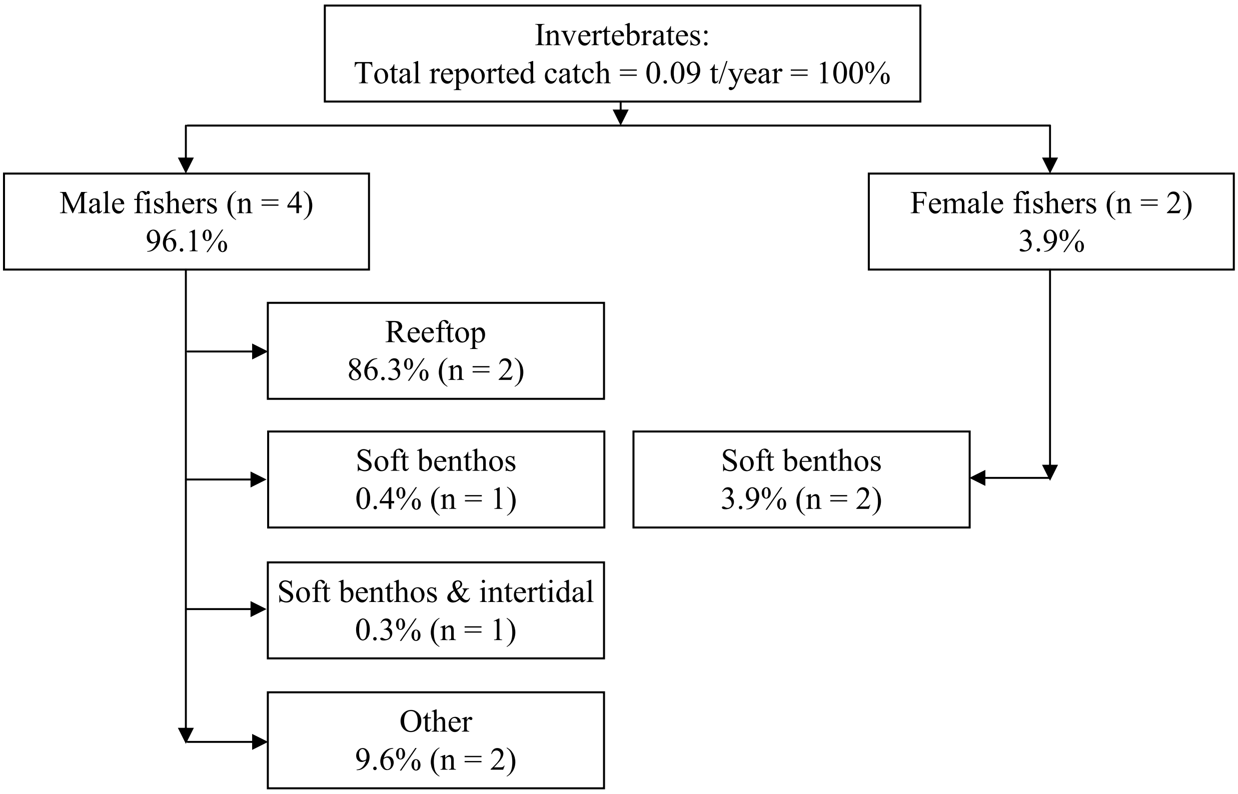

Figure 2.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Yyin.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

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

Parameters	Fishery / Habitat			
	Reeftop	Soft benthos	Soft benthos & intertidal	Other
Fishing ground area (km^2)	0.47	0.95	0.95	2 [(3)]
Number of fishers (per fishery) [(1)]	6	4	7	6
Density of fishers (number of fishers/km^2 fishing ground)	13	4	7	3
Average annual invertebrate catch (kg/fisher/year) [(2)]	37.48 (±12.49)	3.33 (n/a)	0.14 (±0.12)	4.16 (±0.83)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam fishery; [(1)] number of fishers extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only; [(3)] linear measure km reef length.

The parameters presented in Table 2.5 show that, generally speaking, the habitats supporting the various fisheries are small. Taking into consideration the average annual catch recorded per fisher (wet weight) and the density of fishers, fishing pressure on reeftop resources is highest, while fishing pressure on soft-benthos and giant clam resources appears rather low. Without knowledge of the results from the resource surveys, we can only speculate that the low interest of the local community in fishing, a low natural endowment of invertebrate resources, or a previous decline in the status of the community's invertebrate resources explain the low engagement of fishers in invertebrate fishing and the low exploitation levels.

2.2.5 Discussion and conclusions: socioeconomics in Yyin

- Fisheries are not an important sector for income generation in Yyin. Income is mainly derived from salaries and agriculture or other sources, such as small business, and retirement and other social fees.

- All households regularly eat fresh fish and most also eat invertebrates. Fresh-fish and invertebrate consumption is above the regional average but lower than the average across all four study sites in FSM.

- The average household expenditure level represents a moderate lifestyle that combines both traditional and cash-economy based values.

- Finfish fishing is done only by males; females only fish for invertebrates. Some males fish for both finfish and invertebrates. Finfish fishers mainly target the sheltered coastal reefs and lagoon, seldom the outer reef. Invertebrate collection focuses on reef and soft-benthos habitats.

- Finfish fishing is characterised by the combined use of castnets, gillnets, handline and spears. Invertebrate fisheries mainly involve the use of simple tools. Some fishing is done using paddle canoes.

- Highest fishing pressure is on the sheltered coastal reef and lagoon, due not to fisher density, which is relatively low, but to the comparatively high annual catch rates. CPUE for sheltered coastal reef fishing is also substantially higher than that for fishing any other habitat or habitat combination. However, average fish sizes reported are generally small (15–25 cm); only Carangidae and Sphyraenidae are larger in size in the outer reef compared to the coastal reef.

- Invertebrate fisheries only serve the subsistence needs of the Yyin community. Invertebrate fisheries are very limited; only four species were reported, including two giant clam species: *Nerita albica* and *Anadara* spp. The total annual catch reported in wet weight is insignificant. However, the supporting habitats are very small in size.

The above observations result in two major conclusions. Firstly, there is a considerable difference between fishing pressure on finfish and pressure on invertebrate resources in Yyin. Considering the average fish consumption of the community and the limited size of available fishing grounds, finfish fishing may impose a moderate-to-high-impact on the local inshore resources. This conclusion is also based on the fact that most fishers target the sheltered coastal reef and lagoon habitats rather than the outer reef. The outer reef is not only much larger but also presumably offers a higher fishing potential because it is directly connected with the open ocean and possibly other lagoon and reef systems. In contrast, invertebrate consumption is low, supporting habitats small in size and annual exploitation levels marginal. This situation may be either explained by the fact that local people have never been very interested in invertebrates, or that previous exploitation has caused a decline of the resources to the extent that exploitation is no longer viable, or that the natural environmental conditions do not support a diverse and highly exploitable resource. The level of invertebrate fishing currently reported does not give any cause for alarm. The fact that the Yyin community seldom exploits finfish or any other marine resource for the major Yap market, and that fisheries do not play an important role for income generation, leads us to conclude that fisheries management should focus on the community's needs and capacities to maintain or restore their reef resources to full potential. Because fisheries in Yyin are not market- or export-oriented, we can assume that the role fisheries play will not change much in the future.

2.3 Finfish resource surveys: Yyin, YAP

Finfish resources and associated habitats were assessed between 20 April and 5 May 2006, from a total of 24 transects (12 back-reef and 12 outer-reef transects, see Figure 2.19 and Appendix 3.1.1 for transect locations and coordinates respectively).

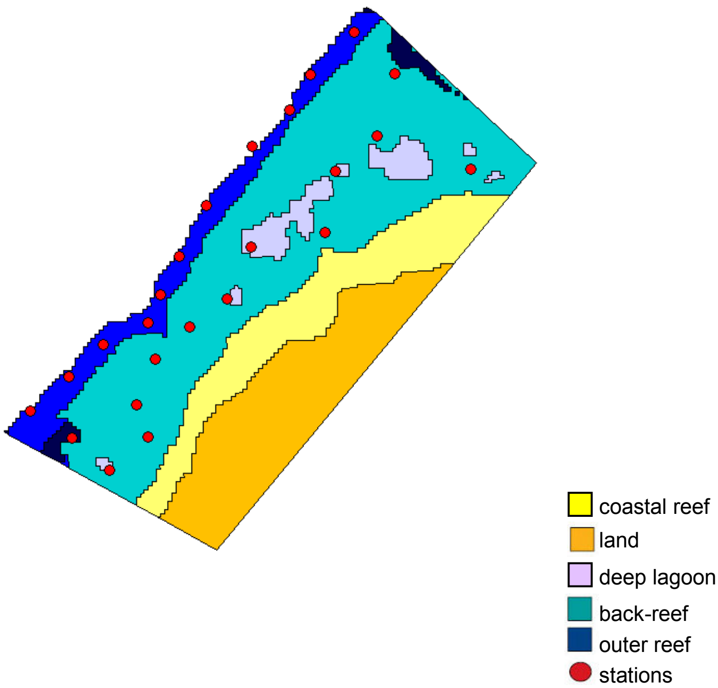

Figure 2.19: Habitat types and transect locations for finfish assessment in Yyin.

2.3.1 Finfish assessment results: Yyin

A total of 22 families, 56 genera, 157 species and 11,936 fish were recorded in the 24 transects (See Appendix 3.1.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 46 genera, 140 species and 11,483 individuals.

Only the two habitats of outer reefs and back-reefs were present at this site. Finfish resources differed greatly between these two reef environments (Table 2.6). The outer reef contained a greater number of fish (1.2 fish/m^2), larger average fish sizes (19 cm FL) and size ratio (60%), larger biomass (274 g/m^2) and higher species richness (52 species/transect) compared to the poorer back-reefs. Outer reefs displayed a very large cover of hard bottom (76% versus 38% in back-reefs) with a relatively low percentage of live coral (22% compared to 27% in the back-reefs).

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

Parameters	Habitat		
	Back-reef [1]	Outer reef [1]	All reefs [2]
Number of transects	12	12	24
Total habitat area (km^2)	3.3	0.7	3.9
Depth (m)	4 (1-12) [3]	8 (3-14) [3]	5 (1-14) [3]
Soft bottom (% cover)	19 ±3	1 ±1	16
Rubble & boulders (% cover)	16 ±5	0 ±0	4
Hard bottom (% cover)	38 ±4	76 ±4	44
Live coral (% cover)	27 ±4	22 ±4	26
Soft coral (% cover)	0 ±0	0 ±0	0
Biodiversity (species/transect)	30 ±3	52 ±3	41 ±3
Density (fish/m^2)	0.5 ±0.1	1.2 ±0.1	0.6
Biomass (g/m^2)	102.8 ±32.0	274.6 ±30.6	131.3
Size (cm FL) [4]	18 ±1	19 ±1	18
Size ratio (%)	56 ±2	60 ±2	57

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

Back-reef environment: Yyin

The back-reef environment of Yyin was dominated by four major families: two herbivorous families, Acanthuridae and Scaridae, and two carnivorous families, Lethrinidae and Lutjanidae (Figure 2.20, Table 2.7). These four families were represented by 40 species; particularly high biomass and abundance were recorded for *Lutjanus gibbus*, *Gnathodentex aureolineatus*, *Monotaxis grandoculis*, *Chlorurus sordidus*, *Acanthurus xanthopterus*, *Ctenochaetus striatus*, *Scarus oviceps*, *Lutjanus monostigma* and *Lutjanus fulvus* (Table 2.7). This reef environment was dominated by hard bottom (38%) and composed of a similar proportion of soft bottom (19%) and rubbles (16%). Live-coral cover was high, particularly for this type of habitat (27%, Table 2.6, Figure 2.20).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.03 ±0.02	16.1 ±9.5
	Lutjanus monostigma	Onespot snapper	0.01 ±0.00	3.9 ±2.6
	Lutjanus fulvus	Flametail snapper	0.01 ±0.01	3.7 ±2.7
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.05 ±0.04	13.6 ±11.0
	Monotaxis grandoculis	Bigeye bream	0.02 ±0.01	12.7 ±6.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05 ±0.01	9.7 ±3.5
	Scarus oviceps	Dark-capped parrotfish	0.01 ±0.00	4.7 ±2.0
Acanthuridae	*Acanthurus xanthopterus*	Yellowfin surgeonfish	0.01 ±0.00	5.4 ±3.6
	Ctenochaetus striatus	Striated surgeonfish	0.07 ±0.02	4.9 ±1.9

The density, size, size ratio, biomass and biodiversity of finfish in the back-reefs of Yyin were smaller than values recorded in the outer reef. These values were also lower than the ones of the eastern side of Yap (Riiken), except for size, higher in Yyin. However, Yyin values were higher than those in Chuuk except for biodiversity, which was the lowest of all back-reefs in the country. The trophic structure in Yyin back-reefs was equally composed of herbivorous and carnivorous species in terms of density, but dominated by carnivores in terms of biomass. Herbivores were mainly represented by Acanthuridae and Scaridae in similar importance. Lethrinidae, Lutjanidae and, in lesser abundance, Mullidae mainly represented the carnivorous composition. Size ratio was below 50% for Serranidae and Labridae.

The back-reefs of Yyin were mainly covered with hard bottom (38%) and a similar proportion of soft and rubble bottom (35% when combined). This type of substrate may explain the type of fish community: herbivorous fish are generally associated with hard bottom, while carnivorous species are generally associated with soft bottom[6]. Mobile soft bottom is a type of environment which favours Lethrinidae, here represented by large quantities of *Gnathodentex aureolineatus* and *Monotaxis grandoculis*, and Mullidae (mainly *Upeneus moluccensis* and *Mulloidichthys vanicolensis*), which feed on small invertebrates.

[6] Soft-bottom environments are generally rich in small invertebrates, which are the main food item of carnivorous fish, while hard-bottom environments are often covered with algae, the food of herbivorous fish.

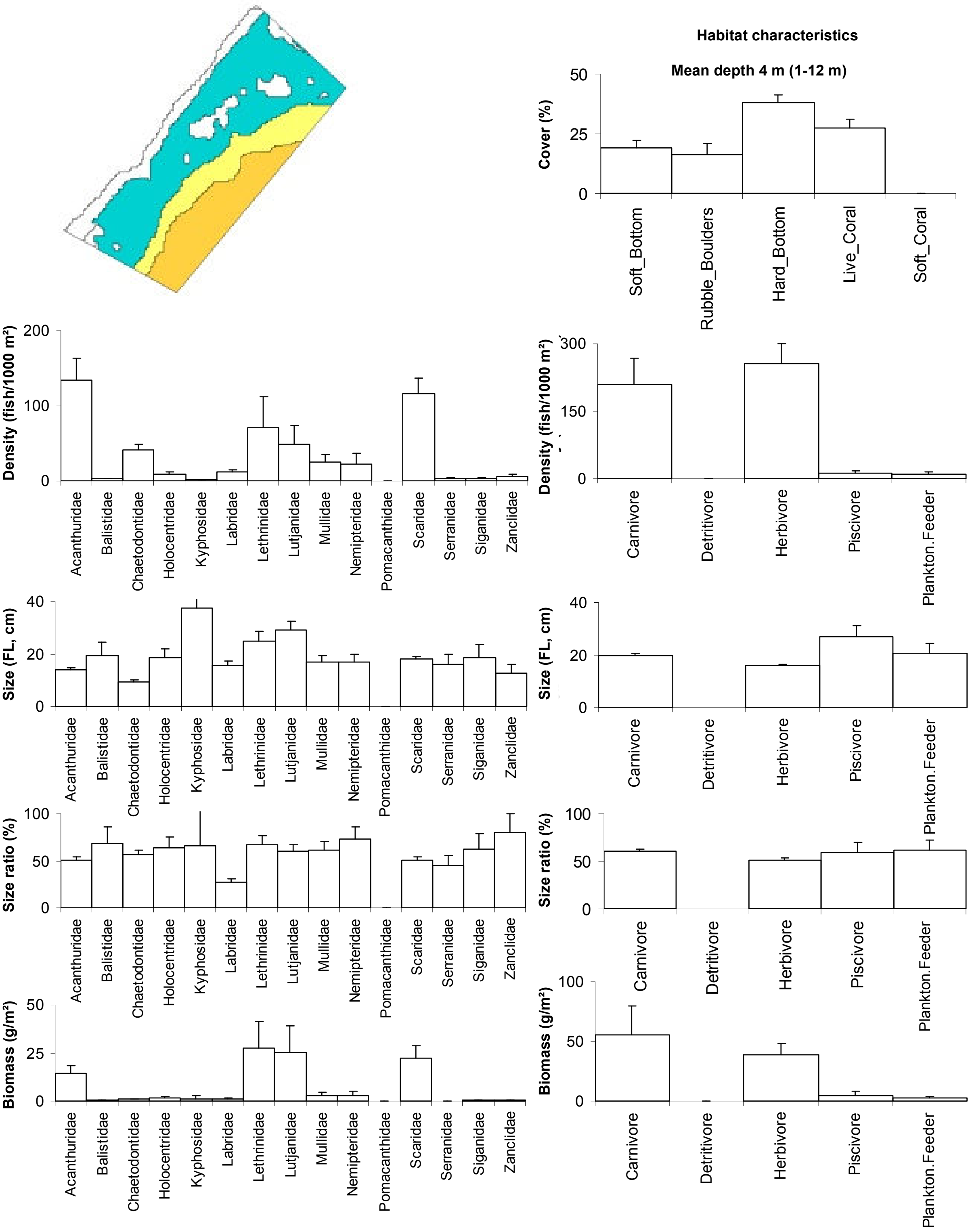

Figure 2.20: Profile of finfish resources in the back-reef environment of Yyin.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Yyin

The outer reef of Yyin was dominated, both in terms of density and biomass, by herbivorous families Acanthuridae and Scaridae and by the carnivorous family Lutjanidae only for biomass (Figure 2.21). These three families were present with 45 species, with the most important in terms of biomass and abundance being: *Lutjanus gibbus*, *Naso lituratus*, *Ctenochaetus striatus*, *Chlorurus sordidus*, *Acanthurus lineatus*, *Scarus oviceps*, *A. nigricans*, *N. vlamingii*, *Bolbometopon muricatum* and *Scarus psittacus* (Table 2.8). Hard-bottom cover (76%) was highly dominant. Live coral was present in high proportion (22%) while mobile substrate was almost absent (Table 2.6, Figure 2.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Naso lituratus*	Orangespine unicornfish	0.05 ±0.01	30.1 ±7.3
	Ctenochaetus striatus	Striated surgeonfish	0.31 ±0.05	27.8 ±4.6
	Acanthurus lineatus	Lined surgeonfish	0.06 ±0.03	19.2 ±11.3
	Acanthurus nigricans	Whitecheeck surgeonfish	0.11 ±0.02	11.7 ±1.9
	Naso vlamingii	Bignose unicornfish	0.01 ±0.01	10.2 ±5.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.10 ±0.02	23.0 ±5.3
	Scarus oviceps	Dark-capped parrotfish	0.03 ±0.00	12.2 ±1.6
	Bolbometopon muricatum	Bumphead parrotfish	0.01 ±0.01	9.1 ±7.4
	Scarus psittacus	Common parrotfish	0.07 ±0.03	7.2 ±2.2
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.04 ±0.01	33.4 ±10.7

The density, biomass, size, size ratio and biodiversity of finfish in the outer reef of Yyin were higher than those recorded in the back-reefs (Table 2.8). When compared to the other Yap site, the outer-reef resources in Yyin displayed higher biological values than those in Riiken, but also higher than in the Chuuk sites. Size ratio was much higher than 50% for all families, evidence of a healthy status of finfish resources. Large schools of *Bolbometopon muricatum* were another indication of the wealth of this reef. The trophic composition was highly dominated by herbivores and, overall, the fish community was not very complex and dominated by only a few families. Among these, Acanthuridae were the main herbivores, with several small- to medium-sized species, such as *Ctenochaetus striatus*, *Acanthurus lineatus* and *A. nigricans.* Lutjanidae were the most important carnivorous family, here represented mainly by *L. gibbus*, a typical outer-reef species. The substrate composition strongly dominated by hard bottom and live coral (98% together) naturally explains the high abundance of Acanthuridae.

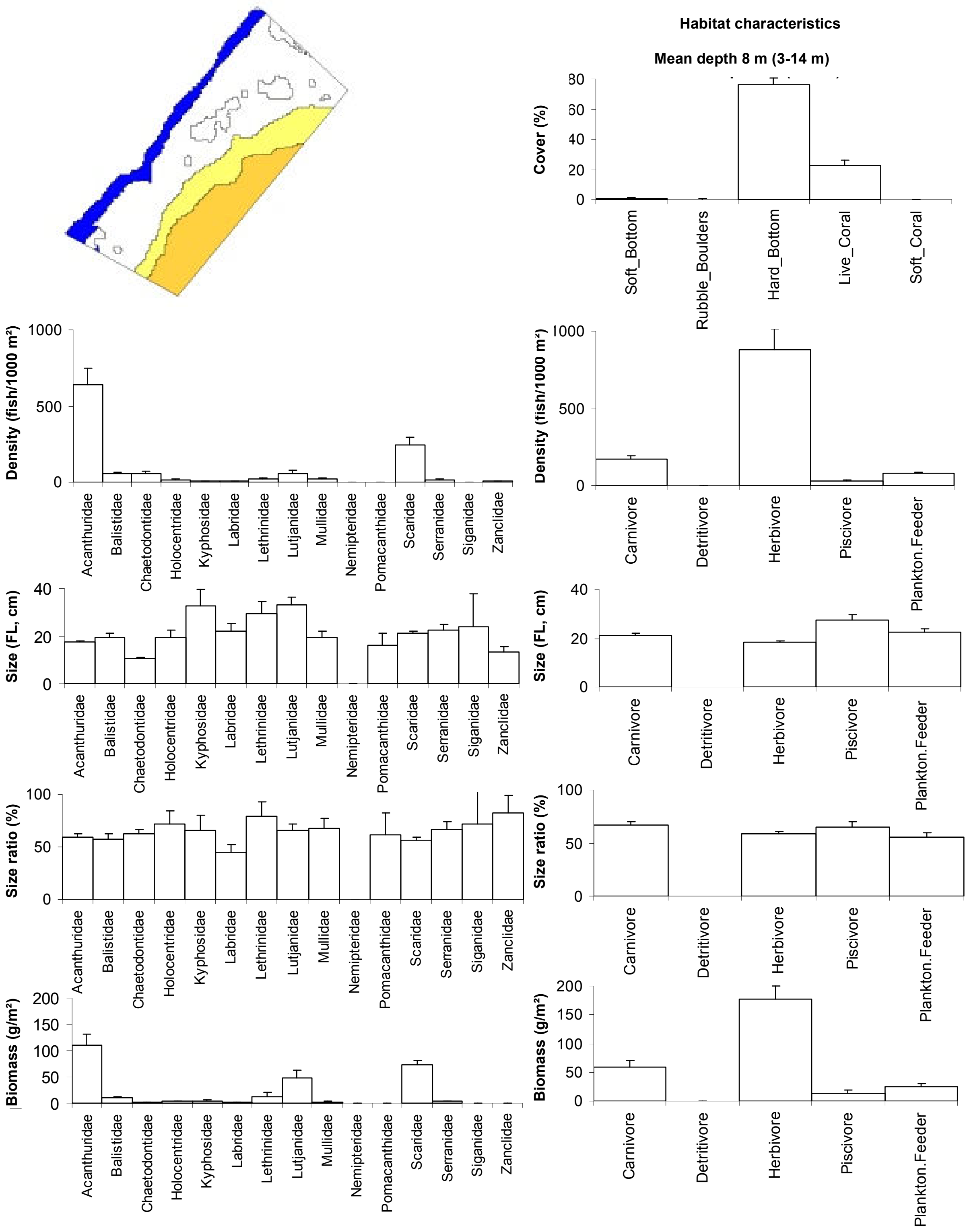

Figure 2.21: Profile of finfish resources in the outer-reef environment of Yyin.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Yyin

Overall, the fish assemblage of Yyin was dominated, in terms of density, by two herbivorous families Acanthuridae and Scaridae and, in terms of biomass, by two carnivorous families Lutjanidae and Lethrinidae (Figure 2.22). These four families were represented by a total of 55 species, dominated by *Ctenochaetus striatus*, *Chlorurus sordidus*, *Gnathodentex aureolineatus*, *Lutjanus gibbus*, *Scarus oviceps*, *Monotaxis grandoculis* and *Naso lituratus* (Table 2.9). Hard-bottom cover (44%) dominated the habitat and cover of live coral was high (26%, Table 2.6 and Figure 2.22). As expected, the overall fish assemblage in Yyin shared characteristics primarily of back-reefs (83% of total habitat) and, to a lesser extent, outer reefs (17%).

Table 4: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Yyin (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.11	8.7
	Naso lituratus	Orangespine unicornfish	0.01	5.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06	11.9
	Scarus oviceps	Dark-capped parrotfish	0.02	5.9
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.04	12.5
	Monotaxis grandoculis	Bigeye bream	0.02	11.5
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.03	19.0

Overall, Yyin showed biological values similar to Riiken. Size, biomass and biodiversity were slightly higher (18 versus 16 cm FL, 131 versus 119 g/m^2 and 41 versus 39 species/transect respectively), while density was lower in Yyin than Riiken (0.6 versus 0.8 fish/m^2). Sites in Chuuk displayed values lower than at both these two sites. However, one has to keep in mind that Riiken presented all types of reef habitats, including coastal and intermediate reefs, which are lacking in Yyin. Size ratio was above 50% for all families except Serranidae, suggesting that finfish resources are still in a healthy condition. The trophic structure was dominated by herbivores in terms of abundance while, for biomass, carnivores and herbivores were equally important. Composition of habitat, dominated by hard bottom and live coral, similar to Riiken, generally favours herbivores such as Acanthuridae, here dominant.

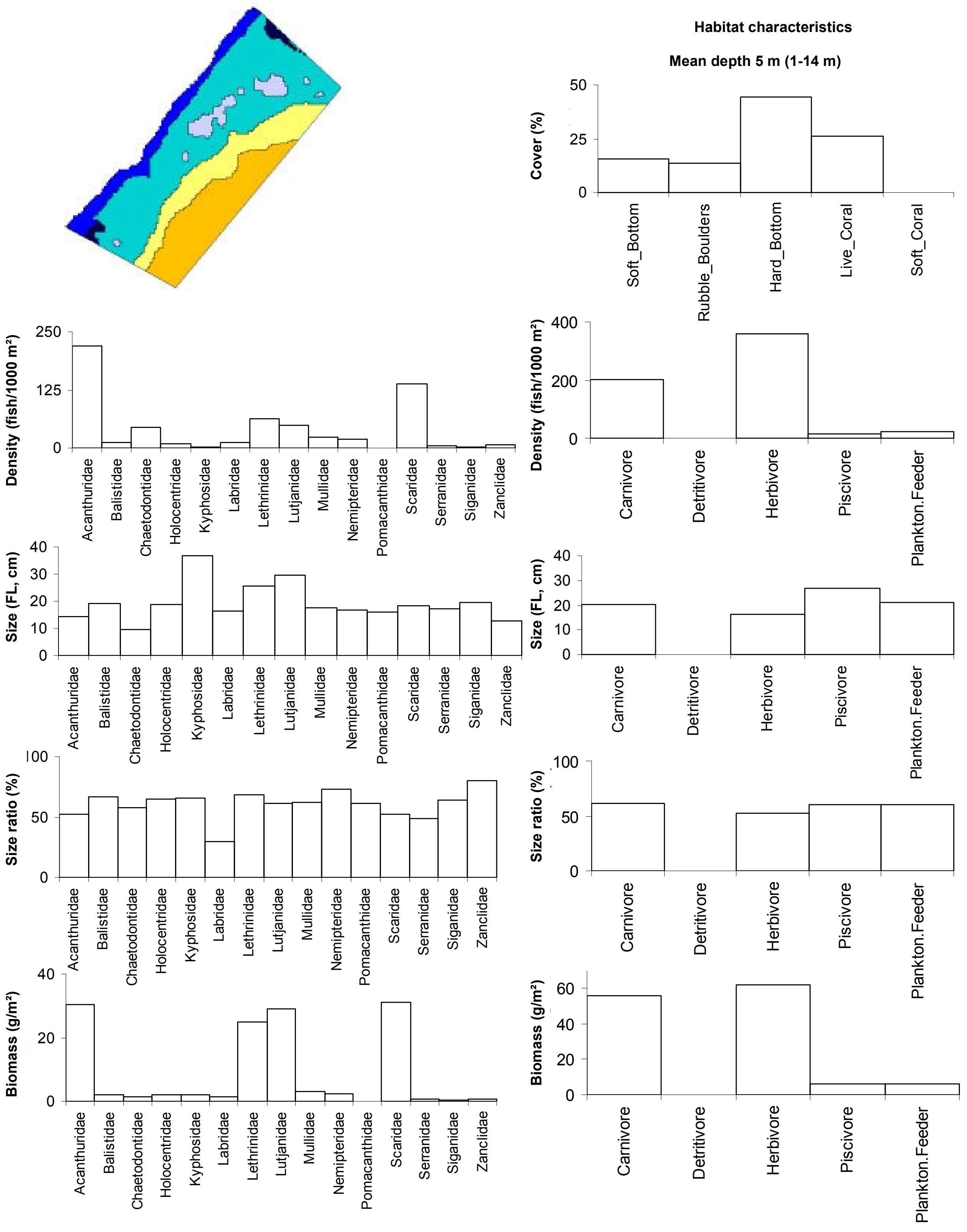

Figure 2.22: Profile of finfish resources in the combined reef habitats of Yyin (weighted average).
FL = fork length.

2.3.2 Discussion and conclusions: finfish resources in Yyin

The assessment indicated that the status of finfish resources in Yyin at the time of surveys was very good. The Yyin community is not dependent on fishing for income generation and, although the community consumes a high quantity of fresh fish, the density of the population per reef habitat areas and per fishing ground does not impose a very high pressure on the overall resources. However, more impact is inflicted on the internal back-reef habitat due to the higher frequency of trips to this habitat compared to the other areas. Outer reefs displayed the highest density, size, biomass and diversity of fish, suggesting that this environment is healthy and only lightly exploited. Both the trophic composition, equally composed of herbivores and carnivores, and the average fish size and size ratio suggest that the system is still healthy. The frequent sightings of the rare and protected species, *Bolbometopon muricatum*, were another sign that resources in Yyin are healthy. Moreover, in both habitats studied, the reefs appeared very healthy and rich in live coral. The customary tenure system is still working and restricts fishing to people of a family clan. In this way, fish resources are controlled and fishing pressure is lower than in an open-access system. The *tabu* areas are also acting as a good management system.

- Resources are healthy and the coral reef is in a healthy state. Density and biomass, as well as trophic structure, displayed high values and general good condition.

- Frequent sightings of large predators (sharks) and rare species, such as *Bolbometopon muricatum*, are further signs of good health.

- Current reef stocks appeared to be within sustainable limits for the subsistence needs of the local community.

2.4 Invertebrate resource surveys: Yyin, YAP

The diversity and abundance of invertebrate species at Yyin were independently determined using a range of survey techniques (Table 2.10): broad-scale assessment (using the 'manta tow'; locations shown in Figure 2.23) and finer-scale assessment of specific reef and benthic habitats (Figures 2.24 and 2.25).

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

Table 2.10: Number of stations and replicates completed at Yyin

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	12	72 transects
Soft-benthos transects (SBt)	12	72 transects
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	5	30 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	4	24 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	3	18 search periods
Sea cucumber night searches (Ns)	2	12 search periods

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

Figure 2.24: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations in Yyin.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

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

Forty-nine species or species groupings (groups of species within a genus) were recorded in the Yyin invertebrate surveys. Among these were 7 bivalves, 15 gastropods, 16 sea cucumbers, 3 urchins, 4 sea stars, 2 cnidarians and 2 lobsters (Appendix 4.1.1). Information on key families and species is detailed below.

2.4.1 Giant clams: Yyin

Although a range of land- and ocean-influenced sites were present, shallow-reef habitat suitable for giant clams was limited in scale at Yyin (4.7 km^2 total: ~3.6 km^2 within the lagoon and 1.1 km^2 on the reef front or slope of the barrier). Similarly to Riiken, the lagoon is not well formed, with only few deep pools and the narrow area (~1 km wide) generally shallow. The surface area of the lagoon at Yyin was small (~7.6 km^2) and can be considered as a pseudo-lagoon. Along the shoreline of the main island, seagrass beds predominated (100–150 m wide). As one travelled west into the pseudo-lagoon, shallow water covered coral heads and patch reef on a white-sand bottom, leading progressively to the back-reef, which had less live coral and more rubble areas on sand. In general, the reef platform was not extensive and the reef slope shoaled for a short period before shelving more steeply into deep water. In the northeast and along the coastline, land influence predominated but waters became more oceanic near the barrier reef and toward the south.

Using all survey techniques, two species of giant clam were noted at Yyin: the elongate clam *Tridacna maxima* and the bear's paw clam *Hippopus hippopus*. Broad-scale sampling provided a good overview of giant clam distribution and density. *T. maxima* had a wider distribution (found in 7/12 stations and 12/72 transects) than *H. hippopus* (5/12 stations and 12/72 transects, see Figure 2.26).

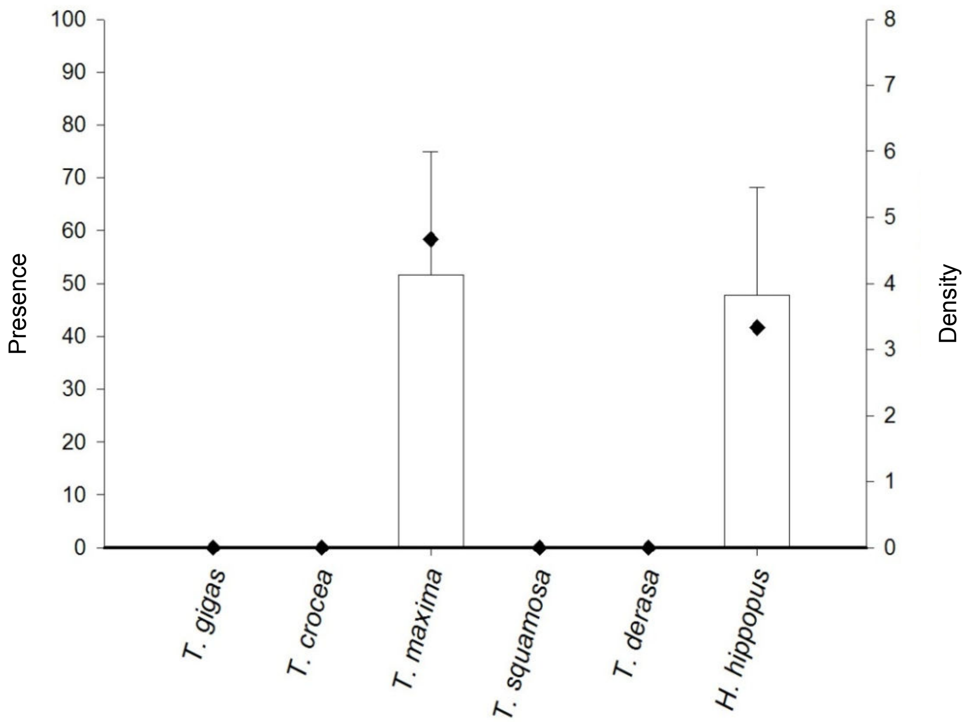

Figure 2.26: Presence and mean density of giant clam species at Yyin based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 2.27). In these reef-benthos surveys (RBt), *T. maxima* was present in 73% of stations, at an average density of 79.9 /ha ±29.2. This density is quite low, and density was not found to be high even at the station with the highest density of elongate clam (333.3 /ha ±105.4). *Hippopus hippopus* was present in 27% of stations at an average of 17.4 /ha ±0.8 (highest density being 83.3 /ha ±52.7). No other species (e.g. *T. squamosa*, *T. derasa*, *T. crocea*, *T. gigas)* were noted.

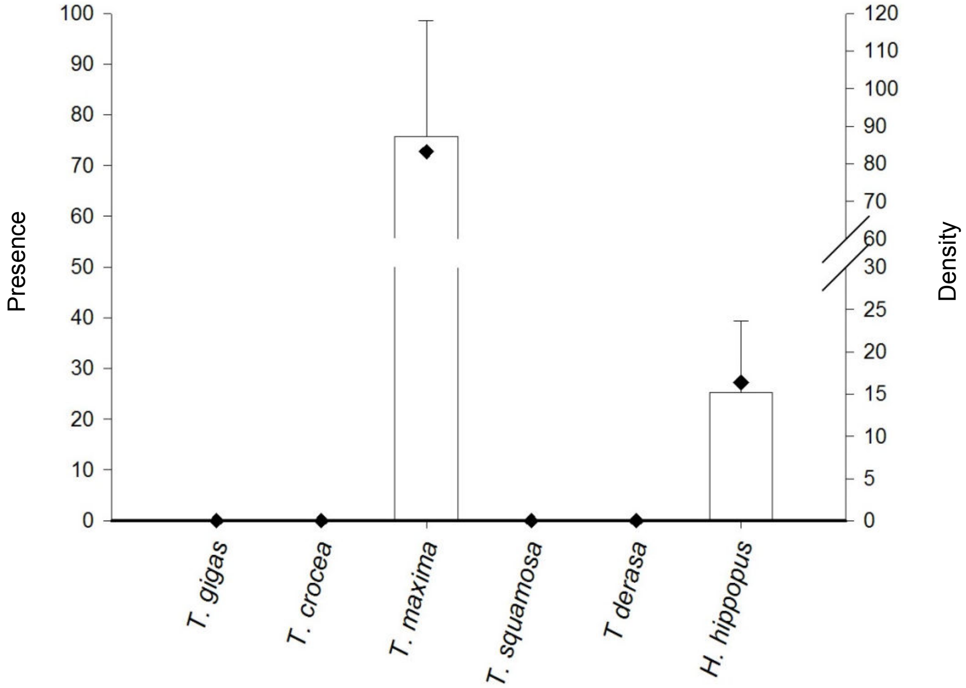

Figure 2.27: Presence and mean density of giant clam species at Yyin based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

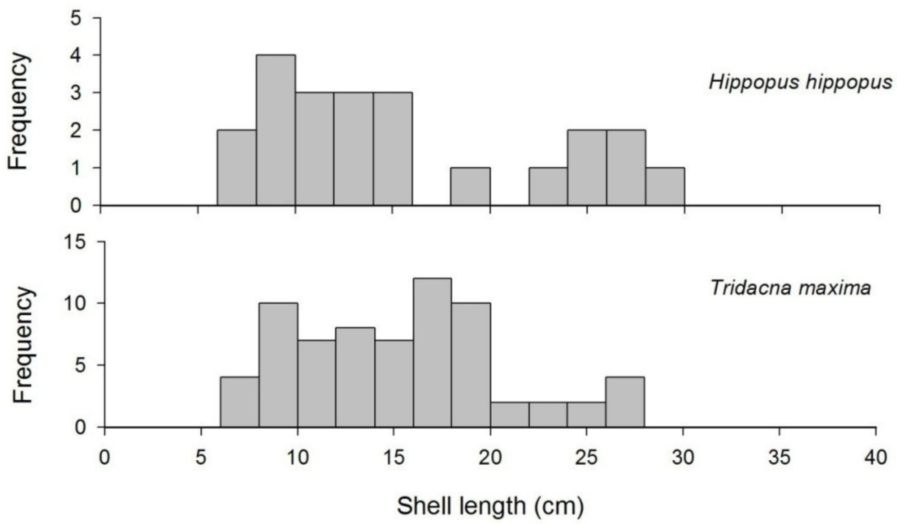

Figure 2.28: Size frequency histograms of giant clam shell length (cm) for Yyin.

The mean size of elongate clams *T. maxima* from RBt stations was 17.5 cm ±1.3, which represents a clam of ~≥8 years old. Sizes recorded from MOPt on the outer slope give an unusual, smaller average of 14.4 cm ±1.2. However, a full range of *T. maxima* lengths was noted in survey, including juveniles and large, mature specimens. *H. hippopus* was quite common but small at an average of 16.9 cm ±2.6 across RBt stations, and a full range of length was also recorded (Figure 2.28). Being faster growing than *T. maxima*, a 17 cm *H. hippopus* clam would be about 3–4 years old.

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

The commercial topshell *Trochus niloticus* is a native species of Yap and has been harvested commercially since Yap was a German Protectorate (1898–1914). Harvests have continued between and after the world wars, the most recent harvest being in 2006. Catches have varied from 10 to 70 t/season, and many trochus have been relocated from Yap in the hope of stimulating a MOP fishery in other Micronesian islands.

The survey of different reef zones at different scales allows the determination of shell distribution and density for commercial trochus. Usually, in addition to standard broad-scale and shallow-reef surveys, trochus information is collected using reef-front searches (RFs) and mother-of-pearl transects (MOPt, see Methods, Table 2.11).

Table 2.11: Presence and mean density of *Trochus niloticus* and *Tectus pyramis* in Yyin
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	2.3	0.7	5/12 = 42	9/72 = 13
RBt	10.4	5.4	3/12 = 25	3/72 = 4
RFs	352.9	62.7	4/4 = 100	23/24 = 96
MOPt	983.3	111.3	5/5 = 100	30/30 = 100
Tectus pyramis				
B-S	0.2	0.2	1/12 = 8	1/72 = 1
RBt	0		0/12 = 0	0/72 = 0
RFs	0		0/4 = 0	0/24 = 0
MOPt	12.5	5.1	3/5 = 60	3/30 = 10

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

At Yyin, only the outer slope held a significant number of trochus, although some individuals were also found sporadically on the edge of the channel and back-reef. The densities observed in the 5 MOPt stations at 3.5–8 m depth were high, with trochus ranging between 625 and 1250 specimens per ha. These sites were quite degraded, with high coral cover, most of which was dead (live-coral cover 5–20%). Most of the inner reef in the pseudo-lagoon was not very suitable for trochus (present in 25% of the RBt stations).

A total of 610 trochus were recorded during the survey, 124 of which were measured (mean basal width of 10.5 cm ±0.1). The range and number of shell sizes give an important indication of the status of stocks by highlighting new recruitment into the fishery, or lack of recruitment, and which sizes of trochus are being removed from the fishery (Figure 2.29).

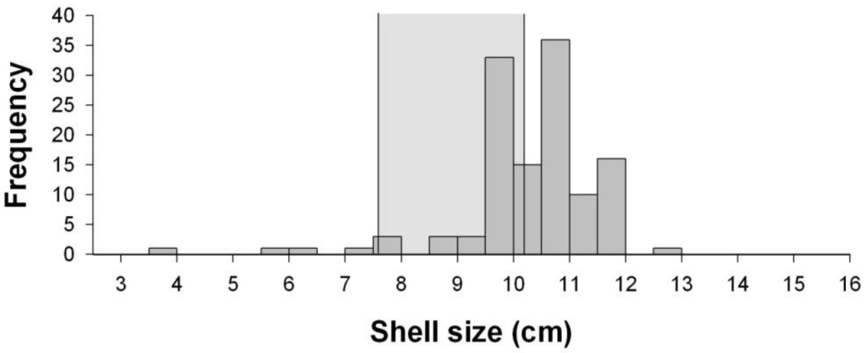

Figure 2.29: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Yyin.
The paler grey shaded area represents the legal capture size (7.6–10.2 cm).

The length frequency graph reveals that a full range of trochus sizes were still in the water at Yyin, and that small amounts of small, juvenile trochus were still entering the capture size classes (indicating recruitment). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic phase, and joining the main stock. As can be seen from the length frequency graph, there was no evidence of a large recruitment pulse of younger trochus at Yyin. In general, the average size of trochus was relatively large, with many large adults in the sampled population. The length frequency results can be interpreted as an indication of the level of fishing in previous harvests. In this case, 60% of the stock is from size classes >10.2 cm basal width (22% over 11 cm), which is quite high, indicating that the mature proportion of a population is large, and overfishing of the 'fishable' year classes (7.6–10.2 cm) has not necessarily occurred. However, noting the lack of young trochus in the fishery, a precautionary approach would suggest waiting until new settlement and recruitment are definitely evident before giving a commercial harvest the green light.

Normally, we also look at the abundance of false trochus or green topshell (*Tectus pyramis*), as this related, but less-valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) can give an indication of the suitability of reefs for grazing gastropods. In this case, despite the ubiquitous nature of trochus, *T. pyramis* was rare (only four recorded in survey).

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera*, was not found at Yyin, despite areas of the shallow pseudo-lagoon having suitable environment for this species.

2.4.3 Infaunal species and groups: Yyin

Soft benthos at the coastal margins of Yyin was suitable for seagrass, and large areas of seagrass were seen in the pseudo-lagoon. There were no reported concentrations of in-ground resources (shell 'beds'), and no infaunal 'digging' surveys (quadrat surveys) were completed.

2.4.4 Other gastropods and bivalves: Yyin

Two *Lambis* species were also noted at low density (*Lambis lambis*, the larger Seba's spider conch, and *L. truncata*, the smaller, more common spider conch). Only two *L. lambis* conchs were noted but *L. truncata* was more common (n = 12) but at low mean density

(10.4 /ha ±7.5). The strawberry or red-lipped conch *Strombus luhuanus* was not common (recorded in 3% of broad-scale transects) and was also at low average density (0.9 /ha ±0.7, Appendices 4.1.2 to 4.1.9).

One species of turban shell (*Turbo argyrostomus*) was noted, mostly recorded at relatively low density on the outer slope. Other resource species targeted by fishers (e.g. *Cerithium*, *Charonia*, *Conus*, *Cypraea*, *Haliotis*, *Oliva*, *Rhinoclavis*, *Strombus* and *Thais*) were also recorded during independent surveys (Appendices 4.1.2 to 4.1.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Isognomon*, *Modiolus*, *Pteria*, *Spondylus* and *Tellina* species, are also in Appendices 4.1.2 to 4.1.9. No creel survey was conducted at Yyin.

2.4.5 Lobsters: Yyin

There was no dedicated night reef-front assessment of lobsters (See Methods.) although night-time assessments for nocturnal sea cucumber species (Ns) offered a small extra opportunity to record lobster species. In Yyin, one lobster species (*Panulirus versicolor*) was recorded in broad-scale surveys and deeper-water sea cucumber day search stations (n = 4 individuals). Prawn killers (*Lysiosquillina maculata*) were recorded in soft-benthos transect stations (3 specimens) and the crab *Etisus splendidus* was recorded commonly during sea cucumber night search stations (6 individuals).

2.4.6 Sea cucumbers[7]: Yyin

At the site of Yyin, shallow- and deep-water sheltered lagoon and barrier reef was relatively limited (lagoon area 7.6 km^2). The deeper northern areas and the shoreline shallows were both much influenced by riverine inputs, and the shallow western area of the lagoon, although receiving a mix of land and oceanic influences, did not provide a full range of suitable habitats for sea cucumber species. 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 the rubble and limestone pavement surfaces were not always suitable for these deposit feeders (Sea cucumber species eat organic matter in the upper few mm of bottom substrates.).

The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.12, Appendices 4.1.1 to 4.1.9, also see Methods). Results from the full range of assessments yielded 15 commercial species of sea cucumber, plus one indicator species (Table 2.12).

A sea cucumber species associated with shallow reef areas, the medium-value leopardfish (*Bohadschia argus*), was moderately common in distribution (in 24% of broad-scale transects) but generally recorded at low-to-moderate density (mean broad-scale transect density 9.3 /ha ±2.4).

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

High-value black teatfish (*Holothuria nobilis*), which is often found in shallow water and easily targeted by commercial fishers, was recorded in small numbers at Yyin (n = 3). This species was only noted in 3% of broad-scale transects and 8% of RBt stations, at an average density <4 /ha (average density in broad-scale and RBt stations was 0.7 /ha ±0.5 and 3.5 /ha ±3.5 respectively), which is below the densities recorded in some protected and highly regulated fishery areas in the Pacific (≥12 /ha).

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was rare across reefs at Yyin (not recorded in broad-scale surveys). It was only recorded during sea cucumber night search stations (at 1 of 2 stations, see Appendix 4.1.7). It is interesting to note that, in a similar environment on the east side of the island, at Riiken, this species was commonly recorded and was noted at moderately high densities at some stations.

Surf redfish (*Actinopyga mauritiana*) were recorded in 75% of the reef-front search stations (RFs). As this species is mostly found, where its name suggests, on reef fronts, RFs provide a valuable indication of its status, although MOPt stations made on SCUBA on the outer slope also target part of its preferred habitat (recorded in 20% of MOPt stations). In Yyin, the density of this medium/high-value species was low (4.9 /ha ±2.0 and 8.3 /ha ±8.3 on RFs and MOPt stations respectively) whereas, in other locations in the Pacific, this species is recorded at commercial densities above 400–500 /ha.

More protected areas of soft benthos in the lagoon also returned distribution and density 'signals' for sea cucumbers found in more sheltered, land-influenced areas. No high-value sandfish (*Holothuria scabra*) were noted, but brown curryfish (*Stichopus vastus*) and a species similar to blackfish (*Actinopyga* sp. nov., yet to be officially named) were present. The brown sandfish (*Stichopus vastus*) was only recorded in one RBt at the average low density of 6.9 /ha ±6.9, whereas *Actinopyga* sp. nov. was recorded in both RBt stations (8%) and SBt stations (17%). The density observed varied from 6.9 /ha ±4.9 on RBt stations to a higher 520.8 /ha ±367.3 in SBt stations. As can be seen from the results, this species was mostly found within seagrass beds in muddy embayments influenced by riverine and land inputs and sheltered from waves. This species can aggregate at high density, reaching 4000 /ha in one SBt station; its best habitat was recorded at the eastern part of the Yyin site. Despite being found at high density, the average length of this commercial species was small (8–21 cm, average 12.0 cm ±0.3); there were few large individuals present (Figure 2.30).

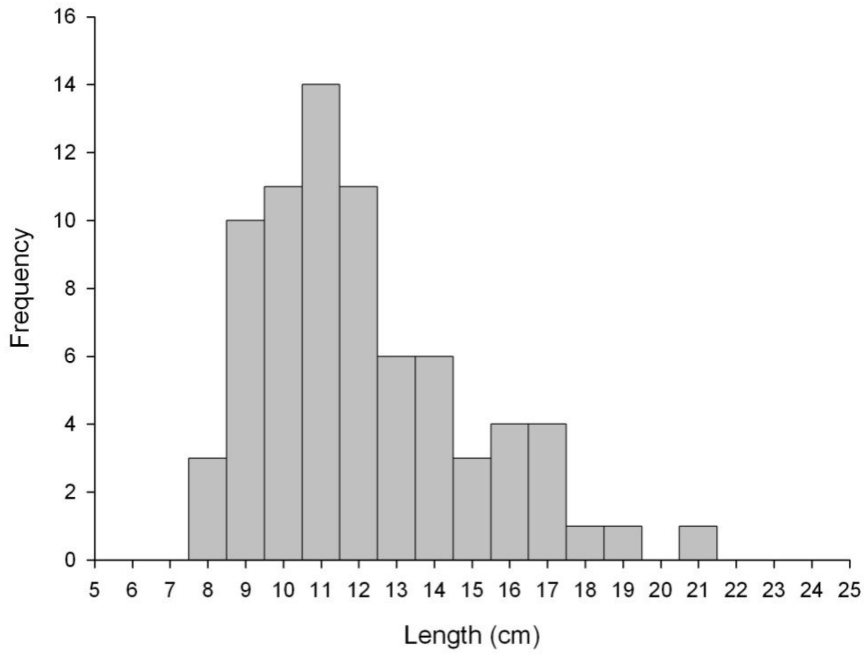

Figure 2.30: Size frequency histogram of *Actinopyga* sp. nov. shell length (cm) for Yyin.

Local anecdotal evidence suggests settlement of this species can be very high in the shallows. In some cases, low spring tides combined with afternoon sun can result in large numbers of small juveniles perishing. Fishery managers might consider some experimental movements by collecting up a large percentage of these juveniles following large settlement events near the shoreline (possibly by placing them in water in the bottom of a flat canoe at high tide) and moving them 300 m offshore, into the shallow-water seagrass that remains submerged at spring tides, to increase rates of survival. It can be noted that the largest specimens also move into even deeper water as they grow, moving from the shallow-water seagrass banks to the edge of the channels. Small-scale experimentation to manipulate the stocks to increase survival and growth would be preferable to the 'cutting and caging' of this species, which is a process that has been attempted by some commercial operators to increase productivity close to Yyin.

Other, lower-value species of sea cucumber, such as snakefish (*Holothuria coluber*), lollyfish (*H. atra*) and pinkfish (*H. edulis*) were noted across the site at reasonable coverage. No high-density areas were located for lollyfish, while snakefish (and a phenotypically similar *H. flavomaculata*) and pinkfish were recorded at higher densities on occasion.

Deep-water assessments (30 five-minute searches 18–30 m deep, average depth 21.6 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Most of the lagoon was shallow at Yyin, and deep-water species were not commonly recorded. The oceanic-influenced narrow passages had suitably dynamic water movement for species such as white teatfish (*H. fuscogilva*), but only *T. ananas* was recorded (in 66% of the stations at average density 2.4 /ha ±1.3).

2.4.7 Other echinoderms: Yyin

While collector urchins (*Tripneustes gratilla*) were present in Riiken, a CoFish site in the east of Yap, none of these common edible urchins were noted in Yyin. Another potentially edible species of urchin (*Echinothrix diadema*) was recorded in surveys at very low density (0.5 /ha ±0.3 on broad-scale stations, with only two specimens recorded). Equally rare in general surveys was *Echinometra mathaei*, which was only noted in 8% of RBt stations at low density (3.5 /ha ±3.5). Only in sea cucumber night search stations were any high-density patches recorded (See Appendices 4.1.1 to 4.1.7.). Non-edible urchins, e.g. *Echinothrix* spp. and *Echinometra mathaei*, can also be used as potential indicators of habitat condition within assessments.

Blue starfish (*Linckia laevigata*) were common (n = 168). In broad-scale surveys they were recorded in 33% of broad-scale transects at moderate density (39.2 /ha ±9.2). Coralivore (coral eating) starfish, such as the pincushion star (*Culcita novaeguineae*) were recorded in 8% of broad-scale stations (n = 36), and the most destructive coral eating starfish, the crown of thorns (*Acanthaster planci*, COTS) was rare, with only five specimens noted.

Table 2.12: Sea cucumber species records for Yyin

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 12; SBt = 12			Other stations RFs = 4; MOPt = 5			Other stations Ds = 4; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H							4.9 8.3	6.5 41.7	75 RFs 20 MOPt			
Actinopyga miliaris	Blackfish	M/H										4.4	8.9	50 Ns
Actinopyga sp. nov.	No name as yet	M	47.2	485.7	10	6.9 520.0	83.3 3125.0	8 RBt 17 SBt				195.6	391.1	50 Ns
Bohadschia argus	Leopardfish	M	9.3	39.6	24	27.8	111.1	25 RBt				22.2	44.4	50 Ns
Bohadschia graeffei	Flowerfish	L												
Bohadschia vitiensis	Brown sandfish	L				3.5	41.7	8 SBt				4.4	8.9	50 Ns
Holothuria atra	Lollyfish	L	95.8	181.5	53	125 149.3	375 224.0	33 RBt 66 SBt				31.1 0.8	31.1 2.4	100 Ns 33 Ds
Holothuria coluber	Snakefish	L	0.2	16.7	1	48.6	194.4	25 SBt				462.2	924.4	50 Ns
Holothuria edulis	Pinkfish	L	1.4	24.5	6	69.4 10.4	416.7 125.0	17 RBt 8 SBt				226.7	226.7	100 Ns
Holothuria flavomaculata		L										71.1	142.2	50 Ns
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M	1.9	44.4	4									
Holothuria leucospilota		L												
Holothuria nobilis [4]	Black teatfish	H	0.7	24.7	3	3.5	41.7	8 RBt						
Holothuria scabra	Sandfish	H												
Stichopus chloronotus	Greenfish	H/M										88.9	178.8	50 Ns
Stichopus hermanni	Curryfish	H/M												
Stichopus horrens	Peanutfish	M/L				3.5	41.7	8 SBt						
Stichopus vastus	Brown curryfish	H/M				6.9	83.3	8 RBt						
Synapta spp.	-	-				10.4	125	8 SBt				4.4	8.9	50 Ns
Thelenota ananas	Prickly redfish	H	0.2	16.7	1	3.5	41.7	8 RBt				2.4	3.6	66 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; H/M is higher in value than M/H; B-S transects= broad-scale transects; RBt = reef-benthos transect; SBt = soft-benthos transect; RFs = reef-front search; MOPt = mother-of-pearl transect; Ds = day search; Ns = night search.

2.4.8 Discussion and conclusions: invertebrate resources in Yyin

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

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

- There was a broad range of shallow-water reef habitats suitable for a full range of giant clams species at Yyin, although most habitats were not extensive. The most developed and extensive habitats available were inshore, land-influenced areas and outer-reef slopes.

- For this part of the Pacific, the two native giant clam species present (the elongate clam *Tridacna maxima* and the bear's paw clam *Hippopus hippopus*) represent a limited range of species for this large island system in the western Pacific, close to the centre of biodiversity. Surprisingly, the fluted clam (*T. squamosa*) and the smooth clam (*T. derasa*) were not noted. Approximately 25,000 *T. derasa* clams were re-introduced in 1984 from Palau, and subsequently reproduced and re-established viable populations (Lindsay 1995).

- The overall density for *T. maxima* is low, especially inside the lagoon, and moderate-to-low on the outer-reef slope. The average density recorded for *H. hippopus* is moderate. Both species presented a full range of size classes from juveniles to large adults, suggesting that, despite the low densities, spawning and recruitment are still occurring. However, giant clams are broadcast spawners, which need to be at large size and in close proximity to one another (at high density) for successful reproduction. At Yyin, the lower densities recorded suggest that ongoing spawning and recruitment will not allow fast recovery of stocks from fishing pressure or from natural events, such as devastating typhoons (e.g. typhoon Sudal in April 2004).

- In addition, giant clam individuals are hermaphrodite (of both sexes), but only mature to produce eggs at larger sizes (This can take up to 10 years in *T. gigas*.). It is therefore important that aggregations contain large, older clams to ensure that sufficient gametes (especially eggs) are produced to create the next generation and maintain the resource.

- In general, the status of giant clams at Yyin was moderately impacted and the habitat available shallow and limited.

Data on MOP habitat, distribution, density and size suggest the following:

- Local reef conditions at Yyin constitute a habitat that is limited in scale but good for both juvenile and adult commercial topshells (*Trochus niloticus*). The pseudo-lagoon was relatively shallow and sandy in places and mainly land-influenced, but the outer slope provided a suitable habitat for trochus. The reef slope in this western site is sheltered from the prevailing easterly winds and thus the bigger swells for most of the year, and the mix of oceanic and land influence provides nutrients for these algal grazers.

- Trochus was not common on shallow-water reef within the lagoon at Yyin, but the density of trochus was high within 'core' aggregations (where trochus are typically in greatest abundance) at the reef slope. The outer slope can hold a significant stock, as the high densities recorded on MOPt stations suggest. In the five MOPt stations made in the outer slope, densities were all much greater than 500–600 shells/ha, which is the threshold density considered as the minimum before commercial harvests can be considered.

- Size-class information reveals that most sizes are present and the high numbers of large, old shells (>10.2 cm basal width) occurring within aggregations indicate that stocks have not been comprehensively fished in previous harvests. Most eggs for the production of future populations originate from the largest individuals: a female trochus of 10 cm in size produces ~2 million eggs, whereas a trochus of 13 cm produces 3 times this number. The presence of large older shells, which have the greatest potential to fuel future populations to support the fishery, is a good indication for the future of the fishery, but the lack of a strong signal from juvenile and newly recruiting trochus suggests that fishery managers might consider waiting a few spawning seasons to recognise a strong recruitment peak before commercial fishing is begun.

- Results from the current assessment suggest that trochus in the Yyin study area are, in general, well managed. The fact that ≥20% of the stock in high-density aggregations on the reef slope are >11 cm basal width, also suggests that stocks are well placed to supply future generations of trochus when natural conditions allow for a good spawning season, subsequent settlement and juvenile growth.

- The blacklip pearl oyster, *Pinctada margaritifera* was absent from Yyin.

A summary of sea cucumber habitat, distribution and density is given below:

- The bêche-de-mer fishery in Yap is likely to have been active for short periods since the 1800s. After 1914, exports resumed and, during World War II, the Japanese troops stationed in Yap were poorly supplied and harvested sea cucumbers heavily for their own consumption. In more recent times, pulses of fishing activity were recorded around 1995 and again in 2003, with the expansion of the Chinese market and fisheries collapses elsewhere in the Pacific. The focus on the Yap sea cucumber fishery was greatest in 2007, with rapid, uncontrolled expansion in this year, before the fishery was closed in September – October 2007, pending the introduction of a sea cucumber fishery management plan.

- Yyin has a limited amount of shallow, sheltered lagoon area suitable for a range of sea cucumber species. The environments are influenced by both land and oceanic factors but, due to the shallow nature of the lagoon and the more extensive areas of seagrass and mangrove in the inshore embayments, the land-influenced areas are the main habitats for these deposit-feeding resources.

- Recent studies have recorded 21 marketable species of sea cucumbers in all of Yap. Fifteen commercial species were recorded at Yyin, plus one indicator species. This species complement is lower than expected for this location in the Pacific (which is relatively close to the centre of biodiversity), but the small size of the site and the lack of developed habitats were limiting factors.

- Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure in the past; however, some species are recorded at reasonable density, especially those in protected inshore areas. There were no high-density stocks identified although, in some areas, *Actinopyga* sp. nov. were still abundant, although few larger individuals (>12 cm) were present.

- Stocks of the high-value sandfish (*Holothuria scabra*) were absent despite the suitability of the environment for this species. Another high-value species, black teatfish (*H. nobilis*) was at low density.

- Sea cucumbers play an important role in 'cleaning' benthic substrates of organic matter and mixing (bioturbating) sands and muds. They also recycle nutrients that are not usually abundant in coral reef systems. When these species are removed, there is the potential for detritus to build up and for substrates to become more compacted, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) and anoxic (oxygen-poor) conditions, unsuitable for life.

- At the moment there is no cost-effective hatchery and grow-out option to restock sea cucumber fisheries, although it is advised that the Fisheries Department continues to watch for any developments in hatchery-based rearing and re-stocking activities. Once research and preliminary experimentation has dealt with some of the important bottlenecks and difficulties, this technique may be used to re-create spawning populations at a number of locations in addition to developing commercial harvests. Maybe in the next decade, there may be an option to develop sea ranching operations. Current hatchery technology only exists only for a couple of species (*Holothuria scabra* and *H. fuscogilva*), is expensive, and to date has had widely variable rates of success with placing juveniles in the wild. Some operators have suggested moving juveniles between countries, which is not recommended, as it presents a number of risks to local sea cucumber populations.

2.5 Overall recommendations for Yyin, YAP

- A monitoring system be established for finfish and selected invertebrate stocks to follow changes in these resources.

- Night spearfishing and shark feeding be controlled.

- The establishment of MPAs be considered by the Yyin community as a possible management tool, as in other areas in Yap.

- Sand mining be carefully located to avoid impacting the fishing grounds.

- Stronger management measures be applied to the small populations of giant clams, especially the larger, older clams, to ensure a viable stock of clams for subsistence use in this part of Yap.

- Before beginning a harvest of the commercial topshell (*Trochus niloticus*), fishery managers wait until a strong recruitment peak is detected, i.e. after a few spawning seasons.

- Black teatfish (*Holothuria nobilis*), a high-value species, needs to be closely managed to ensure that broodstock are protected at viable spawning densities within reserve areas, to ensure continuation of this species in the fishery.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

3. PROFILE AND RESULTS FOR RIIKEN, YAP

3.1 Site characteristics

Riiken is located on the east coast of Gagil Island at 9°33'N latitude and 133°12'E longitude (Figure 3.1). A causeway links Gagil Island to Yap proper. Riiken is about 50 minutes drive or 20–30 minutes by outboard-powered skiff from Colonia, the capital and urban centre of Yap State. Riiken was chosen as a survey site because the community has the only marine protected area on Yap, which was declared to protect its traditional fishing grounds. Reefs in Yap are traditionally owned by families of high rank (cast system), which is the case for the selected communities. Families of lower rank live inland and must ask permission from reef owners before fishing on their reefs and in return give part of their catch to the owners. For the socioeconomic surveys, the neighbouring village of Wanyang to the south was included in the survey.

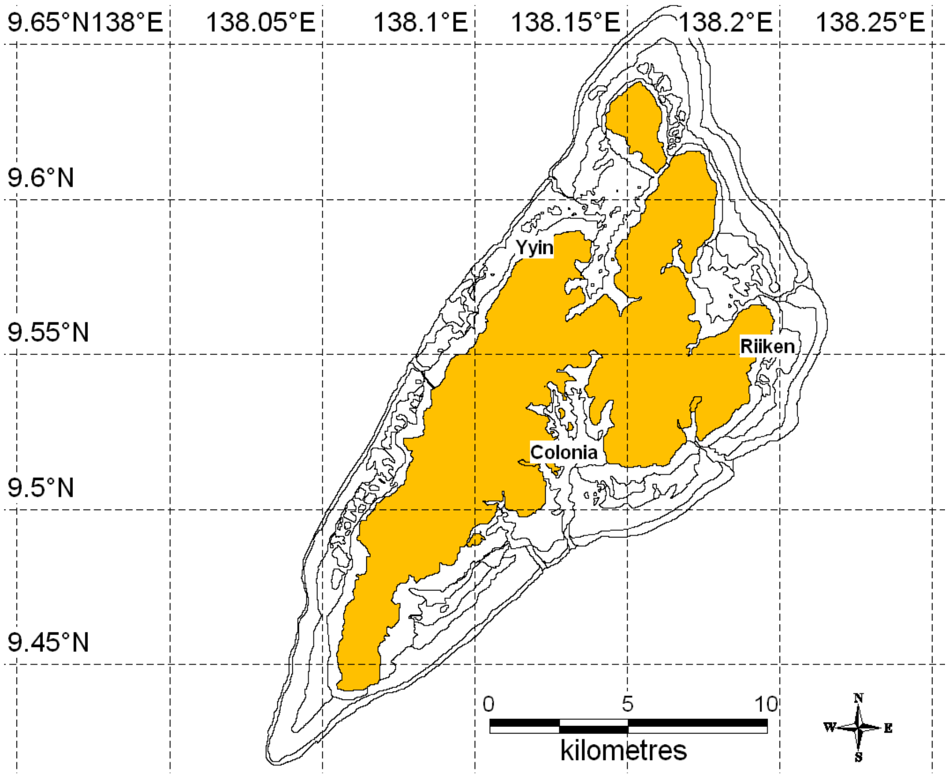

Figure 3.1: Map of Riiken, YAP.

3.2 Socioeconomic surveys: Riiken, YAP

Socioeconomic fieldwork was carried out in the Riiken and Wanyaan community (in the following referred to only as 'Riiken') located on the eastern coast of Yap in April – May 2006. The survey covered a total of 28 households (8 in Riiken, 20 in Wanyaan) and 126 people. Thus, the survey represents about 74% of the community's households (38) and total population (171).

Household interviews aimed at the collection of general demographic, socioeconomic and consumption parameters. A total of 23 individual interviews of finfish fishers (22 males, 1 female) and 10 invertebrate fishers (4 males, 6 females) were conducted. These fishers belonged to one of the 28 households surveyed. Sometimes, the same person was interviewed for both finfish fishing and invertebrate harvesting.

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

Our survey results (Table 3.1) suggest an average of almost two fishers per household. If we apply this average to the total number of households, we arrive at a total of 72 fishers in Riiken. Applying our household survey data concerning the type of fisher (finfish fisher, invertebrate fisher) by gender, we can project a total of 51 finfish fishers only (males, females), a total of 13 invertebrate fishers only (males, females) and 8 fishers (males) who fish for both finfish and invertebrates.

Only 39% of all households in Riiken own a boat. Most (73%) boats are non-motorised canoes; 27% are motorised.

Ranked income sources (Figure 3.2) suggest that fisheries are not an important sector as compared to salaries. None of the households indicated that fisheries is their first source of income, and only 11% quoted fisheries as a secondary income source. Salaries provide 68% of all households with first income, and another 18% gain their cash income mainly from other sources, including business and social fees. Agriculture plays some role. At least 14% of all households consider agricultural production as their first source of income and another 36% obtain secondary income from agricultural activities.

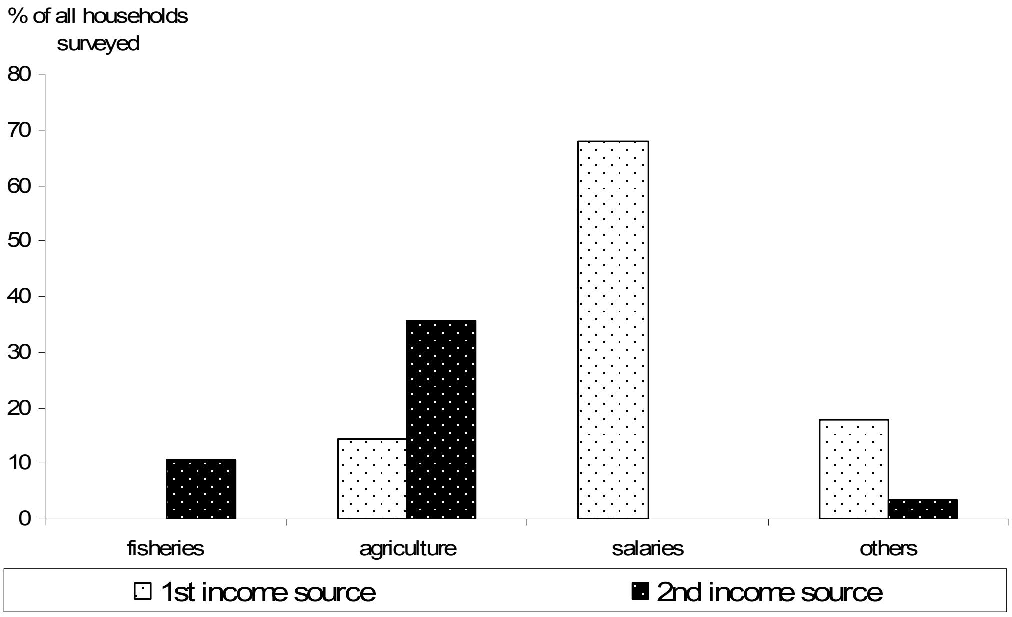

Figure 3.2: Ranked sources of income (%) in Riiken.
Total number of households = 28 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

The importance of fisheries, however, shows in the fact that all households eat fresh fish, and over half (57%) also eat invertebrates. The fish that is eaten is mostly caught by a member of the household (86%), rarely bought (18%) but also often received as a gift (93%). The proportion of invertebrates caught by a member of the household where consumed is lower

(57%). However, invertebrates are not bought in Riiken but may be given on a non-monetary basis. These results suggest that finfish may be sold, at least to some extent, within the Riiken community, but the sale of invertebrates always targets an outside market.

Fresh-fish consumption (~44 kg/person/year ±7.3) in Riiken is above the regional average (FAO 2008) (Figure 3.3), but low if compared to amount determined across all four study sites in FSM. The consumption of invertebrates (meat only) is 10 kg/person/year (Figure 3.4), and is not only significantly lower than that of finfish, but also lower than the average across all four study sites. Canned fish consumption is surprisingly high, even higher than fresh-fish consumption rate (~47 kg/person/year ±6.47) (Table 3.1).

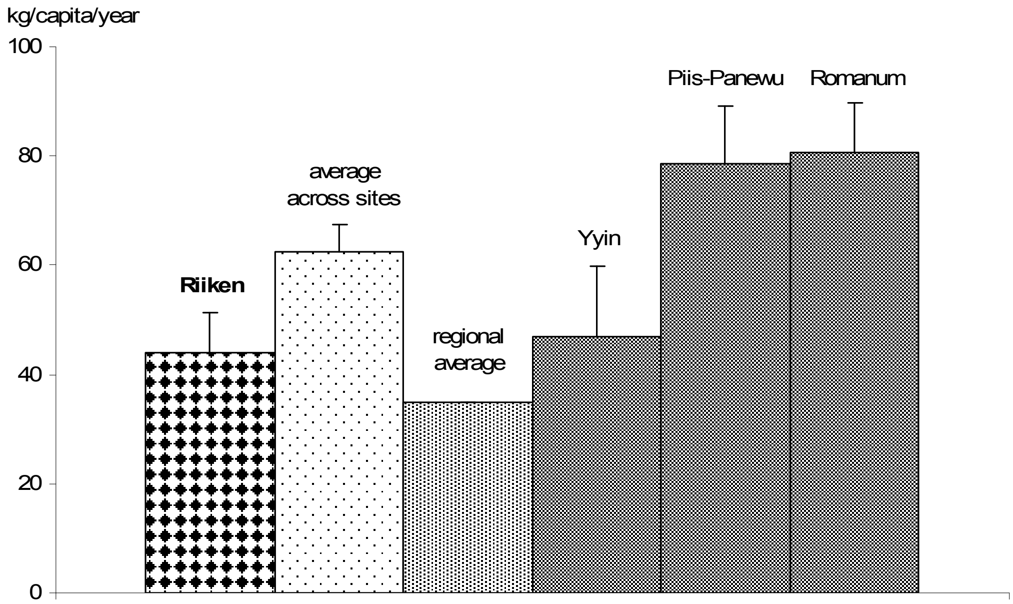

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Riiken (n = 28) compared to the average across sites, the regional average (FAO 2008) and the other three CoFish sites in FSM. Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of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

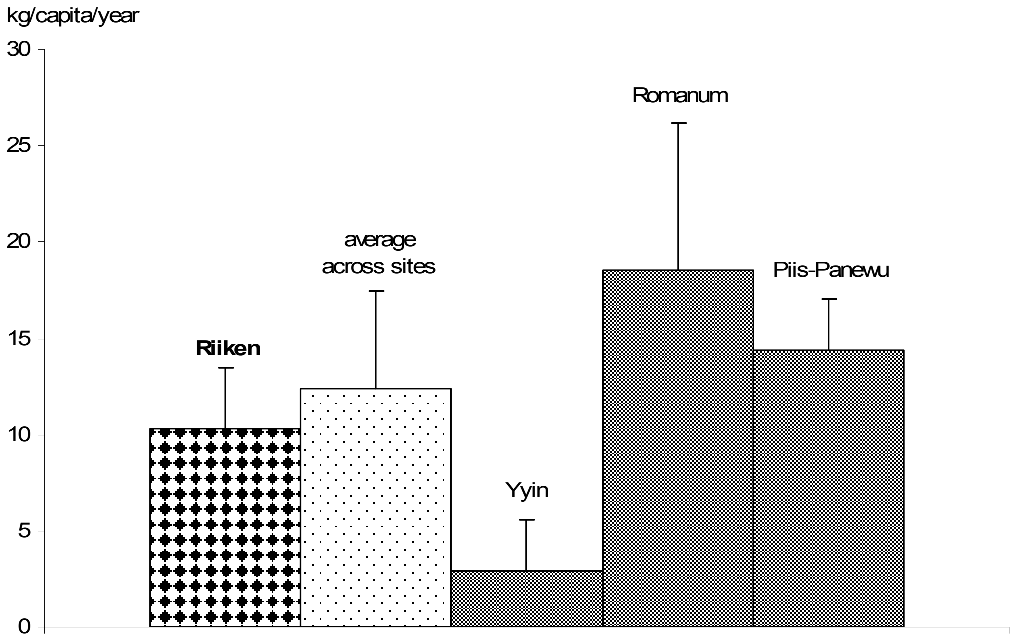

Figure 3.4: Per capita consumption (kg/year) of invertebrates (meat only) in Riiken (n = 28) compared to the average across sites and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparison of results between Riiken and the average of all other CoFish sites studied in FSM (Table 3.1) suggests that the people of Riiken are much less dependent on fisheries for income generation, and eat smaller amounts of both finfish and invertebrates and less often. However, Riiken's people eat a significant amount of canned fish, much more than the average found across all CoFish study sites in FSM. However, there is not much difference in the average household expenditure levels, and remittances play almost no role in Riiken.

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

Survey coverage	Site (n = 28 HH)	Average across sites (n = 83 HH)
Demography		
HH involved in reef fisheries (%)	89.3	96.4
Number of fishers per HH	1.54 (±0.23)	3.17 (±0.32)
Male finfish fishers per HH (%)	60.5	44.1
Female finfish fishers per HH (%)	2.3	1.1
Male invertebrate fishers per HH (%)	2.3	0.4
Female invertebrate fishers per HH (%)	20.9	27.0
Male finfish and invertebrate fishers per HH (%)	14.0	24.0
Female finfish and invertebrate fishers per HH (%)	0.0	3.4
Income		
HH with fisheries as 1st income (%)	0.0	48.2
HH with fisheries as 2nd income (%)	10.7	4.8
HH with agriculture as 1st income (%)	14.3	8.4
HH with agriculture as 2nd income (%)	35.7	20.5
HH with salary as 1st income (%)	67.9	34.9
HH with salary as 2nd income (%)	0.0	4.8
HH with other sources as 1st income (%)	17.9	9.6
HH with other sources as 2nd income (%)	3.6	10.8
Expenditure (USD/year/HH)	3302.22 (±364.39)	3751.42 (±249.95)
Remittance (USD/year/HH) (1)	425.00 (±165.20)	1095.71 (±256.43)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	43.99 (±7.33)	62.54 (±5.01)
Frequency fresh fish consumed (times/week)	2.28 (±0.30)	3.67 (±0.21)
Quantity fresh invertebrate consumed (kg/capita/year)	10.28 (±3.19)	12.40 (±5.01)
Frequency fresh invertebrate consumed (times/week)	0.36 (±0.08)	1.08 (±0.13)
Quantity canned fish consumed (kg/capita/year)	47.21 (±6.31)	23.87 (±3.14)
Frequency canned fish consumed (times/week)	3.98 (±0.34)	2.68 (±0.23)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	57.1	74.7
HH eat canned fish (%)	100.0	91.6
HH eat fresh fish they catch (%)	85.7	100.0
HH eat fresh fish they buy (%)	17.9	0.0
HH eat fresh fish they are given (%)	92.9	38.9
HH eat fresh invertebrates they catch (%)	57.1	100.0
HH eat fresh invertebrates they buy (%)	0.0	0.0
HH eat fresh invertebrates they are given (%)	3.6	33.3

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

3.2.2 Fishing strategies and gear: Riiken

Degree of specialisation in fishing

Fishing in Riiken is performed by both males and females (Figure 3.5). However, 68% of all fishers target exclusively finfish and these fishers are males only. Only a few (2%) females fish for finfish and only 17% collect invertebrates. There are hardly any male fishers who specialise in invertebrates only (~1–2%) but another 11% of male fishers target invertebrates in combination with finfish fishing.

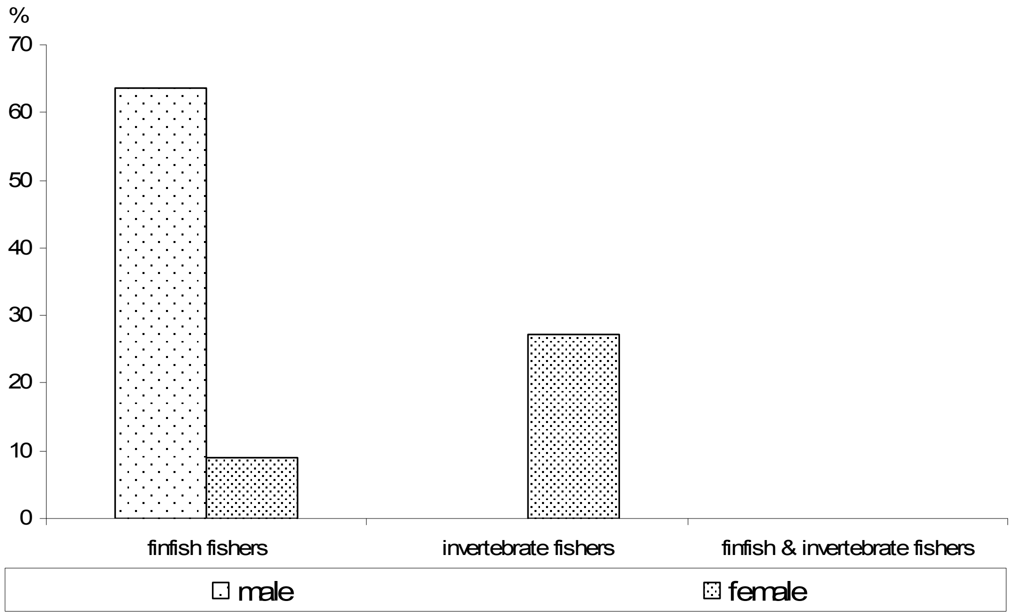

Figure 3.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Riiken.
All fishers = 100%.

Targeted stocks/habitat

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

Resource	Fishery / Habitat	% male fishers interviewed	% female fishers interviewed
Finfish	Sheltered coastal reef	90.9	100.0
	Sheltered coastal reef & passage	4.5	0.0
	Mangrove	13.6	0.0
	Outer reef	4.5	0.0
	Passage	4.5	0.0
Invertebrates	Other	75.0	0.0
	Soft bottom & reeftop	25.0	100.0

'Other' refers to the lobster and giant clam fisheries.
Finfish fisher interviews, males: n = 22; females: n = 1. Invertebrate fisher interviews, males: n = 4; females, n = 6.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip is the basic factor used to estimate the fishing pressure imposed by people from Riiken on their fishing grounds (Table 3.2).

Our survey sample suggests that fishers in Riiken can choose among the sheltered coastal reef, outer reef, passages and mangroves. Some combine the sheltered coastal reef and passages in one fishing trip. Most fishers, males and females, however, target the sheltered coastal reef. Only 5–14% of all male fishers target any of the other habitats.

By comparison, invertebrate fisheries are less diverse and, data suggest, less important than finfish fisheries. Seventy per cent of all fishers target jointly the soft benthos and reeftop habitats; the remaining 30% dive mainly for lobsters and giant clams (Figure 3.6). All female fishers glean, while most of the diving is done by males. Thus, invertebrate collection by females is an exclusive combination of soft benthos and reeftop fishery, and males target both soft benthos and reeftop combined in one fishing trip, as well as diving on the reef. The exclusive participation of males in lobster and giant clam diving confirms the generally observed gender separation, i.e. females in the Pacific Islands region hardly ever dive for invertebrates or any seafood but engage in gleaning fisheries for invertebrates (Figure 3.7).

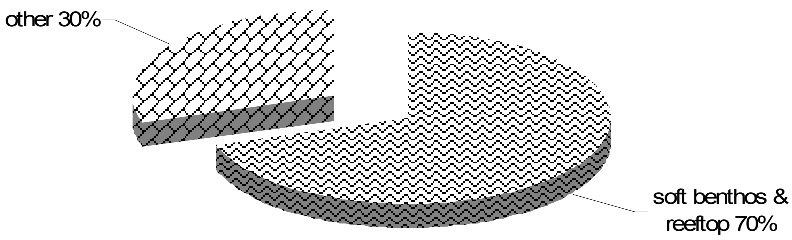

Figure 3.6: Proportion (%) of fishers targeting the two primary invertebrate habitats found in Riiken.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the lobster and giant clam fisheries.

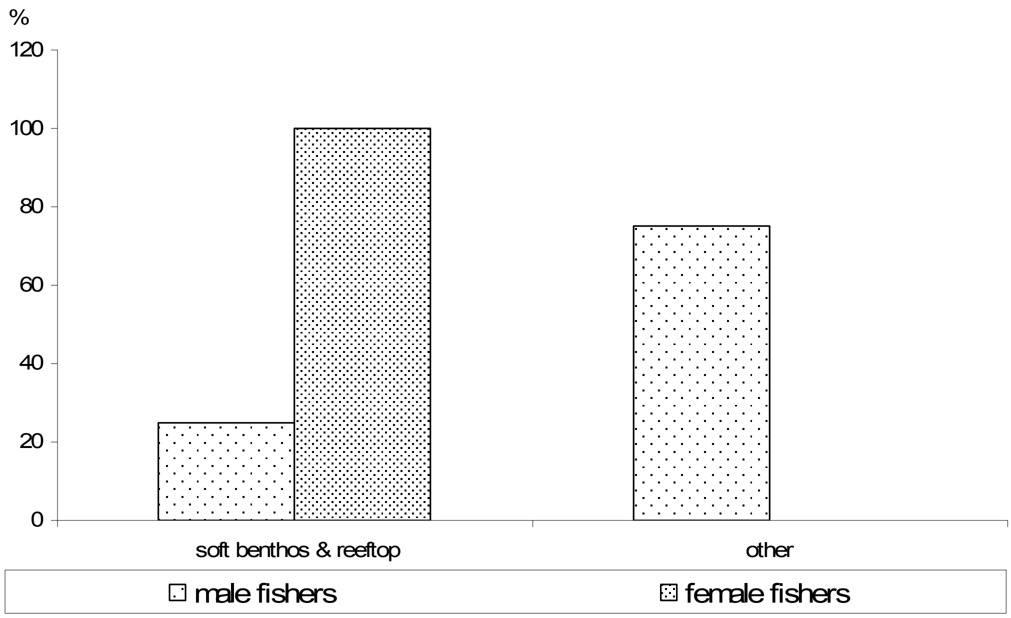

Figure 3.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Riiken.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers that target each habitat: n = 4 for males, n = 6 for females; 'other' refers to the lobster and giant clam fisheries.

Gear

Figure 3.8 shows that fishing methods vary considerably according to the habitats targeted. For example, most fishers who visit the sheltered coastal reef use many techniques: castnets, handlines, spearing and gillnets, with spear diving perhaps the most prominent. If fishers venture out further, either fishing both the sheltered coastal reef and passages in the same trip, or fishing the passages or the outer reef separately, techniques are more distinct: gillnet and spear diving in the combined sheltered coastal reef and passages, spear diving and trolling in the outer reef and spear diving in the passages. Spear diving and handheld spears are used for mangrove fishing. While the sheltered coastal reef and mangroves are hardly ever visited with canoes, trips to the passages and the outer reef mostly require boat transport.

Gleaning and free diving for invertebrates are done using very simple tools only. Lobsters and giant clams are picked up by hand, perhaps using a screwdriver or rod to break loose giant clams. Diving does not involve any gear other than mask, snorkel and possibly fins. Motorised boats are only often used for diving trips for lobsters and giant clams. All other collection activities are done by walking only.

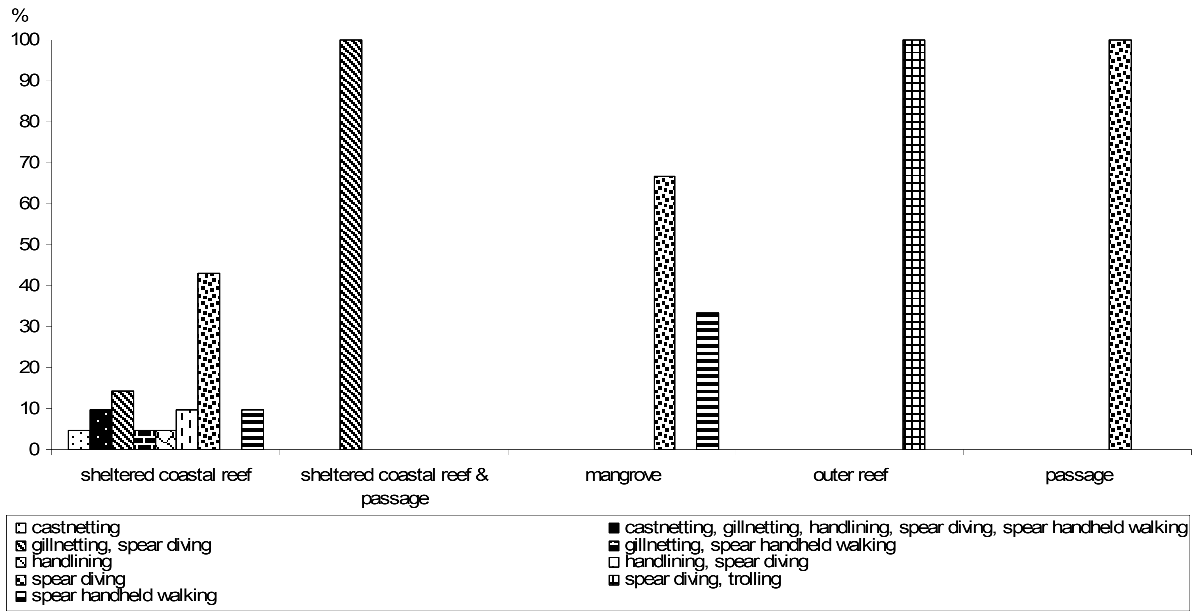

Figure 3.8: Fishing methods commonly used in different habitat types in Riiken.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

As shown in Table 3.3 the frequency of fishing trips is highest the closer the fishing grounds are to the shore. Accordingly, fishers targeting the sheltered coastal reef go usually once a week while those fishing in passages or at the outer reef may do so only once or twice a month. On average a fishing trip takes 2 hours whether targeting the sheltered coastal reef or the passages. However, fishing trips to the outer reef take longer and last on average 4.5 hours each. Invertebrates are collected at most once a week and trips take 3–4 hours each.

Finfish is usually caught according to the tide; hence, fishers may go out during the day or night with a slight preference for night fishing. The same applies to invertebrate collection and diving for lobster and giant clams, with a slight preference for collecting giant clams at night.

While most finfish fishers do not fish all year long, invertebrate fishers continue throughout the year.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.04 (±0.16)	0.06 (n/a)	2.50 (±0.25)	2.00 (n/a)
	Sheltered coastal reef & passage	3.00 (n/a)	0	2.00 (n/a)	0
	Mangrove	1.17 (±0.44)	0	2.00 (±0.58)	0
	Outer reef	0.23 (n/a)	0	4.50 (n/a)	0
	Passage	0.50 (n/a)	0	2.00 (n/a)	0
Invertebrates	Other	0.49 (±0.26)	0	3.00 (±0.76)	0
	Soft benthos & reeftop	1.00 (n/a)	0.61 (±0.11)	4.00 (n/a)	1.67 (±0.21)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the lobster and giant clam fisheries.
Finfish fisher interviews, males: n = 23; females: n = 1. Invertebrate fisher interviews, males: n = 4; females: n = 6.

3.2.3 Catch composition and volume – finfish: Riiken

Catches from the sheltered coastal reef include a variety of different fish species and species groups. The main species *Naso unicornis*, *Acanthurus gahhm* and *Chlorurus* spp. each represent 12–14% of the total annual reported catch. Mangrove catches are less diverse, mainly comprising three species groups, including Acanthuridae and Siganidae. The *Caranx* spp. reported may come, not from the mangroves, but from the adjacent areas. *Acanthurus* spp., *Caranx* sp., *Naso unicornis* and *Scarus* spp. determine the catches at the outer reef, all of which are mainly targeted by spear diving. Catches reported for passage fishing are comparable. (Detailed data are provided in Appendix 2.2.1.).

Our survey sample of finfish fishers interviewed represents only about 32% of the projected total number of finfish fishers in Riiken. However, the survey included all commercial and subsistence fishers. Hence, we have extrapolated our results to estimate the total annual fishing pressure imposed by the people of Riiken on their fishing ground. This estimate does not include any possible impact imposed illegally by external fishers.

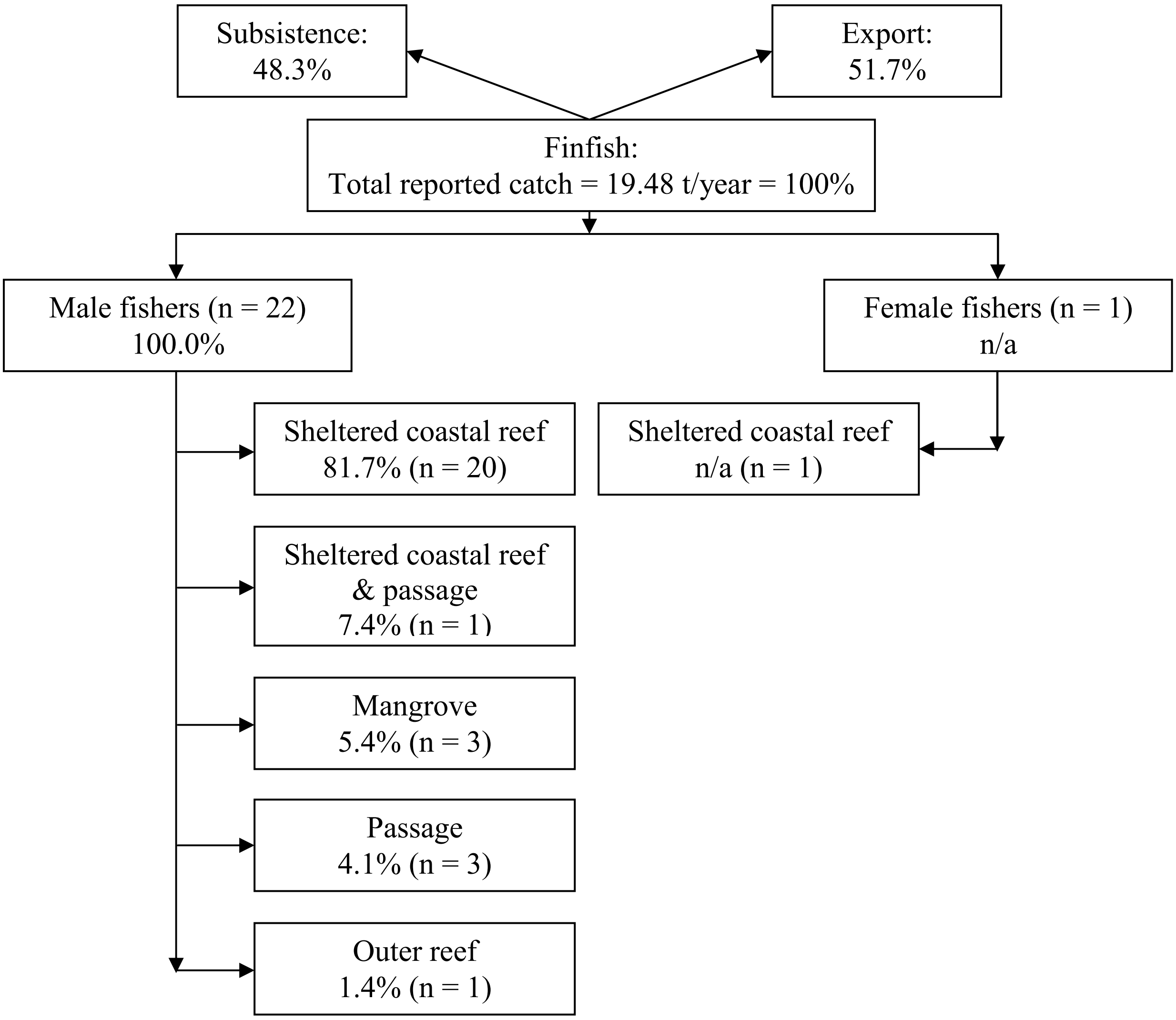

Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Riiken.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey; n/a = no information available.

As shown in Figure 3.9, slightly more than half of the impact is due to commercial reef fishing; i.e. catches that are sold outside the Riiken community account for 52% of the total annual estimated catch (or 10.1 t/year). Subsistence need determines about 48% of all catches, corresponding to a total annual consumption of ~9.4 t. Most of the catch is taken by male fishers; females only play an insignificant role (<1%). Highest pressure is imposed on the combined sheltered coastal reef area, with a minor impact on passages, mangroves and outer reef (~15% of the total annual catch).

The high impact on the combined sheltered coastal reef and lagoon resources is a function of the number of fishers targeting these areas as well as the average annual catch rate. As shown in Figure 3.10, average annual catches range from 100 to 650 kg/year/fisher and, at the sheltered coastal reef, fishers take on average ~350 kg/year each. Comparison among the different habitats suffers from the small sample sizes of passage and outer-reef fishers. However, it is obvious that mangrove fishers catch much less on average than those who fish the sheltered coastal reef.

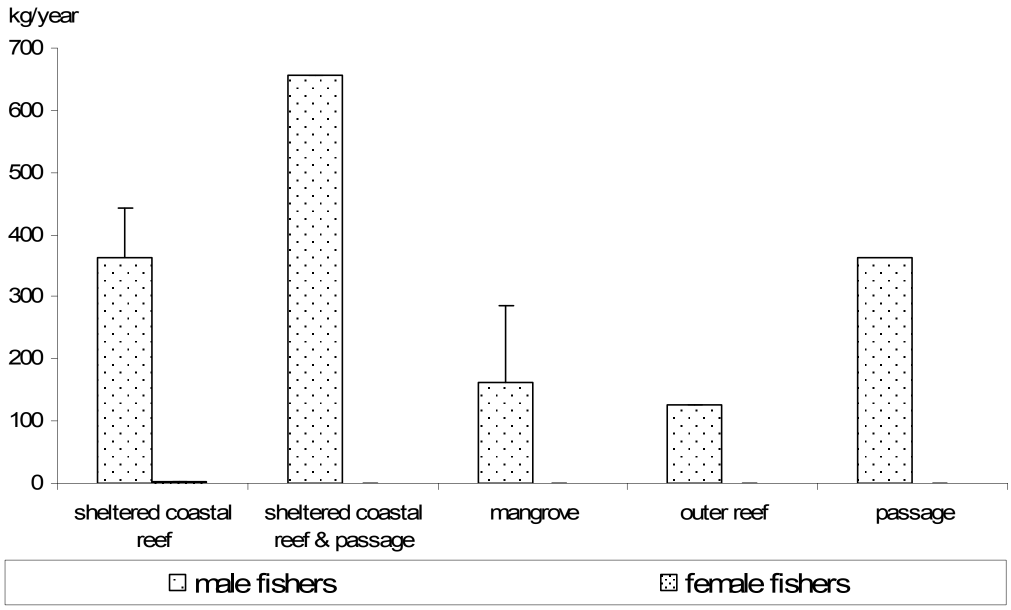

Figure 3.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Riiken.
Bars represent standard error (+SE).

However, comparing the CPUE calculated for the different habitats fished, there does not seem to be much difference in CPUE among the sheltered coastal reef and others. The high CPUE shown for the outer reef may be misleading because of the limited sample size. Because only one female fisher was interviewed, no comparison between CPUEs of male and female fishers can be made.

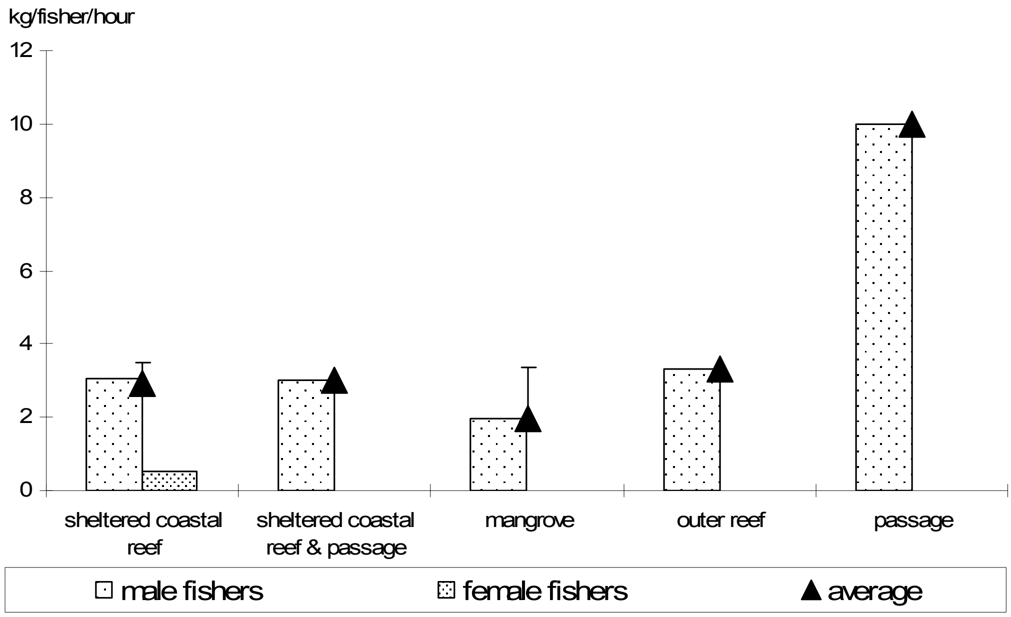

Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Riiken.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Survey data show that most catch from passages and outer reef is intended for sale outside the Riiken community. Mangrove and sheltered coastal reef fishing is mostly done to satisfy subsistence needs. The share of catch caught for non-monetary distribution among community members usually equals the share caught for subsistence purposes (Figure 3.12).

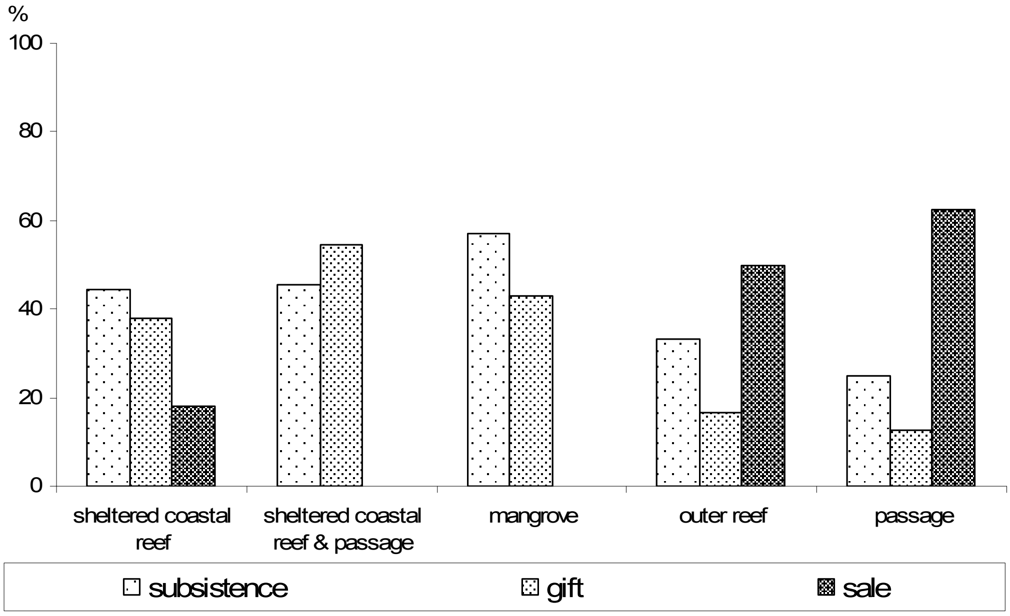

Figure 3.12: The use of finish catches for subsistence, gift and sale, by habitat in Riiken.
Proportions are expressed in % of the total number of trips per habitat.

Data on the average reported finfish sizes by family and habitat (Figure 3.13) shows an increasing trend in average fish size from the sheltered coastal reef towards the outer reef, for Acanthuridae, Carangidae and Scaridae. Average fish sizes reported from sheltered coastal reef, combined sheltered coastal reef and passage, and mangrove catches do not seem to vary considerably. Lethrinidae and Siganidae may be exceptions as they are on average much smaller if caught in the mangroves. Overall, average fish sizes are relatively small, mostly 20–25 cm.

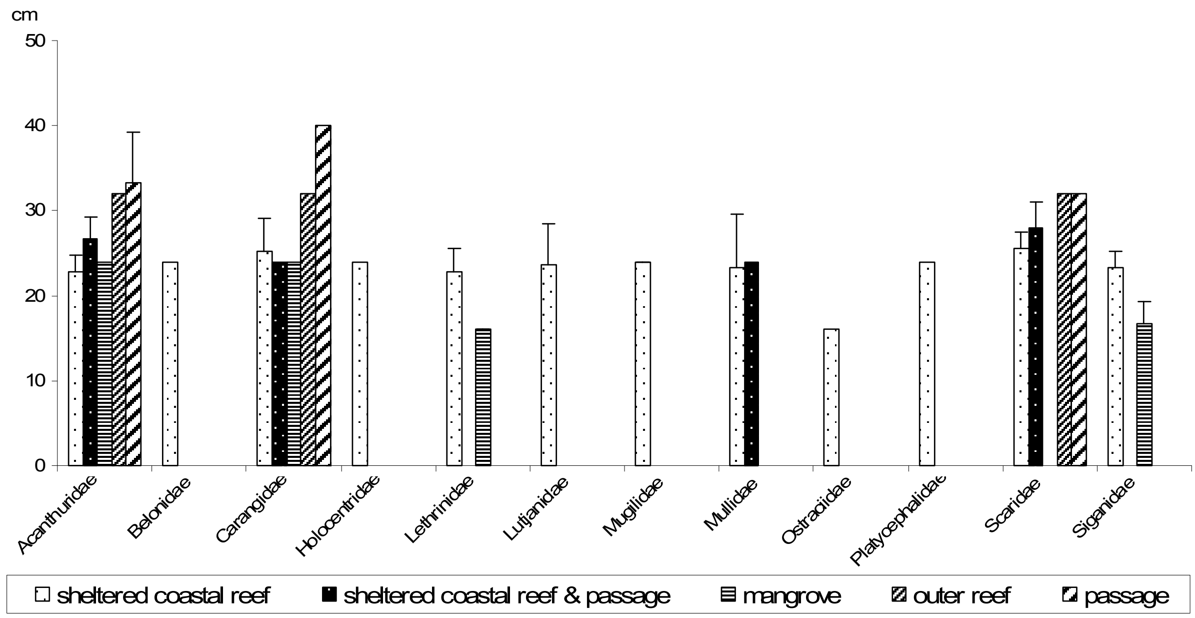

Figure 3.13: Average sizes (cm fork length) of fish caught by family and habitat in Riiken.
Bars represent standard error (+SE).

Some parameters selected to assess the current fishing pressure on Riiken's living reef resources are shown in Table 3.4. The comparison of habitat surfaces that are included in Riiken's fishing ground show that the sheltered coastal reef area determines most of the total reef and total fishing ground areas. Considering that most fishers in Riiken target the sheltered coastal reef and mangrove areas, a very high fisher density results for the mangrove habitat, due to its small area. If fishers were equally using all the available fishing ground, fisher density would drop to a low level. Overall, population density is low, 17 people/km² of total reef and total fishing ground. If we take into account a moderate per capita fish consumption, these observations suggest that fishing pressure on the community's inshore resources is higher than on the outer reef and passages.

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

Parameters	Habitat						
	Sheltered coastal reef & lagoon	Sheltered coastal reef & passage	Mangrove	Passage	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	10.02	n/a	0.09	0.33	2.44	11.58	12.79
Density of fishers (number of fishers/km^2 fishing ground) (1)	4		78	6	2	5	5
Population density (people/km^2) (2)						17	17
Average annual finfish catch (kg/fisher/year) (3)	345.66 (±77.15)	655.77 (n/a)	161.15 (±125.64)	361.90 (n/a)	124.93 (n/a)		
Total fishing pressure of subsistence catches (t/km^2)						1	1

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers (= 58) is extrapolated from household surveys; (2) total population = 171; total subsistence demand = 8.22 t/year; (3) catch figures are based on recorded data from survey respondents only.

3.2.4 Catch composition and volume – invertebrates: Riiken

Calculations of the recorded annual catch rates per species groups are shown in Figure 3.14. The graph shows that the major impact by wet weight is mainly due to lobster catches (*Panulirus penicillatus*). By comparison, catches reported for giant clams, *Gafrarium* spp. and *Nerita polita* are of minor if not insignificant importance. In addition, only five other species or species groups were recorded (Detailed data are provided in Appendices 2.2.2 and 2.2.3.).

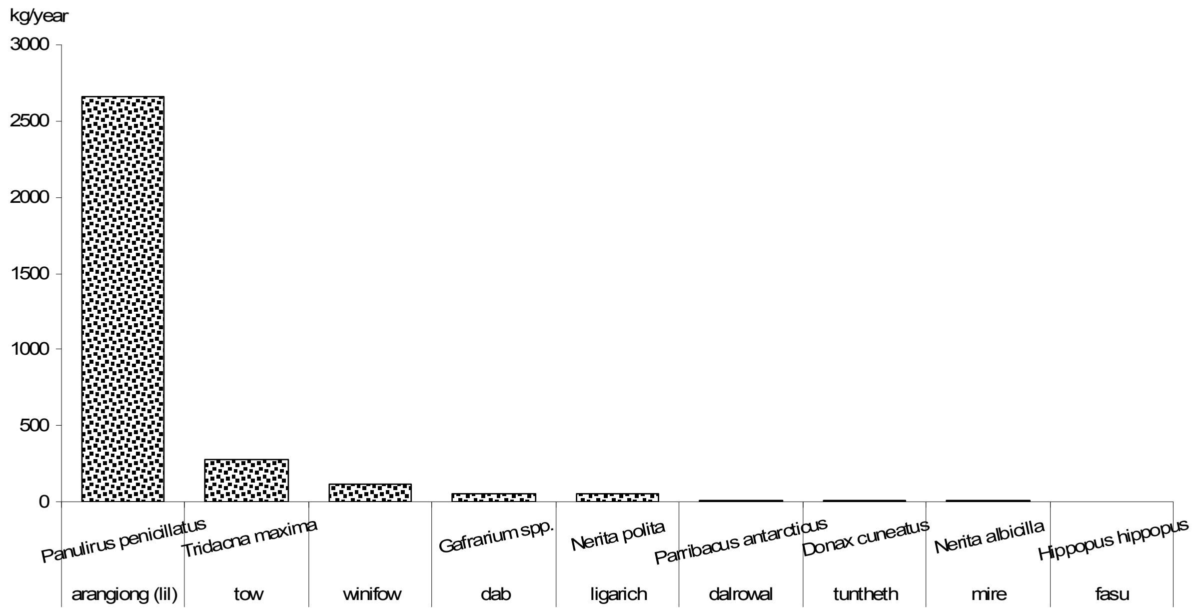

Figure 3.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Riiken.

As already stated, invertebrate fisheries are limited and not of great importance in Riiken. Accordingly, the limited biodiversity reported for catches is not surprising. Catches from the combined soft benthos and reeftop were mainly characterised by seven vernacular names and 'other' dive fisheries (mainly targeting lobsters and giant clams) were described by four vernacular names (Figure 3.15).

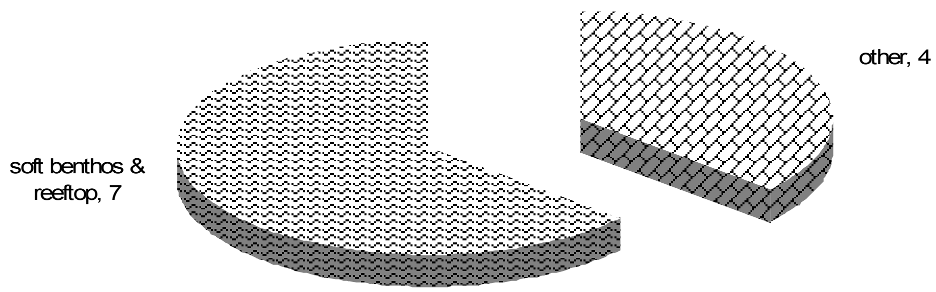

Figure 3.15: Number of vernacular names recorded for each invertebrate fishery in Riiken.
'Other' refers to the lobster and giant clam fisheries.

Figure 3.16 shows that highest average annual catches by wet weight are taken from the combined soft-benthos and reeftop fishery, with over 400 kg/fisher/year on average. Lobster and giant clam divers collect <100 kg/fisher/year. Surprisingly, female fishers jointly targeting soft-benthos and reeftop areas have by far the highest catches.

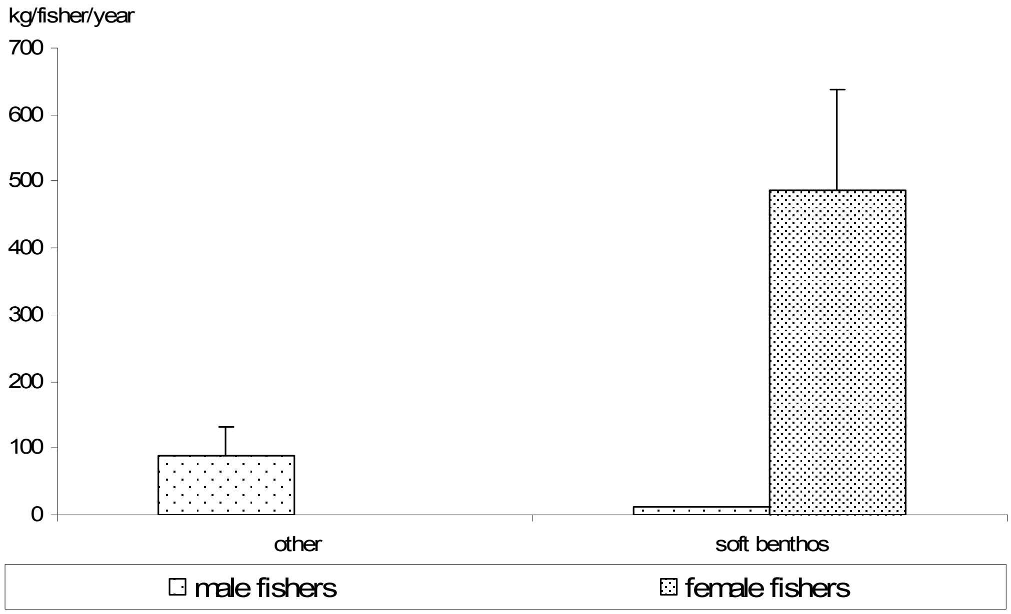

Figure 3.16: Average annual invertebrate catch (kg wet weight/year) by fisher and gender in Riiken.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 4 for males, n = 6 for females). 'Other' refers to the lobster and giant clam fisheries.

In contrast to finfish fisheries, invertebrate fisheries are mainly pursued for subsistence purposes, and the share sold outside the Riiken community is almost negligible (Figure 3.17). It is thus concluded that the current impact of fishing on Riiken's invertebrate resources is determined by the consumption needs of the community.

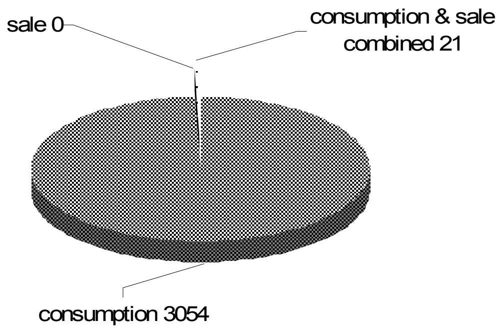

Figure 3.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Riiken.

The total annual catch volume (expressed in wet weight based on recorded data from all respondents interviewed) amounts to 3.08 t/year (Figure 3.18). Catches from combined soft-benthos and reeftop gleaning are prominent, representing ~91% of the total reported annual catch. Other catches (lobsters and giant clams) determine the remaining 9%. While catches from soft benthos and reeftop are taken by female fishers, dive catches are exclusively taken by male fishers.

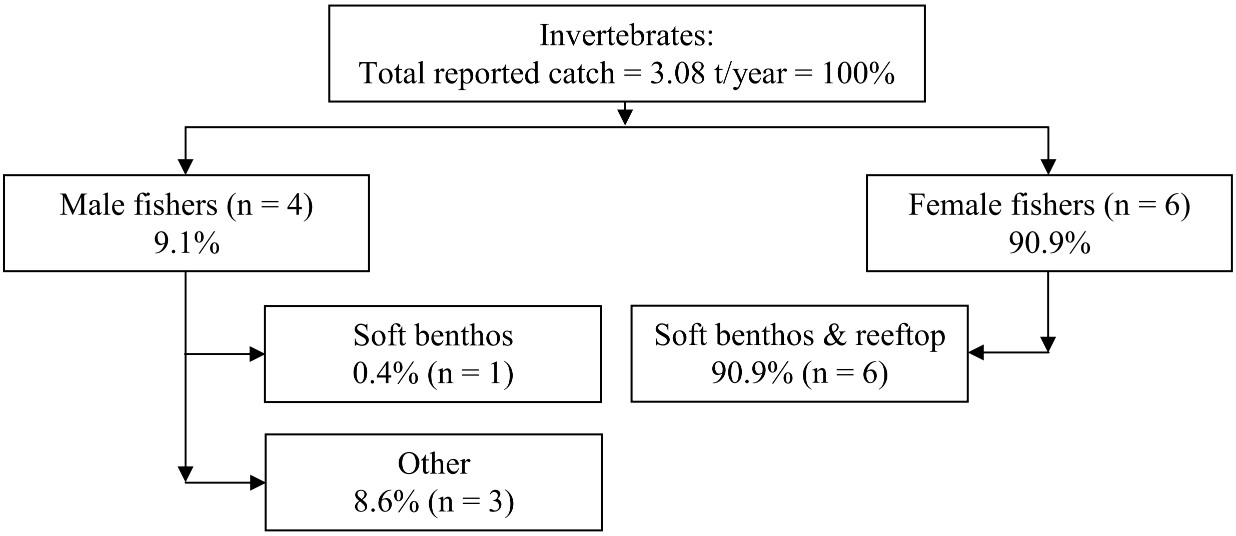

Figure 3.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Riiken.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

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

Parameters	**Fishery / Habitat**	
	Soft benthos & reeftop	**Other**
Fishing ground area (km^2)	2.12	7 [(3)]
Number of fishers (per fishery) [(1)]	15	7
Density of fishers (number of fishers/km^2 fishing ground)	7	1
Average annual invertebrate catch (kg/fisher/year) [(2)]	401.41 (±145.83)	88.44 (±42.70)

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)] reef length.

The parameters presented in Table 3.5 show a high variability in the size of the available fishing grounds for the various fisheries. However, generally speaking, the combined soft benthos and reeftop habitat is small, while the available reef length for lobster and giant clam harvesting seems to be more favourable, with a length of ~7 km. Taking into consideration the average recorded annual catch per fisher (wet weight) and the density of fishers, fishing pressure on the combined soft benthos and reeftop resources is moderate and much higher than on the lobster and giant clam resources alone. Fishing pressure calculated only for the proportion of lobsters and giant clams caught at the outer reef does not give any cause for alarm, either in terms of fisher density or average annual reported catch. However, if regarded by species groups only, the highest overall pressure exists on lobsters, and the greatest share of the reported annual catches comes from the reeftop fishery.

3.2.5 Discussion and conclusions: socioeconomics in Riiken

- Fisheries are not an important sector for income generation in Riiken. Only 11% of all households reported that they obtain secondary income from fisheries. In contrast, salaries are of highest importance, complemented by income from agriculture and other sources, such as small business and retirement and other social fees.

- All households eat fresh fish and more than half also eat invertebrates regularly. Fresh-fish consumption (44 kg/person/year) is above the regional average but below the average across all study sites in FSM. Although to a lesser extent, the same observation is true for invertebrate consumption (10 kg/person/year). Canned fish consumption is much higher than average (47 kg/person/year).

- The average household expenditure level is not of particular note, other than to mention that people in Riiken combine traditional and cash-based economic values. Remittances do not play any role.

- Most finfish fishing is done by males, while females are responsible for collecting invertebrates. Finfish fishers mainly target the sheltered coastal reefs and hardly ever venture out to the outer reef. Invertebrate fishers focus on collecting from the combined soft benthos and reeftop, as well as on harvesting lobsters and giant clams along the reef. A very small proportion of the invertebrate catch (mostly lobsters) is caught for sale outside the community. However, overall, Riiken's invertebrate fisheries are not conducted for sale.

- Finfish fishing uses various techniques, including castnets, gillnets, handlines and spears, but invertebrate fisheries mainly involve the use of simple tools. Most fishing is done without any boat transport, except for outer-reef and passage fishing, which requires paddle canoes.

- Highest fishing pressure exists on the mangroves. This is due to the high fisher density rather than the annual catch rates. Indicators of fishing pressure, such as fisher density and average annual catch rates for sheltered coastal reef, passages or outer-reef fishing, are low. This observation also applies to fishing pressure per total reef and total fishing ground areas. Population density and fisher density per total fishing ground are also low. CPUEs for sheltered coastal reef and lagoon fishing do not substantially vary from those reported for outer-reef fishing. The only outstandingly high CPUEs were recorded for passage fishers; however, results may be biased due to the small sample size. Average fish sizes of Acanthuridae, Carangidae and Scaridae were observed to follow an increasing trend from the nearshore habitats to the outer reef. This suggests that the resources at the outer reef may be less impacted than resources in the sheltered coastal reef and lagoon.

- Invertebrate fisheries mainly serve the subsistence needs of the Riiken community. Highest fishing pressure is observed for the combined resources of the soft-benthos and reeftop fisheries, and for lobsters. In fact, if regarding the total annual catch reported by wet weight it is obvious that lobsters also determine most of the catches reported for the combined harvesting of soft benthos and reeftops. Here fisher density and reported annual catches by wet weight are highest.

- The above observations result in two major conclusions. Firstly, based on fisher and population densities, the current pressure on finfish resources in Riiken is only moderate. However, based on the total annual catches reported by habitat, fishing pressure on the sheltered coastal reef resources appears to be high. The fact that average finfish sizes for certain families are smaller in catches from the sheltered coastal reef than in catches from the outer reef may suggest that fishing pressure close to the shore is high. As for invertebrate fisheries, fisher densities seem to be only moderate. However, if we consider that most of the reported annual catch is accounted for by lobsters, present fishing pressure on this particular resource may be high and needs monitoring. The fact that neither finfish nor invertebrate fisheries represent important income sources for the community members may make easy any future monitoring and, if necessary, the establishment of necessary fisheries management regulations (*tabu*, temporal closure, size limits, etc.). There is no reason to assume that fishing pressure on any other invertebrate resources has reached an alarming level. However, historical trends and the natural potential of the available habitats need to be taken into account before final conclusions are drawn. The limited size of the available fishing ground for the Riiken community and the relatively high consumption needs of the local community give reason to believe that inshore finfish resources are under a relatively high pressure. The already established MPA area nearby may help to release pressure and help conservation and improvement of local conditions. The effects of the MPA on the resource status and thus fishing potential of the local fishing ground need monitoring.

3.3 Finfish resource surveys: Riiken, YAP

Finfish resources and associated habitats were assessed in Riiken on 21–29 April 2005, from a total of 25 transects (6 sheltered coastal, 4 intermediate-, 9 back- and 6 outer-reef transects; see Figure 3.19 for transect locations and Appendix 3.2.1 for coordinates.).

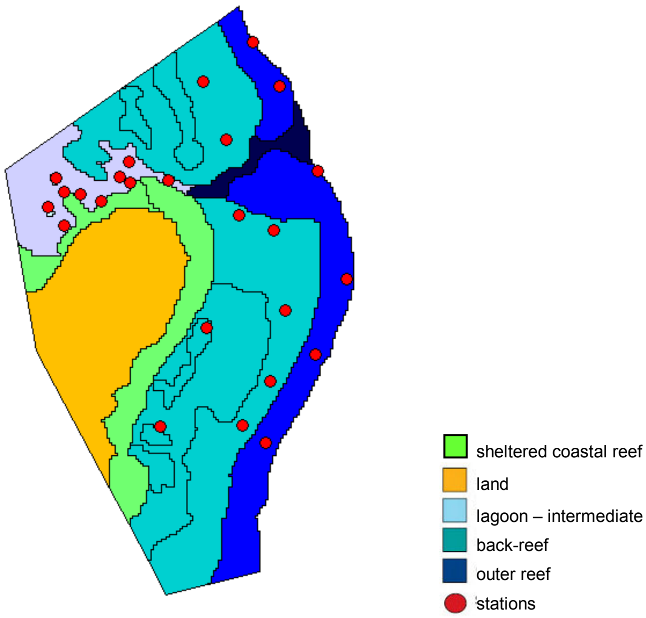

Figure 3.19: Habitat types and transect locations for finfish assessment in Riiken.

3.3.1 Finfish assessment results: Riiken

A total of 22 families, 56 genera, 155 species and 9183 fish were recorded in the 23 transects (See Appendix 3.2.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 47 genera, 141 species and 9081 individuals.

Finfish resources varied slightly among the four reef environments found in Riiken (Table 3.6). The outer reef contained the highest density, size, biomass and biodiversity (0.9 fish/m^2, 17 cm FL, 163 g/m^2, 47 species/transect) among the four habitats, while intermediate reefs displayed the lowest values of such parameters. Back-reefs displayed values only slightly lower than outer reefs (0.8 fish/m^2 and 116 g/m^2 for density and biomass respectively, average size 16 cm FL and biodiversity 40 species/transect). Sheltered coastal reefs had values intermediate between back-reefs and lagoon reef. When compared to the other Yap site, biological parameters at Riiken were slightly poorer in the outer reefs and slightly better in the back-reef.

Table 3.6: Primary finfish habitat and resource parameters recorded in Riiken (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	4	9	6	25
Total habitat area (km^2)	1.3	0.01	6.1	2.3	9.6
Depth (m)	6 (1-14) (3)	7 (1-14) (3)	3 (1-10) (3)	9 (4-15) (3)	5 (1-15) (3)
Soft bottom (% cover)	16 ±5	10 ±6	12 ±4	1 ±1	10
Rubble & boulders (% cover)	2 ±1	15 ±12	3 ±1	1 ±1	3
Hard bottom (% cover)	52 ±7	41 ±7	52 ±6	68 ±5	55
Live coral (% cover)	30 ±3	33 ±10	31 ±4	30 ±4	31
Soft coral (% cover)	0 ±0	0 ±0	1 ±1	0 ±0	1
Biodiversity (species/transect)	34 ±3	29 ±6	40 ±2	47 ±7	39 ±2
Density (fish/m^2)	0.4 ±0.0	0.3 ±0.1	0.8 ±0.1	0.9 ±0.1	0.8
Biomass (g/m^2)	16 ±1	15 ±1	16 ±0	17 ±1	16
Size (cm FL) (4)	55 ±2	56 ±3	56 ±2	58 ±2	56
Size ratio (%)	58.1 ±6.7	39.5 ±13.5	115.9 ±21.6	162.5 ±38.7	119.0

(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: Riiken

The sheltered coastal reef environment of Riiken was dominated by two major herbivorous families: Acanthuridae and Scaridae, and by three carnivorous families: Chaetodontidae in terms of density only and Lutjanidae and Lethrinidae in terms of biomass only (Figure 3.20). The four major families were represented by 48 species; particularly high abundance and biomass were recorded for *Chlorurus sordidus*, *Ctenochaetus striatus*, *Scarus oviceps*, *Lutjanus gibbus*, *S. dimidiatus* and *Lethrinus harak* (Table 3.7). This reef environment presented a moderately diverse habitat with hard bottom predominating (52%), high cover of live corals (30%), and relatively little mobile bottom (18% for soft bottom and rubble together) (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 Riiken

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.09 ±0.03	6.3 ±2.3
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06 ±0.01	10.9 ±1.8
	Scarus oviceps	Dark-capped parrotfish	0.01 ±0.01	3.4 ±3.0
	Scarus dimidiatus	Yellow-barred parrotfish	0.02 ±0.01	3.1 ±1.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.01 ±0.00	3.4 ±2.8
Lethrinidae	*Lethrinus harak*	Thumbprint emperor	0.01 ±0.01	2.9 ±2.6

The size, size ratio and biomass of finfish in the sheltered coastal reefs of Riiken were higher than in the similar habitat in Romanum (the only other site in FSM with coastal habitat). However, density was lower (0.4 versus 0.5 fish/m^2 in Romanum). All biological parameters in this habitat were higher than in the intermediate reefs but lower than in the back- and outer reefs. The trophic structure in Riiken coastal reef was dominated by herbivorous fish, represented mainly by Acanthuridae and Scaridae. Surgeonfish were the most important family in terms of abundance, and mostly represented by *Ctenochaetus striatus*, but parrotfish were the most important in terms of biomass (highest biomass represented by *Chlorurus sordidus*). Both these families were the most-targeted fish in the coastal reefs. High abundance of Chaetodontidae reflected the high live-coral cover at this habitat. Size ratio was low only for Lethrinidae, Mullidae and Serranidae.

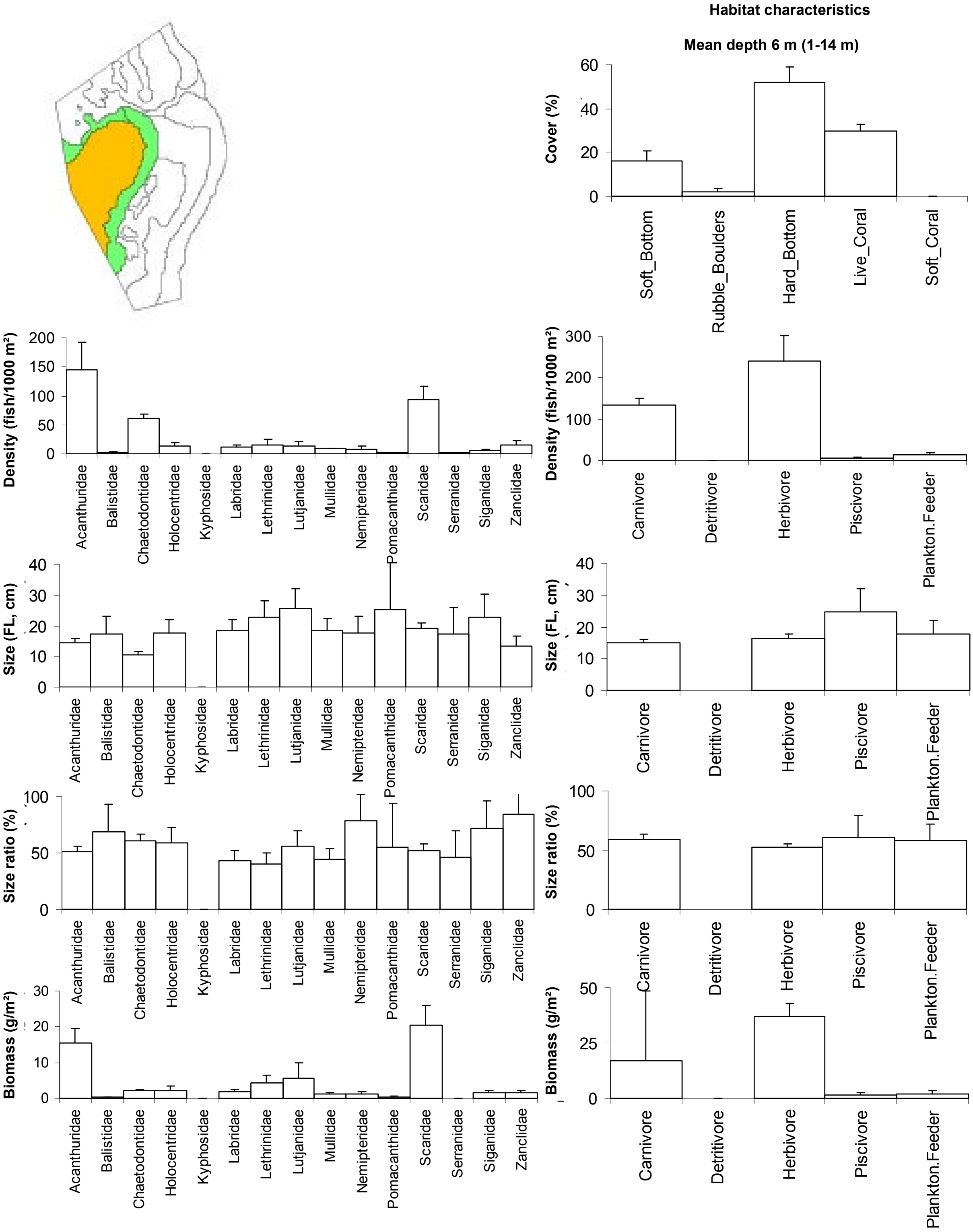

Figure 3.20: Profile of finfish resources in the sheltered coastal reef environment of Riiken.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Riiken

The intermediate-reef environment of Riiken was dominated by four families: the herbivores Acanthuridae and Scaridae and the carnivores Chaetodontidae and Mullidae (only in terms of density) (Figure 3.21). The three major families were represented by 35 species; particularly high biomass and abundance were recorded for *Chlorurus sordidus*, *Ctenochaetus striatus*, *Scarus niger*, *Zebrasoma scopas*, *S. psittacus* and *Mulloidichthys flavolineatus* (Table 3.8). This reef environment presented a diverse habitat with high cover of hard bottom (41%), relatively high cover of mobile bottom (25%) and high live-coral cover (33%, Table 3.8). However, this reef habitat was only represented by a very small surface area (0.01 km^2, 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 Riiken

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05 ±0.03	3.8 ±2.1
	Zebrasoma scopas	Twotone tang	0.05 ±0.02	2.1 ±0.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.03 ±0.01	8.2 ±4.1
	Scarus niger	Black parrotfish	0.01 ±0.00	2.9 ±1.3
	Scarus psittacus	Common parrotfish	0.02 ±0.01	1.8 ±0.9
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.03 ±0.02	1.8 ±1.2

The density, size, size ratio, biomass and biodiversity of finfish in the intermediate reefs of Riiken were the lowest of the site as well as lower than those of Romanum and Piis-Panewu, the other sites in FSM presenting intermediate reefs (Table 3.6). Size ratio (56%) and biodiversity (29 species/transect) were only higher than the values recorded at Romanum. Herbivores were more abundant and presented much higher biomass than carnivores. Mullidae were the most-represented carnivores. Acanthuridae represented the overall most abundant family, while Scaridae displayed the highest biomass. Average size ratios were relatively low for Lethrinidae and Mullidae (<50%).

The intermediate reefs of Riiken displayed a fairly diverse composition of hard and soft bottom, with also a very high percentage cover of live corals, which hosted a high diversity and abundance of Chaetodontidae.

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

Back-reef environment: Riiken

The back-reef environment of Riiken was dominated by two herbivorous families: Acanthuridae and Scaridae (Figure 3.22). These were represented by 29 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus triostegus*, *Chlorurus sordidus* and *Scarus oviceps* (Table 3.9). This reef environment presented a substrate composition with dominance of hard bottom (52% cover), high live-coral cover (31%) and much lower percentage cover of soft bottom (15%, 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 Riiken

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.19 ±0.04	14.5 ±3.4
	Acanthurus triostegus	Convict tang	0.05 ±0.02	3.5 ±1.3
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.08 ±0.03	16.3 ±4.4
	Scarus oviceps	Dark-capped parrotfish	0.02 ±0.01	6.9 ±2.4

The density, size, size ratio, biomass and biodiversity of finfish in the back-reef of Riiken were lower only to values recorded in the outer reef of the same site. When compared to the other three back-reefs studied in the country, Riiken displayed highest values for all parameters except size (16 cm FL versus 18 cm in Yyin and 19 cm in Piis-Panewu). Trophic composition was highly dominated by herbivores, mostly Acanthuridae and Scaridae. Substrate composition with low percentage cover of soft bottom did not favour invertebrate-eating carnivores, such as Lethrinidae or Mullidae. The back-reef of Riiken was, in fact, mostly composed of hard bedrock and live coral (83% cover when combined).

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

Outer-reef environment: Riiken

The outer reef of Riiken was dominated by two herbivorous families, Acanthuridae and Scaridae and, to a much lesser extent and only in terms of biomass, by one carnivorous family, Lutjanidae (Figure 3.23). These three families were represented by 47 species; particularly high biomass and abundance were recorded for *Bolbometopon muricatum, Ctenochaetus striatus*, *Chlorurus sordidus*, *Acanthurus nigricans*, *A. lineatus*, *Lutjanus gibbus* and *Scarus oviceps* (Table 3.10). Hard bottom largely dominated the habitat of this reef environment (68% cover) and live coral was also present in high cover (30%, Table 3.6 and Figure 3.23). Soft bottom was, on the contrary, practically absent.

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.22 ±0.03	16.9 ±2.6
	Acanthurus nigricans	Whitecheek surgeonfish	0.12 ±0.04	12.7 ±4.1
	Acanthurus lineatus	Lined surgeonfish	0.05 ±0.04	11.1 ±9.3
Scaridae	*Bolbometopon muricatum*	Bumphead parrotfish	0.01 ±0.01	18.8 ±11.6
	Chlorurus sordidus	Daisy parrotfish	0.08 ±0.03	14.3 ±2.5
	Scarus oviceps	Dark-capped parrotfish	0.02 ±0.01	5.5 ±1.8
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.02 ±0.01	10.0 ±6.2

The density, size, biomass and biodiversity of finfish in the outer reef of Riiken were the highest at the site (Table 3.6). When compared to the other country sites, values of density, biomass and biodiversity in Riiken were second only to those in Yyin, but size ratio (56%) was lower than both Yyin (60%) and Romanum (63%) values. Herbivores strongly dominated this habitat, with Acanthuridae and Scaridae in very high numbers. The rare and large-sized *Bolbometopon muricatum* were frequent and abundant. Average size ratios were high and individual families never displayed size ratios below 50%. Substrate composition was of a type favouring herbivores and carnivores associated with hard bottom, such as snappers, here very abundant with *Lutjanus gibbus*. Although the outer reefs were targeted by the lowest fisher density and fewest fishing trips, surgeonfish and parrotfish were found to be the most-targeted families, but they did not yet show any signs of fishing impact.

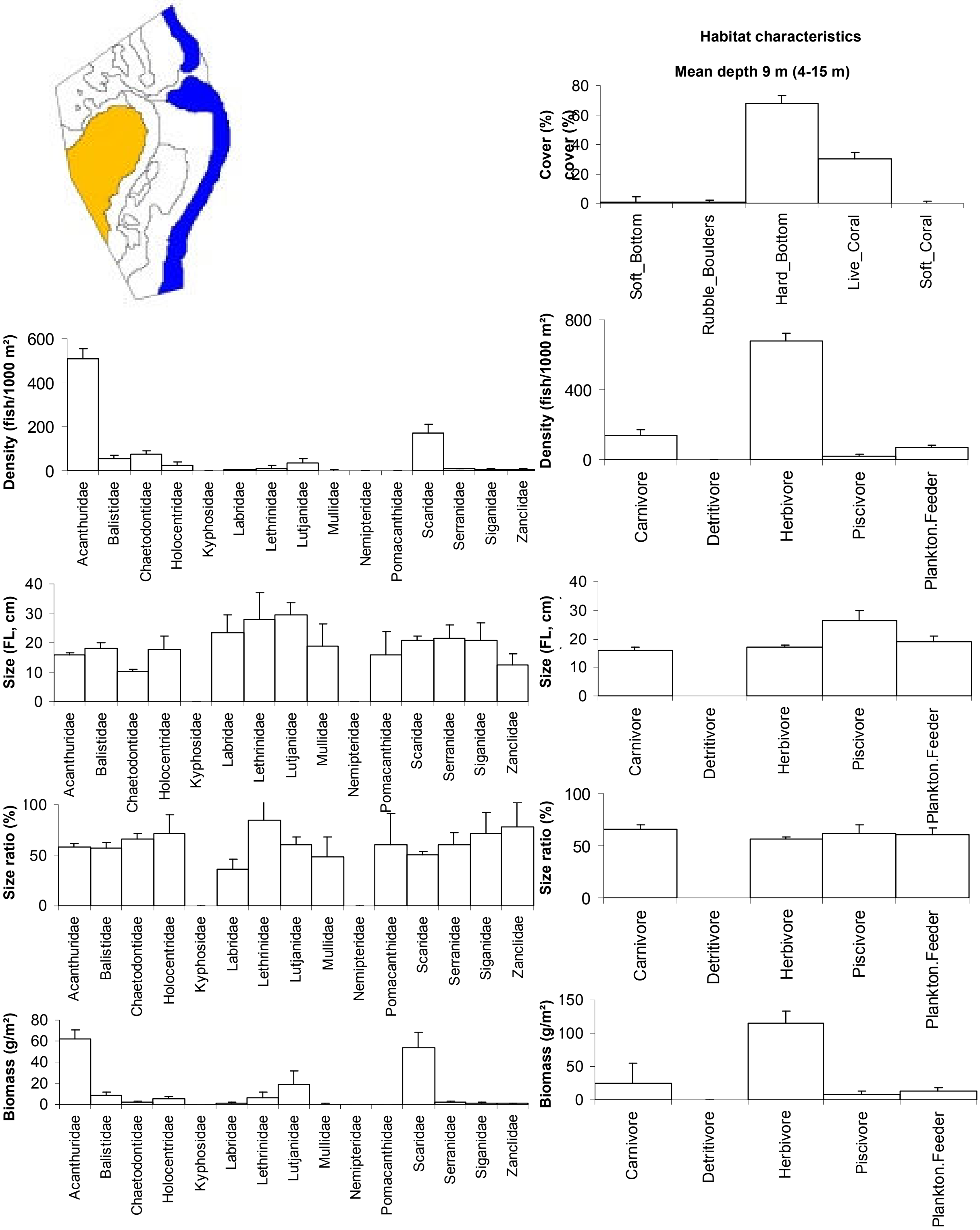

Figure 3.23: Profile of finfish resources in the outer-reef environment of Riiken.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Riiken

Overall, the fish assemblage of Riiken was dominated by two herbivorous families Acanthuridae and Scaridae and, to much lesser extent, the carnivorous families Chaetodontidae (in terms of density only), Lutjanidae and Lethrinidae (in terms of biomass only) (Figure 3.24). The four major families were represented by a total of 82 species, dominated (in terms of biomass and density) by *Chlorurus sordidus*, *Ctenochaetus striatus*, *Scarus oviceps*, *Naso lituratus*, *Acanthurus lineatus*, *A. nigricans*, *S. dimidiatus*, *Gnathodentex aureolineatus* and *Lutjanus gibbus* (Table 3.11). The average substrate was dominated by hard bottom (55%), with high cover of live coral (31%) and a low proportion of mobile bottom (14%). One has to keep in mind that the overall fish assemblage in Riiken shared characteristics primarily of back-reefs (63% of total habitat) and outer reefs (23%). Coastal reefs (13% of habitat) and intermediate reefs (0.1%) had far less influence.

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.18	14.0
	Naso lituratus	Orangespine unicornfish	0.01	5.9
	Acanthurus lineatus	Lined surgeonfish	0.02	5.7
	Acanthurus nigricans	Whitecheek surgeonfish	0.05	4.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.08	15.1
	Scarus oviceps	Dark-capped parrotfish	0.02	6.1
	Scarus dimidiatus	Yellow-barred parrotfish	0.02	4.4
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.01	4.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.01	3.5

Overall, Riiken appeared to support a rather healthy finfish resource, with higher density, biomass, average size and biodiversity than the values recorded in Romanum and Piis-Panewu, and only slightly lower biomass, size and biodiversity compared to Yyin (119 g/m^2 versus 131 fish/m^2, 16 versus 18 cm FL , 56% versus 57%, and 39 versus 41 species/transect, Table 3.6). However, average density was the highest among the four country sites (0.8 fish/m^2) and one of the highest in the region. These results suggest that the finfish resource in Riiken was in good condition. A detailed assessment at the family level revealed a constant dominance of herbivores over carnivores. However, this trend could be explained by the composition of the habitat, mostly composed of hard rock and live coral, with very little percentage cover of soft substrate, which normally favours most invertebrate-feeding carnivores, such as Mullidae and Lethrinidae. Overall, size ratios were high for most families except for Mullidae. A large percentage of catches comes from spearfishing, normally targeting larger fish. However, the impact on Scaridae and Acanthuridae was not yet obvious, at least in terms of average size.

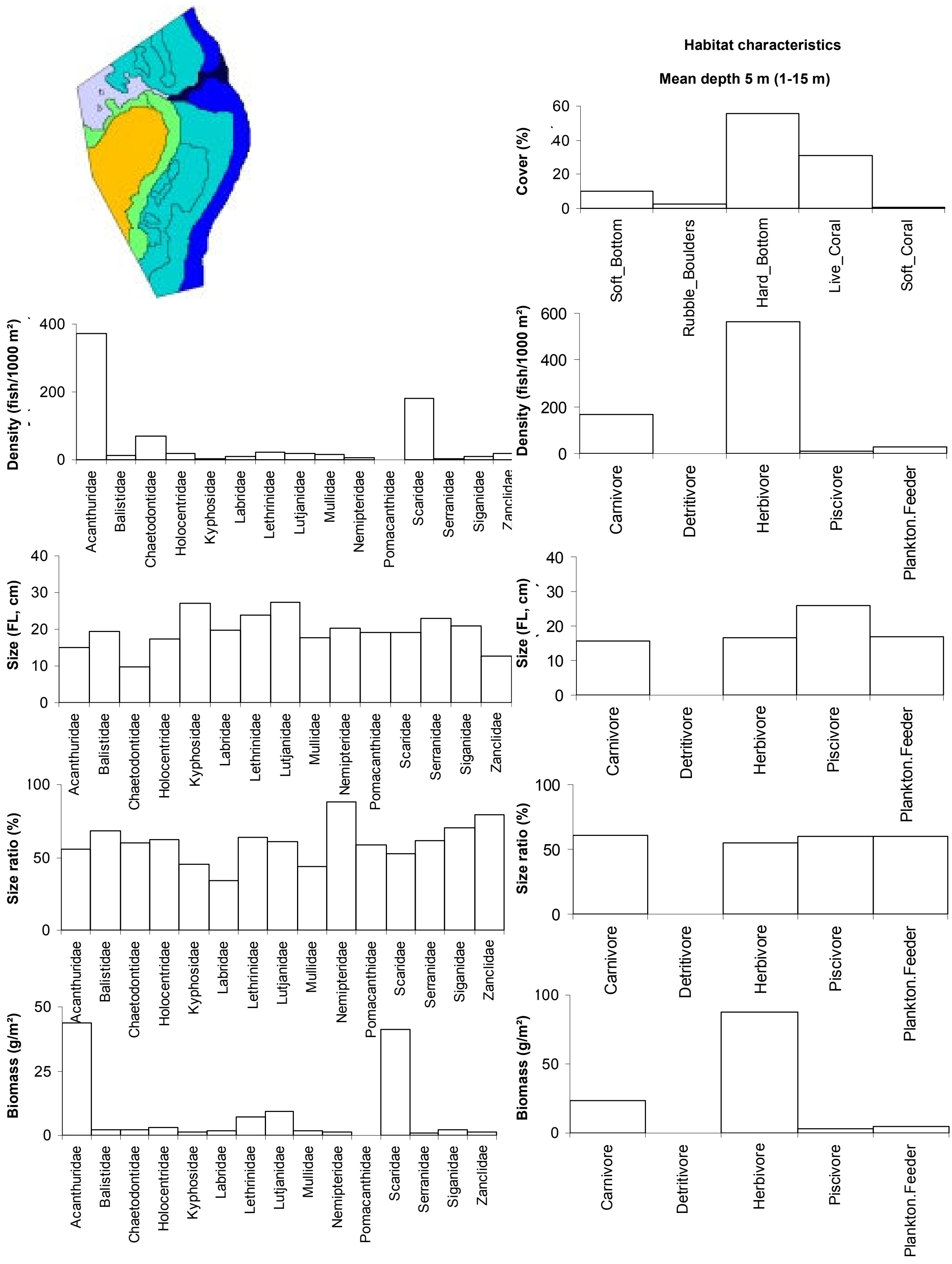

Figure 3.24: Profile of finfish resources in the combined reef habitats of Riiken (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Riiken

The assessment indicated that the status of finfish resources in this site was good. This is due to the naturally rich condition of the reefs, with high live-coral cover. Fish density was, in fact, the highest in the country and biomass the second-highest; biodiversity was high compared to the average for the region. However, when analysed at the reef-habitat level, resources were very variable: coastal reefs as well as the scant intermediate reefs displayed the lowest fish density and biomass at this site. It is in these habitats that most of the fishing is carried out. Therefore, the fisher density is here is fairly high and is causing some changes in the resources, i.e. smaller fish sizes, numbers of fish and number of species. We conclude that, in these habitats, the fishing pressure is rather high and visible in biological parameters.

- Overall, Riiken finfish resources appeared to be in good condition. The reef habitat is naturally rich, although not particularly diverse. The substrate was mostly coral rock, with a large amount of live coral, advantaging selected families of herbivores, such as Acanthuridae and Scaridae, which were dominant here.

- The frequent sightings of large predators (sharks) and rare species, such as *Bolbometopon muricatum*, are further signs of good health.

- The coastal and intermediate reefs displayed the first signs of high fishing pressures in terms of lower density and biomass, size and biodiversity compared to the back-reefs and outer reefs, where fishing occurs much less often.

3.4 Invertebrate resource surveys: Riiken, YAP

The diversity and abundance of invertebrate species at Riiken were independently determined using a range of survey techniques (Table 3.12): broad-scale assessment (using the 'manta tow'; 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 was to describe the distribution pattern of invertebrates (rareness/commonness, patchiness) at large scale and, importantly, to identify target areas for further, fine-scale assessment. Then, fine-scale assessments were conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat.

Table 3.12: Number of stations and replicates completed at Riiken

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	14	84 transects
Soft-benthos transects (SBt)	12	72 transects
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	3	18 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	0	0 search period
Reef-front search 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

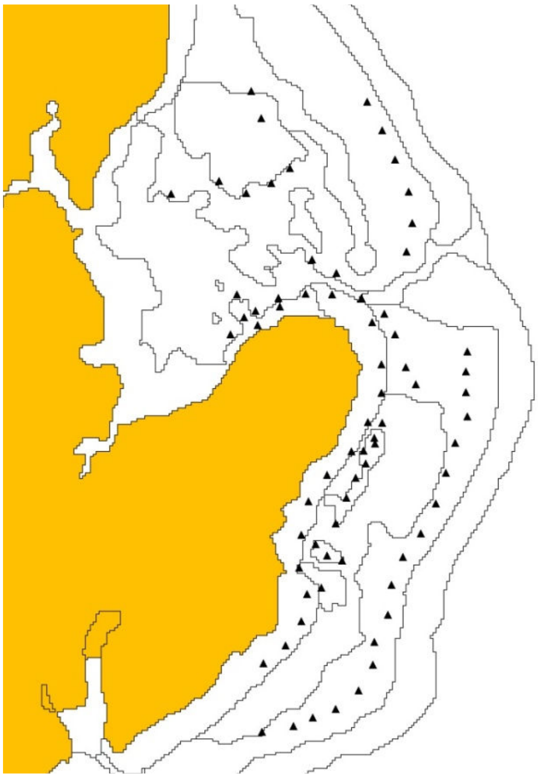

Figure 3.25: Broad-scale survey stations for invertebrates in Riiken.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

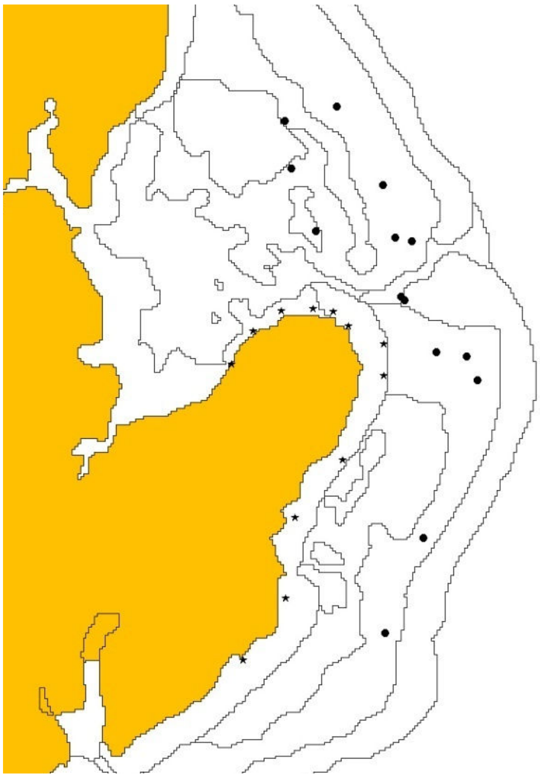

Figure 3.26: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey in Riiken.
Black circles: reef-benthos transect stations (RBt);
black stars; soft-benthos transect stations (SBt).

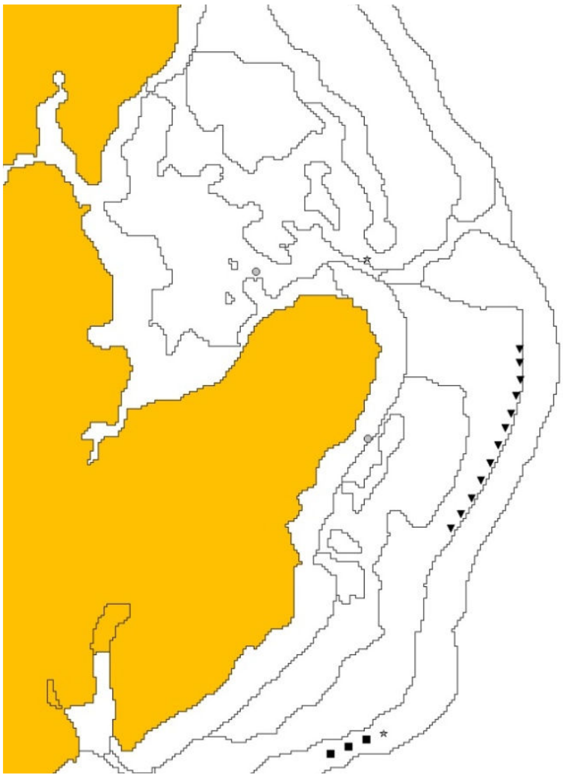

Figure 3.27: Fine-scale survey stations for invertebrates in Riiken.
Inverted black triangles: reef-front search stations (RFs);
black squares: mother-of-pearl transect stations (MOPt);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Fifty-four species or species groupings (groups of species within a genus) were recorded in the Riiken invertebrate surveys. Among these were 9 bivalves, 21 gastropods, 14 sea cucumbers, 6 urchins, 3 sea stars, and 2 cnidarians (Appendix 4.2.1). Information on key families and species is detailed below.

3.4.1 Giant clams: Riiken

Shallow-reef habitat that is suitable for giant clams was small at Riiken, only 6.9 km^2: ~3.9 km^2 within the lagoon and 3 km^2 on the reef front of the barrier or slope. The lagoon was not extensive (~14.5 km^2 – more of a pseudo-lagoon) and there were only a few areas where deeper water was found. Along the shoreline, seagrass beds predominated (~150–300 m in width), graduating into the pseudo-lagoon of white-sand bottom (400–800 m wide) before it reached back-reef. At the barrier reef and along the passages, coral was more developed, even along the back-reef. Beyond the reef crest the reef slope did not shelve quickly into deep water and shoaling reef was noted on the ocean side. In the northern part of Riiken, land (allochthonous) influence dominated; and to the east and closer to the channel, waters became more oceanic.

Using all survey techniques, three species of giant clam were noted: the elongate clam *Tridacna maxima*, the bear's paw clam *Hippopus hippopus* and the smooth giant clam *T. derasa*. *T. derasa* had been ranched from stock introduced from Palau. Broad-scale sampling provided a good overview of giant clam distribution and density, and records reveal that *T. maxima* had the widest distribution (found in 4/12 stations and 12/72 transects), followed by *H. hippopus* (4/12 stations and 5/72 transect, while the translocated *T. derasa* was only recorded twice in broad-scale surveys (Figure 3.28).

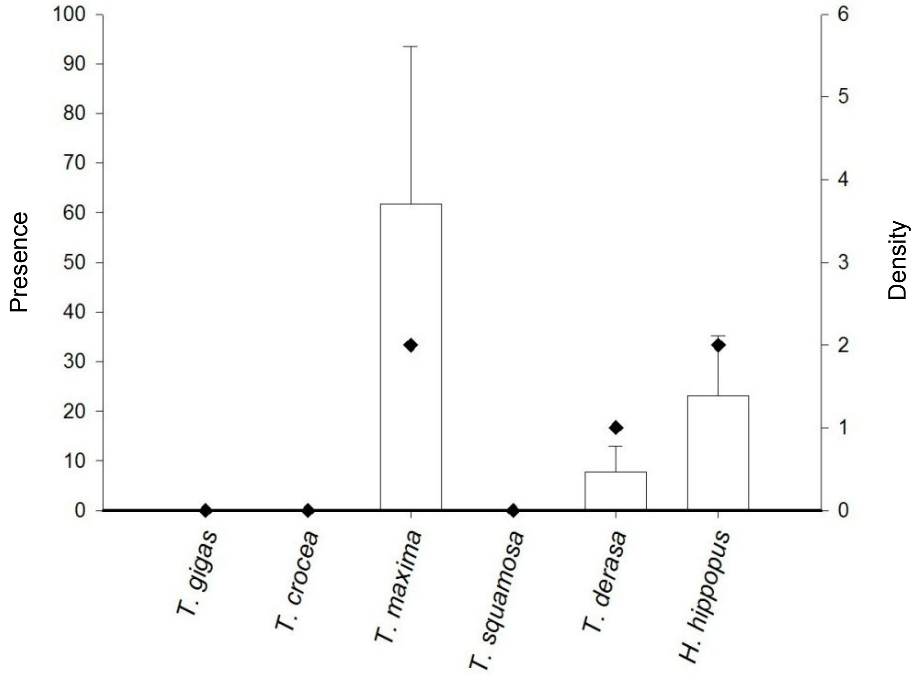

Figure 3.28: Presence and mean density of giant clam species at Riiken based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 3.29). In these reef-benthos assessments (RBt), *T. maxima* was present in 71.4% of stations (mean density 68.5 /ha ±19.8), the highest station density being 250.0 /ha ±91.3. *Hippopus hippopus* was present in 35.7% of stations at an average density of 26.76 /ha ±11.9. No *T. squamosa* were noted in RBt stations.

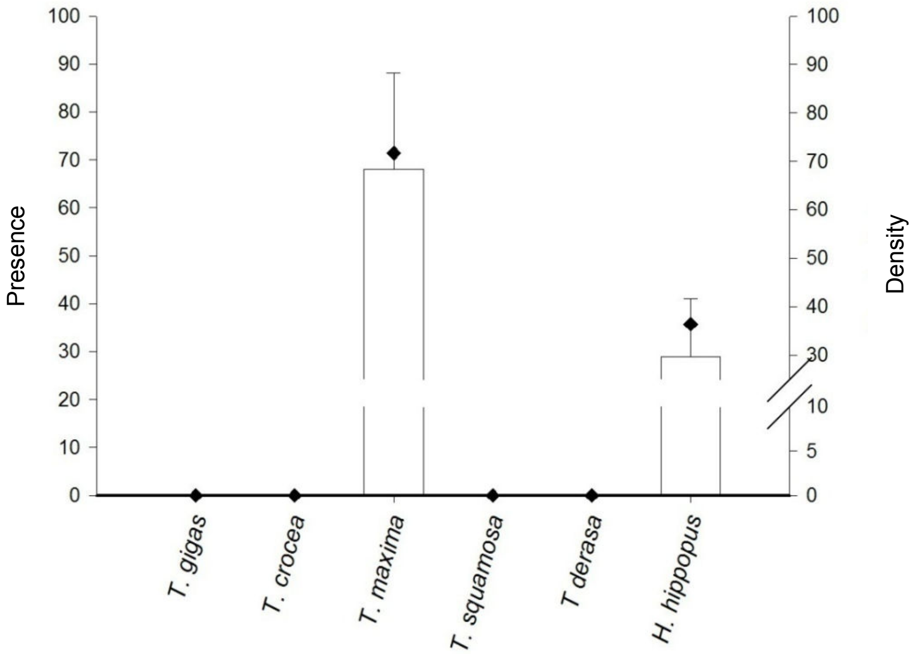

Figure 3.29: Presence and mean density of giant clam species at Riiken based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

The mean length of elongate clams *T. maxima* from RBt stations was 15.6 cm ±0.9, which represents a clam of >6–7 years old. In addition, a full range of *T. maxima* lengths was noted in survey, including few large mature specimens (Figure 3.30). *H. hippopus* was quite common, averaging 18.0 cm ±0.2 across RBt stations, and a full range of length was also noted for this species. Only two individuals of the large species *T. derasa* (asymptotic length L_∞ of 60 cm) were recorded in broad-scale surveys (15 and 40 cm in length).

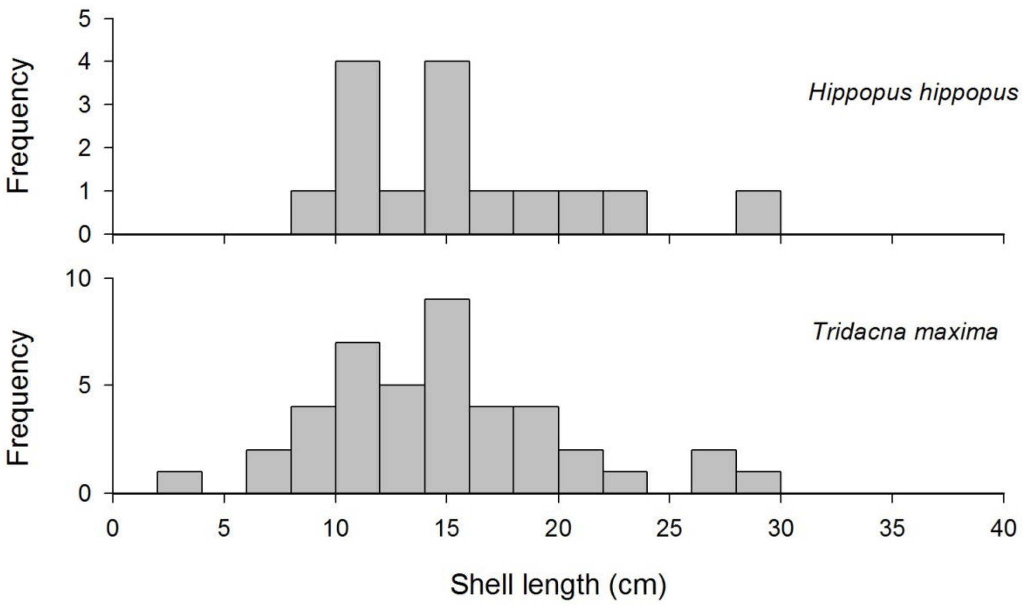

Figure 3.30: Size frequency histograms of giant clam shell length (cm) for Riiken.

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

The commercial topshell *Trochus niloticus* is a native species of Yap. Yap has been a source country for many translocations. In 1930, trochus were moved to several islands of the old Caroline Islands (a former German protectorate comprising ~500 small coral islands in Micronesia) and in 1939 (or 1940) to Ulithi, an atoll of Yap state. In 1984, 4708 live trochus were taken from Yap to Woleai atoll (12 died). In 1985, 1979 trochus were sent to Ifalik and Eaurpik atolls (80 died). Later, during the 1980s and the 1990s, other translocations occurred among atolls of Yap state (Gillett 2002b).

Trochus is seen as an important resource by communities and has been harvested commercially, at least since the 'German times' (1898–1914). The catches varied from 10 to 70 t in the past and, for Yap proper (the actual island of Yap), the long-term sustainable yield has been tentatively estimated at 23–25 t, based on historical landings (Clarke and Ianelli 1995).

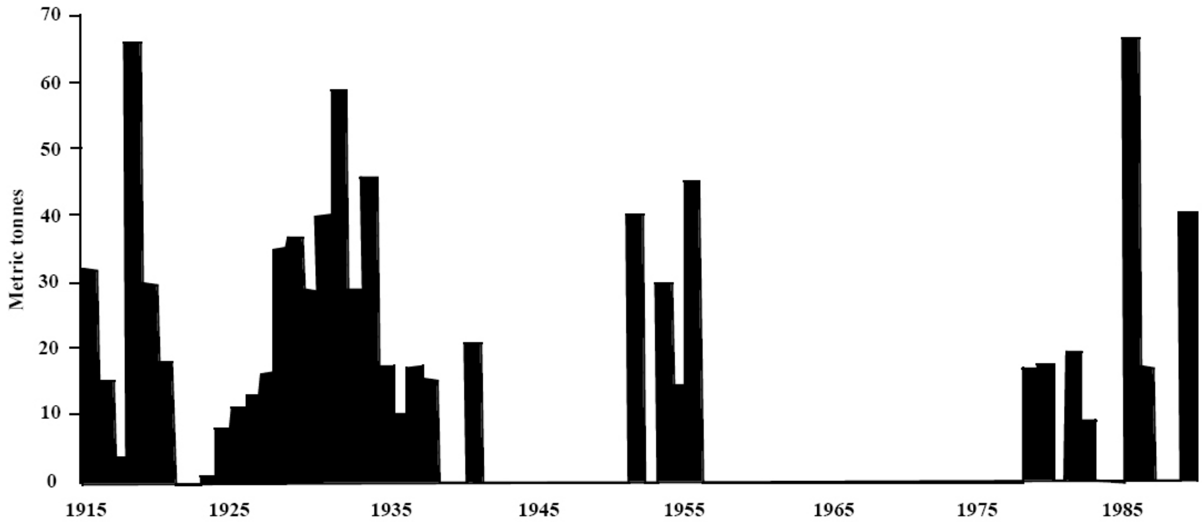

Figure 3.31: Time trend of Yap trochus harvests.
Sources: Asano 1939, McGowan 1958, Smith 1947, Smith 1990, cited in Clarke and Ianelli 1995.
Note: Yap MRMD indicates 32 t harvested in 1994.

The survey of different reef zones at different scales allows the determination of shell distribution and density for commercial trochus adult and juvenile populations. Usually, in addition to standard broad-scale and shallow-reef surveys, trochus information is collected using reef-front searches (RFs) and mother-of-pearl transects (MOPt, see Methods, Table 3.13). The shallow reef south of the passage is mostly reserve, and the outer reef at Yap was also suitable for trochus. Unfortunately, most of the outer-slope area was not surveyed due to strong swell and bad weather during the survey period.

Table 3.13: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Riiken
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	0.7	0.4	3/12 = 25	3/72 =4
RBt	83.3	52.8	4/14 = 29	10/84 = 12
RFs_w	1.4	1.4	1/4 = 25	1/24 = 4
MOPt	736.1	84.5	3/3 = 100	18/18 = 100
Tectus pyramis				
B-S	0.2	0.2	1/12 = 8	1/72 = 1
RBt	11.9	8.1	2/14 = 14	4/84 = 5
RFs_w	0	0	0/4 = 0	0/24 = 0
MOPt	375.0	133.9	3/3 = 100	13/18 = 72
Pinctada margaritifera				
B-S	0	0	0/12 = 0	0/72 = 0
RBt	3.0	3.0	1/14 = 7	1/84 = 1
RFs_w	0	0	0/4 = 0	0/24 = 0
MOPt	0	0	0/3 = 0	0/18 = 0

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

Most of the inner reef in the pseudo-lagoon was not very suitable for trochus (present in only 12% of RBt stations). The reef in the protected area in front of the passage, however, was very suitable and held trochus at high density, with the two RBt stations at this location yielding average densities of 291.7 /ha ±198.1 and 708.3 /ha ±305.6.

As mentioned above, we could not survey most of the outer slope, but in the southern part of the area, where it was possible to dive on one day when wind and swell were more favourable, densities at three MOPt stations conducted at 7–11 m depth were 583–875 specimens/ha. All three stations held shells at >500 /ha, the highest average station density being 875 /ha ±221.3.

The coral environment in this area was much degraded, constituted mostly of dead corals and boulder, showing the strong influence of wave impact and possibly the effects of the previous typhoon (Typhoon Sudal, April 2004), which was devastating.

In total, 101 trochus were recorded during the survey, 55 of which were measured; these yielded a mean basal width of 9.8 cm ±0.3. The range and amount of the different shell sizes give an important indication of the status of stocks, by highlighting new recruitment, or lack of recruitment, into the fishery. The shell size frequency also shows which sizes of trochus are being removed from the fishery and the presence of older larger shells, which are important providers of gametes to produce new generations (Figure 3.32).

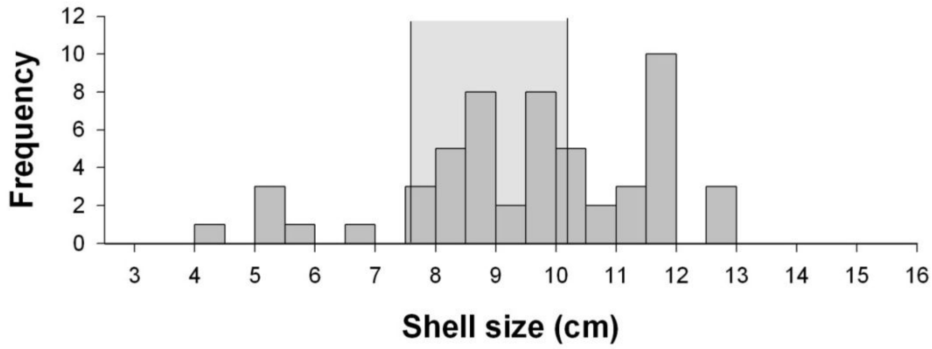

Figure 3.32: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Riiken.
The paler grey shaded area represents the legal capture size (7.6–10.2 cm).

The length frequency graph reveals that a full range of trochus sizes was still in the water at Riiken, and that small juvenile trochus shells were still entering the pre-capture size classes. For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic phase of life and joining the main stock. As can be seen from the length frequency graph, this part of the population was detected in these surveys, showing that successful reproduction of trochus was still occurring at Riiken. However, the average size of trochus was relatively large, with 29% of the shell size records being large adults >11 cm basal width. This result can be interpreted as an indication of the level of fishing in previous harvests. Based on the 10.2 cm maximum legal size, 36.4% of the stock was calculated to be from size classes greater than this basal width. This percentage suggests that stocks have not been too hard hit by previous harvests, and the number of older, larger, mature trochus in the population also suggests that the maximum size limit regulation has been largely respected in the past.

Normally, we also look at the presence of false trochus or green topshell (*Tectus pyramis*), as this related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) can give an indication of the suitability of reefs for grazing gastropods. In this case, despite the ubiquitous nature of trochus, *Tectus pyramis* was rare and at low density (only n = 17 individuals recorded in survey).

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera* was recorded, but in survey only one was found (length 12.0 cm dorso-ventral height).

3.4.3 Infaunal species and groups: Riiken

Soft benthos at the coastal margins of Riiken was suitable for seagrass, and large areas of seagrass were seen in the pseudo-lagoon. There were no reported concentrations of in-ground resources (shell 'beds') and, therefore, no infaunal 'digging' surveys (quadrat surveys) were completed.

3.4.4 Other gastropods and bivalves: Riiken

Three *Lambis* species were noted in survey (*Lambis lambis*, *L. chiragra* and *L. truncata*), but they were not common across Riiken and at low density (*L. lambis* was noted in 17% of soft-benthos transect stations, at 6.9 /ha ±4.7). The strawberry or red-lipped conch *Strombus* *luhuanus* was moderately common (recorded in 25% of broad-scale stations) but, in general, high-density aggregations were not extensive (Appendices 4.2.2 to 4.2.9).

Two species of turban shell, *Turbo argyrostomus* and *T. chrysostomus*, were noted and both were recorded at low density. Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Conus*, *Cypraea*, *Haliotis*, *Pleuroploca* and *Vasum*) were also recorded during independent surveys (Appendices 4.2.2 to 4.2.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Anadara*, *Chama*, *Hyotissa and Pinna* species are also in Appendices 4.2.2 to 4.2.9. No creel survey was conducted at Riiken.

3.4.5 Lobsters: Riiken

There was no dedicated night reef-front assessment of lobsters (See Methods.), although night-time assessments for nocturnal sea cucumber species (Ns) offered a small extra opportunity to record lobster species. No records for lobsters (*Panulirus* spp.), prawn killers (*Lysiosquillina maculata*) or mud lobsters (*Thalassina* spp.) were made in surveys at Riiken. One crab (*Eriphia sebana*) was recorded on the reef crest.

3.4.6 Sea cucumbers[8]: Riiken

Around Riiken, shallow and deep-water sheltered lagoon and areas around the barrier reef are relatively limited (total lagoon area: 14.5 km^2). The northern shoreline is composed largely of mangrove with some inshore seagrass. There were deeper sections and pools in the northern section of the lagoon but these were heavily influenced by riverine inputs. Although the shallow outer (eastern) area of the lagoon had more water exchange with the ocean, there was not a full range of suitable habitats for sea cucumber species.

A sea cucumber species' presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.14, Appendices 4.2.1 to 4.2.9; also see Methods). Results from the full range of assessments yielded 13 commercial species of sea cucumber (plus one indicator species; see Table 3.14).

Sea cucumber species associated with shallow reef areas, the medium-value leopardfish (*Bohadschia argus*), was moderately common in distribution (in 21% of broad-scale transects) but recorded at moderately low density (mean broad-scale transect density was 6.2 /ha ±2.0).

The high-value black teatfish (*Holothuria nobilis*), which is often found in shallow water and easily targeted by commercial fishers, was noted at Riiken (in 18% of broad-scale transects and 14% of RBt stations, total of n = 19 individuals). The average density observed and RBt stations was 4.4–6.0 /ha, which is at the lower end of natural densities recorded across the Pacific (Densities >12 /ha are considered 'healthy'.).

[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.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was well distributed across reefs at Riiken (in 33% and 57% of broad-scale and reef-benthos transect stations). The average density observed across broad-scale and RBt stations was 90.0 /ha ±57.3 and 333.3 /ha ±155.8, respectively. The greatest concentrations were at high density, with one RBt station returning a record close to 2000 /ha, and two RBt returning close to 1000 /ha. These three stations were situated on the shallow back-reef north of the channel.

Surf redfish (*Actinopyga mauritiana*) were recorded in 25% of the reef-front search by walking stations (RFs_w). As this species is mostly found, where its name suggests, on reef fronts, RFs_w provide a valuable signal on its status. In Riiken, the density of this medium/high-value species was low (0.5 /ha), and at RBt stations it was at 3.0 /ha ±3.0. In other locations in the Pacific, this species is recorded at commercial densities >400–500 /ha.

More protected areas of soft benthos of the lagoon returned distribution and density records for sea cucumbers such as sandfish (*Holothuria scabra*), brown curryfish (*Stichopus vastus*) and a species similar to blackfish (*Actinopyga* sp. nov., which is yet to be named). The high-value sandfish *H. scabra* was recorded in only one SBt station but the average density at this station was reasonably good (666.7 /ha ±247.2). The range of *H. scabra* lengths recorded was 14.8–26.5 cm (mean 18.1 cm ±0.8, n = 16 individuals).

The unnamed species similar to blackfish (*Actinopyga* sp. nov.) and commercialised under this name was recorded only once on a SBt station (n = 1). The brown sandfish (*Stichopus vastus*) was recorded in 17% of SBt stations at the low density of 13.9 /ha ±9.4. These three species have been recorded in the same area, in the north-northeast, close to the mangrove, on a muddy, sandy bottom that had a high percentage cover of seagrass (30–60%).

Other, lower-value species of sea cucumber, such as flowerfish (*Bohadschia graeffei*), snakefish (*Holothuria coluber*) and lollyfish (*H. atra*) were noted at reasonable distribution, but no high-density areas were located. The pinkfish (*H. edulis*) also had a small distribution (7% of RBt stations) but was recorded at one RBt station at moderately high density (292 /ha).

Deep-water assessments (30 five-minute searches, 18–29 m deep, average depth 21.7 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and elephant trunkfish (*H. fuscopunctata*). With most of the lagoon at Riiken being shallow, many of the deeper-water species were not recorded. The oceanic-influenced narrow passages had dynamic water movement, suitable for species such as white teatfish (*H. fuscogilva*) and prickly redfish (*T. ananas*). The south corner of the outer slope was also checked, but none of the above species were noted, except for one prickly redfish individual recorded in broad-scale, shallow-water transects.

3.4.7 Other echinoderms: Riiken

At Riiken, only two edible collector urchins (*Tripneustes gratilla*: n = 3 and *Echinothrix* spp.: n = 6) were noted. No slate urchins (*Heterocentrotus mammillatus*) were recorded in survey. *Diadema* spp., the long-spined urchin, was also present in small numbers (n = 4), and even the usually common *Echinometra mathaei* was rare in surveys (n = 4), at a low mean density of 6.0 /ha ±6.0 in RBt (Appendices 4.2.1 to 4.2.7). Urchins are recorded in survey both because some are eaten in the Pacific and because we can use them within assessments as potential indicators of habitat condition.

Blue starfish (*Linckia laevigata*) were more common (n = 163), found in 28% of broad-scale transects. The overall density recorded was 18.3 /ha ±5.4. The coralivore (coral eating) pincushion star (*Culcita novaeguineae*) was recorded in 15% of broad-scale stations (n = 26). However, the most destructive coral-eating starfish, the crown of thorns (*Acanthaster planci*), was rare with only three specimens noted.

Table 3.14: Sea cucumber species records for Riiken

Species	Common name	Commercial value [5]	B-S transects n = 72			Other stations RBt = 14; SBt = 12			Other stations RFs_w = 4; MOPt = 3			Other stations Ds = 2; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H				3.0	41.7	7 RBt	0.5	1.9	25 RFs_w			
Actinopyga miliaris	Blackfish	M/H												
Actinopyga sp. nov.	No name as yet	M				3.5	41.7	8 SBt						
Bohadschia argus	Leopardfish	M	6.2	29.9	21	47.6	166.7	29 RBt						
Bohadschia graeffei	Flowerfish	L										3.6	7.1	50 Ds
Bohadschia vitiensis	Brown sandfish	L	0.2	16.7	1	10.4	41.7	25 SBt				48.9	97.8	50 Ns
Holothuria atra	Lollyfish	L	31.2	132.3	24	131.0 173.6	305.6 208.3	43 RBt 83 SBt	78.7	78.7	100 RFs_w	168.9	168.9	100 Ns
Holothuria coluber	Snakefish	L				3.0	41.7	7 RBt				435.6	871.1	50 Ns
Holothuria edulis	Pinkfish	L	7.2	64.5	11	20.8	291.7	7 RBt				102.2	204.4	50 Ns
Holothuria flavomaculata		L												
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M												
Holothuria leucospilota		L												
Holothuria nobilis [4]	Black teatfish	H	4.4	24.4	18	6.0	41.7	14 RBt	1.9	2.5	75 RFs_w	1.2	2.4	50 Ds
Holothuria scabra	Sandfish	H				55.6	666.7	8 SBt						
Stichopus chloronotus	Greenfish	H/M	90.0	270.0	33	333.3 6.9	583.3 41.7	57 RBt 17 SBt	2.8 250.0	11.1 250.0	25 RFs_w 100 MOPt	44.4	88.9	50 Ns
Stichopus hermanni	Curryfish	H/M												
Stichopus horrens	Peanutfish	M/L												
Stichopus vastus	Brown curryfish	H/M				13.9	83.3	17 SBt						
Synapta spp.	-	-	0.2	16.7	1	6.9	41.7	17 SBt						
Thelenota ananas	Prickly redfish	H	0.2	16.7	1									
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; H/M is higher in value than M/H; B-S transects= broad-scale transect; RBt = reef-benthos transect; SBt = soft-benthos transect; RFs_w = reef-front search by walking; MOPt = mother-of-pearl transect; Ds = day search; Ns = night search.

3.4.8 Discussion and conclusions: invertebrate resources in Riiken

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

Data on the environment at Riiken and the distribution, density and shell size of giant clams suggest the following:

- At Riiken, a full range of shallow-water reef habitats suitable for giant clams was present; however, these areas were not extensive. The outer slope, which could hold suitable habitat for *Tridacna maxima* and *T. squamosa*, was not surveyed due to the large swell that was present during the survey period.

- For this part of the Pacific, only two native giant clam species were present: the elongate clam *Tridacna maxima* and the bear's paw clam *Hippopus hippopus*. The fluted clam *T. squamosa* was not noted, although not all habitats were accessed. The smooth clam *T. derasa* was noted but these records were derived partially from imported shells. The re-introduction of ~25,000 *T. derasa* individuals in 1984 resulted in only ~8% survival. However, subsequently the surviving *T. derasa* stock matured, reproduced and re-established viable populations (Lindsay 1995). As we can see, the 15 cm *T. derasa* specimen recorded in this survey is most likely a result of successful reproduction from the initial cohorts released in Yap.

- Giant clam densities are quite low, which gives cause for concern, especially knowing that giant clams are broadcast spawners and that large individuals need to be at close proximity to one another (at high density) for successful reproduction. Nevertheless, the size frequency distribution showed that recruitment was still occurring, and there is hope for recovery as the full size range (from juveniles to large, reproductive adults) is present. In addition, as giant clams only mature to produce eggs at large sizes (which can take up to 10 years in *T. gigas*) it is important that aggregations of large older clams are protected from fishing, to ensure there is sufficient production of gametes (especially eggs) to create the next generation and therefore maintain sustainability of the resource.

- In general, the status of giant clams at Riiken was moderately impacted by fishing. Clam density was low, although the range of clam size classes present was complete.

Data on the environment, and the distribution, density and size recordings of MOP species suggest the following:

- Local reef conditions at Riiken provided suitable habitat for juvenile and adult commercial topshell trochus (*Trochus niloticus*), although the scale of the area was limited and the outer-reef slope was not comprehensively examined in the current surveys due to unsuitable weather conditions.

- Trochus was not common across reefs at Riiken, but the density of trochus was high within 'core' aggregations (where trochus are typically in greatest abundance). The outer slope may hold a significant stock, as suggested by the high densities recorded in the limited amount of work completed in the southern part of the study area. High densities were also recorded in the MPA, offering good potential for the surrounding reefs. From the five RBt and MOPt stations surveyed in the MPA and outer reef slope, four held trochus at densities >500–600 shells/ha, which is the minimum density recommended before commercial harvests can be considered.

- Size class information reveals that most trochus sizes were present, and that previous harvests have not comprehensively fished the stock or targeted mature shells larger than the maximum size limit. Aggregations held large numbers of mature trochus (>10.2 cm basal width). The number of eggs produced increases disproportionately with size: a female trochus of size 10 cm produces ~2 million eggs, while a female of 13 cm produces three times this amount. The presence of large, older individuals, which have the greatest potential to produce future generations, is a good indication for the future of this fishery.

- Survey results suggest that trochus in the Riiken study area are marginally impacted by fishing.

- The blacklip pearl oyster, *Pinctada margaritifera*, was rare at Riiken.

A summary of the habitat, distribution, and density of sea cucumbers species is given below.

- The bêche-de-mer fishery in Yap is likely to have been active for short periods since 1800s. After 1914, exports resumed and, during World War II, the Japanese troops stationed in Yap were poorly supplied and harvested sea cucumbers heavily for their own consumption. In more recent times, pulses of fishing activity have been recorded around 1995 and again starting in 2003 with the expansion of the Chinese market and fishery collapses elsewhere in the Pacific. The focus on Yap's sea cucumber fishery was greatest in 2007, with rapid, uncontrolled expansion in this year, before the fishery was closed in September – October 2007, pending the introduction of a sea cucumber fishery management plan.

- Riiken has suitable areas of shallow, sheltered lagoon suitable for a range of more inshore sea cucumber species. However, the lack of a more typical lagoon, with deeper-water pools and water exchange with the ocean, limits the potential for a full range of species. Although the reef environments are influenced by both land and oceanic factors, the shallow-water mangrove and seagrass beds that extend along the coastline dominated the system profile.

- Fourteen species of sea cucumber were recorded at Riiken, thirteen being commercial species. This species complement is lower than expected for this location in the Pacific (which is relatively close to the centre of biodiversity), but the small scale of the site and the relative lack of more oceanic-influenced habitats limit the range of species. Recent studies noted that there were 21 marketable species of sea cucumber in Yap.

- Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure in the past; however, some species were recorded at reasonable density. Although most of the higher-value species were present, no high-density stocks were identified.

- Stocks of the high-value sandfish (*Holothuria scabra*) were still present, but not well distributed across the site, and represent the last remnants of a critically important stock for future fishery considerations or future aquaculture opportunities.

- Sea cucumbers play an important role in 'cleaning' benthic substrates of organic matter and mixing (bioturbating) sands and muds. They also recycle nutrients that are not usually abundant in coral reef systems. When these species are removed, there is the potential for detritus to build up and for substrates to become more compacted, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) and anoxic (oxygen-poor) conditions, unsuitable for life.

- At the moment there is no cost-effective hatchery and grow-out option to restock sea cucumber fisheries, although it is advised that the Fisheries Department continues to watch for any developments in hatchery-based rearing and re-stocking activities. Once research and preliminary experimentation has dealt with some of the important bottlenecks and difficulties, this technique may be used to re-create spawning populations at a number of locations in addition to developing commercial harvests. In the next decade, there may be an option to develop sea ranching operations. Current hatchery technology exists only for a couple of species (*Holothuria scabra* and *H. fuscogilva*), is expensive, and to date has had widely variable rates of success with placing juveniles in the wild. Some operators have suggested moving juveniles between countries, which is not recommended, as it presents a number of risks to local sea cucumber populations.

3.5 Overall recommendations for Riiken, YAP

- Fishing pressure on lobsters be monitored and managed, as this particular resource makes up most of the reported invertebrate annual catch.

- A monitoring programme be established so the effects of the already established MPA on resource status and thus fishing potential of the local fishing ground can be followed and documented.

- Careful consideration be given in the location of sand mining in order to avoid impacting the fishing grounds.

- Management measures be introduced to ensure that aggregations of large, older giant clams are protected from fishing and therefore the sustainability of the resource can be maintained.

- High-value sea cucumber species, such as sandfish (*Holothuria scabra*) and black teatfish (*H. nobilis*), be given extra management scrutiny, to ensure that broodstock of these species remains at viable spawning densities in order to ensure continuation of the fishery.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

4. PROFILE AND RESULTS FOR PIIS-PANEWU, CHUUK

4.1 Site characteristics

Chuuk is a large, semi-enclosed shallow atoll lagoon system. Both low and high islands are common with many patch reefs in the lagoon. The main influence is predominantly oceanic, although fringing, intermediate and offshore reefs are present. Piis-Panewu is located in the north of Chuuk lagoon, centred around 7°40'N latitude and 151°50'E longitude (Figure 4.1). Piis-Panewu is an hour by outboard-powered skiff from Weno, the capital and business centre of Chuuk State. Piis-Panewu a coral atoll with two villages, Nukan and Sopotiw, and there are several passages through the reef that provide a strong ocean influence. The communities at Piis-Panewu rely on the harvesting of marine resources as a source of income, regularly transporting their catch to Weno for marketing.

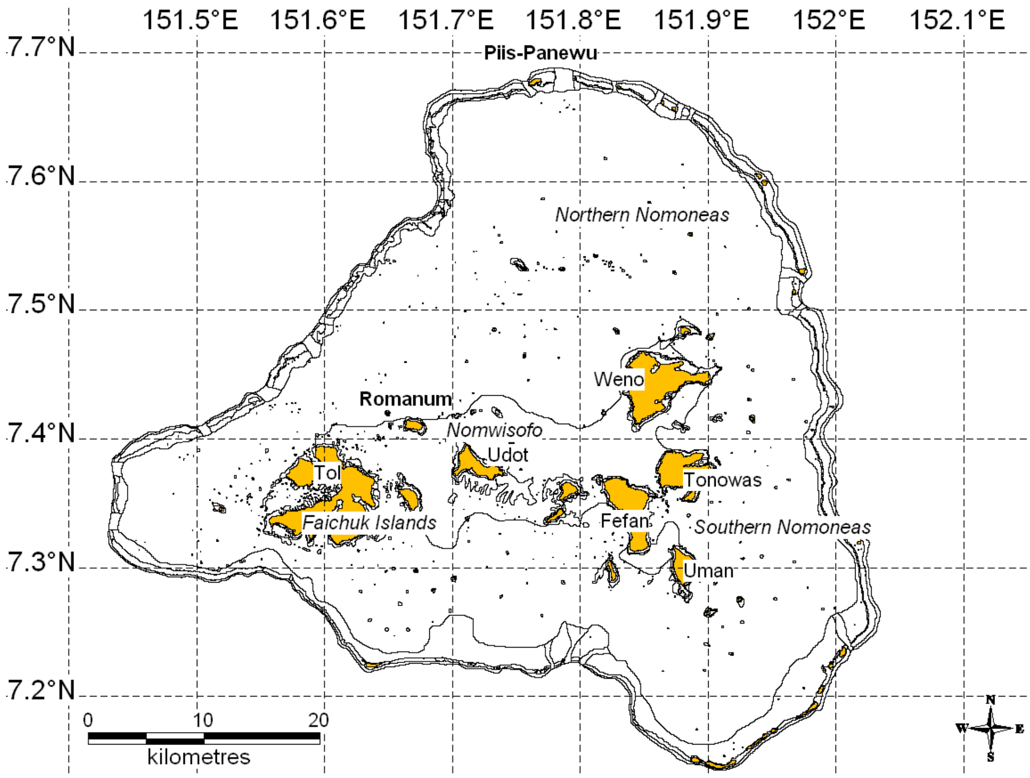

Figure 4.1: Map of Piis-Panewu, CHUUK.

4.2 Socioeconomic surveys: Piis-Panewu, CHUUK

Piis-Panewu Island, located in the Chuuk lagoon, is part of the Federated States of Micronesia (FSM). The socioeconomic field survey was carried out on 10–15 April 2006. The fieldwork included household and fisher surveys in the two villages on the island, i.e. Nukan and Sopotiw, as well as interviews of middle sellers and buyers in Weno. In the following, the site location is referred to as 'Piis-Panewu'. Access to the capital city Weno is relatively easy and takes about one hour by motorised boat. This easy access has made it possible for the people from Piis-Panewu to sell fishery produce at the Weno market. For some of the fishers or for certain fisher groups this may even be done on a daily basis. In addition, some of the reef fish that people sell to agents at Weno is exported internationally. Invertebrates are commercialised locally, i.e. in the capital's markets or supermarkets, as well as exported to international markets.

The Piis-Panewu community has a resident population of 548 with a total of 45 households. In total, 18 households, which is 40% of the total households in the community, were surveyed, with all (100%) of these households being engaged in some form of fishing activities. In addition, a total of 14 finfish fishers (males only) and 20 invertebrate fishers (8 males and 12 females) were interviewed. The average household size is large, with 12 people on average.

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. General information on sales and distribution of fisheries resources was gathered through interviews with shopkeepers and boat owners. A general survey of shops was also conducted to establish prices of tinned fish and other food items consumed.

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

Our results (Figure 4.2) show that fisheries are the primary source of income for all (100%) households. Fisheries income source includes both finfish and selected invertebrates, including octopus, giant clams, bêche-de-mer, lobsters and trochus. There is a little complementary income generated from other activities, mainly selling homemade food from home or operating small shops. Income from agriculture and salaries is complementary and applies only to a very few households on the island. Although people on the island have access to higher school education, the lack of employment causes a high rate of school drop-outs among young people and a high rate of unemployed household members. The only choice left for most people is fishing for food and income.

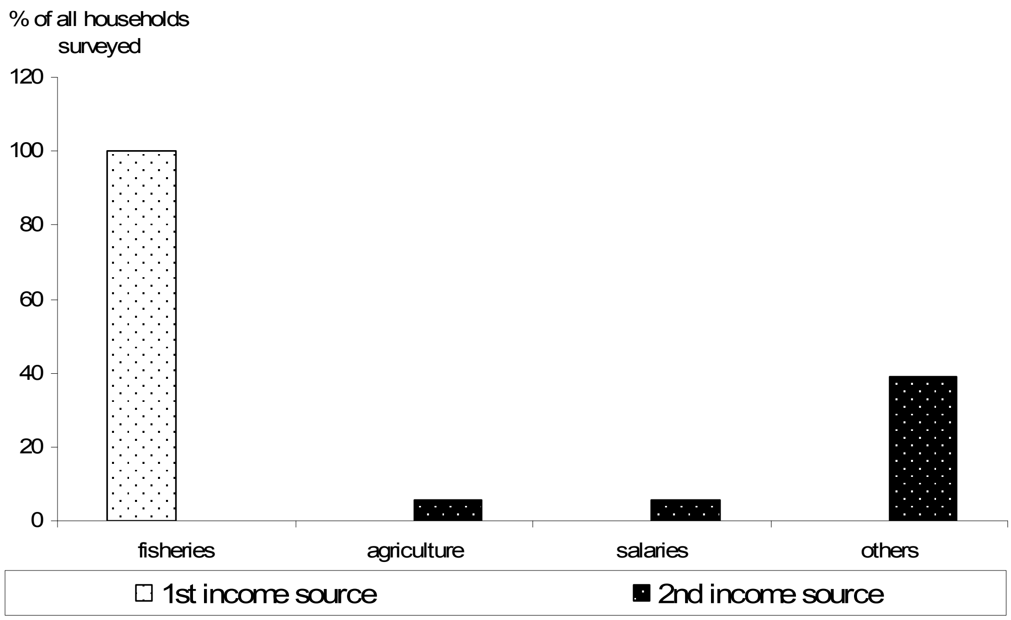

Figure 4.2: Ranked sources of income (%) in Piis-Panewu.
Total number of households = 18 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

About one-third of all households on Piis-Panewu own one or two pigs and chickens. Almost all households interviewed have access to some agricultural land subsistence production. The average garden size is ~0.4 ha only. Home gardens are mainly used to produce root crops;

however, imported items such as rice, tinned beef and luncheon meat seem to constitute a considerable share of the household's staple food items. It should also be noted that water is a sensitive subject on Piis-Panewu, and the fetching of water to cook and wash is at times difficult and time-consuming.

Our results (Table 4.1) show that annual household expenditures are high, with an average of USD 3909, because families purchase any food or household item that they do not produce themselves, either in the village shop or in Weno, the capital city. Most food and household items are imported and expensive due to the limited market size of Chuuk and the costs of transport and import duty. It should also be mentioned that the average family size on Romanum is large and many of the household members have only a low level of education and are unemployed.

Remittances are received by only 11% of all households in the community. These households benefit from an annual average of USD 1400, equivalent to about 36% of the average annual household expenditure. However, more than 11% of the households on the island have family members living in Weno, who often send food items to help support their families on Piis-Panewu.

Table 4.1: Fishery demography, income and seafood consumption patterns in Piis-Panewu

Survey coverage	Site (n = 18 HH)	Average across sites (n = 83 HH)
Demography		
HH involved in reef fisheries (%)	100.0	96.4
Number of fishers per HH	5.33 (±0.98)	3.17 (±0.32)
Male finfish fishers per HH (%)	30.2	44.1
Female finfish fishers per HH (%)	0.0	1.1
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	36.5	27.0
Male finfish and invertebrate fishers per HH (%)	28.1	24.0
Female finfish and invertebrate fishers per HH (%)	5.2	3.4
Income		
HH with fisheries as 1st income (%)	100.0	48.2
HH with fisheries as 2nd income (%)	0.0	4.8
HH with agriculture as 1st income (%)	0.0	8.4
HH with agriculture as 2nd income (%)	5.6	20.5
HH with salary as 1st income (%)	0.0	34.9
HH with salary as 2nd income (%)	5.6	4.8
HH with other sources as 1st income (%)	0.0	9.6
HH with other sources as 2nd income (%)	38.9	10.8
Expenditure (USD/year/HH)	3908.73 (±530.66)	3751.42 (±249.95)
Remittance (USD/year/HH) (1)	1400.00 (±1000.00)	1095.71 (±256.43)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	78.60 (±10.46)	62.54 (±5.01)
Frequency fresh fish consumed (times/week)	3.94 (±0.10)	3.67 (±0.21)
Quantity fresh invertebrate consumed (kg/capita/year)	14.37 (±2.68)	12.40 (±5.01)
Frequency fresh invertebrate consumed (times/week)	2.32 (±0.26)	1.08 (±0.13)
Quantity canned fish consumed (kg/capita/year)	2.38 (±0.69)	23.87 (±3.14)
Frequency canned fish consumed (times/week)	0.64 (±0.16)	2.68 (±0.23)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	100.0	74.7
HH eat canned fish (%)	66.7	91.6
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	0.0	0.0
HH eat fresh fish they are given (%)	38.9	38.9
HH eat fresh invertebrates they catch (%)	100.0	100.0
HH eat fresh invertebrates they buy (%)	0.0	0.0
HH eat fresh invertebrates they are given (%)	33.3	33.3

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

Survey results indicate an average of five fishers per household and, when extrapolated, the total number of fishers in Piis-Panewu is 240, including 140 males and 100 females. Among these are 72 exclusive finfish fishers (males only), 68 exclusive invertebrate fishers (females only), and 80 fishers who fish for both finfish and invertebrates (68 males, 12 females). About two-thirds of all households (~78%) own a boat; most (~85%) are non-motorised canoes, only ~15% are equipped with an outboard engine.

Fresh-fish consumption is relatively high at ~79 kg/person/year, a consumption figure that is much higher than the average across all four study sites in FSM, and more than twice as high as the regional average of ~35 kg/person/year (Figure 4.3). By comparison, consumption of invertebrates (edible meat weight only) (Figure 4.4) is much lower at 14.4 kg/person/year, however, still considerable compared to the average across all four sites investigated in FSM. Canned fish (Table 4.1) adds another ~2.4 kg/person/year to the protein supply from seafood, which is low. This consumption pattern highlights the fact that people in Piis-Panewu do not have access to good agricultural land or imported food items, but enjoy a traditional lifestyle and are highly dependent upon seafood.

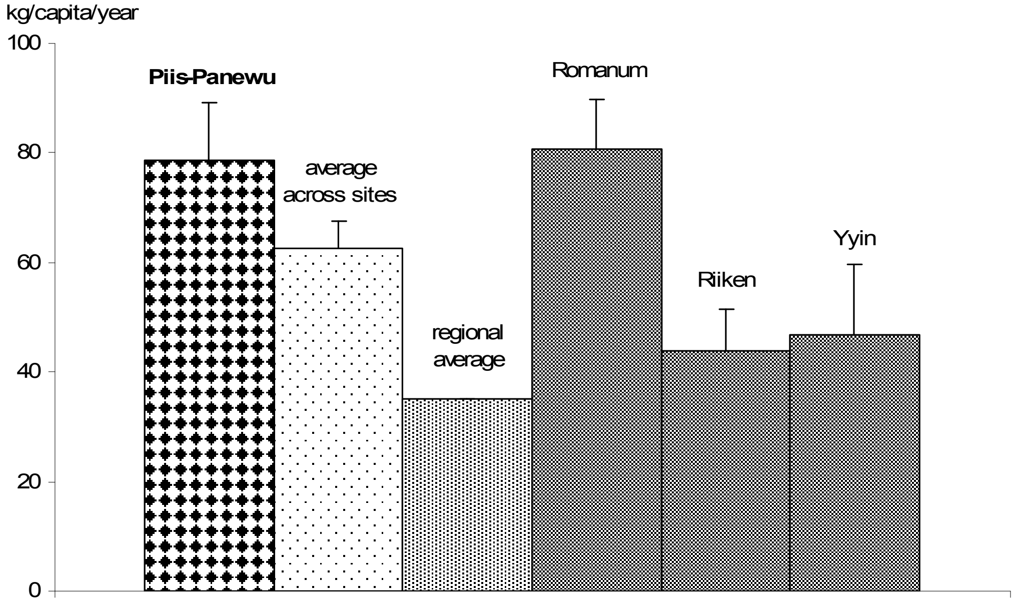

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Piis-Panewu (n = 18) compared to the average across sites, the regional average (FAO 2008) and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

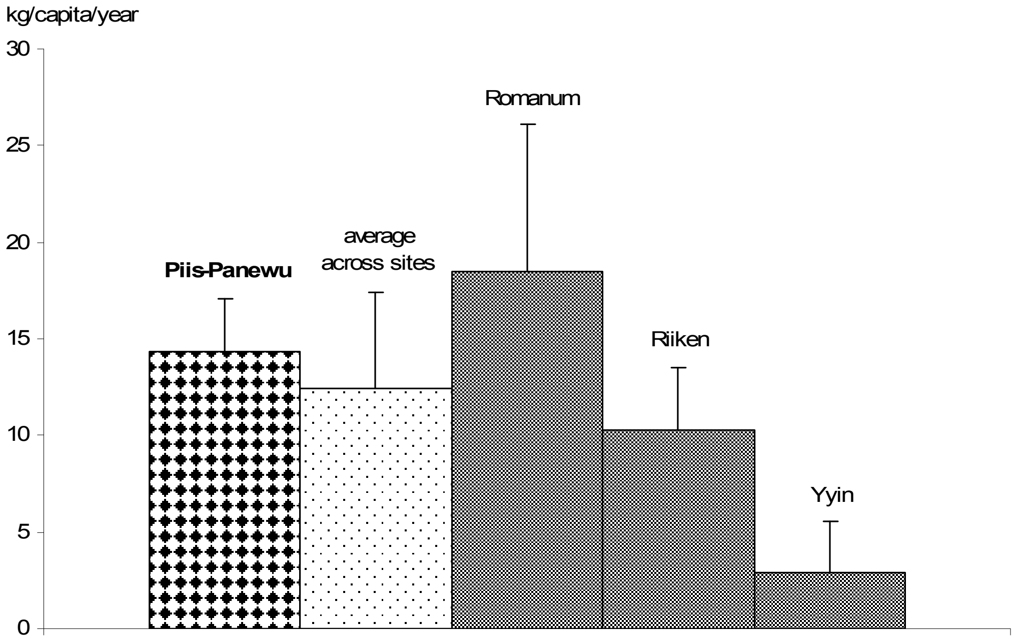

Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Piis-Panewu (n = 18) compared to the average across sites and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results obtained for Piis-Panewu to the average figures across all four study sites surveyed in FSM, people of the Piis-Panewu community eat fresh fish as often but in higher quantities and invertebrates more often and in larger quantities than average. However, the frequency and amount of canned fish eaten are well below the average. This suggests that the Piis-Panewu people enjoy a very traditional lifestyle and are dependent upon fisheries, with little access to agricultural land and cash income. Hence, access to alternative protein and other food items is limited. This interpretation is supported by the large proportion of households that eat fish and invertebrates that they have caught themselves or received from somebody in the community as a gift, and the fact that the fish and invertebrates consumed are never bought.

Fishing is the only option for generating cash income; only a very few households have alternative income sources, and these mainly provide secondary income. Household expenditure level in Piis-Panewu is high and slightly above the average across all study sites. This is due to the fact that Piis-Panewu people need to purchase food and household items that they do not produce themselves, on the mainland or in the village shop. Remittances do not play a major role for the well-being of the entire community but only for 11% of households. At least two-thirds of households own a boat; most boats are motorised.

4.2.2 Fishing strategies and gear: Piis-Panewu

Degree of specialisation in fishing

While community life in Piis-Panewu is rather traditional, some social institutions have already undergone modernisation. For example, the village chief has been replaced by a mayor. Nevertheless, daily life is determined by fishing, and fishing is still pursued in a rather low-investment style, targeting mostly the closest fishing grounds, i.e. the sheltered coastal reef and lagoon, for subsistence needs, and venturing out to the farther outer-reef areas for commercial catches. Although all members in the community are engaged in fishing, traditional roles are still evident in the fact that females hardly ever participate in fishing for finfish. The few females (~5% of fishers) who reported catching both invertebrates and finfish catch finfish mostly as a by-product, often using only knives or sticks. Sometimes, they fish for a couple of smaller fish for the family's meal using handlines but do not plan extended finfish fishing trips. While male fishers exclusively fish for finfish, females are the only fishers who specialise in invertebrate collection only. Male invertebrate fishers target particular commercially valued species to complement income from finfish fishing (Figure 4.5). Male fishers who target both invertebrates and finfish represent about 28% of all fishers in the community.

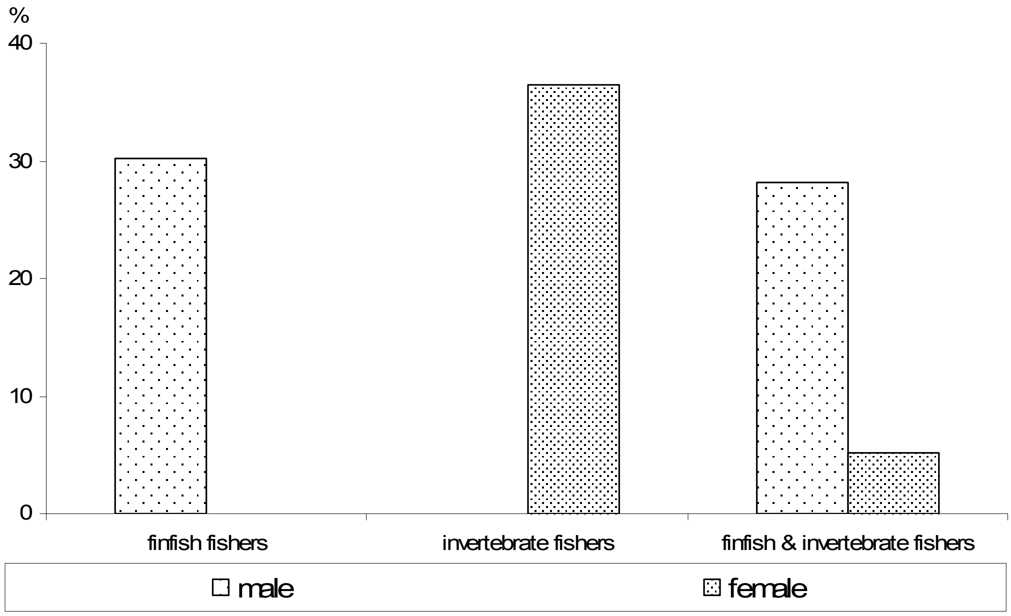

Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Piis-Panewu.
All fishers = 100%.

Targeted stocks/habitat

The large number of motorised boats and the undisputed importance of finfish fishing for income explain why most male fishers (64%) target the lagoon and outer reef, and outer reef and passages. Only 7% of all fishers stay close to shore, fishing the sheltered coastal reef. Another ~20% combine the sheltered coastal reef and lagoon in one fishing trip, and a small group (7%) combine the sheltered coastal and outer reef. The combination of the latter may be explained by the need for catching bait prior to venturing out to the outer reef (Table 4.2). Differences show in the habitats targeted by male and female fishers who collect invertebrates. Most females target the reeftops, and so do ~38% of all male fishers. A quarter of all female fishers also collect invertebrates in mangroves, another 8% combine soft benthos and mangroves, and 8% also combine intertidal and reeftop habitats. As already mentioned, male fishers mainly target commercial species. Thus, one quarter of all male fishers collect bêche-de-mer, another 38% trochus and ~13% lobsters. In addition, ~13% of all male fishers harvest in soft-benthos environments (Table 4.2). If comparing the intentions of Piis-Panewu invertebrate fishers with those interviewed on Romanum, Piis-Panewu fishers are more intent on commercial fisheries. In Romanum, fishers mostly regarded invertebrate fisheries as providing both subsistence and income, but did not particularly differentiate between the two.

In addition to fishing, boats are also used as a means of transport, in particular to reach Weno. Investment and operation costs, particularly fuel costs, are high and of major concern for those who own a motorised boat. As a result, fisher groups have formed, usually consisting of 10–14 males, who share fuel costs, go fishing together, and who either sell as a group or share the money received after selling the joint catch. These groups may fish throughout the night, spending some time on an atoll, and directly accessing Weno for selling their catch. Most of the younger males in the community are charged with marketing and selling fisheries produce. Some of these groups sell fish on a pre-arranged basis; others have a confirmed buyer who guarantees a fixed price or quotas; and others just sell whatever they may have caught at the Weno market. Females are organised into small groups for octopus fishing and selling, mostly done on command or pre-arranged, and often involving two trips to Weno for delivery of the orders.

Finfish is usually sold to Weno outlets, markets or middlemen who export to Hawaii and possibly elsewhere. The current price for fish, and giant clam and trochus meat, is about USD 2 /kg. Lobsters, trochus and giant clams are sold at Weno outlets and to middlemen. There is a special buyer for trochus shells in Weno, who buys from all fishers in Chuuk. Bêche-de-mer is sold to a buyer who visits the island once or twice per month, or to an Asian trader in Weno. Bêche-de-mer are mostly cooked and dried and then sold for USD 3.5 /kg if quality criteria are met. Bêche-de-mer may also be sold raw for USD 1.5 /kg.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef	7.1	0.0
	Sheltered coastal reef & lagoon	21.4	0.0
	Sheltered coastal reef & outer reef	7.1	0.0
	Lagoon & outer reef	50.0	0.0
	Lagoon & outer reef & passage	7.1	0.0
	Outer reef	7.1	0.0
Invertebrates	Reeftop	37.5	91.7
	Intertidal & reeftop	0.0	8.3
	Soft benthos	12.5	0.0
	Soft benthos & mangrove	0.0	8.3
	Soft benthos & reeftop	12.5	0.0
	Mangrove	0.0	25.0
	Bêche-de-mer	25.0	0.0
	Lobster	12.5	0.0
	Trochus	37.5	0.0

Finfish fisher interviews, males: n = 14; females: n = 0. Invertebrate fisher interviews, males: n = 8; females, n = 12.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip is the basic factor used to estimate the fishing pressure imposed by people from Piis-Panewu on their fishing grounds (Tables 4.2 and 4.3).

Our survey sample suggests that fishers from Piis-Panewu have a good choice among sheltered coastal reef, lagoon and outer reef fishing, including access to passages. However, reeftop (49%), mangrove (12%) and soft benthos (12%) are the main habitats that support invertebrate fisheries (Figure 4.6). Commercial fisheries, including bêche-de-mer (9%), trochus (9%) and lobster (3%) are less represented. Gender separation shows in the fact that females dominate the gleaning fisheries of reeftop, mangroves and intertidal habitats, while only males target bêche-de-mer, lobsters and trochus (Figure 4.7). However, the fact that female fishers do not particularly target any of these three fisheries does not mean that they do not collect bêche-de-mer in soft benthos and on reeftops, or any other species that they may sell.

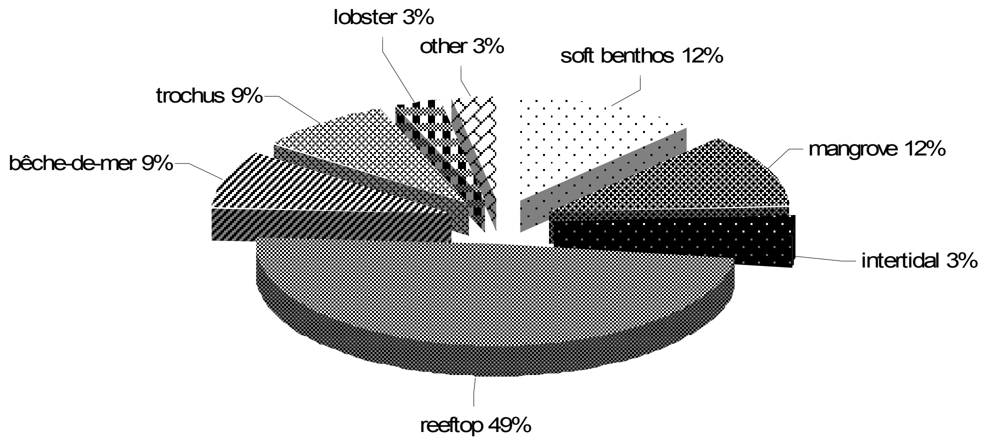

Figure 4.6: Proportion (%) of fishers targeting the primary invertebrate habitats found in Piis-Panewu.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to free diving for trochus and giant clams.

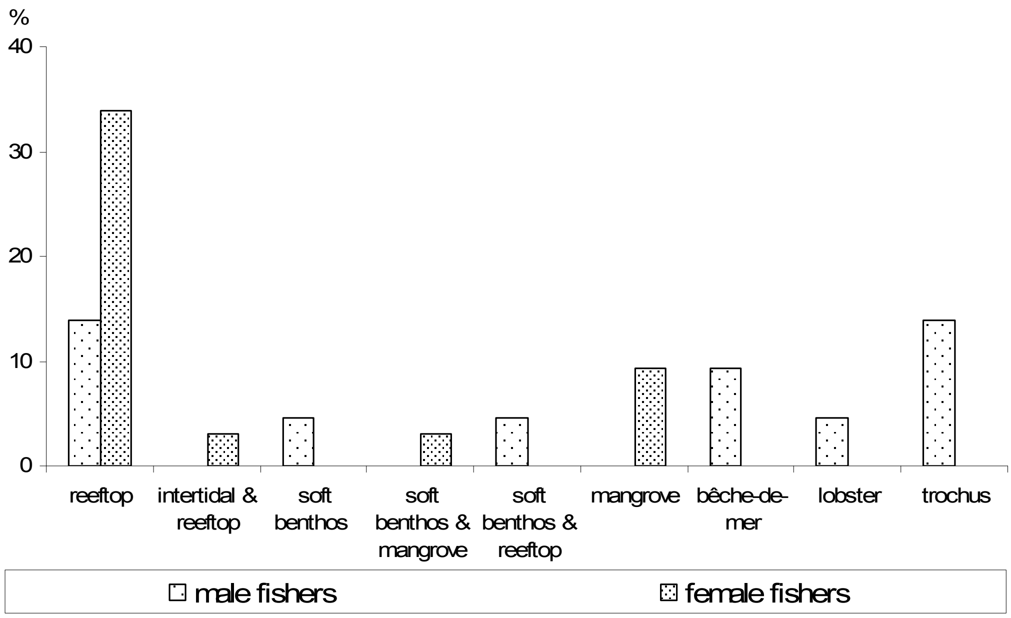

Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Piis-Panewu.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 8 for males, n = 12 for females.

Gear

Figure 4.8 shows that Piis-Panewu fishers use a variety of different gear and that most gear is used in a particular habitat. For instance, spear diving is the most important fishing technique used at the outer reef, while handlines, perhaps combined with spear diving are mainly used at the sheltered coastal reef. Gillnets, handlines and spear diving are used if fishers combine lagoon, outer reef and passages in one fishing trip. Deep-bottom lines and other techniques, such as handlines, spear diving and gillnetting, are mostly used in the combined fishing of the sheltered coast and outer reef, but also in the combined sheltered coastal and lagoon habitats. Generally, people on Piis-Panewu were found to be highly skilled in traditional fishing techniques and to also have a good knowledge of seasonality, moon phase and tidal conditions. However, the pressing need to generate income from fisheries has encouraged fishers to replace traditional techniques with more modern and more efficient fishing gears.

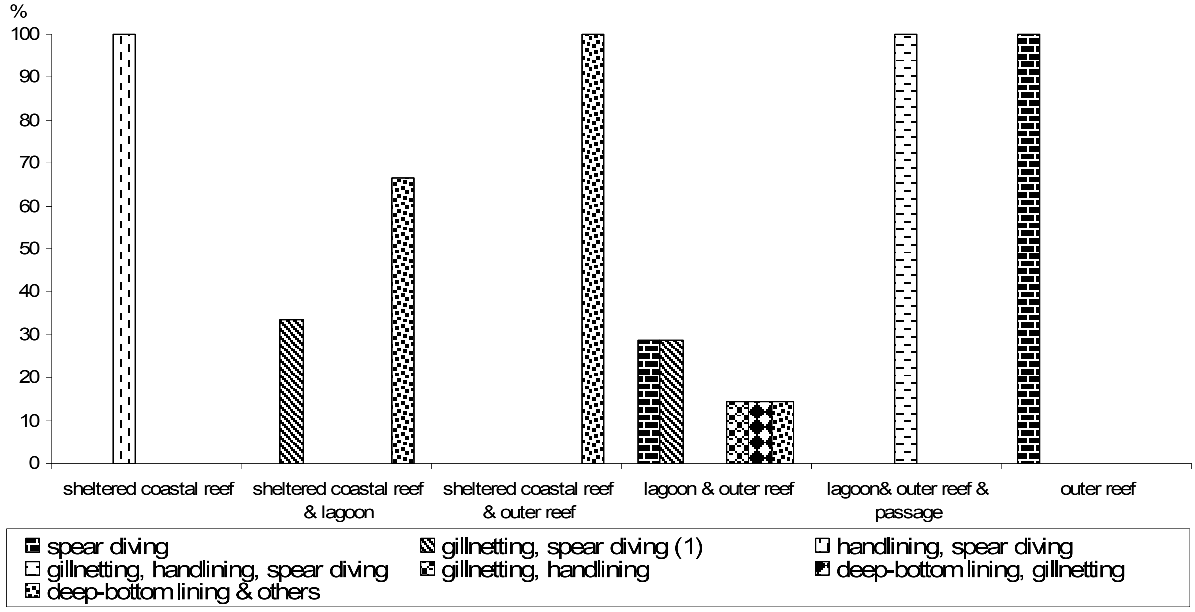

Figure 4.8: Fishing methods commonly used in different habitat types in Piis-Panewu.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. 'Others' may include handlining, spear diving, gillnetting or any combination of these; (1) including handheld spearing which is rarely employed.

Frequency and duration of fishing trips

Finfish fishers go out to any of the finfish habitats about once or twice per week, but one fisher may target various habitats in one week. The average fishing trip takes 5–6 hours and, sometimes, male fishers may spend the night on an atoll island (Table 4.3). However, to determine the average fishing trip duration, only the time spent fishing and transport time to reach the fishing ground are included here.

Invertebrate male fishers go out less frequently, about once every two weeks or once a month only. Others, particularly targeting soft benthos and reeftops in one fishing trip, may do so twice a week. Female fishers collecting invertebrates are more consistent. They go fishing on a weekly basis, regardless of which habitat they may target. Male fishers go out less often, but their fishing trips take ~3–5 hours, while female invertebrate fishers' trips usually last ~2 hours (Table 4.3).

Male fishers use boats for finfish fishing, except for a few fishers targeting the sheltered coastal reef and lagoon. For invertebrate collection, most females who target reeftops, mangroves, soft benthos and intertidal areas do so by walking. Male fishers, on the other hand, who collect bêche-de-mer, trochus and lobsters, use boat transport to reach their fishing grounds.

Due to the traditional and indigenous knowledge of people from Piis-Panewu, most fishing is done according to tidal conditions, i.e. at day or night. However, due to the difficult conditions if fishing at the outer reef and in passages, these activities are done only during the day. Interestingly, all invertebrate collection is done only during the day except for mangrove harvesting, which females do at night. All fishing for finfish and invertebrates is done throughout the year.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.50 (n/a)		5.00 (n/a)	
	Sheltered coastal reef & lagoon	1.83 (±0.17)	0	5.00 (±0.58)	0
	Sheltered coastal reef & outer reef	1.50 (n/a)	0	6.00 (n/a)	0
	Lagoon & outer reef	1.57 (±0.13)	0	4.71 (±0.29)	0
	Lagoon & outer reef & passage	2.00 (n/a)	0	5.00 (n/a)	0
	Outer reef	1.50 (n/a)	0	5.00 (n/a)	0
Invertebrates	Reeftop	1.33 (±0.33)	1.20 (±0.25)	3.00 (±0.00)	3.45 (±0.21)
	Intertidal & reeftop	0	1.00 (n/a)	0	3.00 (n/a)
	Soft benthos	0.46 (n/a)	0	4.00 (n/a)	0
	Soft benthos & mangrove	0	1.00 (n/a)	0	2.00 (n/a)
	Soft benthos & reeftop	2.00 (n/a)	0	3.00 (n/a)	0
	Mangrove	0	0.97 (±0.51)	0	2.00 (±0.00)
	Bêche-de-mer	0.46 (±0.00)	0	4.00 (±0.00)	0
	Lobster	0.23 (n/a)	0	5.00 (n/a)	0
	Trochus	0.54 (±0.08)	0	4.00 (±0.58)	0

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 14; females: n = 0. Invertebrate fisher interviews, males: n = 8; females: n = 12.

4.2.3 Catch composition and volume – finfish: Piis-Panewu

The reported catches from the sheltered coastal reef in Piis-Panewu only contain four major species groups: *Parupeneus* spp., *Scarus* spp., *Cephalopholis* spp. and *Siganus* spp., each representing ~23–29% of the total annual reported catch. Catches reported from the combined sheltered coastal reef and lagoon are mainly determined by Scaridae (>50%), Acanthuridae (~19%) and Serranidae (~28%). Catches from the sheltered coastal reef and outer reef again are represented by a few species: *Acanthurus triostegus*, *Cephalopholis* spp., *Naso* spp., *Epinephelus* spp. and *Siganus* spp. The most diverse catches were reported from the combined fishing of the lagoon and the outer reef. From the 18 species groups identified by distinct vernacular names, Scaridae, Acanthuridae, and Serranidae are the most important by weight. Lagoon, outer reef and passage fishing mainly produce *Cephalopholis* spp. (~35%), *Naso lituratus* (~32%) and Scaridae. Outer-reef catches differ from all others as they are mainly determined by *Lethrinus* spp. (~43%), *Lutjanus monostigma* (~32%) and *Siganus* spp. (~26%). Detailed information on catch compositions by species, species groups and habitats are reported in Appendix 2.3.1.

Figure 4.9 highlights earlier findings from the socioeconomic survey, that finfish fishing serves both subsistence and commercial interests. The latter are by far the most important factor that determines fishing pressure on Piis-Panewu's reef and lagoon resources. The total annual catch is estimated to amount to ~104 t of which 67% is used for commercial sale outside the community (export) while only 33% is used to satisfy the community's subsistence demand. As reported earlier, the largest number of fishers and the largest catches by weight are recorded for the combined lagoon and outer reef (~51%). Catches from the combined sheltered coastal reef and lagoon are also substantial as they represent ~20% of the total annual reported catch. Male fishers catch 100% of the total annual finfish catch.

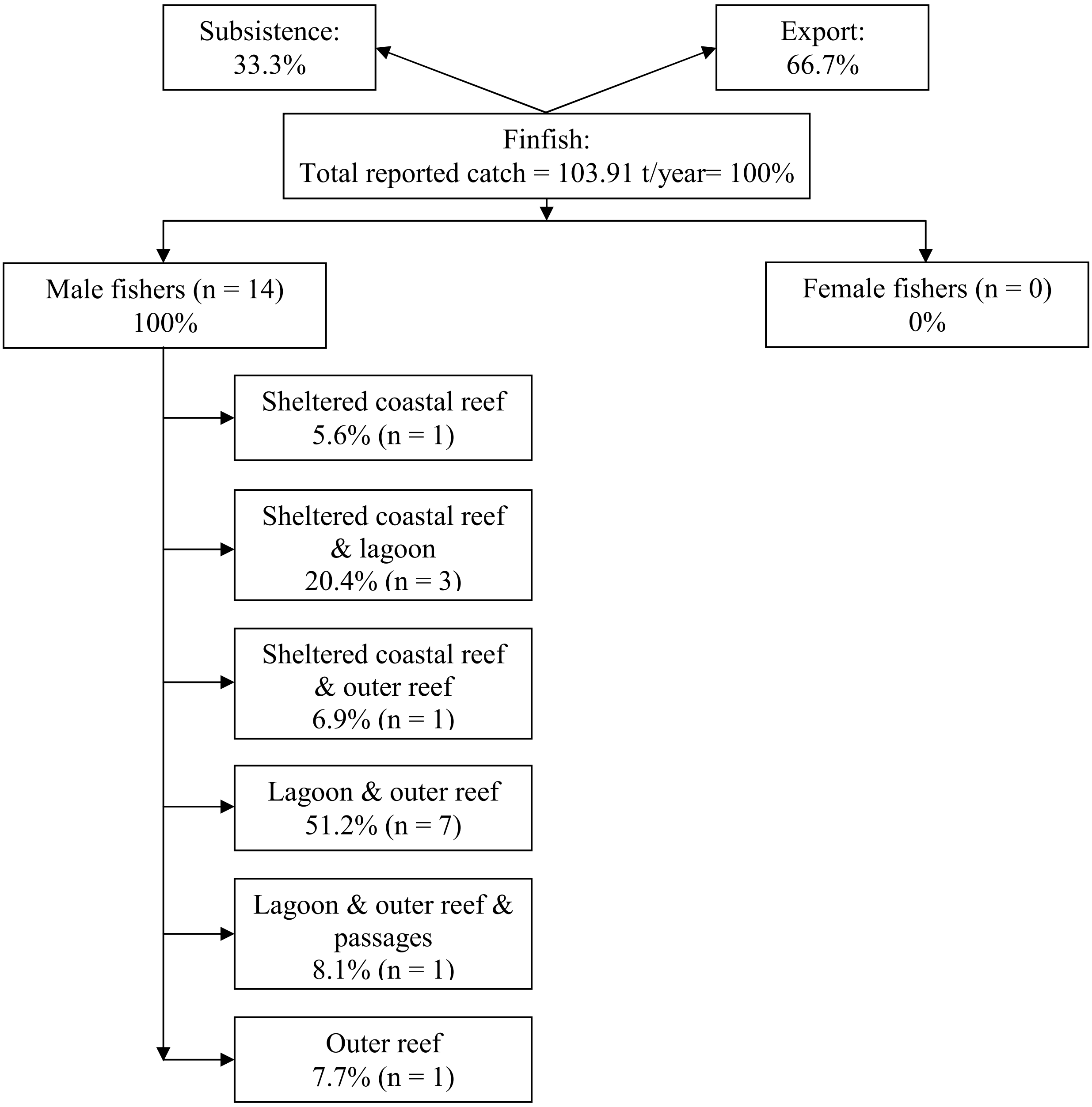

Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Piis-Panewu.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

The distribution of annual catch weight among the more easily accessible sheltered coastal reef, lagoon and further distant outer reef and passages, is a consequence of the number of fishers rather than differences in the annual catch rates. As shown in Figure 4.10, the average annual catch per fisher is comparative among the different habitats and combinations of habitats fished, ~700 kg/fisher/year. However, caution is advised in interpreting these results as sample sizes vary and, in some cases, are small.

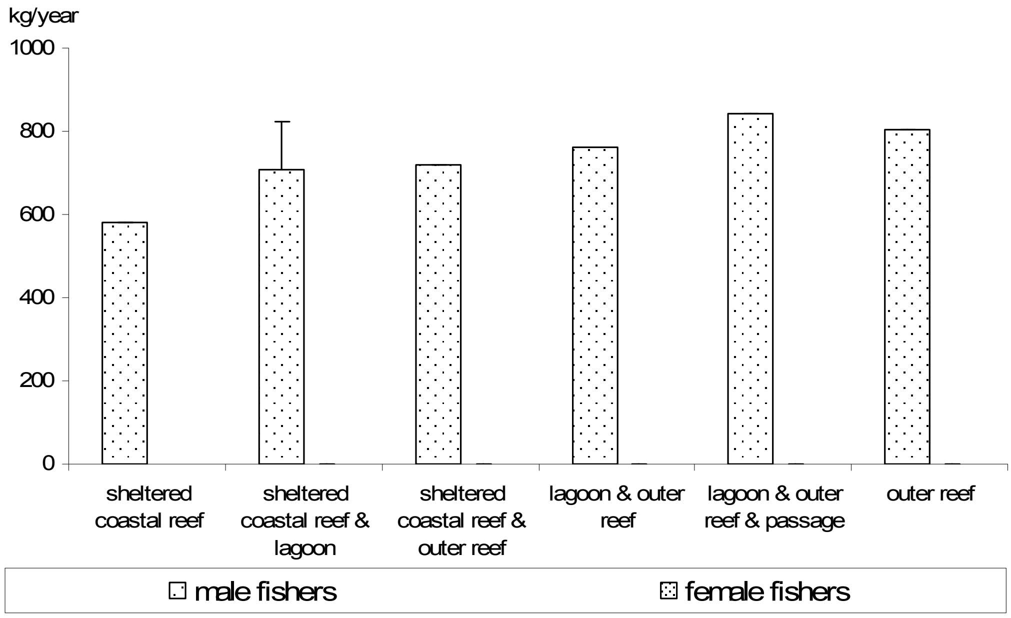

Figure 4.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Piis-Panewu.
Bars represent standard error (+SE).

Comparing productivity rates (CPUE) among habitats fished reveals significant differences (Figure 4.11). The combined fishing of lagoon and outer reef, and the exclusive fishing at the outer reef are by far the most productive, with an average of 2.5 kg/hour of fishing trip. All other habitats fished provide on average ~1.7–1.8 kg catch/hour of fishing trip.

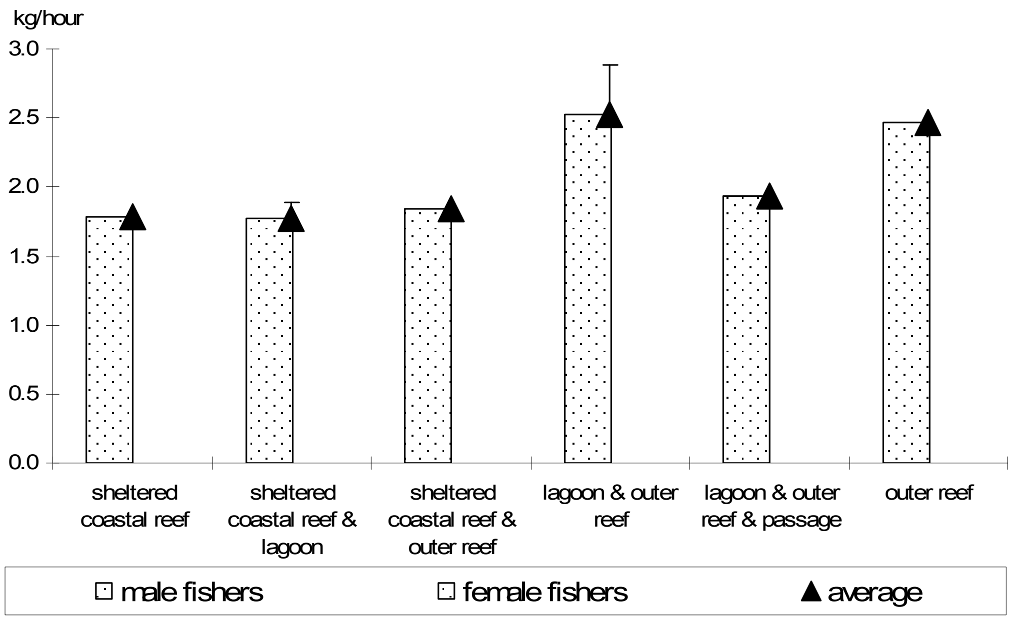

Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Piis-Panewu.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The fact that commercial fishing is more important than subsistence fishing for Piis-Panewu's people clearly shows in Figure 4.12. Any fishing trip to any habitat or combination of habitats, is done primarily for income purposes, and secondly for food for the family and for social networking.

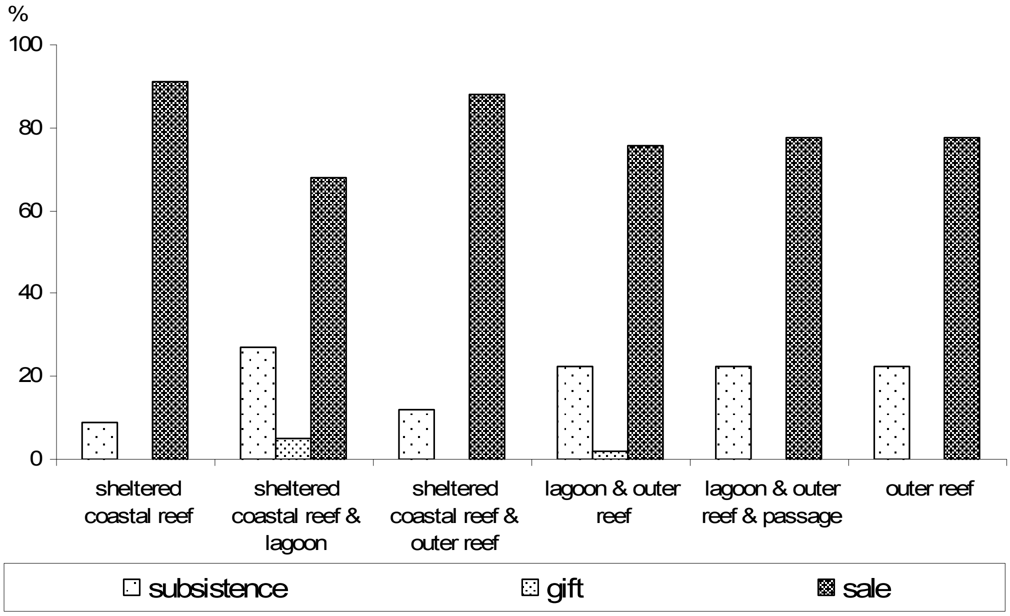

Figure 4.12: The use of finish catches for subsistence, gift and sale, by habitat in Piis-Panewu. Proportions are expressed in % of the total number of trips per habitat.

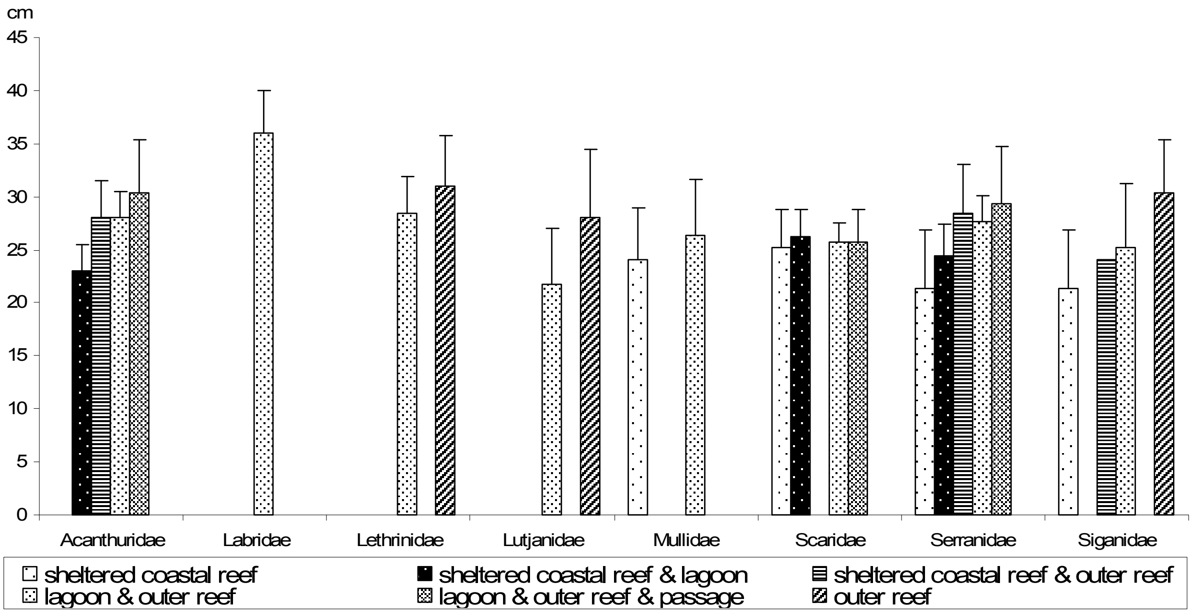

Figure 4.13: Average sizes (cm fork length) of fish caught by family and habitat in Piis-Panewu. Bars represent standard error (+SE).

The overall finfish fishing productivity (CPUE) per habitat was slightly higher from the outer reef (lagoon included, passages excluded) rather than the sheltered coastal reef and lagoon (Figure 4.11). This observation is supported by analysis of the reported average fish sizes (fork length) for the major families caught (Figure 4.13), i.e. Acanthuridae, Serranidae, Siganidae, Lethrinidae and Lutjanidae. However, the reported average sizes of Scaridae are similar in all four habitats (Figure 4.13). Scaridae are mainly targeted by spear divers, and spear diving is used throughout all habitats targeted. Because the usual trend does apply to all other families but Scaridae, this information may indicate that past and current fishing pressure on Scaridae has caused impact. While, generally, average fish sizes are ~25 cm in catches from habitats close to shore, they are on average 30 cm in catches reported from the outer reef and passages. Again, this is true for most of the major families except for Scaridae. Scaridae, regardless of where caught remain on average in the 25 cm length class.

The parameters selected to assess current fishing pressure on Piis-Panewu's reef and lagoon resources are shown in Table 4.4. Because male fishers combine several habitats in one fishing trip, parameters are difficult to calculate. Also, the sheltered coastal reef habitat is included in the lagoon area. Thus, parameters are reduced to the total available reef surface and the total fishing ground area. Here, fisher density, population density and catch from subsistence needs only, all suggest that fishing pressure is very low. If the total annual reported catch is considered, fishing pressure in terms of tonnes of fish caught per km² of reef and total fishing ground surface is 1.7 and 0.25 respectively. These ratios are also small and do not suggest a high current fishing pressure. Nevertheless, the observed lack of average fish length increase for Scaridae, and their relatively small average size would normally suggest fishing pressure is affecting this family. Therefore the findings of the socioeconomic survey need to be considered together with those of the resource surveys before final assessment is made.

Table 4.4: Parameters used in assessing fishing pressure on finfish resources in Piis-Panewu

Parameters	Habitat							
	Sheltered coastal reef	Sheltered coastal reef & lagoon	Sheltered coastal reef & outer reef	Lagoon & outer reef	Lagoon & outer reef & passage	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	n/a					4.8	19.97	139.04
Density of fishers (number of fishers/km^2 fishing ground) (1)	n/a	n/a	n/a	n/a	n/a	1	7	1
Population density (people/km^2) (2)							27	1
Average annual finfish catch (kg/fisher/year) (3)	582.51 (n/a)	707.34 (±117.02)	720.41 (n/a)	760.25 (±74.42)	841.47 (n/a)	802.56 (n/a)		
Total fishing pressure of subsistence catches (t/km^2)							1.74	0.25
Total number of fishers	10	30	10	70	10	10	140	140

Figures in brackets denote standard error; n/a = standard error not calculated; (1) total number of fishers (= 140) is extrapolated from household surveys; (2) total population = 548; total subsistence demand = 34.62 t/year; (3) catch figures are based on recorded data from survey respondents only; difference of 15.17 km² to total reef = back-reef included in lagoon.

4.2.4 Catch composition and volume – invertebrates: Piis-Panewu

Catches reported by invertebrate fishers by wet weight show that lobsters (*Panulirus penicillatus*), sea cucumbers (*Holothuria* spp., including *H. scabra* and *H. nobilis* and *Stichopus* spp.) and giant clams (*Tridacna* spp., *Hippopus hippopus*) are the most important species collected, followed by octopus and trochus (Figure 4.14). The crab *Cardisoma* sp. is of less importance. Others, including *Serpulorbis* spp., *Saccostrea* sp., *Nerita polita* and

Turbo spp. are only collected in very small amounts. Somewhat surprisingly, plenty of mud crabs were observed in the mangrove areas; however, none of these were harvested or reported of interest.

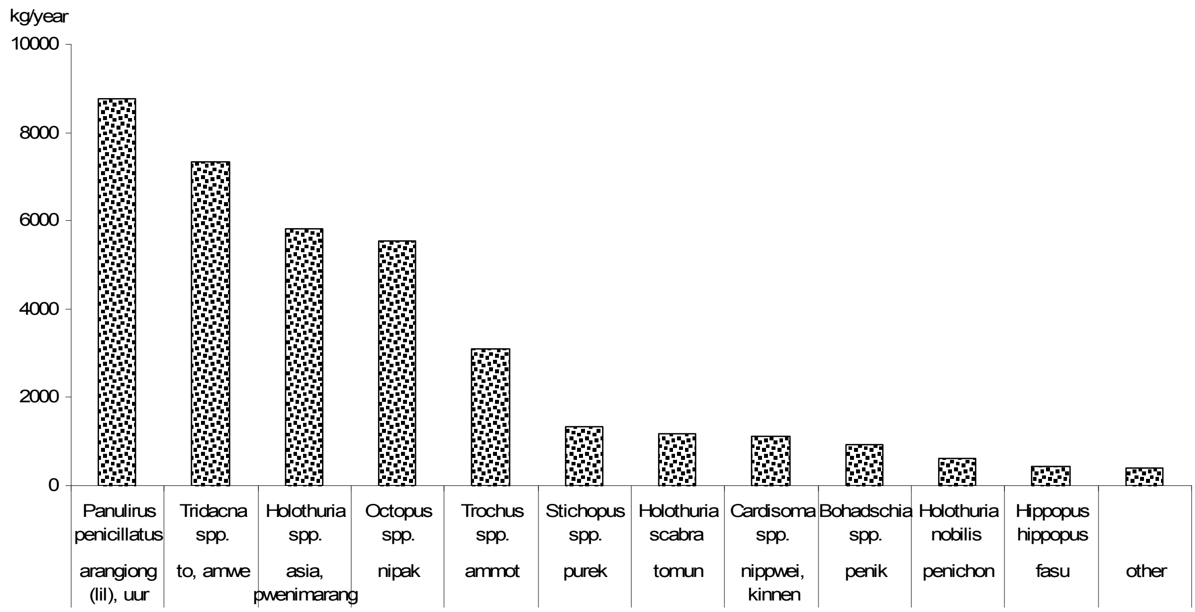

Figure 4.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Piis-Panewu.
'Others' include: *anipwi* (*Serpulorbis* sp.), *onon* (*Saccostrea* sp.), *ongi* (*Nerita polita*) and *neangepar* (*Turbo* spp.).

The fact that most impact is due to a few species only also shows in the number of vernacular names registered from respondents (Figure 4.15). Reeftop fishing shows the highest variety with 14 different vernacular names reported. All other fisheries, including combined fishing of two habitats, are represented by one to four vernacular names only.

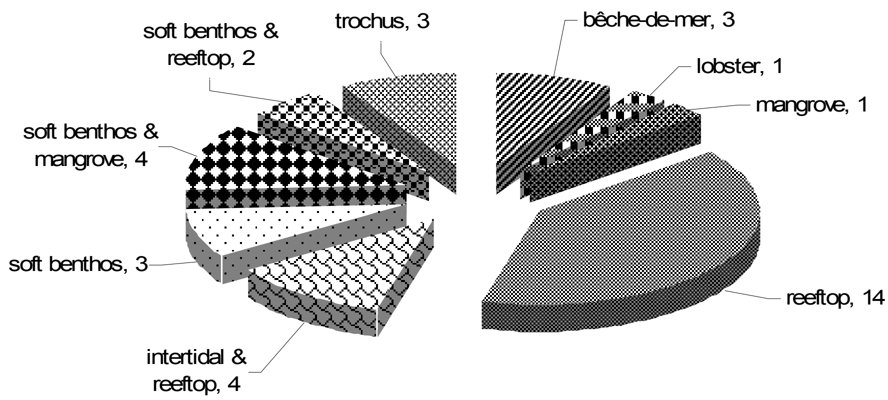

Figure 4.15: Number of vernacular names recorded for each invertebrate fishery in Piis-Panewu.

The average annual catch per fisher by gender and fishery (Figure 4.16) reveals substantial differences. Although fewer males collect invertebrates than females, male fishers who target reeftops catch on average almost twice as much in a year as females. Reeftop collection provides the highest average annual catches for both gender groups. By comparison, average annual catches by both male and female fishers are small 0.5–1 t/fisher/year (wet weight).

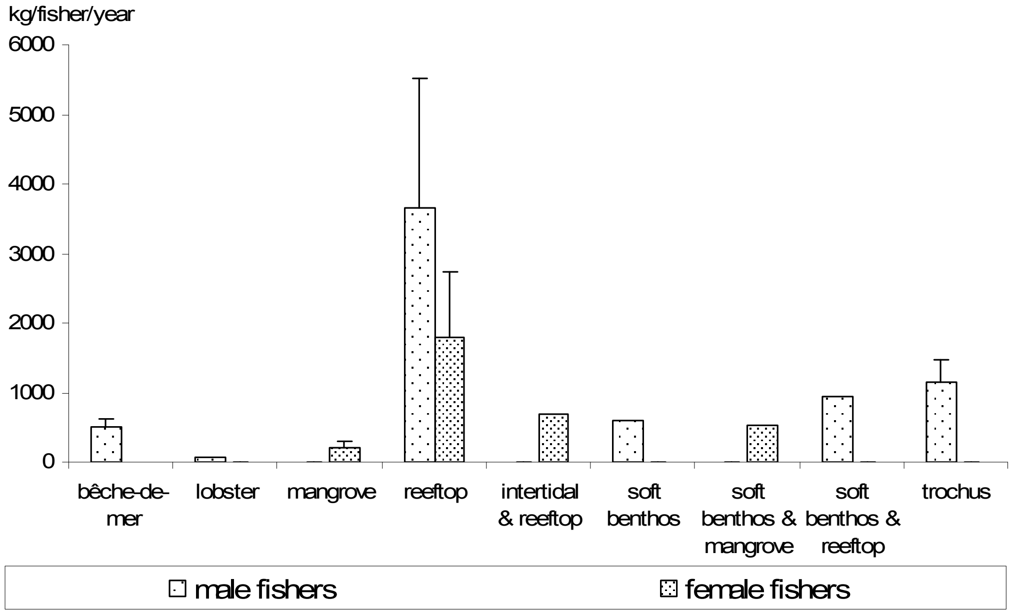

Figure 4.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Piis-Panewu.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 8 for males, n = 12 for females). Bars represent standard error (+SE).

Figure 4.17 highlights the importance of invertebrates for subsistence and sale. While about 69% of wet weight collected serves subsistence demand, 31% is sold. This calculation is based on the assumption that half of the amount (wet weight) collected for either subsistence or sale is consumed by the Piis-Panewu community, and the other half is sold.

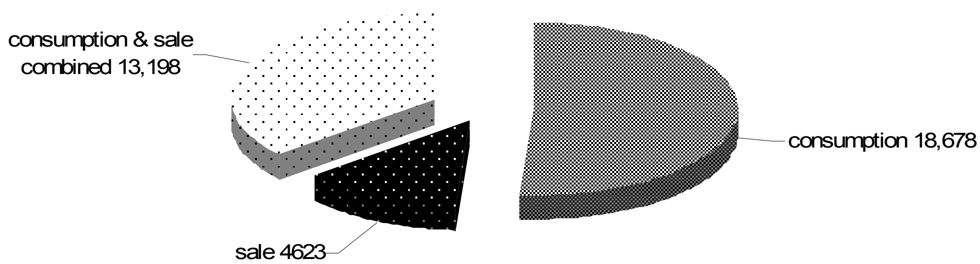

Figure 4.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Piis-Panewu.

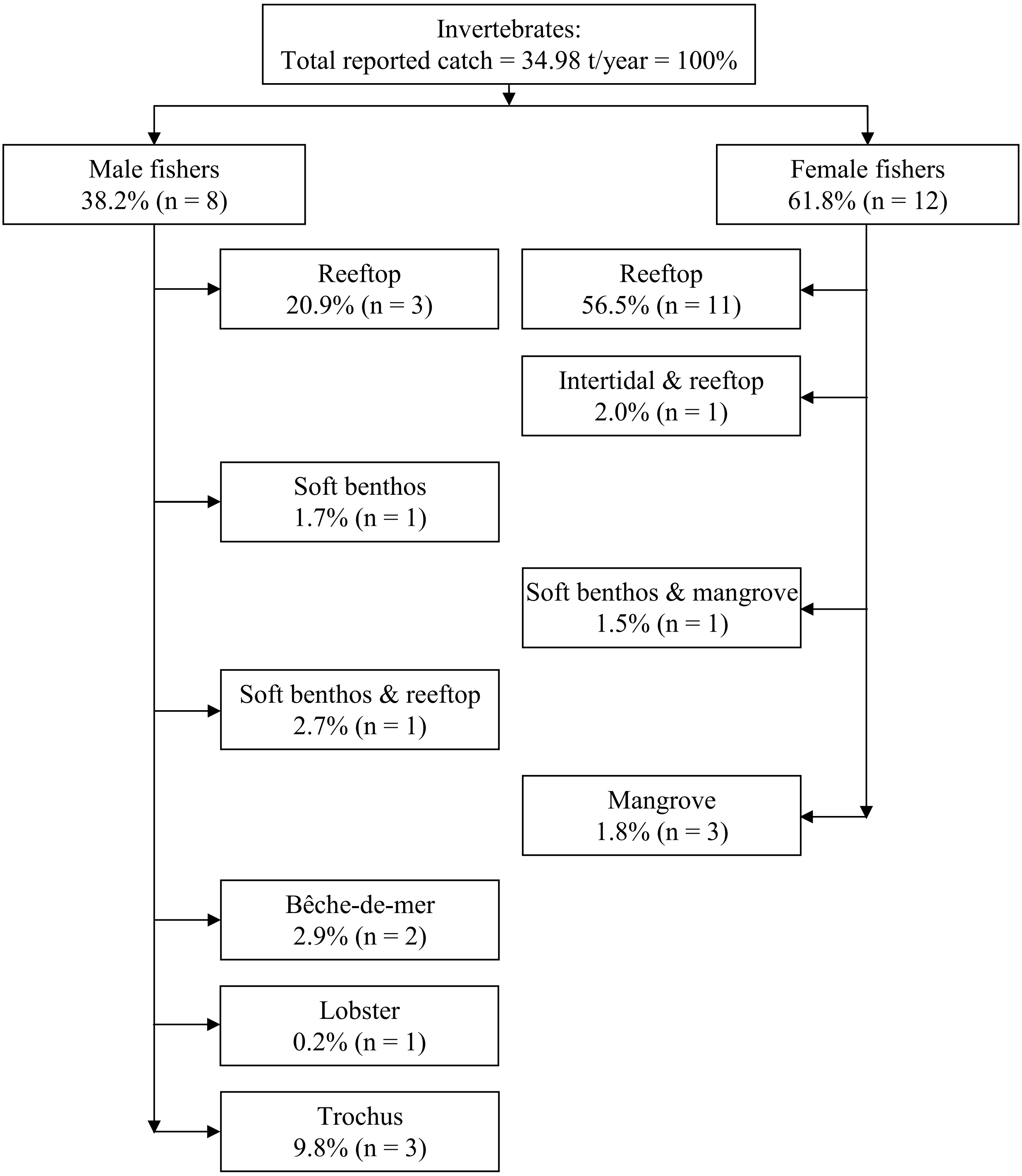

Figure 4.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Piis-Panewu.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

As mentioned earlier, males in Piis-Panewu are much less engaged in invertebrate fisheries than females. While males collect ~38% of the total catch (wet weight) only, females are responsible for ~62% (Figure 4.18). Most of the invertebrate catch taken by males is sourced from reeftops, while all other fisheries contribute only 2–10% of the total annual reported catch. Female fishers also source most of their catch from reeftops, and only ~2% each is contributed by catches from the combined gleaning of intertidal and reeftop areas, soft benthos and mangroves, and mangroves.

Table 4.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Piis-Panewu

Parameters	Fishery / Habitat			
	Reeftop	Intertidal & reeftop	Lobster	Trochus
Fishing ground area (km^2)	24.45	24.45	54.16	15.53
Number of fishers (per fishery) (1)	117	8	8	25
Density of fishers (number of fishers/km^2 fishing ground)	4.8	0.3	0.2	1.6
Average annual invertebrate catch (kg/fisher/year) (2)	2081.40 (±845.20)	698.98 (n/a)	79.96 (n/a)	1147.70 (±334.88)

Figures in brackets denote standard error; n/a = standard error not calculated; (1) number of fishers extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only; surface areas of soft benthos, soft benthos & mangrove, soft benthos & intertidal, mangrove and bêche-de-mer fisheries are not known; number of fishers per fishery: soft benthos = 8, soft benthos & mangrove = 8, soft benthos & intertidal = 8, mangrove = 25, bêche-de-mer = 17; average recorded catch (kg biomass wet weight/fisher/year): soft benthos = 604.07 (n/a), soft benthos & mangrove = 535.97 (n/a), soft benthos & intertidal = 933.71 (n/a), mangrove = 207.83 (±94.89), bêche-de-mer = 502.62 (±127.03).

Taking into account available figures on the shallow-reef areas that are considered to support reeftop and the combined intertidal and reeftop gleaning, the outer-reef area relevant to trochus, and the length of the outer reef that may support lobster fisheries, fishing pressure for any of these habitats is low. This conclusion is based on the low fisher density, i.e. a maximum of 5 fishers/km² for the shallow-reef surface, ~2 fishers/km² for the trochus fishery and ≤1 fisher/km² for the lobster fishery. Regarding the amount that is taken in terms of wet weight per each habitat and fisher, the average annual catch for fishers targeting reeftops and trochus is high. However, average annual catch rates for lobsters are low (Table 4.5). Unfortunately, there are no exact surface area figures available to apply the same parameters to the bêche-de-mer, soft-benthos and mangrove fisheries. Taking into account average annual catch rates of any of these fisheries, figures do not suggest any alarming exploitation level. However, as most fisheries are represented by a very few target species only, impacts may be detrimental on these target species. Therefore, before final assessment is made, these findings need comparison with those of the resource surveys.

4.2.5 Management issues: Piis-Panewu

At the time of the survey, no fisheries management strategies at either government or community level were in place. People on Piis-Panewu were aware of the national laws against the use of dynamite for fishing. Governmental authorities did check catches for signs of dynamite use. However, little other attention was given by the fisheries department to monitoring catches and fishing activities. The open-access system does not favour growing coastal and small-scale artisanal fisheries.

People's perception was that fish were plentiful in the outer reef and in coastal reef and lagoon areas that are further away from settlements.

Given the importance of reef fisheries for subsistence and income, and the growing demand for export to Hawaii and elsewhere, fisheries management is urgently needed. The marine rapid ecological assessment (REA) that is being planned by the Protected Areas Network Program within the FSM Department of Resource Management and Development in cooperation with the assistance of a technical team from TNC, national and state partners, including the Department of Marine Resources, Environmental Protection Agency and Chuuk

Conservation Society (CCS) may be of further help to identify problem areas and to start a fisheries management strategy programme.

4.2.6 Discussion and conclusions: socioeconomics in Piis-Panewu

The Piis-Panewu community has good access to a wide range of habitats, including sheltered coastal reef, lagoon, mangroves, outer reef and passages in an open-access environment. However, the community has few if any alternatives to fishing, limited access to agricultural production, and needs motorised boat transport to sell fishery produce at Weno, the capital centre. Other, important factors regarding the current situation of fishing and its possible future development include the following:

- The Piis-Panewu community is completely dependent on marine resources for home consumption and for almost all cash income. The availability of motorised boats, the short, one-hour boat journey to the urban market of Weno, and the regular visits of agents to the island make it possible for the community to commercially exploit its fishery resources.

- Consumption of fresh fish (79 kg/person/year) and invertebrates (14.4 kg/person/year) is high. Both figures are above the average found across all study sites in FSM. By comparison, canned fish consumption is less (2.4 kg/person/year).

- Consumption and income patterns highlight the traditional lifestyle of the community. However, the import prices of staple food items and the transport and fuel costs increase the need to generate cash income to satisfy the relatively high costs of living. Remittances do not play an important role for many households; more households rather rely on food sent from family members in Weno.

- Traditional roles show in the fact that males fish for finfish, while females do most of the invertebrate collection. Given the current, very low sales price for finfish, changes in gender roles may show when both finfish and invertebrates are caught to provide income, as invertebrates are currently a more lucrative source. Females are organised into smaller groups serving agents and supermarkets that give orders for octopus, and perhaps other invertebrates. Males are the main commercial fishers of invertebrates, including bêche-de-mer, lobsters, trochus and giant clams.

- Overall, CPUEs are moderate (1.7–2.5 kg/hour fishing trip) and higher at the outer reef than in sheltered coastal reef areas close to shore.

- Spear diving, handlining, gillnetting and deep-bottom lining are the main techniques used, and the extent to which they are used depends on the habitat targeted.

- Reported average catch sizes increase, as expected, with distance from shore. Overall, sizes are large, starting with an average length of 25 cm in catches from the sheltered coastal reef and reaching about 35 cm in catches from the outer reef. However, this observation does not apply to Scaridae; their average size remains at 25 cm and does not change according to habitat.

- The main families caught in any of the habitats fished correspond to the main fishing technique used in that habitat, i.e. Mullidae (gillnetting), Scaridae and Acanthuridae (spear diving), and Serranidae, Labridae and Lethrinidae (gillnetting, handlining, spear diving).

- Results from the invertebrate fisher survey show that commercial catches of lobsters, bêche-de-mer, giant clams, trochus and octopus account for most of the annual harvest (wet weight) of invertebrates.

- Fishing pressure indicators calculated for finfish suggest low fisher, population and catch densities due to the size of the available reef and total fishing ground area. However, the low selling price of fish, the lack of alternative income sources, and the lack of any fisheries management all give reason for caution.

- Fishing pressure indicators calculated for invertebrate fisheries show low fisher densities. However, the fact that fishing targets a very few species only, that the average annual catch per fisher is very high for reeftop gleaning, and the lack of any fisheries management give reason for concern.

4.3 Finfish resource surveys: Piis-Panewu, CHUUK

Finfish resources and associated habitats were assessed between 13 and 17 April 2005, from a total of 14 transects (4 intermediate-reef, 6 back-reef, and 4 outer-reef transects, see Figure 4.19 and Appendix 3.3.1 for transect locations and coordinates respectively). Coastal reef habitat was absent in this area and remaining analysed transects were not included in this report due to their exclusion from the local fishing area. Therefore only the results from 14 transects are reported here below.

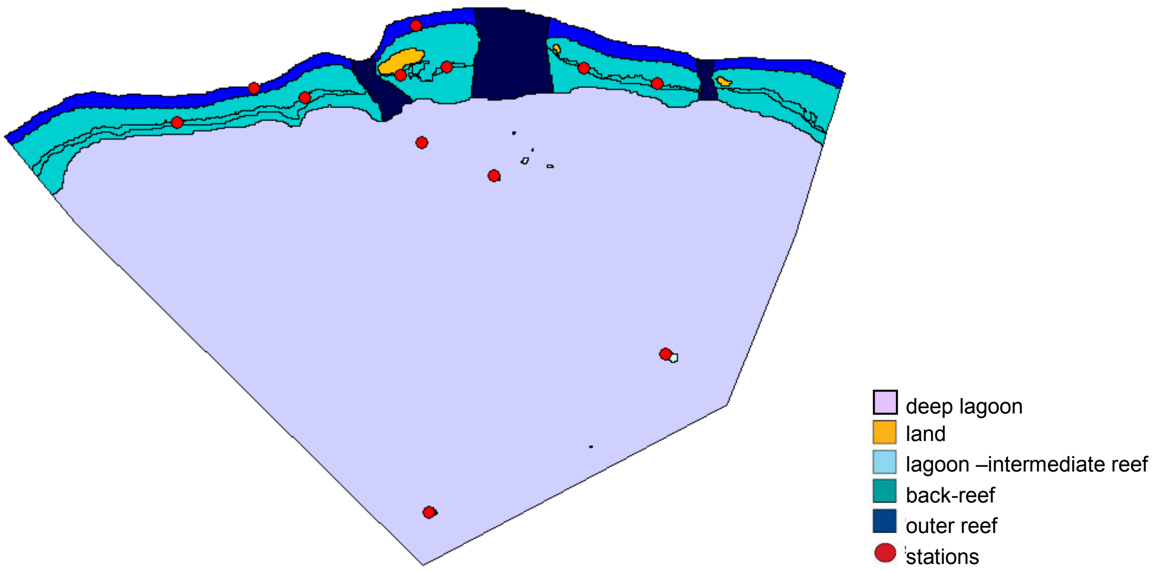

Figure 4.19: Habitat types and transect locations for finfish assessment in Piis-Panewu.

4.3.1 Finfish assessment results: Piis-Panewu

A total of 22 families, 56 genera, 139 species and 5602 fish were recorded in the 14 transects (See Appendix 3.3.2 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 46 genera, 127 species and 5461 individuals.

Finfish resources varied slightly among the three reef environments found in Piis-Panewu (Table 4.6). The intermediate reef contained the highest density, biomass and biodiversity (0.7 fish/m^2, 100 g/m^2, 46 species/transect), while back-reefs displayed the lowest values of these parameters (0.3 fish/m^2, 36 g/m^2, 35 species/transect), and outer reefs presented values intermediate between the other reef habitats, but lowest average size (16 cm FL) and size ratio (52%).

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

Parameters	Habitat			
	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	4	6	4	14
Total habitat area (km^2)	0.1	15.1	4.8	20.0
Depth (m)	7 (4-10) (3)	4 (2-6) (3)	7 (5-11) (3)	5 (2-11) (3)
Soft bottom (% cover)	5 ±1	23 ±5	1 ±1	17
Rubble & boulders (% cover)	33 ±10	13 ±4	1 ±1	10
Hard bottom (% cover)	28 ±6	30 ±4	56 ±5	36
Live coral (% cover)	33 ±9	31 ±7	39 ±6	33
Soft coral (% cover)	0 ±0	2 ±1	1 ±1	2
Biodiversity (species/transect)	46 ±2	35 ±1	39 ±3	39 ±2
Density (fish/m^2)	0.7 ±0.1	0.3 ±0.0	0.6 ±0.1	0.4
Biomass (g/m^2)	99.5 ±27.4	35.7 ±4.7	60.7 ±4.6	42.0
Size (cm FL) (4)	18 ±1	16 ±1	16 ±1	16
Size ratio (%)	57 ±3	54 ±3	52 ±3	53

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

Intermediate-reef environment: Piis-Panewu

The intermediate-reef environment of Piis-Panewu was dominated by two herbivorous families: Acanthuridae and Scaridae (Figure 4.20). These two families were represented by 27 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Naso lituratus*, *Chlorurus sordidus*, *C. bleekeri*, *Acanthurus olivaceus*, *C. microrhinos*, *S. psittacus* and *A. nigricans* (Table 4.7). This reef environment presented a diverse habitat with equal amounts of the surface covered by hard bottom (28%), live coral (33%) and rubble (33%) (Table 4.6). However, this reef covered only a very small surface area (0.1 km^2, <0.1% of all reefs of Piis-Panewu, Table 4.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.197 ±0.018	26.6 ±3.0
	Naso lituratus	Orangespine unicornfish	0.039 ±0.032	8.7 ±7.1
	Acanthurus olivaceus	Orangeband surgeonfish	0.021 ±0.021	6.7 ±6.7
	Acanthurus nigricans	Whitecheek surgeonfish	0.043 ±0.035	3.1 ±2.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.061 ±0.013	7.9 ±2.1
	Chlorurus bleekeri	Bleeker's parrotfish	0.030 ±0.017	7.5 ±5.1
	Chlorurus microrhinos	Steephead parrotfish	0.008 ±0.005	4.2 ±2.4
	Scarus psittacus	Common parrotfish	0.045 ±0.042	3.5 ±2.7

The density, size ratio, biomass and biodiversity of finfish in the intermediate reefs of Piis-Panewu were the highest at this site and higher than the values at the other two sites in FSM with intermediate reefs, Romanum and Yyin (Table 4.6). Average fish size (18 cm FL) was second to the value in the back-reef but still the highest for all intermediate-reef values. Herbivores were highly dominant over the other trophic classes and carnivores were almost absent. Acanthuridae represented the most numerous family, mainly represented by the small-sized *Ctenochaetus striatus*. Scaridae were the second-most abundant family with several small species. These two families are the main fishing targets. Average size ratios were relatively low for Lethrinidae and Mullidae (<50%). This could indicate a first response to fishing pressure; emperorfish are in fact a target group in internal reefs. However, substrate was almost equally composed of hard bottom, coral and rubble, not presenting any real soft bottom, which favours families such as emperors and goatfish.

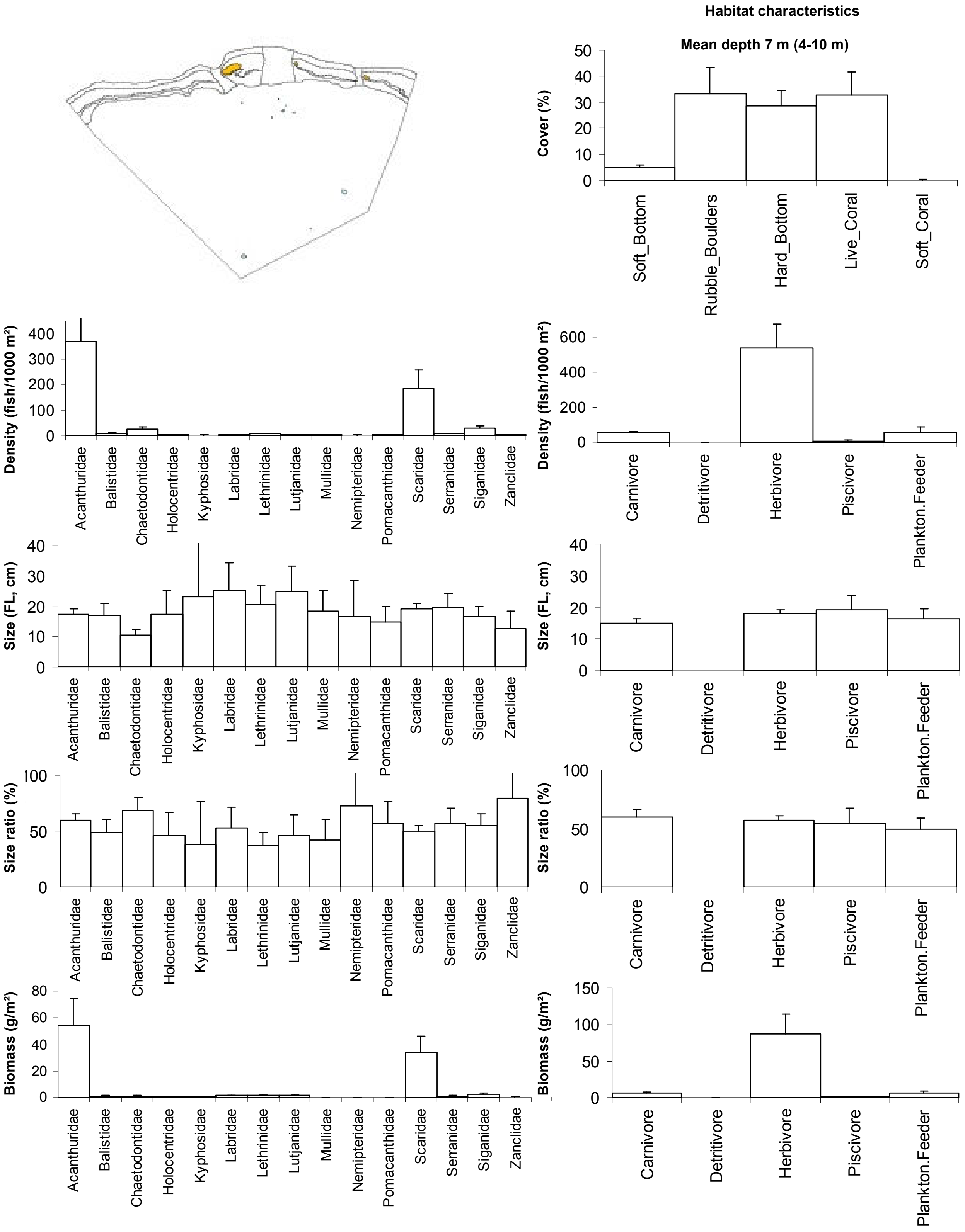

Figure 4.20: Profile of finfish resources in the intermediate-reef environment of Piis-Panewu.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Piis-Panewu

The back-reef environment of Piis-Panewu was dominated by two major families of herbivores, Acanthuridae and Scaridae and, to a lesser extent, by Lethrinidae (Figure 4.21). These three major families were represented by 30 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus psittacus*, *Hipposcarus longiceps* and *S. globiceps* (Table 4.8). This reef environment presented a substrate composition with very similar percentage cover of hard bottom (31%), live coral (30%) and soft bottom (23%), with presence of rubble as well (13%, Table 4.6 and Figure 4.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.089 ±0.014	11.3 ±2.7
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.043 ±0.016	3.6 ±1.4
	Scarus psittacus	Common parrotfish	0.011 ±0.009	1.4 ±0.9
	Hipposcarus longiceps	Pacific longnose parrotfish	0.004 ±0.003	1.3 ±0.7
	Scarus globiceps	Globehead parrotfish	0.006 ±0.003	1.0 ±0.5

The density, biomass and biodiversity of finfish in the back-reef of Piis-Panewu were the lowest among the three reefs present at the site. Also, when compared to the other three back-reefs studied in the country, Piis-Panewu displayed the lowest values recorded. Only average fish size (19 cm FL) was the largest, both inside the site as well as among the similar habitats at the other sites. Average size ratio was relatively high (54%), the third-ranked value in the country and the second-highest at the site. Trophic composition was dominated by herbivores, mostly Acanthuridae and Scaridae. However, carnivores usually associated with soft bottom, such as Lethrinidae and, to a lesser extent, Mullidae, were also present. Bottom composition was very diverse, offering a variety of habitats for several families.

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

Outer-reef environment: Piis-Panewu

The outer reef of Piis-Panewu was dominated by two herbivorous families, Acanthuridae and Scaridae and, to a much lesser extent, one carnivorous family, Balistidae (Figure 4.22). These three families were represented by 22 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Melichthys vidua*, *Odonus niger*, *Naso lituratus* and *S. rubroviolaceus* (Table 4.9). Hard bottom and live coral practically covered the entire substrate of this reef environment (95% cover) with live coral presenting a very high cover (39%, 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 outer-reef environment of Piis-Panewu

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.284 ±0.060	26.9 ±6.3
	Naso lituratus	Orangespine unicornfish	0.009 ±0.004	1.9 ±0.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.077 ±0.023	7.2 ±1.7
	Scarus rubroviolaceus	Ember parrotfish	0.010 ±0.005	1.9 ±0.9
Balistidae	*Melichthys vidua*	Pinktail triggerfish	0.044 ±0.008	4.8 ±0.9
	Odonus niger	Redtooth triggerfish	0.026 ±0.020	3.1 ±2.2

The density, biomass and biodiversity of finfish in the outer reef of Piis-Panewu were lower than in the intermediate reef and higher than in back-reefs (Table 4.6). Size and size ratio were the absolute lowest. When compared to the other country sites, density, biomass, size, size ratio and biodiversity in Piis-Panewu were the minimum recorded and extremely low. Herbivores strongly dominated this habitat, with Acanthuridae and Scaridae in very high numbers. However, carnivores were also present, with the most important family being Balistidae. Average size ratio was below 50% only for Scaridae. Substrate composition, dominated by hard bottom and coral, was the type that favours herbivores and only few carnivore families associated with hard bottom. However, snappers were almost absent here. These are the fish that are most targeted at the outer reefs and their absence is most probably a sign of serious impact.

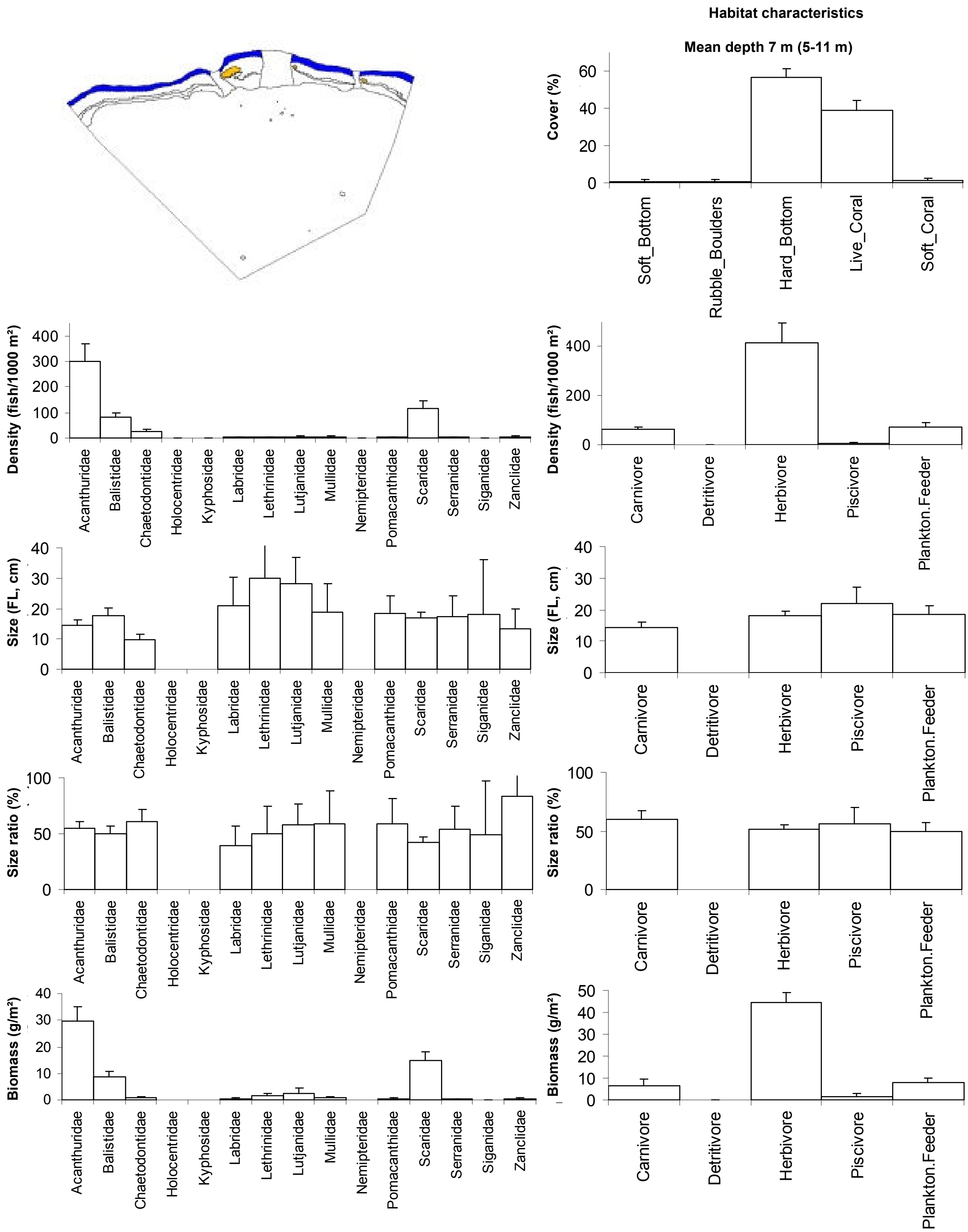

Figure 4.22: Profile of finfish resources in the outer-reef environment of Piis-Panewu.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Piis-Panewu

Overall, the fish assemblage of Piis-Panewu was dominated by herbivorous Acanthuridae and Scaridae and, to much lesser extent, carnivorous Lethrinidae, Balistidae and Chaetodontidae (these only for density) (Figure 4.23). These five families were represented by a total of 58 species dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Chlorurus sordidus*, *Gnathodentex aureolineatus*, *Scarus psittacus*, *Melichthys vidua*, *Naso lituratus* and *S. globiceps* (Table 4.10). The average substrate was dominated by hard bottom (36%), with high cover of live coral (33%), and a lower proportion of mobile bottom (27%). The overall fish assemblage in Piis-Panewu shared characteristics of primarily back-reefs (75% of total habitat) and outer reefs (24%) and, to a minimal extent, intermediate reefs (<1% of habitat).

Table 4.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Abaiang (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.14	15.1
	Naso lituratus	Orangespine unicornfish	0.01	1.1
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05	4.4
	Scarus psittacus	Common parrotfish	0.01	1.4
	Scarus globiceps	Globehead parrotfish	0.01	1.0
Balistidae	*Melichthys vidua*	Pinktail triggerfish	0.01	1.2
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.02	1.5

Overall, Piis-Panewu appeared to support a poorer finfish resource compared to the two sites at Yap, and a similar to slightly healthier resource compared to Romanum. Romanum displayed higher biomass (52 versus 42 g/m^2) than Piis-Panewu and the same density (0.4 fish/m^2), but lower size (15 versus 16 cm FL), size ratio (45 versus 53%) and biodiversity (33 versus 39 species/transect). These results suggest that the finfish resource in Piis-Panewu is fairly poor. A detailed assessment at the family level revealed a constant dominance of herbivores over carnivores, although somewhat less marked in the back-reef. However, this trend could be partially explained by the composition of the habitat, mostly hard rock and live coral, with very little percentage cover of soft substrate, which normally favours most invertebrate-feeding carnivores such as Mullidae and Lethrinidae. Overall, size ratios were high for most families, except for Lethrinidae and Scaridae, two of the most targeted fished families.

Figure 4.23: Profile of finfish resources in the combined reef habitats of Piis-Panewu (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Piis-Panewu

The assessment indicated that the status of finfish resources in this site was rather poor. Although the reefs are naturally rich, with high cover of live coral, they lack the type of substrate capable of hosting carnivores associated with soft bottom, such as Lethrinidae and Mullidae. However, Lutjanidae, usually associated with hard, outer-reef substrates, were fairly poor as well. When analysed at the reef-habitat level, resources were rather variable. The scant intermediate reefs provided the richest habitat, with highest density and biomass of finfish; back-reefs were the poorest of the three habitats. The outer reefs were unusually poor for an oceanic location: the density, biomass and biodiversity of finfish were lower than the intermediate-reef values, and size and size ratio were the absolute lowest. Average size ratio was below 50% for Scaridae. Outer-reef values of all biological parameters analysed were also the lowest in the country. Fishing in Piis-Panewu is performed for subsistence and at the same time provides the only source of income generation. Moreover, the amount of fresh fish eaten is very high (78 kg/person/year) and, as a consequence, the frequency of fishing and fisher density are also high. Fishing is done mostly by gillnetting and spearfishing, both highly impacting methods. All these facts result in a noticeable impact on finfish. Herbivores strongly dominated all reefs, including the outer reefs, with Acanthuridae and Scaridae in very high numbers and Lutjanidae almost totally absent. Snappers were the main fish caught in the outer reefs and their absence in such habitat is most probably a sign of serious impact. In fact, the outer reefs were found to be more frequently targeted than the other habitats, an unusual case compared to the other sites in the country.

- Overall, Piis-Panewu finfish resources appeared to be in poor condition. The reef habitat is naturally rich in coral although not particularly diverse (mostly coral rock and live coral), advantaging selected families of herbivores.

- The dominance of herbivores, especially Acanthuridae and Scaridae, could be partially explained by the type of environment, which is mainly composed of hard bottom.

- Resources in the outer and back-reefs showed the first signs of high fishing pressures in terms of lower fish density, biomass, size and biodiversity compared to intermediate reefs at the site, and to similar habitats in the country.

- Lutjanidae were absent from their typical habitats in the outer reefs, where they are most frequently fished: this is another sign of impact of fishing on specific target species.

4.4 Invertebrate resource surveys: Piis-Panewu, CHUUK

The diversity and abundance of invertebrate species at Piis-Panewu were independently determined using a range of survey techniques (Table 4.11): broad-scale assessment (using the 'manta tow'; locations shown in Figure 4.24) and finer-scale assessment of specific reef and benthic habitats (Figures 4.25 and 4.26).

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

Table 4.11: Number of stations and replicates completed at Piis-Panewu

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	14	81 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)	6	36 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	6	36 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	5	30 search periods
Sea cucumber night searches (Ns)	2	12 search periods

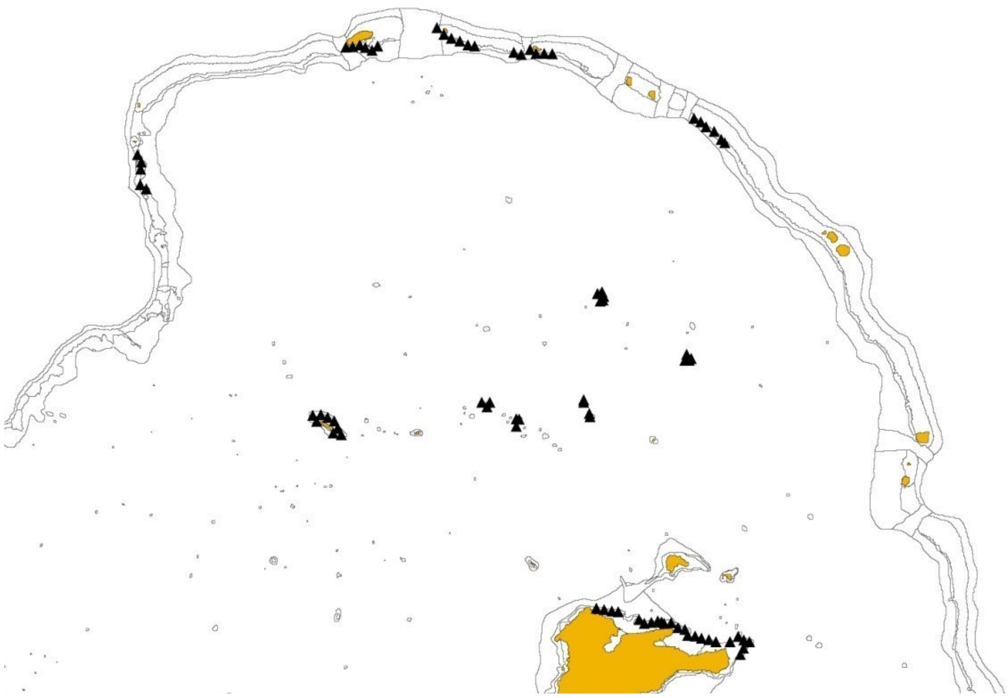

Figure 4.24: Broad-scale survey stations for invertebrates in Piis-Panewu.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

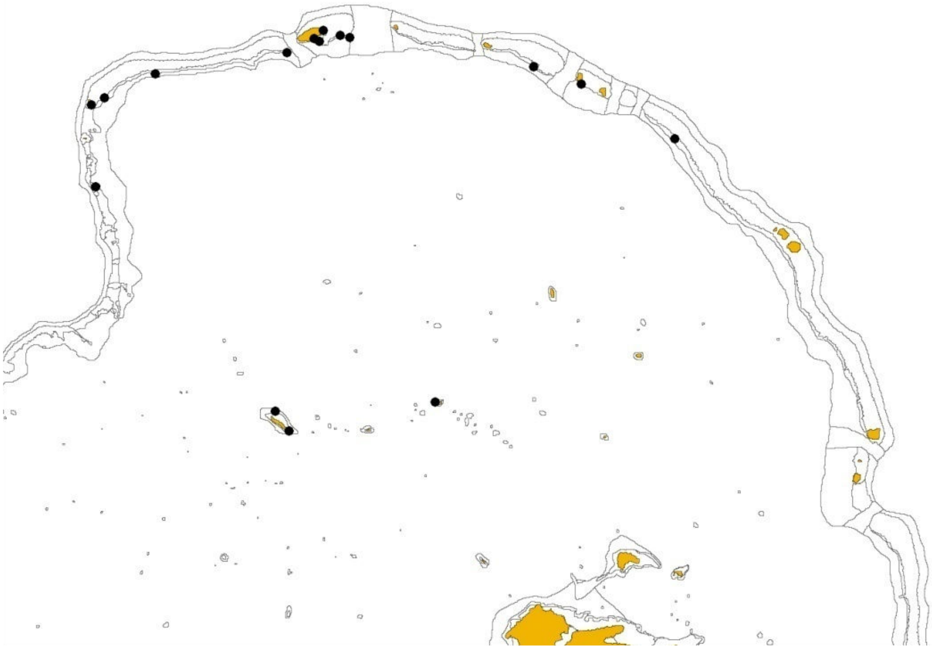

Figure 4.25: Fine-scale reef-benthos transect survey stations in Piis-Panewu.
Black circles: reef-benthos transect stations (RBt).

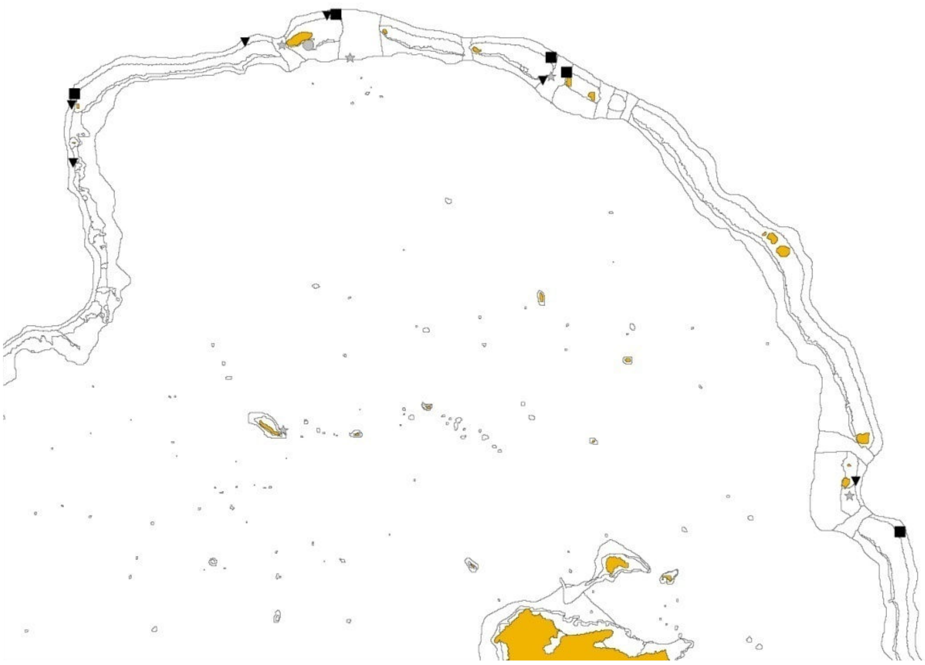

Figure 4.26: Fine-scale survey stations for invertebrates in Piis-Panewu.
Inverted black triangles: reef-front search stations (RFs);
black squares: mother-of-pearl transect stations (MOPt);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Fifty-three species or species groupings (groups of species within a genus) were recorded in the Piis-Panewu invertebrate surveys. Among these were 8 bivalves, 20 gastropods, 14 sea cucumbers, 4 urchins, 3 sea stars, 1 cnidarian and 1 lobster (Appendix 4.3.1). Information on key families and species is detailed below.

4.4.1 Giant clams: Piis-Panewu

Shallow reef habitat that is suitable for giant clams was extensive at Piis-Panewu (40 km^2: ~24.5 km^2 within the lagoon and 15.5 km^2 on the reef front or slope of the barrier). The main lagoon of this section of Chuuk was very extensive at ~533.6 km^2 and stretched from the north of Weno across a range of reef structures before reaching the barrier reef at Piis-Panewu.

At the island of Piis-Panewu, reef structure was characterised by sandy, shallow back-reef and patch coral within a pseudo-lagoon surrounding the *motu*-style islands on the wider sections of the barrier. Passage and exposed reef at the barrier-reef slope were exposed to oceanic swell; in general, shoaling reef was not extensive on the ocean side of the barrier. An oceanic influence prevailed throughout the system.

Using all survey techniques, four species of giant clam were noted: the elongate clam *Tridacna maxima*, the boring clam *Tridacna crocea*, the fluted clam *Tridacna squamosa*, and the bear's paw clam *Hippopus hippopus*. Broad-scale sampling provided a good overview of the distribution and density of three of the four clam species recorded. Records revealed that *T. maxima* had the widest distribution (found in 10 stations and 41 transects), followed by *T. squamosa* (2 stations and 2 transects) and *H. hippopus* (1 station and 1 transect, see Figure 4.27). *T. crocea* was not recorded in survey.

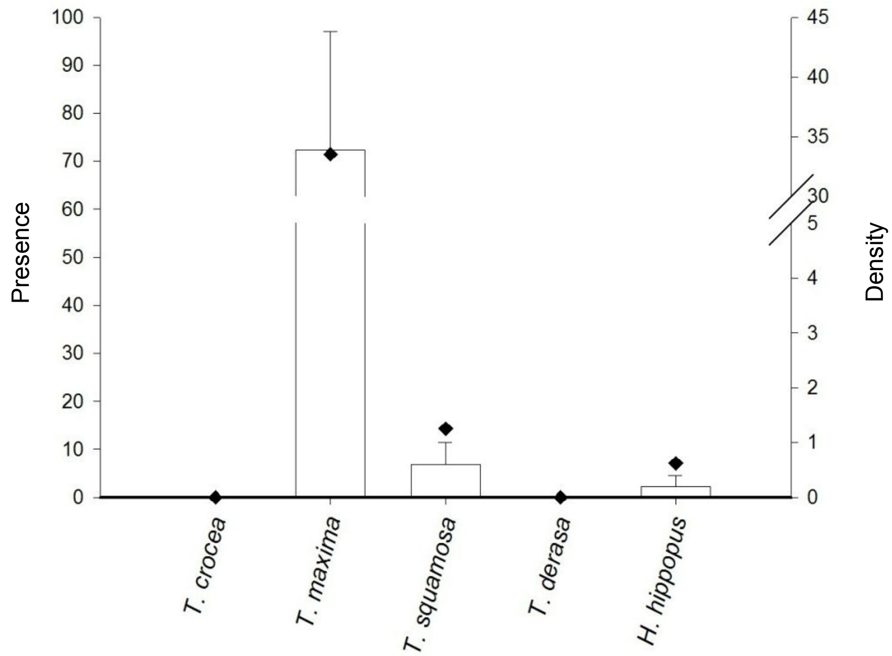

Figure 4.27: Presence and mean density of giant clam species at Piis-Panewu based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 4.28). In these reef-benthos assessments (RBt), *T. maxima* was present in 88% of stations, the highest station density being 417 /ha ±105.4. *T. crocea* and *H. hippopus* were only recorded at a single station each, and at a low density (125 and 42 individuals/ha, respectively).

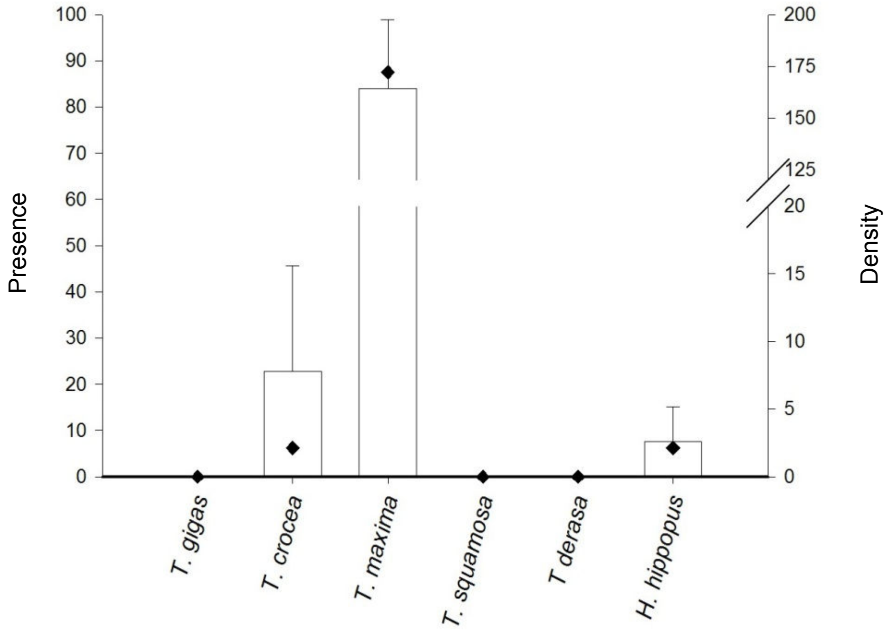

Figure 4.28: Presence and mean density of giant clam species at Piis-Panewu based on reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

The mean size of elongate clams *T. maxima* from RBt stations was 10.9 cm ±0.3, which represents a clam of about 5 years old. A full range of *T. maxima* lengths was noted in survey, although the largest sizes (≥15 cm) were not common. Only two of the faster-growing clams *T. squamosa* (asymptotic length L_∞ of 40 cm) were recorded. The single specimen measured was of adult size and equates to a clam of ~4 years of age). *H. hippopus* was also rare and found in larger sizes (mean length 21.5 cm ±3.5, see Figure 4.29).

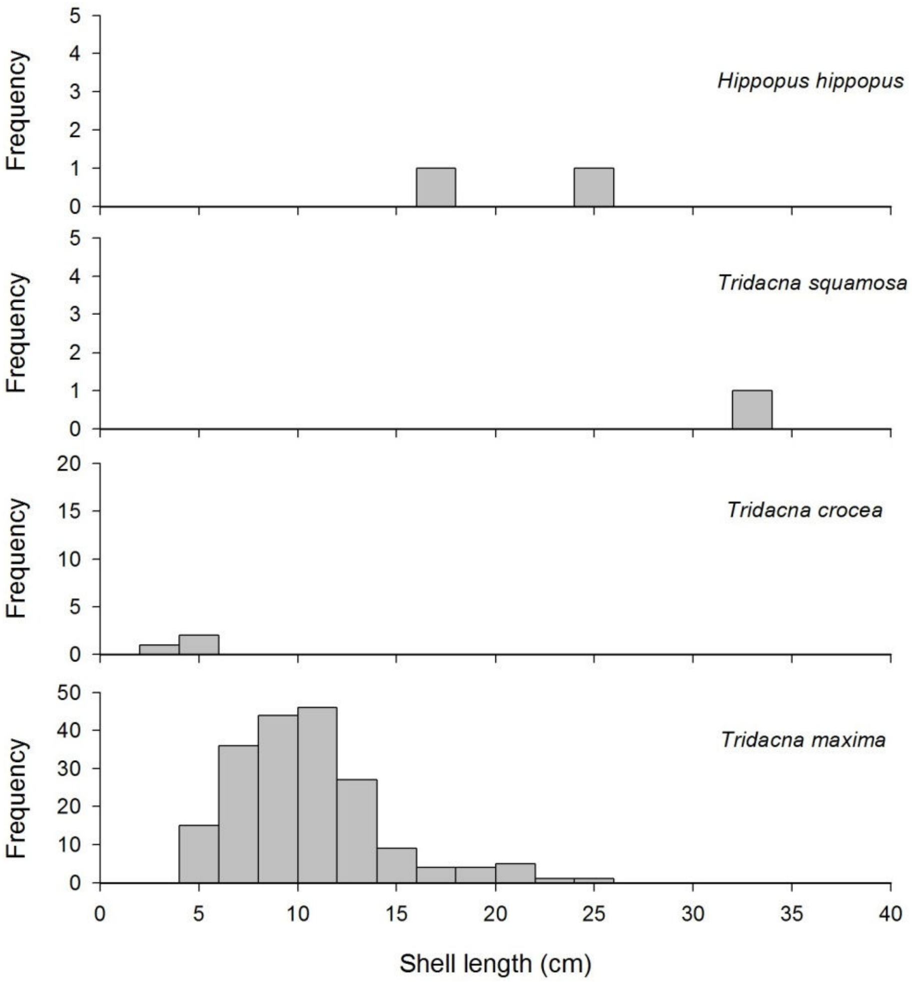

Figure 4.29: Size frequency histograms of giant clam shell length (cm) for Piis-Panewu.

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

Chuuk does not seem to have supported natural stocks of the commercial topshell *Trochus niloticus* before 1927, as there are reports of unsuccessful translocations of live shell from Palau. Despite the various early attempts to introduce trochus, a total of 6724 shells were transferred in bait wells of skipjack boats in 1927 and five years elapsed before this introduction was judged successful (Gillett 2002b). The first harvest was in 1939 and the greatest annual harvest in the early days of the fishery was in 1952 (230 t, or 233.7 t of shell). Later, trochus from Chuuk were used to make introductions to Jaluit and Pohnpei (Gillett 2002b).

Trochus is one of the few inshore species that is protected by Chuuk law. The Department of Marine Resources (DMR) monitors the trochus species and declares whether the species is ready for harvesting or not. However, illegal harvests are commonly noted. There was an incident in 2003 that involved a particular company buying trochus from the local people although the DMR had not declared an open season for harvesting. The company bought the trochus for 25 cents per pound although it is a known fact that trochus cost a lot more when exported. During the current survey, officers noted that trochus harvests were occurring and noted the remains of trochus processing on uninhabited *motu*.

The inshore, intermediate and barrier reefs at Chuuk were all suitable for trochus. CoFish survey work revealed that juvenile and adult *T. niloticus* shells were well distributed around reefs throughout northern Chuuk, with even broad-scale surveys picking up trochus in all stations (Total lineal distance of exposed reef perimeter was 54.2 km.). The survey of reef zones allows the determination of shell distribution and density for commercial trochus. Usually, in addition to standard broad-scale and shallow-reef surveys, trochus information is collected using reef-front searches (RFs) and mother-of-pearl transects (MOPt, see Methods, Table 4.12).

Table 4.12: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Piis-Panewu
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	8.1	1.3	14/14 = 100	31/81 = 38
RBt	59.9	15.2	10/16 = 63	20/96 = 22
RFs	9.2	3.0	5/6 = 83	11/36 = 31
MOPt	107.6	59.8	5/6 = 83	14/36 = 39
Tectus pyramis				
B-S	1.0	0.4	4/14 = 29	5/81 = 6
RBt	39.1	14.5	8/16 = 50	12/96 = 13
RFs	3.3	1.9	3/6 = 50	4/36 = 11
MOPt	72.9	10.4	6/6 = 100	16/36 = 44
Pinctada margaritifera				
B-S	1.2	0.5	4/14 = 29	6/81 = 7
RBt	0		0/16 = 0	0/96 = 0
RFs	0		0/6 = 0	0/36 = 0
MOPt	0		0/6 = 0	0/36 = 0

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

The majority of the stock was on shallow reef (~1.5–3 m deep) that was easily accessible to fishers working with a mask and snorkel. The majority of broad-scale and reef-benthos transect stations held trochus, and stations where they were present yielded a density of 4–396 trochus/ha.

Although *T. niloticus* was commonly recorded in northern Chuuk, the average density of trochus at all stations was generally low (<100 /ha). The most significant trochus aggregation noted was in the east of the system; the barrier reef in the north and northwest supported aggregations at slightly lower densities, and trochus was also recorded on reef in the middle of the lagoon (near Fanos Island). If we adopt the threshold of 500 shells/ha as an indication of the minimum density required before main aggregations can be considered for commercial fishing, trochus density records from Piis-Panewu generally indicated that aggregations still need to increase in overall abundance before commercial fishing can be considered.

A total of 110 trochus were recorded during the survey, although many opercula (the plates of exoskeletal material on the foot of a gastropod, n <300) were also found at makeshift processing stations on Pisininin Island (west of Piis-Panewu). Shell size (and shell size calculated from operculum size) gives an important indication of the status of stocks by highlighting new recruitment or lack of recruitment into the fishery, and which sizes of trochus are being removed from the fishery.

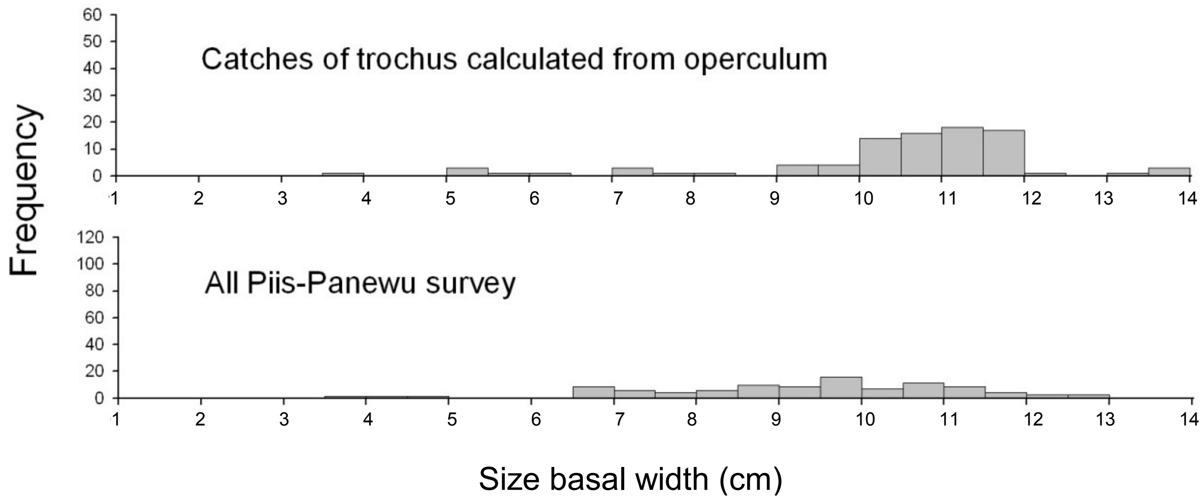

Figure 4.30: Size frequency histograms of trochus (*Trochus niloticus*) shell base diameter (cm) for Piis-Panewu.

The mean basal width of trochus at Piis-Panewu taken during in-water surveys was 9.4 cm ±0.2 (Figure 4.30). The length frequency graph reveals that a full range of trochus sizes were still in the water at Piis-Panewu, and that small numbers of small, juvenile shells were still entering the capture-size classes. For this cryptic species, younger shells are normally only picked up in surveys from a size of about 5.5 cm, when small trochus are emerging from a cryptic phase of life and joining the main stock. As can be seen from the length frequency graph, a small recruitment pulse of younger trochus is evident from size records collected at Piis-Panewu. Unfortunately, there is no clear evidence of large, successful recruitment in recent spawnings.

The length frequency results can be interpreted as an indication of the level of fishing in past harvests. In this case, only 19% of the stock was from size classes >11 cm basal width, which is slightly low, indicating that the older, larger, mature proportion of the population has been actively fished. In some other trochus fisheries, where stock has not been fished for an extended period or where there is a maximum basal width for commercial sale of >11 cm, this portion of the stock usually makes up between 20–50% of the population.

The level of suitability of reefs for grazing gastropods was also highlighted by results for the false trochus or green topshell (*Tectus pyramis*). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was common but at moderate-to-low density at Piis-Panewu (n = 46 recorded in surveys). The mean size (basal width) of *T. pyramis* was 5.5 cm ±0.2.

Another mother-of-pearl species, the blacklip pearl oyster (*Pinctada margaritifera*) is cryptic and normally sparsely distributed in open lagoon systems. Although passages were present in the northern lagoon of Chuuk, the lagoon was still relatively enclosed and, therefore, the abundance of this species could have been high, as in other, more enclosed lagoon systems of the Pacific. In surveys only seven blacklip were recorded (average length 13.5 cm).

4.4.3 Infaunal species and groups: Piis-Panewu

Soft benthos at the coastal margins of Piis-Panewu was generally suitable for seagrass, but no obvious or reported concentrations of in-ground resources (shell 'beds') were noted and therefore, no infaunal 'digging' surveys (quadrat surveys) were completed.

4.4.4 Other gastropods and bivalves: Piis-Panewu

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded both in deep-water searches (Ds) and broad-scale surveys (n = 6 individuals). Four other, smaller *Lambis* species were also noted (*Lambis lambis*, *L. chiragra*, *L. crocata*, *L. scorpius*), and the strawberry or red-lipped conch (*Strombus luhuanus*) was moderately common in RBt stations, although no dense patches were noted (Appendices 4.3.2 to 4.3.9).

Only one species of turban shell (*Turbo argyrostomus*) was noted. This large, silver-mouthed turban was recorded at moderate distribution (recorded in 100% of MOPt stations and 50% of RBt stations) and at average station densities of 52–118 /ha. Other resource species targeted by fishers (e.g. *Astralium*, *Cerithium*, *Chicoreus*, *Conus*, *Cypraea*, *Ovula*, *Pleuroploca*, *Thais* and *Vasum*) were also recorded during independent surveys (Appendices 4.3.2 to 4.3.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama*, *Hyotissa* and *Spondylus* are also in Appendices 4.3.2 to 4.3.9. No creel survey was conducted at Piis-Panewu.

4.4.5 Lobsters: Piis-Panewu

There was no dedicated night reef-front assessment of lobsters (See Methods.) although night-time assessments for nocturnal sea cucumber species (Ns) offered a small extra opportunity to record lobster species. Only one record for lobster (*Panulirus* sp.) was made in surveys at Piis-Panewu, and no prawn killers (*Lysiosquillina maculata*) or mud lobsters (*Thalassina* spp.) were noted.

4.4.6 Sea cucumbers[9]: Piis-Panewu

Around Piis-Panewu there were extensive areas of shallow- and deep-water sheltered lagoon and barrier reef (lagoon area 533.6 km^2). Coastal areas around Piis-Panewu were very oceanic-influenced and characteristic of an oceanic atoll system that has no elevated land mass. At the section of northern Chuuk where Piis-Panewu is located, the total land area of smaller islands and *motu* was small (<4 km^2) and land inputs (allochthonous matter) were negligible. Reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were extensive throughout the lagoon but the nature of these environments only provided a range of suitable habitats for a smaller subset of sea cucumber species.

Sea cucumber species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 4.13, Appendices 4.3.1 to 4.3.9, also see Methods).

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

Results from the full range of assessments yielded 13 commercial species of sea cucumber (plus one indicator species, see Table 4.13).

Sea cucumber species associated with shallow-reef areas, such as the medium-value leopardfish (*Bohadschia argus*), were not common in distribution (recorded in 9% of broad-scale transects) and were never recorded at even moderately high density (mean RBt density was 13.0 /ha ±5.0). Unusually, the high-value black teatfish (*Holothuria nobilis*), which is easily targeted by commercial fishers, was absent at Piis-Panewu (despite being found in small numbers in neighbouring Romanum). This species is hardly ever recorded at high density (>20 /ha), but is consistently found, even at well targeted sites around the Pacific.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was quite well distributed (in 10% and 31% of broad-scale and reef-benthos transect stations) but not at high density. In RBt stations, the greatest average station density recorded was 375 /ha ±190.9 (See Appendix 4.3.3).

Surf redfish (*Actinopyga mauritiana*) was recorded in 4 of 6 reef-front search stations (RFs). As this species is mostly found, where its name suggests, on reef fronts, RFs provide a valuable indication of its status. In Piis-Panewu, the density of this medium/high-value species was not high (<15 /ha), whereas in other locations in the Pacific this species is recorded in densities >400–500 /ha.

More protected areas of reef and soft benthos at relatively embayed areas of the lagoon also returned distribution and density records for sea cucumbers. Curryfish (*Stichopus hermanni*) and blackfish (*Actinopyga miliaris*) were rare (only one individual of each noted in survey). The brown curryfish (*S. vastus*) was absent; although small numbers of brown sandfish (*Bohadschia vitiensis*) were noted during night searches (Ns).

The high-value sandfish (*H. scabra*) was not recorded, but other, lower-value species of sea cucumber, such as flowerfish (*B. graeffei*), pinkfish (*H. edulis*) and lollyfish (*H. atra*) were still noted at reasonable distribution and moderate density.

Deep-water assessments (30 five-minute searches, average depth 25.2 m, maximum depth 33 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the narrow and wide passages had suitably dynamic water movement for these species, but only four *H. fuscogilva* were recorded. At Ds stations, the average station density of *H. fuscogilva* was low (1.9 /ha ±0.9) and, in general, the density of other deep-water species was also low, with greater abundance of *T. anax* (n = 9) than *T. ananas* (n = 1).

4.4.7 Other echinoderms: Piis-Panewu

At Piis-Panewu, small numbers of edible collector urchins *Tripneustes gratilla* (n = 9) and slate urchins *Heterocentrotus mammillatus* (n = 5) were recorded in survey. *Diadema* sp. was absent from the records taken, and the stronger-spined *Echinothrix* spp. were also seen only irregularly (in 63% of RBt stations) at low-to-moderate density (109.4 /ha ±40.6, total n = 45). Unusually, *Echinometra mathaei* was also rare in surveys (in 38% of RBt stations, see Appendices 4.3.1 to 4.3.7). Non-edible urchins, such as *Echinothrix* spp. and

Echinometra mathaei, can be used within assessments as potential indicators of habitat condition.

Starfish, such as the common blue starfish (*Linckia laevigata*) were not common in broad-scale survey (recorded in 26% of broad-scale transects) and at very low density (5.5 /ha ±1.9). Corallivore (coral eating) starfish, such as the pincushion star (*Culcita novaeguineae*) were even less common (in 16% of broad-scale transects, n = 32). The most destructive coral-eating starfish, the crown of thorns (*Acanthaster planci*, COTS), were moderately common. The distribution of COTS was very wide around reefs at northern Chuuk (recorded in 79% of broad-scale stations and 42% of transects). Overall, they were at moderate density (28.6 /ha ±7.1 in broad-scale transects); however, certain areas recorded high densities of COTS (6% of broad-scale transects recorded >100 COTS/ha, see Figure 4.31). All these transects were localised to reefs within the lagoon, especially reefs that fringed the higher island of Weno. All the density estimates are likely to be conservative, as COTS are not active during the day time, when the broad-scale recordings were conducted.

This level of colonisation can be considered as an 'active outbreak' in some of the areas sampled. On the Great Barrier Reef of Australia, the following system is used for defining outbreaks of crown-of-thorns starfish (COTS):

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

This is of concern as COTS can consume significant amounts of live coral (2–6 m^2 of coral per year) and, in some areas, COTS are at a density that could result in extensive coral damage.

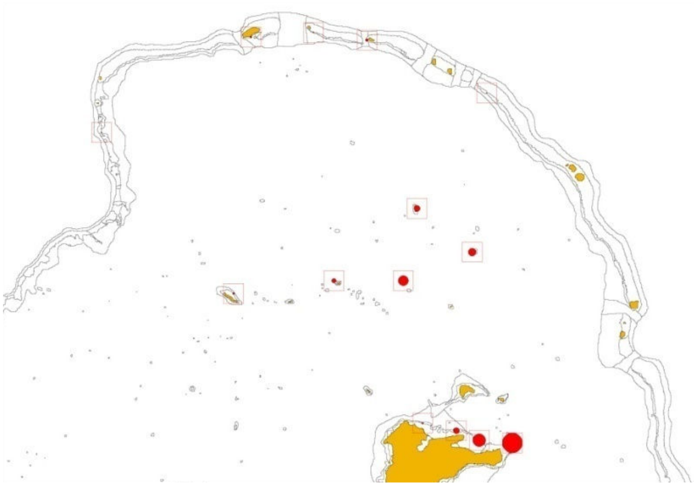

Figure 4.31: Average density of COTS recorded in broad-scale assessment stations at the study area, Piis-Panewu.
The circles highlight broad-scale survey station densities ranging from a mean of 3 to 169 /ha.

No horned or chocolate chip stars (*Protoreaster nodosus*) or doughboy sea stars (*Choriaster granulatus*) were recorded.

Table 4.13: Sea cucumber species records for Piis-Panewu

Species	Common name	Commercial value [5]	B-S transects n = 81			Reef-benthos stations n = 16			Other stations RFs = 6; MOPt = 6			Other stations Ds = 5; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.8	16.7	5	15.6	83.3	19	13.1 3.5	19.6 20.8	66 RFs 17 MOPt			
Actinopyga miliaris	Blackfish	M/H										4.4	8.9	50 Ns
Actinopyga sp. nov.	No name as yet	M												
Bohadschia argus	Leopardfish	M	2.2	26.0	9	13.0	41.7	31				22.2 1.0	22.2 2.4	100 Ns 40 Ds
Bohadschia graeffei	Flowerfish	L	12.7	46.9	27	18.2	145.8	13				22.2	44.4	50 Ns
Bohadschia vitiensis	Brown sandfish	L										13.3	26.7	50 Ns
Holothuria atra	Lollyfish	L	89.8	316.1	28	138.0	315.5	44				8.9 0.5	17.8 2.4	50 Ns 20 Ds
Holothuria coluber	Snakefish	L												
Holothuria edulis	Pinkfish	L	0.6	16.7	4	2.6	41.7	6				13.3	26.7	50 Ns
Holothuria flavomaculata		L												
Holothuria fuscogilva [4]	White teatfish	H										1.9	3.2	60 Ds
Holothuria fuscopunctata	Elephant trunkfish	M										0.5	2.4	20 Ds
Holothuria leucospilota		L												
Holothuria nobilis [4]	Black teatfish	H												
Holothuria scabra	Sandfish	H												
Stichopus chloronotus	Greenfish	H/M	4.5	45.7	10	41.7	133.3	31	4.6 10.4	13.7 62.5	33 RFs 17 MOPt			
Stichopus hermanni	Curryfish	H/M	0.2	16.7	1									
Stichopus horrens	Peanutfish	M/L												
Stichopus vastus	Brown curryfish	H/M												
Synapta spp.	-	-				5.2	41.7	13						
Thelenota ananas	Prickly redfish	H										0.5	2.4	20 Ds
Thelenota anax	Amberfish	M	0.4	16.5	2							3.3	4.2	80 Ds

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

4.4.8 Discussion and conclusions: invertebrate resources in Piis-Panewu

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

The data collected on giant clam habitat, distribution, density and shell size are summarised below.

- There was a wide range of shallow-water reef habitats that were suitable for giant clams at the enclosed lagoon site of Piis-Panewu. This was despite much of the protected reef shorelines (back-reef) being sandy and without significant amounts of hard benthos, and most of the environment being exposed (Typhoons occurred in 2002 and 2003.) and predominantly under oceanic influence. Chuuk state has seen large population growth; more than half the population of FSM live on the 15 inhabited islands.

- For this part of the Pacific, a limited range of four giant clam species were present; the elongate clam *Tridacna maxima*, boring clam *T. crocea*, fluted clam *T. squamosa*, and bear's paw clam *Hippopus hippopus*.

- Giant clam distribution, density and size measures indicate that all stocks are impacted by fishing, and stocks of the larger species, which are becoming rare in other parts of the Pacific, are severely depleted. Interestingly, a NOAA Coral report (Waddell 2005) says that over USD 20,000 worth of live clams were exported from Chuuk in 2002.

- As giant clams are broadcast spawners, they need to be at close proximity to one another for successful reproduction. In addition, as giant clams only mature to produce eggs at large sizes (which can take up to 10 years in *T. gigas*), it is important that aggregations of large, older clams are protected from fishing, to ensure there is sufficient production of gametes (especially eggs) to create the next generation and therefore maintain sustainability of the resource.

A summary of the environment, distribution, density and length recordings of MOP species is given below.

- Local reef conditions at Piis-Panewu constitute an extensive and reasonably good habitat for juvenile and adult trochus. Hard substrates were not as 'rich' as they could have been in most of the oceanic-influenced system of northern Chuuk, but water movement was significant.

- Trochus (*Trochus niloticus*), the commercial topshell, was relatively common across reefs at Piis-Panewu but the density of trochus within the 'core' aggregations (where trochus are typically in greatest abundance) and across reefs in general was low to moderate. This suggests there is still significant potential for stocks to increase in number. No areas were noted where densities had reached 500 shells per ha, a threshold density that is considered a minimum measure before commercial harvests can be considered.

- Ongoing commercial fishing was noted and there were anecdotal reports that trochus could be sold in Weno, despite the current ban on commercial fishing.

- Size-class information revealed that most sizes were present but no strong year class was currently visible below the commercial size class range, also that previous harvests have comprehensively fished the stock, as aggregations are holding depleted levels of large, old shells (>11 cm basal width).

- Results from the current assessment suggested that trochus in the Piis-Panewu study area were heavily impacted by fishing and presently well below the threshold density at which commercial fishing should be contemplated.

- The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Piis-Panewu.

A summary of the environment, distribution, and density of sea cucumbers species is given below.

- Piis-Panewu has extensive areas of shallow- and deep-water sheltered lagoon and barrier reef that is suitable for sea cucumbers. The environment was very oceanic-influenced and characteristic of an oceanic atoll system (with no elevated land mass in the north of the system). The lack of rich inshore embayments somewhat limited the range of sea cucumber species that could be present.

- Fourteen species of sea cucumber were recorded at Piis-Panewu. This is not a particularly large number of species for this location in the Pacific (relatively close to the centre of biodiversity), but local environmental factors play a part in limiting the abundance of species.

- There have been a number of reports that Chuuk was the centre of a sea cucumber fishery in the 1930s that has had a long-term effect on stocks. Bob Richmond stated that "Commercially valuable sea cucumbers have provided an example of how populations of reef organisms may be affected by reproductive and recruitment failure. In the 1930s, hundreds of tons of sea cucumbers were harvested and exported from Chuuk to Japan. 1988 found only two specimens of black teatfish on 8 sites (survey method not given). From interviews with local residents and fishers it was apparent that stock failed to recover. It is conceivable that once stocks are reduced below a threshold value, chances of successful reproduction are low (due to gamete dilution)". The information on large harvests was supported by an article by Beardsley (1971), which stated that the Japanese administration in the early 1940s had harvested as much as 454 tonnes of bêche-de-mer annually at that time. However the article also stated that, in 1971, some recovery of stocks was underway.

- Commercial sea cucumber stocks typically taken for commercial export are rare and only at low density at Piis-Panewu. Presence and density data suggest that sea cucumbers have been under significant fishing or environmental pressure. If there has been no recurrent fishing at this site, then it appears that species that are easily targeted (and depleted), such as the black teatfish (*Holothuria nobilis*), have not recovered from earlier fishing activities.

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

4.5 Overall recommendations for Piis-Panewu, CHUUK

- Baseline studies be undertaken to identify possible problem areas so that a fisheries management strategy that addresses major problem areas can be developed to stop and preferably reverse detrimental fisheries exploitation and, at the same time, to secure the community's livelihood.

- All communities and community members (male and female) on Piis-Panewu and other nearby islands be involved in the development of the fisheries management strategy covering both finfish and invertebrates, in order to ensure cooperation and compliance with management measures.

- State and national partners, in close cooperation with the Piis-Panewu community and all male and female fishers concerned, develop and enforce standards to control the commercial exploitation of bêche-de-mer, lobsters, trochus, giant clams and octopus as part of the fisheries management strategy.

- As a first step, the fishing of commercial species of sea cucumbers for export be strictly controlled through a moratorium until stocks recover.

- Consideration be given to establishing an MPA, where adult sea cucumbers and other species could be placed for protection in viable spawning aggregations (20–50 individuals placed within one section of their normal reef habitat – 5 m apart for sea cucumbers); however, strict enforcement would be needed to protect these potential spawning groups.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

- Spear diving, the most frequent fishing method used, should be regulated and night spearfishing banned. The use of gillnets in lagoon reefs should also be controlled.

- Careful attention be given to the location of sand mining, in order to avoid impacting fishing grounds.

5. PROFILE AND RESULTS FOR ROMANUM, CHUUK

5.1 Site characteristics

Chuuk is a large, semi-enclosed shallow atoll lagoon system. Both low and high islands are common with many patch reefs in the lagoon. The main influence is predominantly oceanic, although fringing, intermediate and offshore reef are present. Romanum is located in the north-northwest of Chuuk lagoon and centred around 7°27'N latitude and 151°35'E longitude (Figure 5.1). Romanum is less than an hour by outboard-powered skiff from Weno, the capital and main urban centre of Chuuk State. Romanum is a small volcanic island with two villages, Winisi and Chorong. Habitat within the lagoon system generally reflects the oceanic influence. The communities at Romanum rely on the harvesting of marine resources for their own subsistence needs and as a source of income, regularly transporting their catch to Weno for marketing.

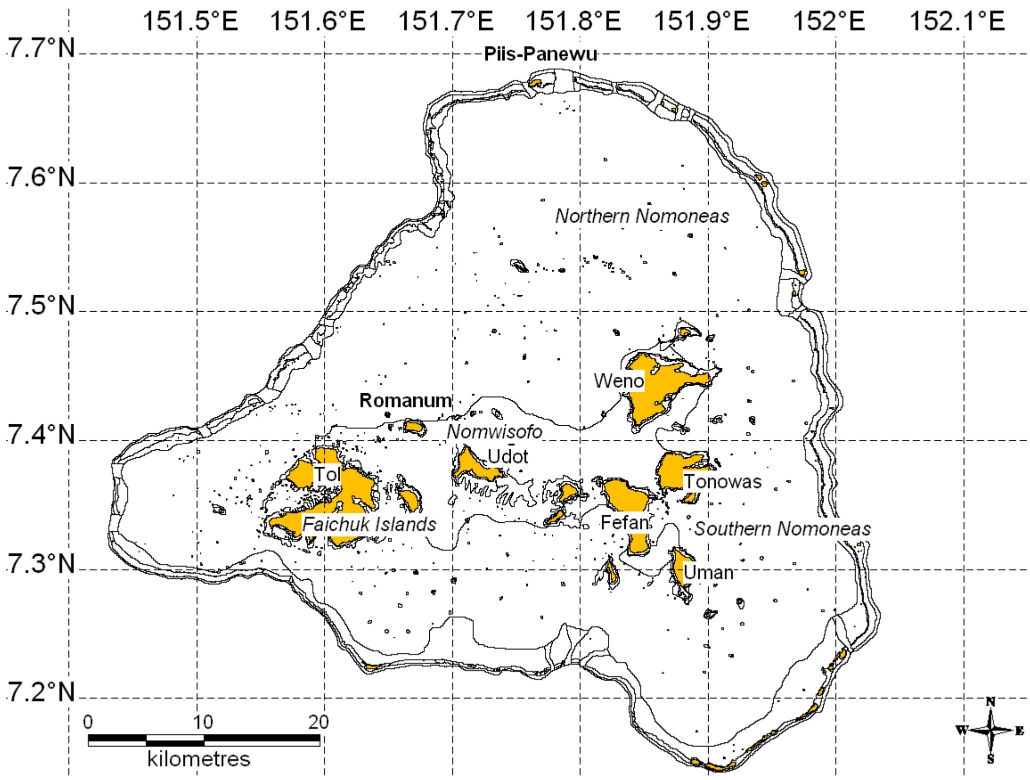

Figure 5.1: Map of Romanum, CHUUK.

5.2 Socioeconomic surveys: Romanum, CHUUK

Romanum Island, located in the Chuuk lagoon, is part of the Federated States of Micronesia (FSM). The socioeconomic field survey was carried out on 18–23 April, 2006. The fieldwork included household and fisher surveys in the communities of Cherong and Winisi, as well as interviews of middle sellers and buyers in Weno. In the following, all survey results are referred to as 'Romanum'. Access to the capital city Weno is relatively easy and takes only about one hour by motorised boat. The easy access has made it possible for the people from Romanum to sell fishery produce at the Weno market. For some of the fishers or for certain fisher groups this may even be done on a daily basis. In addition, some of the reef fish is exported internationally by buyers based at Weno. Invertebrates are sold locally in the capital's markets or supermarkets and are exported to international markets by agents and middlemen.

The Romanum community has a resident population of 700 with a total of 60 households. A total of 24 households, which is 40% of the total households in the community, were surveyed, with all (100%) of these households being engaged in some form of fishing activities. In addition, a total of 17 finfish fishers (15 males and 2 females) and 12 invertebrate fishers (4 males and 8 females) were interviewed. The average household size is large, with 11 people on average.

Household interviews focused on the collection of general demographic, socioeconomic and consumption data. General information on sales and distribution of fisheries resources was gathered through interviews with shopkeepers and boat owners. A general survey of shops to establish prices of canned fish and other food items was also conducted.

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

Our results (Figure 5.2) show that fisheries are the main source of household income, with ~92% of households stating fisheries as providing their primary income. By comparison, alternative income sources from agriculture, salaries or private business are rare, and concern very few households in the community, either as first or second income source. Although people on the island do have access to higher school education, the lack of employment causes a high rate of school drop-outs among young people and a large number of unemployed household members; most people fish for food and income as the only choice left.

Half of all households in Romanum have one or two pigs, and about one-third of the households have chickens. Almost all households have access to some agricultural land for subsistence production, with an average size of only ~0.4 ha. Home gardens are mainly used to produce root crops; however, imported items, such as rice, tinned beef and luncheon meat seem to constitute a considerable share of the household's staple food items. It should also be noted that water is a sensitive subject on Romanum, and the fetching of water for cooking and washing is at times difficult and time-consuming.

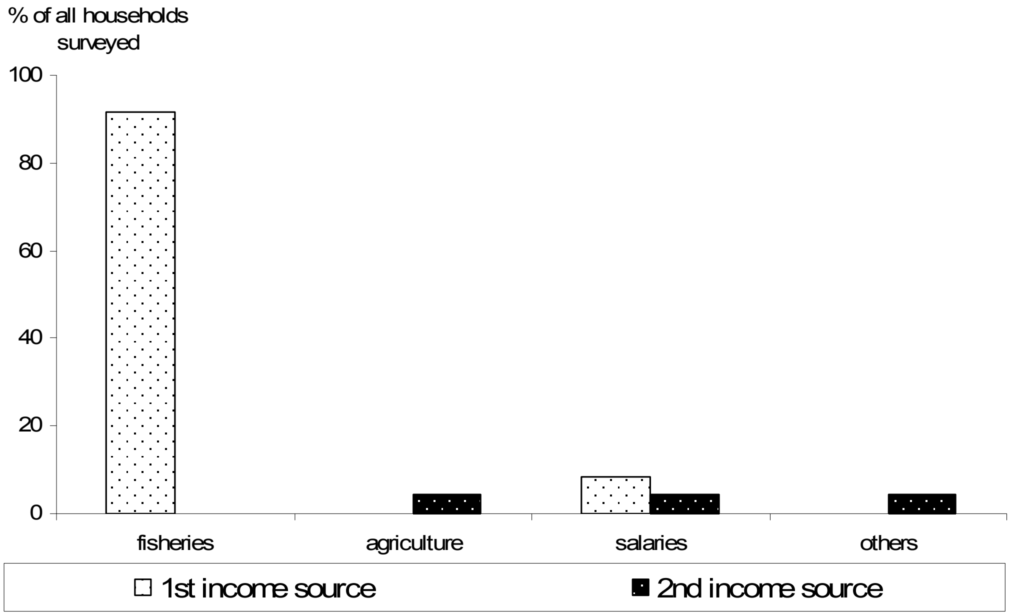

Figure 5.2: Ranked sources of income (%) in Romanum.
Total number of households = 24 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

Our results (Table 5.1) show that annual household expenditures are high, with an average of USD 4033, because families purchase any food or household item that they do not produce themselves, either in the village shop or in Weno, the capital city. Most food and household items are imported and expensive due to the limited market size of Chuuk and the costs of transport and import duty. It should also be borne in mind that the average family size on Romanum is large (~11 people), and many have only a low educational level and are unemployed.

Remittances are received by ~60% of all households in the community. These households benefit from an annual average of USD 1244, equivalent to ~30% of the average annual household expenditure.

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

Survey coverage	Site (n = 24 HH)	Average across sites (n = 83 HH)
Demography		
HH involved in reef fisheries (%)	100.0	96.4
Number of fishers per HH	4.08 (±0.52)	3.17 (±0.32)
Male finfish fishers per HH (%)	51.0	44.1
Female finfish fishers per HH (%)	2.0	1.1
Male invertebrate fishers per HH (%)	0.0	0.4
Female invertebrate fishers per HH (%)	21.4	27.0
Male finfish and invertebrate fishers per HH (%)	21.4	24.0
Female finfish and invertebrate fishers per HH (%)	4.1	3.4
Income		
HH with fisheries as 1st income (%)	91.7	48.2
HH with fisheries as 2nd income (%)	0.0	4.8
HH with agriculture as 1st income (%)	0.0	8.4
HH with agriculture as 2nd income (%)	4.2	20.5
HH with salary as 1st income (%)	8.3	34.9
HH with salary as 2nd income (%)	4.2	4.8
HH with other sources as 1st income (%)	0.0	9.6
HH with other sources as 2nd income (%)	4.2	10.8
Expenditure (USD/year/HH)	4032.53 (±505.15)	3751.42 (±249.95)
Remittance (USD/year/HH) (1)	1243.88 (±334.53)	1095.71 (±256.43)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	80.60 (±9.12)	62.54 (±5.01)
Frequency fresh fish consumed (times/week)	5.58 (±0.28)	3.67 (±0.21)
Quantity fresh invertebrate consumed (kg/capita/year)	18.52 (±7.62)	12.40 (±5.01)
Frequency fresh invertebrate consumed (times/week)	1.41 (±0.27)	1.08 (±0.13)
Quantity canned fish consumed (kg/capita/year)	11.88 (±2.91)	23.87 (±3.14)
Frequency canned fish consumed (times/week)	2.48 (±0.36)	2.68 (±0.23)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	79.2	74.7
HH eat canned fish (%)	100.0	91.6
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	4.2	0.0
HH eat fresh fish they are given (%)	45.8	38.9
HH eat fresh invertebrates they catch (%)	75.0	100.0
HH eat fresh invertebrates they buy (%)	4.2	0.0
HH eat fresh invertebrates they are given (%)	41.7	33.3

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

Survey results indicate an average of four fishers per household and, when extrapolated, the total number of fishers in Romanum is 245, including 177 males and 68 females. Among these are 130 exclusive finfish fishers (125 males, 5 females), 53 exclusive invertebrate fishers (females only), and 63 fishers who fish for both finfish fishing and invertebrates (53 males, 10 females). About half of all households (~46%) own a boat; most (~87%) are non-motorised canoes, only ~13% are equipped with an outboard engine.

Per capita consumption of fresh fish is relatively high with ~81 kg/person/year, much higher than the average across all four study sites in FSM, and more than twice as high as the regional average of ~35 kg/person/year (Figure 5.3). By comparison, consumption of invertebrates (edible meat weight only) (Figure 5.4) is much lower, with 18.5 kg/person/year, although still considerable compared to the average across all four sites investigated in FSM. Canned fish (Table 5.1) adds another ~12 kg/person/year to the protein supply from seafood, which is relatively low. The consumption pattern of seafood found in Romanum highlights the fact that people do not have access to good agricultural land or imported food items, but that this island community enjoys a traditional lifestyle, highly dependent upon seafood.

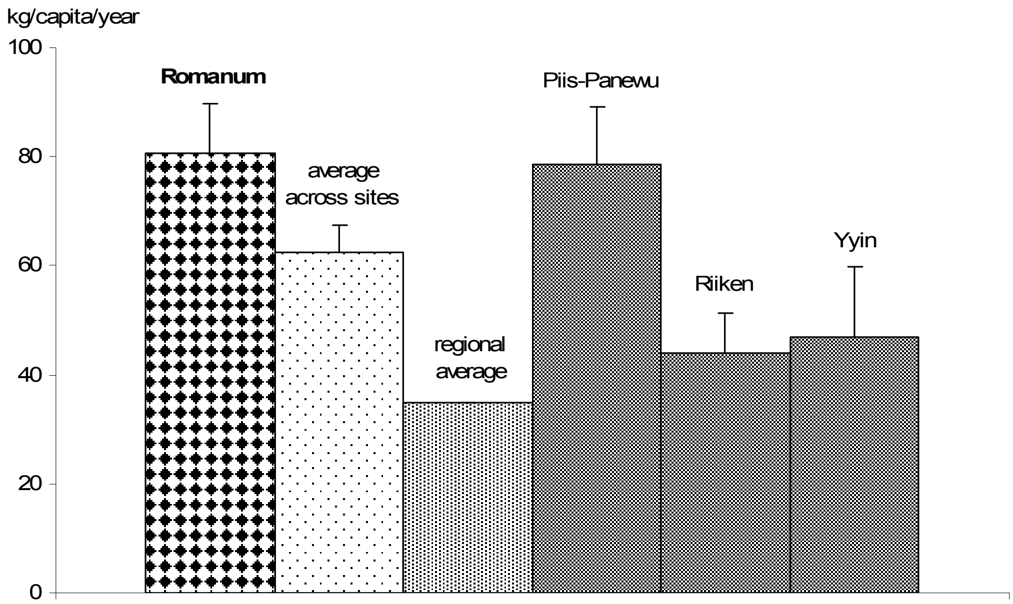

Figure 5.3: Per capita consumption (kg/year) of fresh fish in Romanum (n = 24) compared to the average across sites, the regional average (FAO 2008) and the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

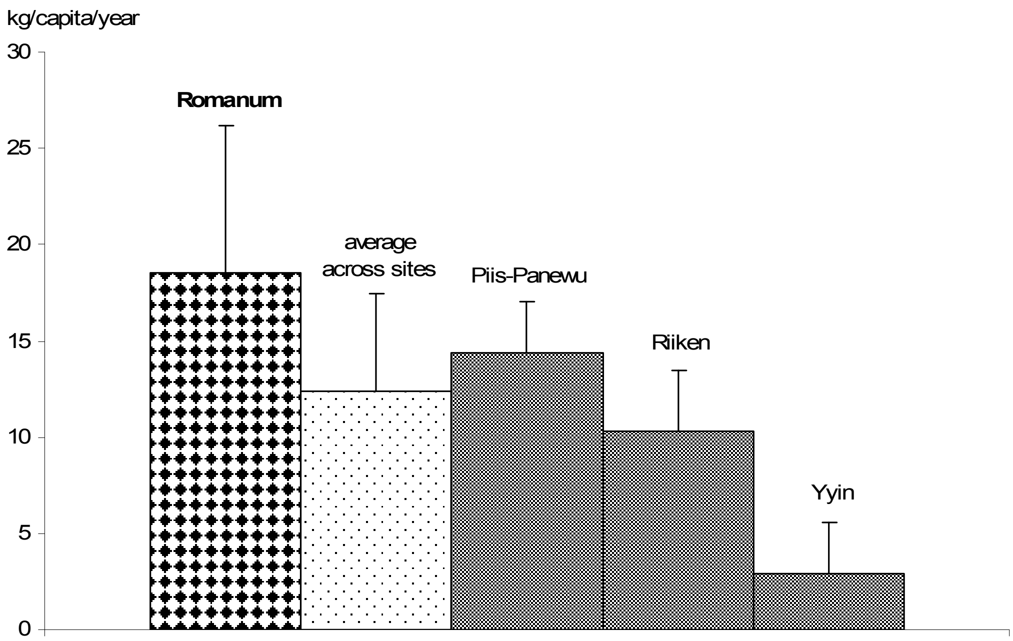

Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Romanum (n = 24) compared to the other three CoFish sites in FSM.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results obtained for Romanum to the average figures across all four study sites surveyed in FSM, people of the Romanum community eat much more fresh fish and invertebrates and more often than found on average. However, the canned fish consumption is well below the average found across all study sites in FSM, suggesting that Romanum people enjoy a very traditional, fishery-dependent lifestyle, with little access to agricultural land and thus alternative protein and food. This interpretation is supported by the large numbers of households that eat fish and invertebrates that they have caught themselves or received from somebody in the community as a gift, and the extremely rare occasions when fresh fish or other seafood is purchased.

Fishing is the only option for generating cash income; all other alternatives only concern a very few households in the community, and mainly provide only secondary income. Household expenditure level in Romanum is high and slightly above the average across all study sites. This is due to the fact that Romanum people need to purchase all food and household items that they do not produce themselves, on the mainland or in the village shop. Romanum is the only community surveyed in FSM where remittances play a role in terms of the number of households that benefit from such payments and the average annual amount that they receive. Boats that exist in the community are mostly motorised, as elsewhere in FSM. Boat ownership is low compared to other FSM study sites. This is surprising due to the island situation and high dependence on the mainland's market. On the other hand, the traditional lifestyle, high living costs and limited income opportunities demand that motorised boat transport is shared.

5.2.2 Fishing strategies and gear: Romanum

Degree of specialisation in fishing

While community life is rather traditional, some social institutions have already undergone modernisation, e.g. the village chief has been replaced by a mayor. Nevertheless, life is determined by fishing, and fishing is still pursued in a rather low-investment style. Fishers target mostly the closest fishing grounds, i.e. the sheltered coastal reef and lagoon for subsistence needs, and venture out to the more distant outer reef for commercial catches. Although all members in the community are engaged in fishing, traditional roles still show in the low participation of females in finfish fishing. While males do most of the exclusive finfish fishing, females do most of the exclusive collection of invertebrates (Figure 5.5). While >20% of male fishers fish both for finfish and invertebrates, only a very few female fishers (~5%) occasionally fish for both.

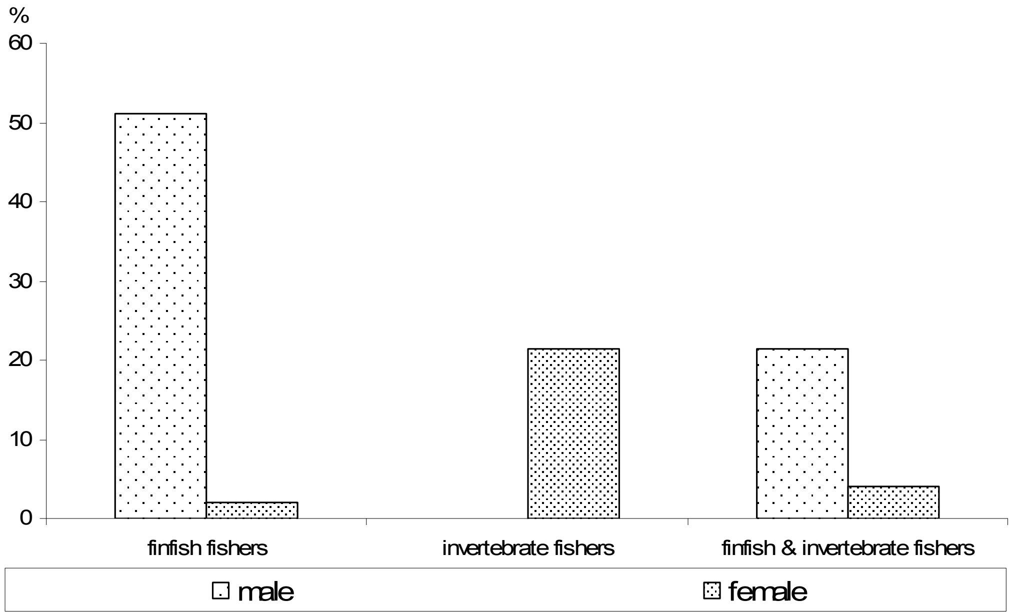

Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Romanum.
All fishers = 100%.

Targeted stocks/habitat

Considering that only half of all households own a boat, it is not surprising that most female fishers only target the easily accessible and nearshore areas, mainly the lagoon. This observation is only partially true for males, as ~60% target the sheltered coastal reef (~7%) and lagoon (~53%). However, the number of male fishers who target either the lagoon and outer reef combined in one fishing trip or exclusively the outer reef, or the outer reef and passages combined, is almost the same as the number of fishers who stay closer to shore (Table 5.2). There is no gender difference in the habitats targeted by fishers who collect invertebrates. Most target the combined intertidal and reeftop habitats, and the remainder either target reeftops only, or combine the intertidal and soft benthos habitats (Table 5.2). No particular commercial invertebrate fishery was reported, e.g. bêche-de-mer, trochus, or lobster fisheries.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef	6.7	0.0
	Sheltered coastal reef & lagoon	53.3	100.0
	Lagoon & outer reef	26.7	0.0
	Outer reef	20.0	0.0
	Outer reef & passage	13.3	0.0
Invertebrates	Reeftop	25.0	25.0
	Intertidal & reeftop	50.0	50.0
	Soft benthos & intertidal	25.0	25.0

Finfish fisher interviews, males: n = 54; females: n = 5. Invertebrate fisher interviews, males: n = 4; females, n = 8.

Fishing patterns and strategies

The combined information on the number of fishers, the frequency of fishing trips and the average catch per fishing trip is the basic factor used to estimate the fishing pressure imposed by people from Romanum on their fishing grounds (Tables 5.2 and 5.3).

Our survey sample suggests that fishers from Romanum have a wide choice among sheltered coastal reef, lagoon and outer reef, including passages. However, reeftop (41%), intertidal (45%) and soft benthos (14%) are the main habitats that support invertebrate fisheries (Figure 5.6). Gender separation only shows in the fact that females dominate the gleaning fisheries (reeftop, intertidal and soft benthos) but both male and female fishers target all three habitats (Figure 5.7).

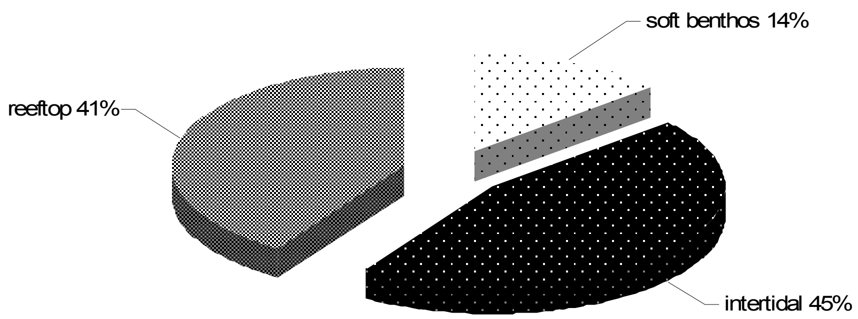

Figure 5.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Romanum.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

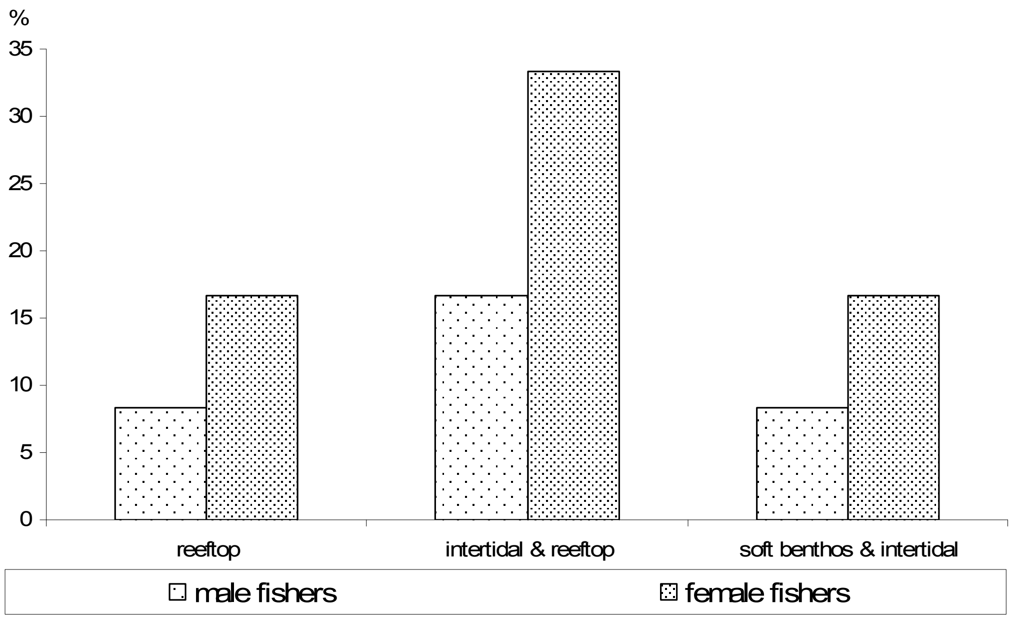

Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Romanum.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 4 for males, n = 8 for females.

Gear

Figure 5.8 shows that Romanum fishers mainly spear dive in any of the habitats targeted. However, fishing at the outer reef may also involve deep-bottom lining and trolling. Gillnets are not common but may sometimes be used by fishers going to the lagoon and outer reef (Figure 5.8). Although male fishers were still well aware of traditional fishing methods, modern and more efficient fishing gear is used, due to the increasing need to generate income.

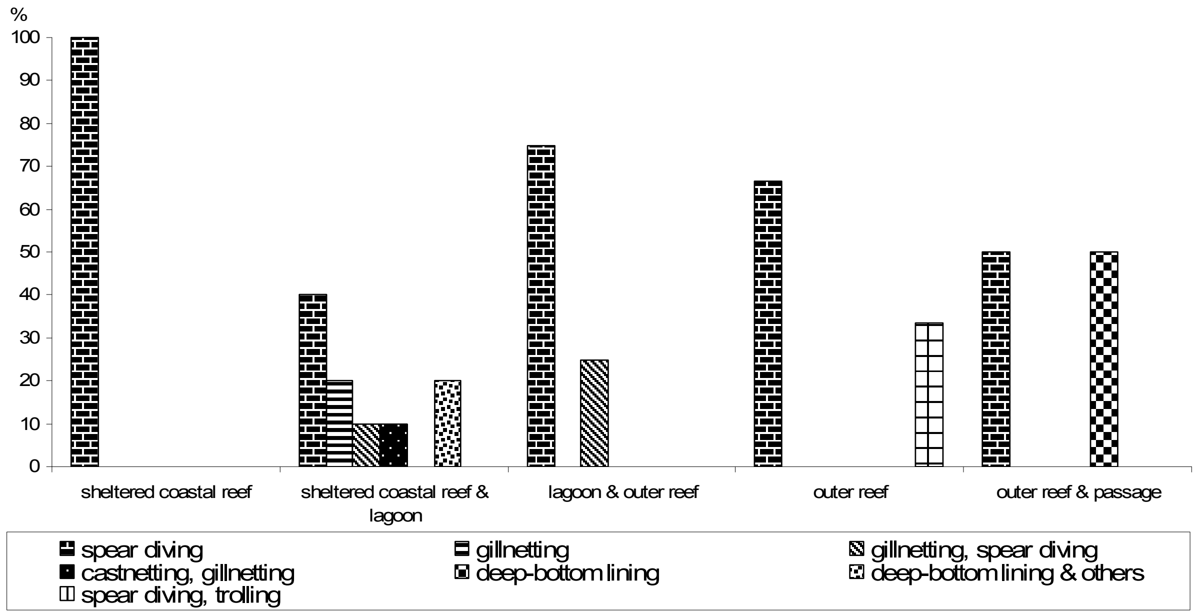

Figure 5.8: Fishing methods commonly used in different habitat types in Romanum.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. 'Others' may include any or several of the following: gillnetting, handlining, spear diving.

Frequency and duration of fishing trips

Male finfish fishers go out to any of the finfish habitats ~1–1.5 times/week, but one fisher may target various habitats in one week. Female fishers only target the lagoon area, fishing on average 1–2 times/week. As shown in Table 5.3, there is no major difference between genders in the duration of an average fishing trip; both male and female fishers spend 4.5–6 hours. However, commercial fishing, which is mainly done by male fishers, sometimes involves camping overnight on one of the small atoll islands in the Chuuk lagoon, which considerably prolongs fishing trips. However, in this analysis, we have only considered the time spent fishing, and not included time spent camping.

Concerning invertebrate harvesting, for both male and female fishers the frequency of fishing trips is 1–2 times/week and the average time spent on each invertebrate collection trip is 3–4 hours (Table 5.3).

All male and female fishers use a boat to fish for finfish, mostly motorised boats. Because not all households own a boat, boats are shared and part of the catch is paid to cover the use of the boat and fuel costs. Invertebrate collection is mostly done by walking, but two-thirds of reeftop gleaning and one-third of all other collection activities are done using motorised or, in rare cases, non-motorised boats.

Generally, fishers were found to be well acquainted with the best places to fish according to season, tide, and moon phase, and with other knowledge collected over generations. Thus, it is not surprising that most finfish fishing is performed according to the tide, i.e. either at day or night. The fishers who fish only during the day are mostly females. Invertebrates are only collected during daytime. Ice is not normally used on fishing trips; however, several male fishers stated that they use ice at least sometimes during their fishing trips. Generally, both male and female fishers fish all year round.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef	1.50 (n/a)		6.00 (n/a)	
	Sheltered coastal reef & lagoon	1.81 (±0.19)	1.50 (±0.00)	4.63 (±0.38)	5.50 (±0.50)
	Lagoon & outer reef	1.38 (±0.13)	0	5.50 (±0.29)	0
	Outer reef	1.33 (±0.33)	0	4.33 (±1.20)	0
	Outer reef & passage	1.25 (±0.25)	0	5.50 (±0.50)	0
Invertebrates	Reeftop	1.00 (n/a)	2.00 (±0.00)	4.00 (n/a)	4.00 (±0.00)
	Intertidal & reeftop	1.50 (±0.50)	1.75 (±0.48)	3.50 (±0.50)	3.50 (±0.29)
	Soft benthos & intertidal	2.00 (n/a)	2.00 (±0.00)	3.00 (n/a)	3.50 (±0.50)

Figures in brackets denote standard error; n/a = standard error not calculated.
Finfish fisher interviews, males: n = 15; females: n = 2. Invertebrate fisher interviews, males: n = 4; females: n = 8.

5.2.3 Catch composition and volume – finfish: Romanum

The reported catches from the sheltered coastal reef in Romanum are described by only five vernacular names, representing two species of Siganidae, *Epinephelus* spp. and two unidentified species: *mettin* and *urupin*, each representing ~17–29% of the total annual reported catch. Catches reported for the combined sheltered coastal reef and lagoon habitats are mainly determined by Scaridae, Acanthuridae and Siganidae. Catches from the lagoon and the outer reef are similar, dominated by Scaridae and Acanthuridae; however, Labridae also contribute ~10% to the reported catch. The more the outer reef is involved, the more fish such as Serranidae and Carcharhinidae are reported, which are caught using techniques other than spear diving. Lethrinidae become increasingly visible in catches from outer reef and passage fishing combined. Detailed information on catch compositions by species, species groups and habitats are reported in Appendix 2.4.1.

Figure 5.9 highlights findings from the socioeconomic survey reported earlier, that finfish fishing serves subsistence, but also commercial interests. The latter are by far the most important factor that determines fishing pressure on Romanum's reef and lagoon resources. The total annual catch is estimated to amount to ~139.2 t, 66% of which is used for commercial sale outside the community (export) while only 34% is used to satisfy the community's subsistence demand. The dominance of male fishers shows in the proportion of catch that they take, i.e. >90% of the total annual catch. Thus, it can be concluded that male fishers are mainly responsible for supplying fish for home consumption and for generating income. Females may occasionally fish and are more likely to provide food for the family rather than to fish for sale. Most of the reported catch is sourced from the nearshore areas, i.e. the sheltered coastal reef and lagoon. Up to 20% of the total annual catch comes from the outer reef and passages, and another 24% comes from the combined fishing of the lagoon and outer reef.

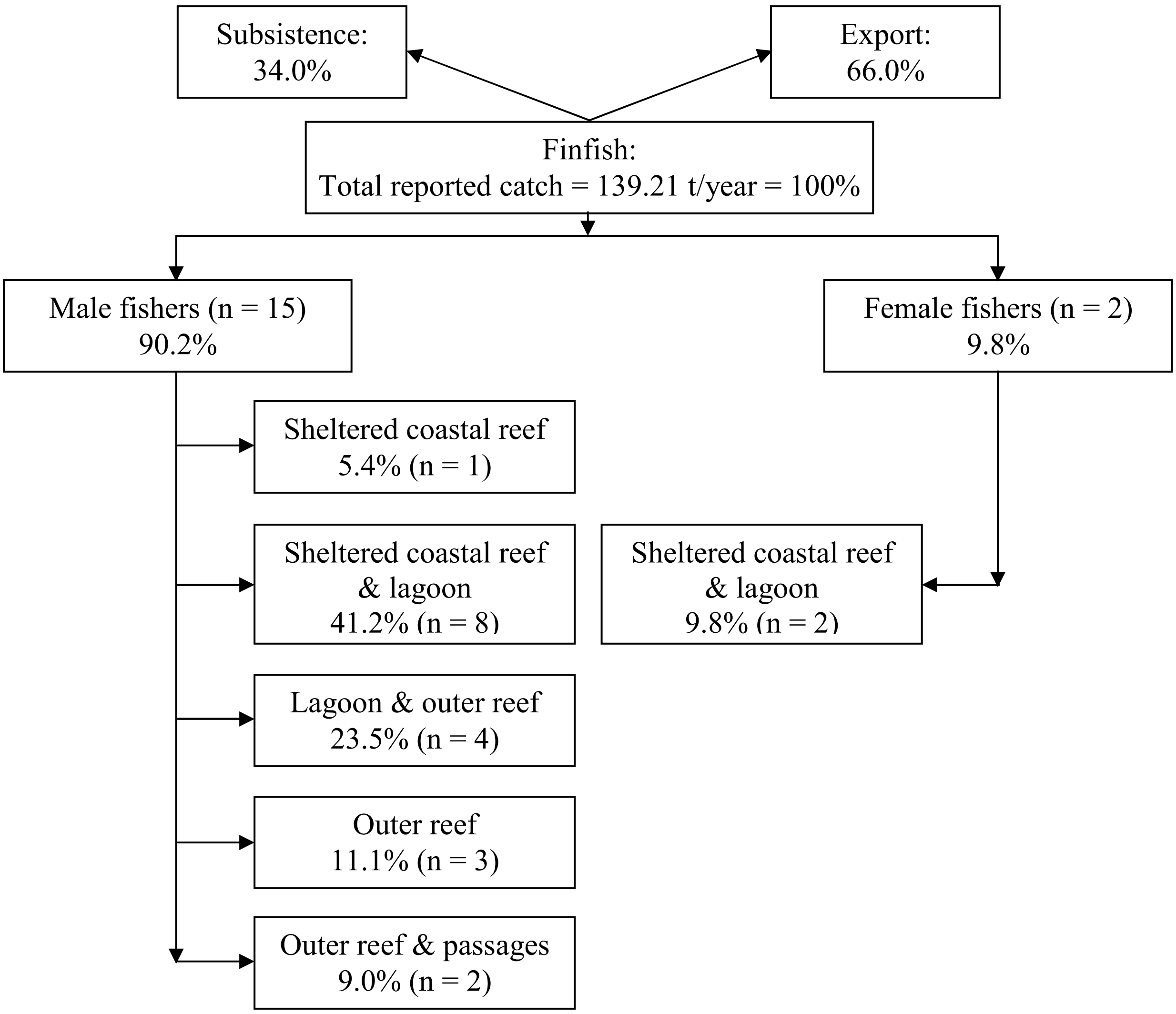

Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Romanum.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The distribution of annual catch weight among the more easily accessible sheltered coastal reef, lagoon and more distant outer reef and passages is a consequence of the number of fishers rather than differences in the annual catch rates. As shown in Figure 5.10, the average annual catch per fisher is similar among the different habitats and combinations of habitats fished, ~800 kg/fishers/year. Comparison between male and female fishers both targeting the combined sheltered coastal reef and lagoon, does not reveal any major differences.

The fact that income generation is difficult for Romanum people and that fishing with motorised boats in distant areas requires high operational costs, especially for fuel, forces people to fish close to shore and to minimise fuel and other costs as much as possible.

Comparing productivity rates between genders for the same habitat combination, i.e. the sheltered coastal reef and lagoon (Figure 5.11), again there is no obvious difference between male and female fishers. However, overall, CPUEs seem to be slightly higher for the outer reef and passages. However, the differences observed are not that significant.

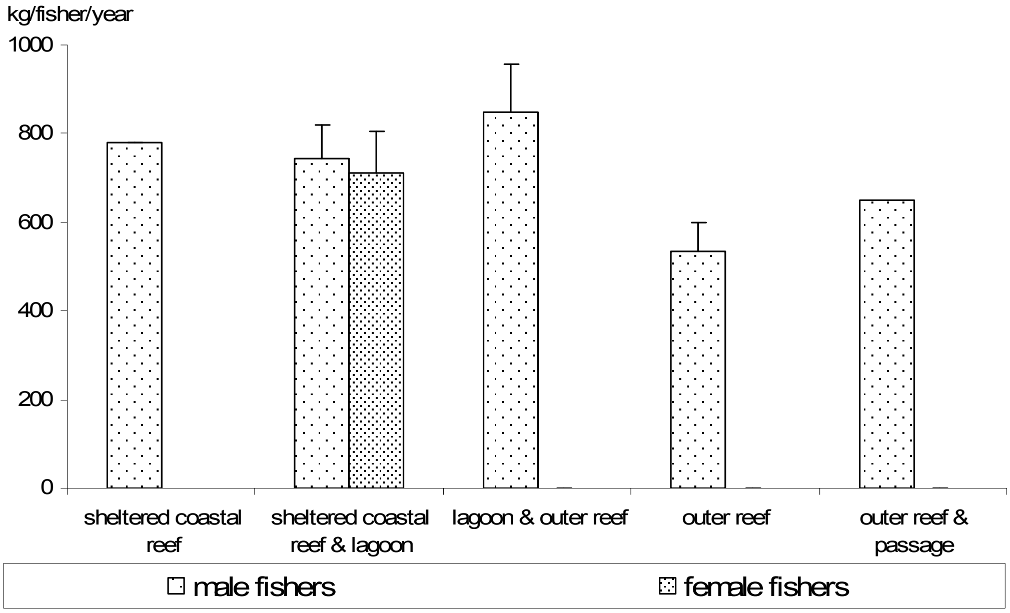

Figure 5.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Romanum.
Bars represent standard error (+SE).

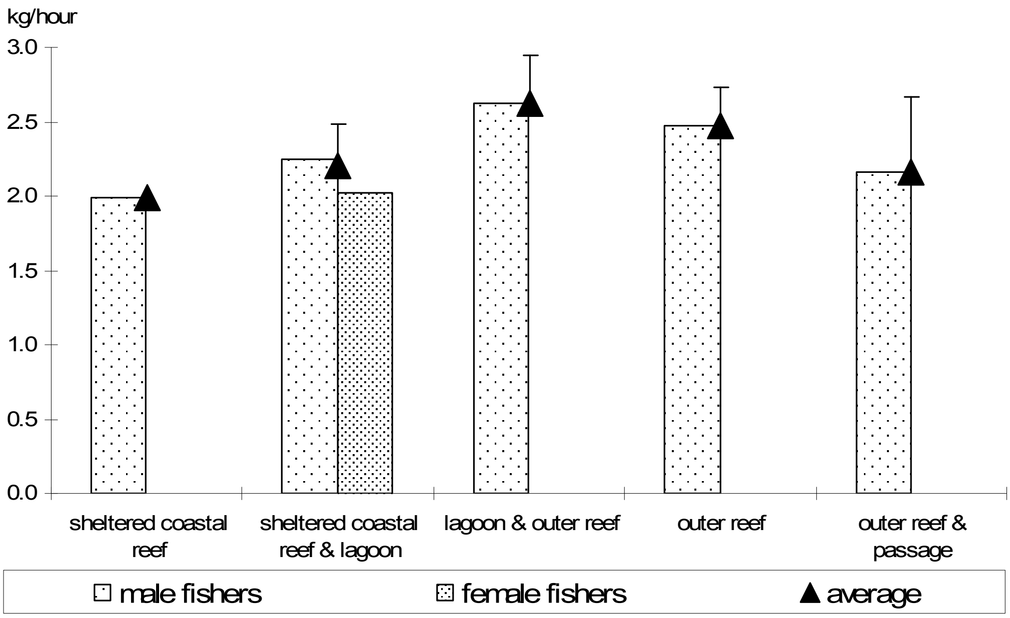

Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Romanum.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The fact that commercial fishing is more important than subsistence fishing for Romanum's people clearly shows in Figure 5.12. All fishing trips to any of the habitats or combinations thereof, are conducted firstly to generate income, and secondly to provide food for the family and for social networking.

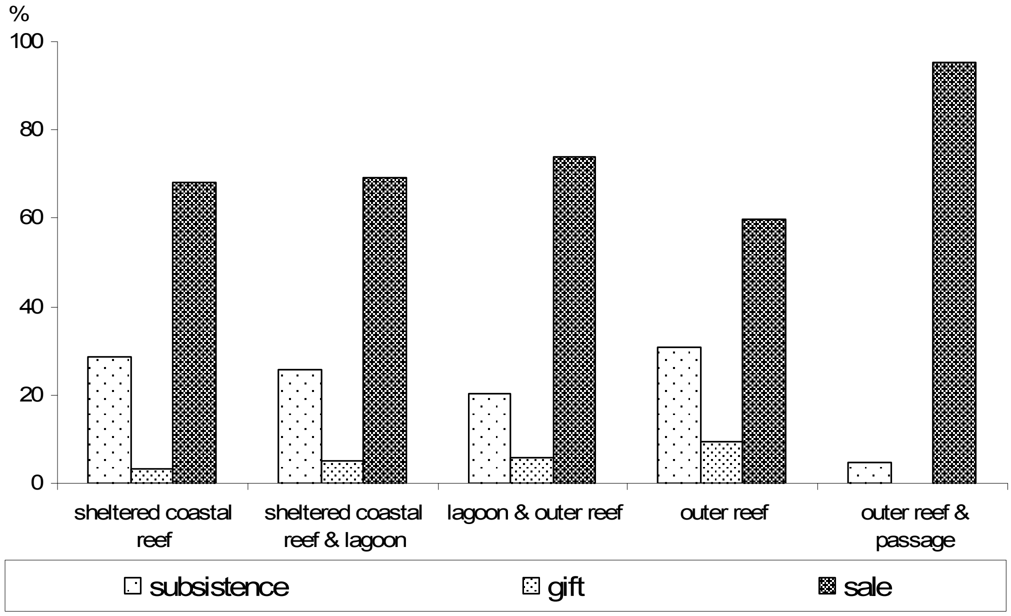

Figure 5.12: The use of finish catches for subsistence, gift and sale, by habitat in Romanum. Proportions are expressed in % of the total number of trips per habitat.

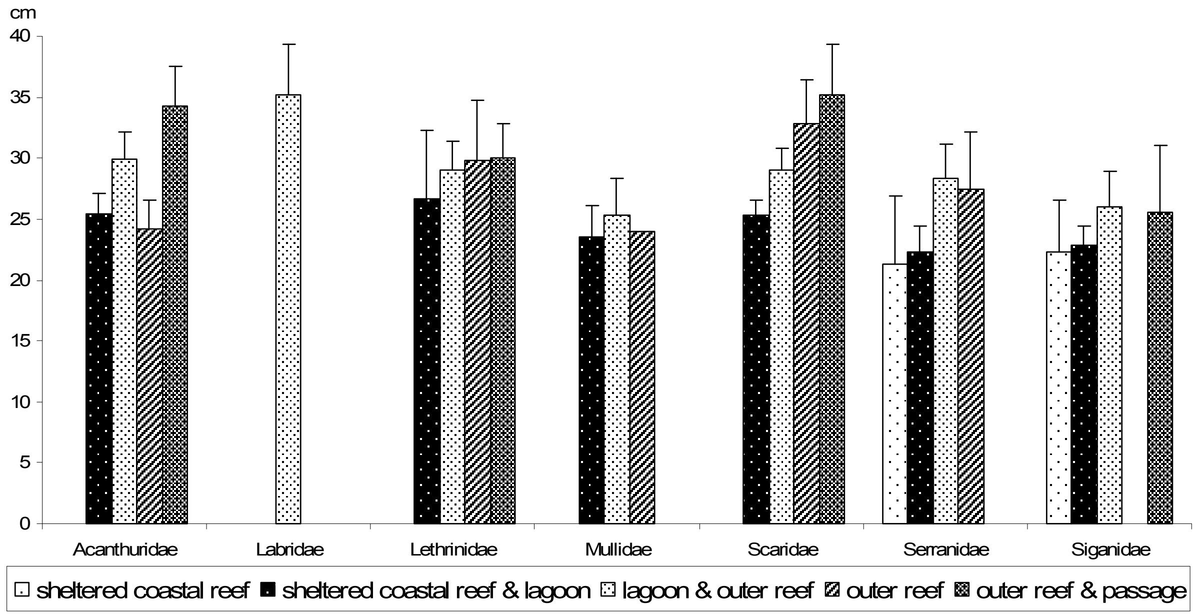

Figure 5.13: Average sizes (cm fork length) of fish caught by family and habitat in Romanum. Bars represent standard error (+SE).

The overall finfish fishing productivity (CPUE) per habitat was slightly higher if fishing the outer reef (lagoon included, passages excluded) rather than the sheltered coastal reef and lagoon (Figure 5.11). This observation is in agreement with the average fish sizes (fork length) reported for the major families caught (Figure 5.13). The expected increase in the average reported fish length with increasing distance from shore is apparent for all families, except for Mullidae. Considering the fact that spear diving is the most important fishing technique used everywhere, the observation that fish caught at the outer reef and passages are larger than those caught closer to shore is important, as certain fish species, in particular Scaridae and Acanthuridae, are sensitive to high fishing pressure from spear diving. Generally, the average fish sizes reported are reasonably large, on average >20–35 cm.

The parameters selected to assess current fishing pressure on Romanum's reef and lagoon resources are shown in Table 5.4. Due to the available reef and total fishing ground areas, population density, fisher density and catch rates per unit areas of reef and fishing ground are low. By comparison, the highest fisher density occurs for the total reef, and the same is true for the highest population density (25 people/km^2 total reef area). However, these figures are low by any standard, and so is the calculated total fishing pressure if only the subsistence demand of Romanum is considered. The calculated catches per total reef and total fishing ground areas amount to 1.7 or 0.2 t/km^2/year only. Even if the total annual catch is taken into account, thus including fishing pressure induced by catch for income, the resulting fishing pressure only rises to 5.6 t/km^2 of total reef area and 0.5 t/km^2 of total fishing ground area.

The fact that selling prices for reef and lagoon fish to various outlets at Weno supplying fish for local consumption and also international export are very low, i.e. USD 2/kg of fish, is alarming as it will force Romanum fishers to catch more fish to satisfy their basic cash income needs.

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

Parameters	Habitat						
	Sheltered coastal reef	Sheltered coastal reef & lagoon	Lagoon & outer reef	Outer reef	Outer reef & passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	3.52			7.04		28.22	277.15
Density of fishers (number of fishers/km^2 fishing ground) (1)	2.2	n/a	n/a	4.3	n/a	7	0.7
Population density (people/km^2) (2)						25	3
Average annual finfish catch (kg/fisher/year) (3)	779.30 (n/a)	738.29 (±61.78)	848.67 (±107.24)	533.94 (±66.65)	649.54 (±218.81)		
Total fishing pressure of subsistence catches (t/km^2)						1.68	0.17
Total number of fishers	10	94	39	30	20	193	193

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; lagoon area = 266.58 km²;(1) total number of fishers (= 193) is extrapolated from household surveys; (2) total population = 700; total subsistence demand = 47.35 t/year; (3) catch figures are based on recorded data from survey respondents only.

5.2.4 Catch composition and volume – invertebrates: Romanum

Calculating catches reported from invertebrate fishers by wet weight shows that sea cucumbers (*Stichopus* spp., *Holothuria* spp., including *H. nobilis)* are the most important species collected, followed by lobsters (*Panulirus penicillatus*), trochus (*Trochus* spp.) and giant clams (*Tridacna* spp.). Octopus, and the crabs *Etisus splendidus* and *Cardisoma* spp. are less important. Others, including *Turbo* spp., *Serpulorbis* spp., and *Nerita polita*, are only collected in very small amounts (Figure 5.14).

Sea cucumbers are collected upon command, and so are lobsters, trochus and octopus. While females are the main invertebrate collectors, they mainly supply particular orders from buyers in Weno, for example, for bêche-de-mer and other species. Octopus are mostly sold directly to supply pre-arranged orders from the main supermarkets at Weno. Land crabs (*Cardisoma* spp.) are collected, but mostly during the spawning season when numbers are high and they are easy to catch. Male fishers are specialised more in collecting the most lucrative species: bêche-de-mer, trochus (meat and shells) and lobsters. Male fishers seem to sell more to the middleman who visits Romanum regularly. Male fishers or their wives sell the trochus meat and shells to an export agent at Weno.

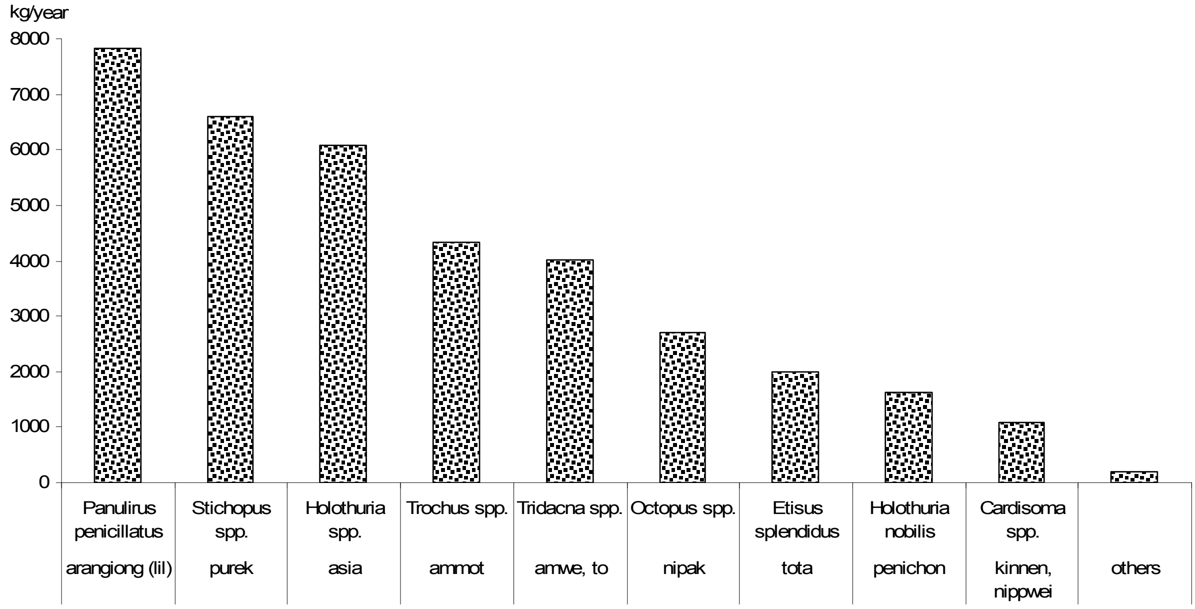

Figure 5.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Romanum.
Others include: *neangepar* (*Turbo* spp.), *anipwi* (*Serpulorbis* spp.) and *ongi* (*Nerita polita*).

The fact that most impact is due to a few species only also shows in the number of vernacular names reported by respondents. Reeftop fishing shows the highest diversity, with seven vernacular names reported. Comparison to other fisheries is difficult as Romanum invertebrate collectors often combine a variety of different habitats (Figure 5.15). Therefore, the combined fishing of intertidal and reeftop habitats, which was described by 11 vernacular names, may include another four vernacular names that are associated with the intertidal habitat in addition to the seven vernacular names reported for reeftop fisheries.

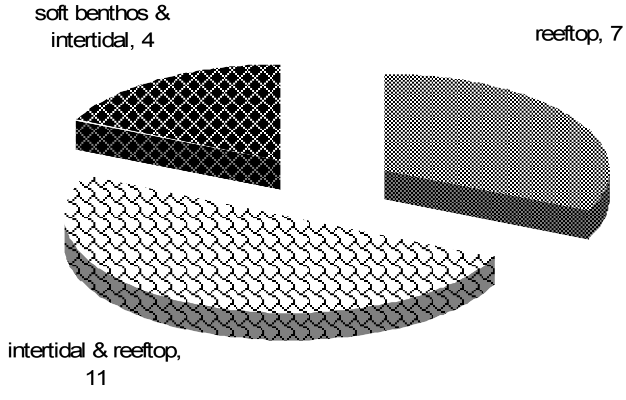

Figure 5.15: Number of vernacular names recorded for each invertebrate fishery in Romanum.

The average annual catch per fisher by gender and fishery (Figure 5.16) reveals substantial differences. First, male and female fishers collect about the same quantities from reeftops alone. However, this comparison may be incorrect due to the very small sample size of male fishers' performances. When intertidal and reeftop habitats are combined in one fishing trip, the average annual catch taken by female fishers is at least three times as high as that of male fishers. The average annual catches cannot be compared between gender groups for soft benthos and intertidal, again, due to the small sample size of male fishers. Most invertebrate collection is done by females, and most female fishers target the combined intertidal and reeftop habitats. Thus, most impact is suspected to be imposed on these two habitats, with the exclusive fishing of reeftops alone adding to the fishing pressure on these. The average annual productivity of female fishers is considerable (6 t/fisher/year wet weight).

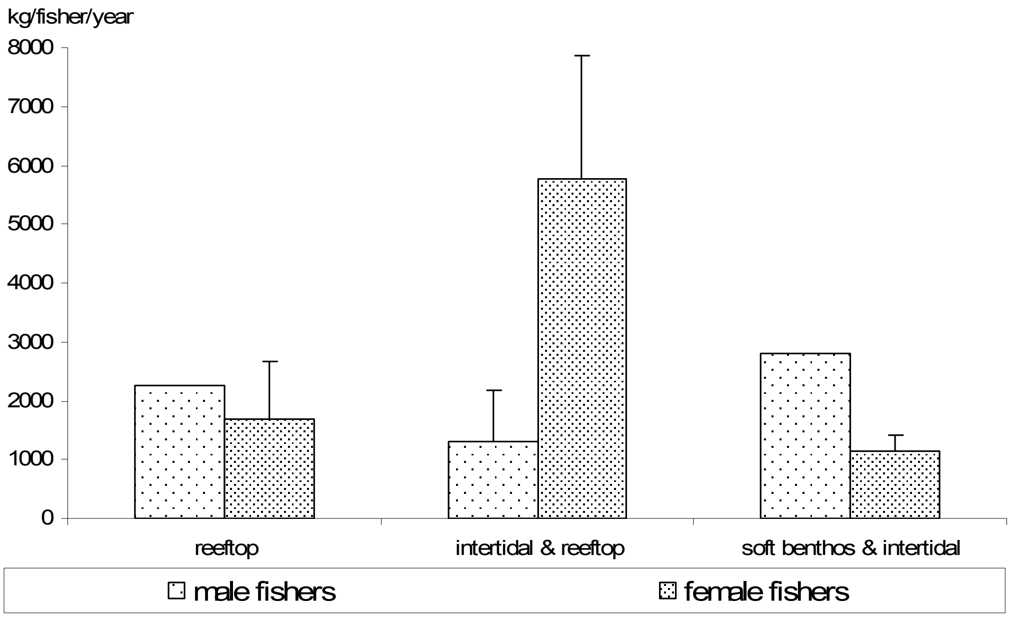

Figure 5.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Romanum.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 4 for males, n = 8 for females). Bars represent standard error (+SE).

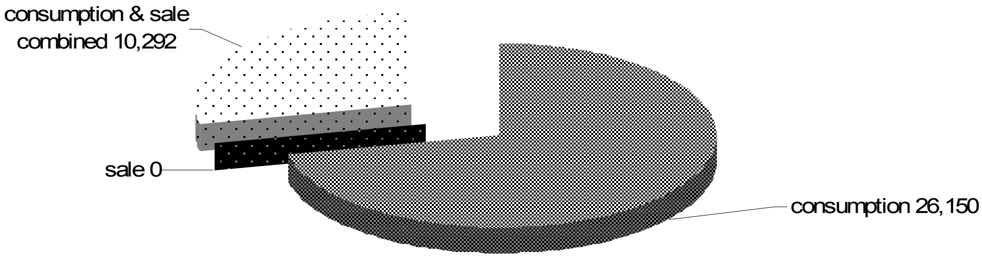

Figure 5.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Romanum.

Figure 5.17 shows that invertebrate collection mainly serves subsistence needs in Romanum. The proportion that is sold on the local markets may not exceed 14% if we assume that half of the share that may be consumed or sold is, indeed, sold.

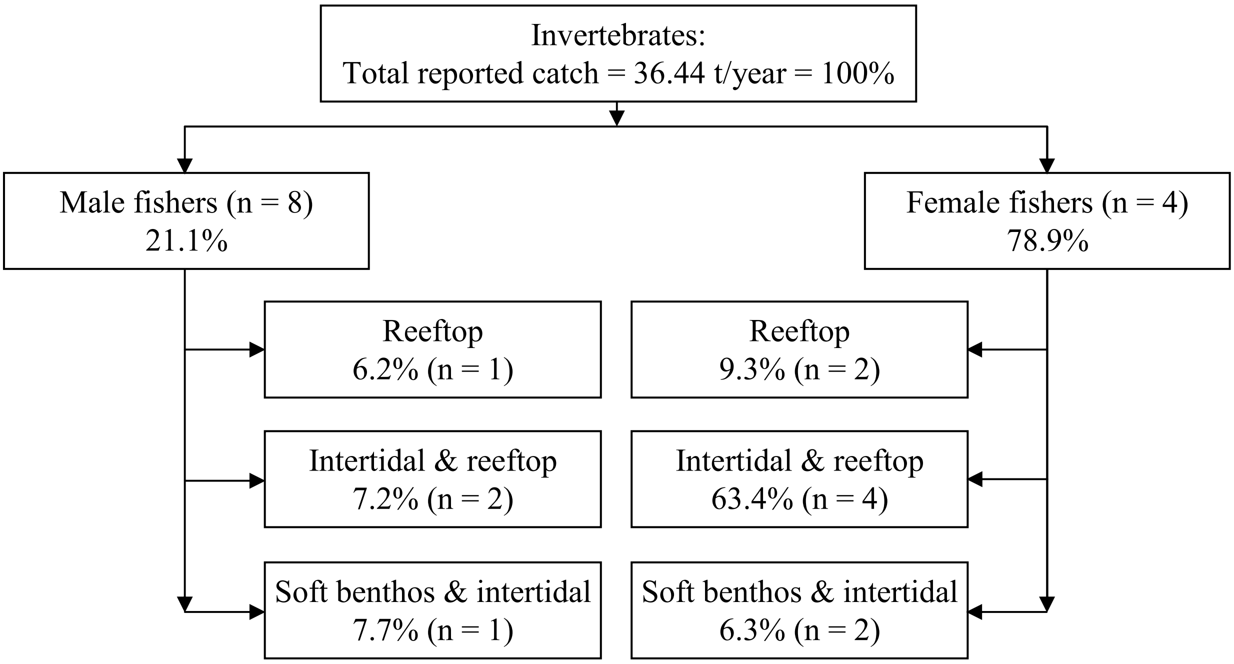

Figure 5.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Romanum.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

As mentioned earlier, male fishers from Romanum are much less engaged in invertebrate fisheries than are females. While males account for ~21% of the total catch (wet weight) only, females are responsible for ~79% (Figure 5.18). Most of Romanum's male invertebrate fishers target the combined intertidal and reeftop habitats, while 15.5% of the catch is taken from the reeftops only, and 14% from the combined soft benthos and intertidal habitats.

Table 5.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Romanum

Parameters	Fishery / Habitat		
	Reeftop	Intertidal & reeftop	Soft benthos & intertidal
Fishing ground area (km^2)	17	17	n/a
Number of fishers (per fishery) (1)	29	58	29
Density of fishers (number of fishers/km^2 fishing ground)	1.7	3.4	n/a
Average annual invertebrate catch (kg/fisher/year) (2)	1877.03 (±585.12)	4288.23 (±1640.59)	1693.86 (±570.73)

Figures in brackets denote standard error; n/a = no information available; (1) number of fishers extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only.

Taking into account figures available on the shallow-reef areas that support the reeftop fishery, and the combined reeftop and intertidal gleaning fishery, fishing pressure for both is low. This conclusion is based on the low fisher density. Regarding the amount that is taken in terms of wet weight per habitat and fisher, the average annual catch for most fishers who combine intertidal and reeftops is, however, very high. These figures need to be verified using the results from the resource survey to see to what extent the impact on the few selected species (sea cucumbers, lobsters, trochus and giant clams) already shows in the resource status (Table 5.5).

5.2.5 Management issues: Romanum

At the time of the survey, no fisheries management strategies at either governmental or community-based level were in place. It was also found that little attention to monitoring catches was given by the Fisheries Department. Discussions had started regarding the need for fisheries management, but there were no signs that initiatives were planned or had been started. Apparently, the community cannot embark on any traditional strategies of resource use or there is a general lack of knowledge if, at any stage in the past, such management practices existed. The fact that Romanum enjoys an open-access system does not look promising for any growth in coastal and small-scale artisanal fisheries. The marine rapid ecological assessment (REA) that is being planned by the Protected Areas Network Program within the FSM Department of Resource Management & Development in cooperation with the assistance of a technical team from TNC, and national and state partners, including the Department of Marine Resources, Environmental Protection Agency and Chuuk Conservation Society (CCS), may be of further help to identify problem areas and to start a fisheries management strategy programme.

5.2.6 Discussion and conclusions: socioeconomics in Romanum

The Romanum community has good access to a wide range of habitats, including sheltered coastal reef, lagoon, outer reef and passages in an open-access environment. However, the community has few if any alternatives to fishing and limited access to agricultural production. Also, motorised boat transport is needed to sell fishery produce at Weno, the capital centre. Other, important factors affecting the current fishing situation and its possible future development include the following:

- The Romanum community is highly dependent on marine resources for home consumption and for almost all cash income. The availability of motorised boats, the short, one-hour boat journey to the urban market of Weno, and the regular visits of agents to the island make it possible for the community to commercially exploit its fishery resources.

- Consumption of fresh fish (81 kg/person/year) and invertebrates (18.5 kg/person/year) is high. Both figures are above the average found across all study sites in FSM. Canned fish consumption is less (12 kg/person/year).

- Consumption and income patterns highlight the traditional lifestyle. However, Chuuk's political affiliation, and the import prices of staple food items also require cash income to satisfy basic living costs, which are relatively high. Remittances play a certain role but only benefit about half of the population to a limited extent only.

- Traditional roles show in the fact that males fish for finfish, while females do most of the invertebrate collection. Given the current, very low sales price for finfish, changes in gender roles may show when both finfish and invertebrates are caught to provide income, as invertebrates are currently a more lucrative source. Female fishers are organised into smaller groups serving agents and supermarkets that order octopus and other invertebrates. Males are the main commercial fishers of invertebrates, including bêche-de-mer, lobsters, trochus and giant clams.

- Overall, CPUEs are moderate with 2–2.5 kg catch per hour fishing trip and do not vary significantly among habitats.

- Spear diving is the main technique used, sometimes complemented by deep-bottom lining and gillnetting.

- Reported catch sizes increase, as expected, with distance from shore. Overall, reported average fish lengths are large: 25 cm in catches from the sheltered coastal reef and ~35 cm in outer-reef catches.

- The main families caught in any of the habitats fished reflect the major use of spear diving, i.e. Scaridae and Acanthuridae represent a major share of reported catches.

- Results from the invertebrate fisher survey show that commercial catches of bêche-de-mer species account for most of the annual invertebrate harvest (wet weight), followed by the other commercial target species: lobsters, trochus and giant clams.

- Fishing pressure indicators calculated for finfish suggest low fisher, population and catch densities due to the size of the available reef and total fishing ground area. However, the low selling price of fish, the lack of alternative income sources, and the lack of any fisheries management all give reason for caution.

- Fishing pressure indicators calculated for invertebrate fisheries show low fisher densities. However, the fact that fishing targets a very few species only, that the average annual catch per fisher is very high for reeftop gleaning, and the lack of any fisheries management give reason for concern.

5.3 Finfish resource surveys: Romanum, CHUUK

Finfish resources and associated habitats were assessed in Romanum on 20–28 April 2005, from a total of 19 transects (6 sheltered coastal, 4 intermediate-, 4 back- and 5 outer-reef transects; see Figure 5.19 and Appendix 3.4.1 for transect locations and coordinates respectively).

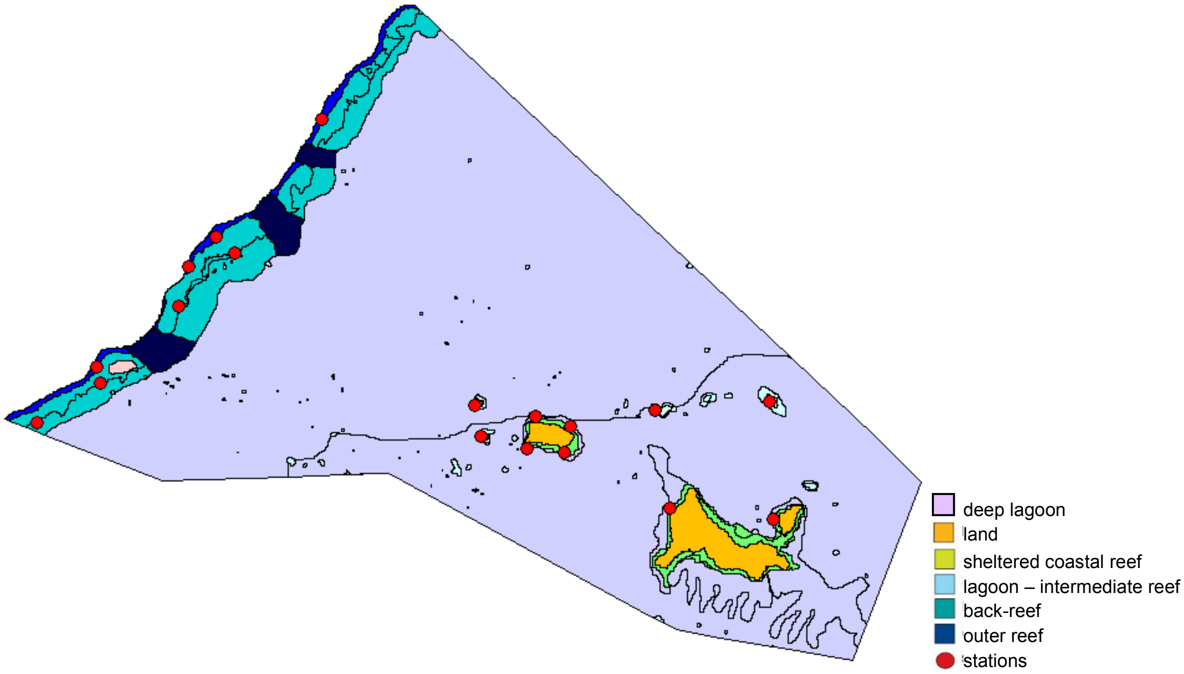

Figure 5.19: Habitat types and transect locations for finfish assessment in Romanum.

5.3.1 Finfish assessment results: Romanum

A total of 23 families, 54 genera, 147 species and 8878 fish were recorded in the 19 transects (See Appendix 3.4.3 for list of species.). Only data on the 15 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 42 genera, 129 species and 7680 individuals.

Finfish resources varied slightly among the four reef environments found in Romanum (Table 5.6). The outer reef contained the far highest density, size, size ratio, biomass and biodiversity of the site (0.7 fish/m^2, 19 cm FL, 123 g/m^2, 39 species/transect), while sheltered coastal reefs displayed the lowest values of size (as low as 11 cm FL), size ratio (32%), biomass (four times lower than in outer reefs, 29 g/m^2). Back-reefs displayed values only slightly lower than outer reefs but density was the lowest at the site, and similar to density in the intermediate reefs (0.4 fish/m^2). The intermediate reefs had similar values of density and biomass than the back-reefs but lower average fish size, size ratio and biodiversity.

Table 5.6: Primary finfish habitat and resource parameters recorded in Romanum (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	4	4	5	19
Total habitat area (km^2)	3.5	2.0	17.7	2.6	25.8
Depth (m)	4 (1-8) (3)	3 (1-6) (3)	3 (1-7) (3)	5 (1-10) (3)	4 (1-10) (3)
Soft bottom (% cover)	16 ±3	12 ±6	21 ±16	2 ±1	18
Rubble & boulders (% cover)	22 ±3	30 ±3	16 ±4	2 ±1	17
Hard bottom (% cover)	32 ±6	35 ±9	40 ±14	77 ±2	42
Live coral (% cover)	28 ±8	20 ±4	21 ±5	16 ±3	22
Soft coral (% cover)	1 ±1	3 ±2	1 ±1	3 ±1	1
Biodiversity (species/transect)	31 ±5	27 ±7	32 ±7	39 ±6	33 ± 3
Density (fish/m^2)	0.5 ±0.1	0.4 ±0.1	0.4 ±0.1	0.7 ±0.1	0.4
Biomass (g/m^2)	29.1 ±7.3	40.9 ±20.2	48.0 ±19.1	123.2 ±17.8	52.4
Size (cm FL) (4)	11 ±1	14 ±1	16 ±1	19 ±1	15
Size ratio (%)	32 ±2	43 ±3	46 ±3	63 ±3	45

(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: Romanum

The sheltered coastal reef environment of Romanum was dominated by three major families: Acanthuridae, Scaridae, and Siganidae; relatively high biomass was also recorded for Mullidae and Labridae (Figure 5.20). These five families were represented by 37 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Hipposcarus longiceps*, *Chlorurus bleekeri*, *Scarus rivulatus*, *S. flavipectoralis*, *Siganus doliatus*, *Naso brevirostris*, *S. vulpinus*, *Cheilinus undulatus* and *Mulloidichthys flavolineatus* (Table 5.7). This reef environment presented a moderately diverse habitat with hard bottom dominating (32%), a large cover of live corals (28%), and good percentage of mobile bottom (38% for soft bottom and rubble together) (Table 5.6 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 Romanum

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.008 ±0.004	3.1 ±2.0
	Chlorurus bleekeri	Bleeker's parrotfish	0.013 ±0.004	2.2 ±0.9
	Scarus rivulatus	Rivulated parrotfish	0.027 ±0.016	1.3 ±0.6
	Scarus flavipectoralis	Yellowfin parrotfish	0.019 ±0.008	1.3 ±0.4
Siganidae	*Siganus spinus*	Little spinefoot	0.103 ±0.096	0.3 ±0.1
	Siganus doliatus	Barred spinefoot	0.009 ±0.003	0.9 ±0.3
	Siganus vulpinus	Foxface rabbitfish	0.006 ±0.003	0.8 ±0.5
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.090 ±0.026	8.7 ±2.5
	Naso brevirostris	Spotted unicornfish	0.006 ±0.003	0.9 ±0.6
Mullidae	*Mulloidichthys flavolineatus*	Yellowstripe goatfish	0.016 ±0.010	0.7 ±0.7
Labridae	*Cheilinus undulatus*	Napoleon wrasse	0.002 ±0.001	0.8 ±0.8

Density and diversity of finfish in the sheltered coastal reefs were lower than in the back-reefs and outer reefs. All other parameters were the lowest of the site. When compared to Riiken, the only other site presenting coastal reef habitat among FSM study sites, Romanum displayed much lower values for all parameters except for density, which was average (0.5 versus 0.4 fish/m^2 in Riiken). Size and size ratio were particularly low (11 cm FL and 32%). The trophic structure in Romanum coastal reef was highly dominated by herbivorous fish, represented mainly by Scaridae and Acanthuridae. Siganidae were also very important numerically, with *Siganus spinus* the most abundant species overall. Size ratio was below the 50% threshold for many families, mostly Scaridae (19%) and Siganidae (22%), as well as for carnivores Labridae, Lethrinidae, Lutjanidae and Mullidae.

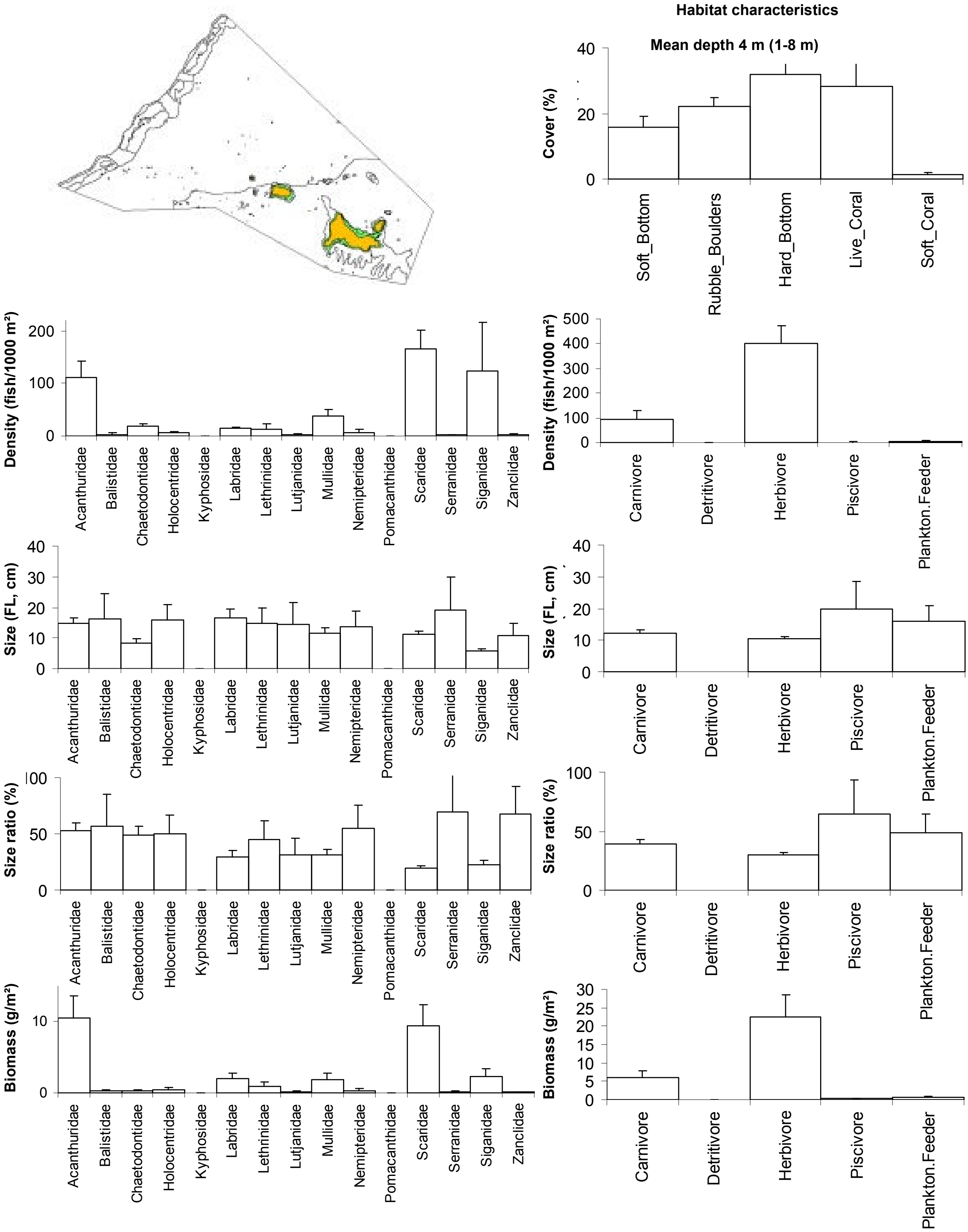

Figure 5.20: Profile of finfish resources in the sheltered coastal reef environment of Romanum.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Romanum

The intermediate-reef environment of Romanum was dominated by four families: herbivorous Scaridae and Acanthuridae and, to a much lower extent, carnivorous Lutjanidae (only in terms of density) and Lethrinidae (Figure 5.21). These four families were represented by 22 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Scarus rivulatus*, *Lutjanus bohar*, *Gnathodentex aureolineatus*, *S. flavipectoralis*, *Chlorurus sordidus*, *Lethrinus harak* and *Acanthurus lineatus* (Table 5.8). This reef environment presented a diverse habitat with high cover of hard bottom (35%) and mobile bottom (42%), and relatively high cover of live coral (20%) (Table 5.8).

Table 5.8: Finfish species contributing most to main families in terms of densities and biomass in the intermediate-reef environment of Romanum

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.115 ±0.047	13.7 ±6.6
	Acanthurus lineatus	Lined surgeonfish	0.018 ±0.018	1.0 ±1.0
Scaridae	*Scarus rivulatus*	Rivulated parrotfish	0.023 ±0.017	8.0 ±7.3
	Scarus flavipectoralis	Yellowfin parrotfish	0.028 ±0.014	2.0 ±0.7
	Chlorurus sordidus	Daisy parrotfish	0.026 ±0.017	1.8 ±1.5
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.030 ±0.030	2.6 ±2.6
	Lethrinus harak	Thumbprint emperor	0.003 ±0.002	1.3 ±1.0
Lutjanidae	*Lutjanus bohar*	Twinspot snapper	0.001 ±0.001	4.3 ±4.3

The density, size and size ratio of finfish in the intermediate reefs of Romanum were the lowest of the site; only biomass was higher than that recorded at coastal reefs (41 versus 30 g/m^2). Density, biomass and size were intermediate between the values recorded at Piis-Panewu and Riiken. However, biodiversity (27 species/transect) and size ratio were the lowest recorded for intermediate reefs. Herbivores were four times more abundant and six times higher in biomass than carnivores. Lethrinidae were the most-represented carnivores. Acanthuridae and Scaridae were similarly important in both density and biomass. Average size ratio was very low for both Mullidae (38%) and Scaridae (25%), indicating a high impact from fishing on these two families. Scaridae, Acanthuridae and Mullidae are among the most highly fished families in coastal and lagoon reefs.

The intermediate reefs of Romanum displayed a quite diverse composition of hard bottom, rubble, soft bottom and coral, normally advantaging a wide range of families that are, however, not well represented here.

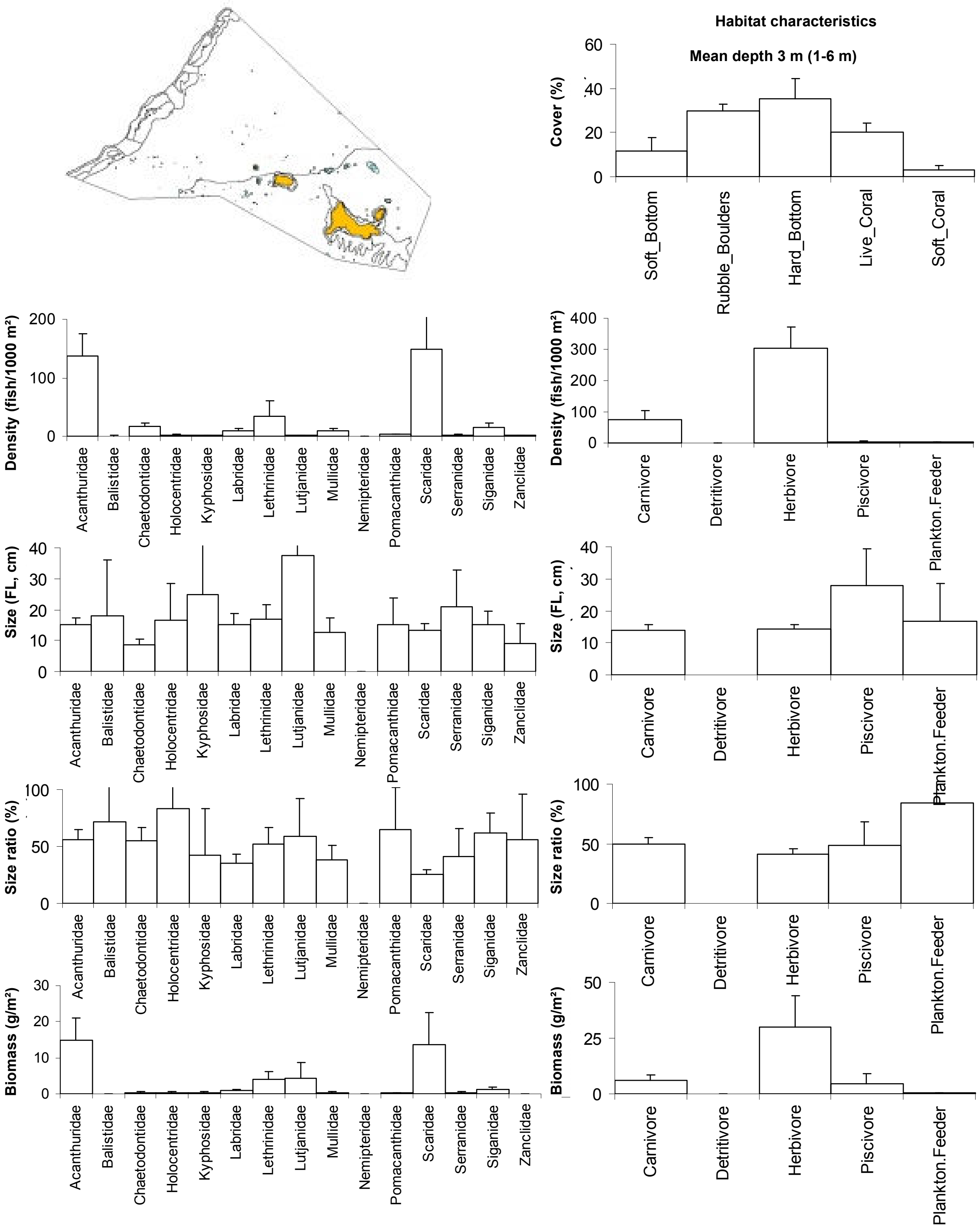

Figure 5.21: Profile of finfish resources in the intermediate-reef environment of Romanum.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Romanum

The back-reef environment of Romanum was dominated by two herbivorous families: Scaridae and Acanthuridae (Figure 5.22). These were represented by 24 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus rubroviolaceus*, *S. rivulatus*, *Naso lituratus*, *N. unicornis* and *Acanthurus lineatus* (Table 5.9). This reef environment presented a diverse habitat with very high cover of hard bottom (40%), relatively high cover of live coral (21%) and high cover of mobile bottom (37%, Table 5.6).

Table 5.9: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Romanum

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.09 ±0.02	9.7 ±1.8
	Naso lituratus	Orangespine unicornfish	0.01 ±0.01	2.3 ±1.4
	Naso unicornis	Bluespine unicornfish	0.01 ±0.01	2.2 ±2.1
	Acanthurus lineatus	Lined surgeonfish	0.02 ±0.01	1.5 ±1.2
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06 ±0.04	5.8 ±4.1
	Scarus rubroviolaceus	Ember parrotfish	0.01 ±0.01	4.9 ±4.9
	Scarus rivulatus	Rivulated parrotfish	0.04 ±0.04	3.3 ±3.3

The size, size ratio, biomass and diversity of finfish in the back-reefs of Romanum were ranked second after the values in the outer reefs; only density was the same as that of intermediate reefs and the lowest at the site (0.4 fish/m^2). When compared to the back-reefs of the other three sites in FSM, Romanum presented the second-lowest values of biomass and density, only slightly better than in Piis-Panewu. However, size and size ratio were the lowest recorded of all back-reefs. Herbivores highly dominated the trophic structure, being five times more abundant and six times more important in terms of biomass than carnivores. No carnivore families were abundant. Acanthuridae and Scaridae were similarly important in both density and biomass. Average size ratio was especially low for Lethrinidae (36%) and Scaridae (35%), probably indicating a high impact on these two families from fishing. The back-reefs of Romanum displayed quite a diverse composition of substrate with dominance of hard coral (40%) but also good coverage of mobile bottom, offering ground to carnivore as well as herbivore species. However, carnivores were almost absent here, probably due to fishing impact.

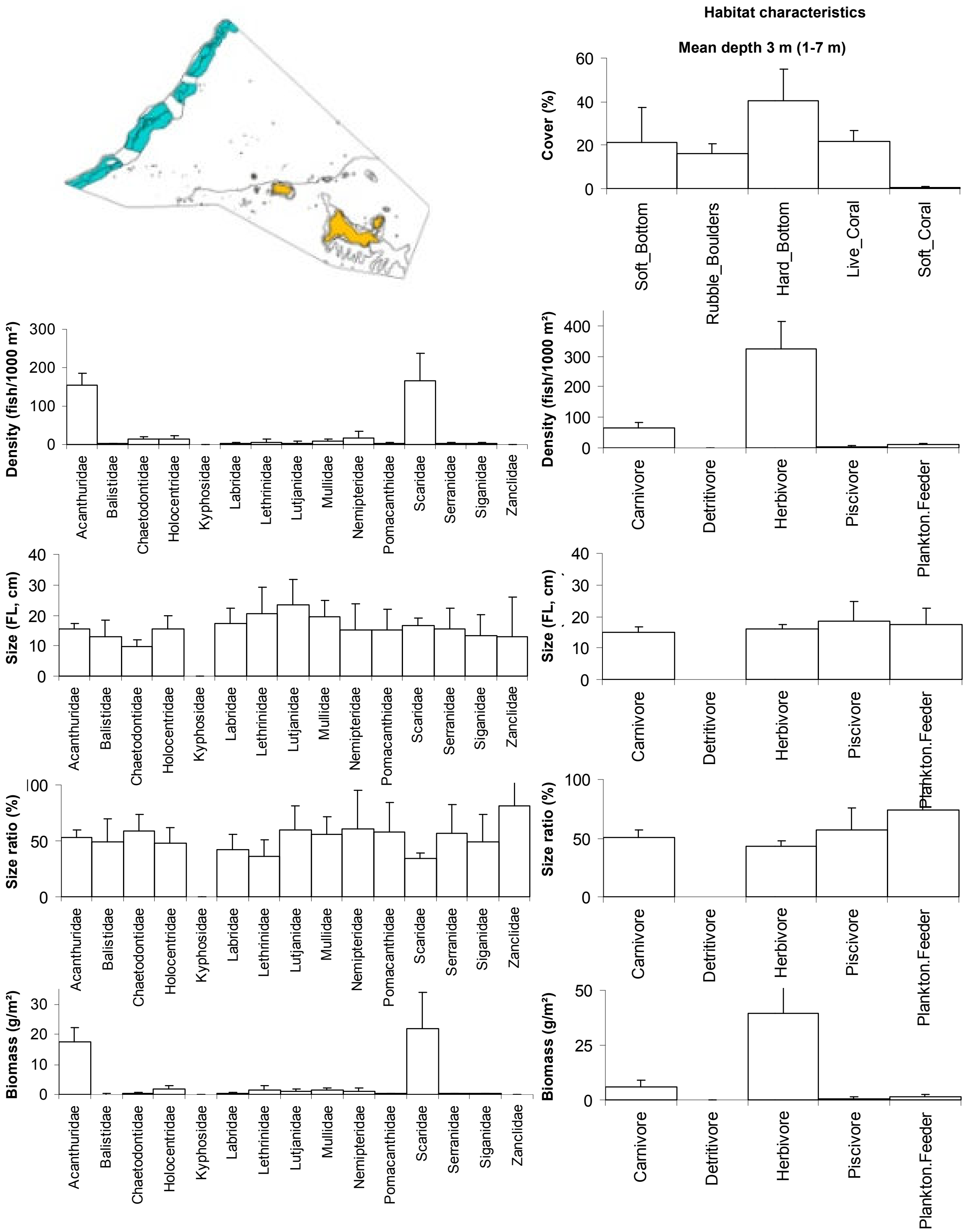

Figure 5.22: Profile of finfish resources in the back-reef environment of Romanum.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Romanum

The outer reef of Romanum was dominated by two herbivorous families: Acanthuridae and Scaridae for both density and biomass and, to a much lesser extent and only in terms of biomass, by two carnivorous families: Lutjanidae and Lethrinidae (Figure 5.23). These four families were represented by 32 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus microrhinos*, *Acanthurus nigricans*, *Naso lituratus*, *C. sordidus*, *A. lineatus*, *Lutjanus gibbus* and *C. frontalis* (Table 5.10). Hard bottom largely dominated the habitat of this reef (77% cover) and live coral was present in much less cover than at other habitats (16%, Table 5.6 and Figure 5.23). Soft bottom was practically absent.

Table 5.10: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Romanum

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.265 ±0.051	38.2 ±5.9
	Acanthurus nigricans	Whitecheek surgeonfish	0.127 ±0.066	11.3 ±5.7
	Naso lituratus	Orangespine unicornfish	0.031 ±0.007	8.5 ±2.0
	Acanthurus lineatus	Lined surgeonfish	0.013 ±0.009	3.5 ±2.4
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.018 ±0.007	15.5 ±6.8
	Chlorurus sordidus	Daisy parrotfish	0.042 ±0.023	4.8 ±2.1
	Chlorurus frontalis	Tan-faced parrotfish	0.004 ±0.004	2.0 ±2.0
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.005 ±0.004	2.4 ±1.9

The density, size, size ratio, biomass and biodiversity of finfish in the outer reef of Romanum were the highest at the site (Table 5.6). When compared to the other country sites, Romanum values of density, biomass and biodiversity were higher only than those at Piis-Panewu but much lower than those at Yap. However, size and size ratio were here the highest of all the outer reefs. Herbivores very strongly dominated this habitat, with Acanthuridae and Scaridae in very high numbers and biomass. The rare and large-sized fish *Bolbometopon muricatum* were frequent and abundant. Average size ratios were very low for Mullidae (37%), Scaridae (25%) and Serranidae (41%). Substrate composition was of a type which normally favours herbivores and carnivores associated with hard bottom, such as snappers, here mainly *Lutjanus gibbus*. Outer reefs were targeted more often by fishers compared to other habitats and the fishing impact, especially from the use of gillnets and spearfishing, is evident in the small numbers of carnivores and small average fish sizes.

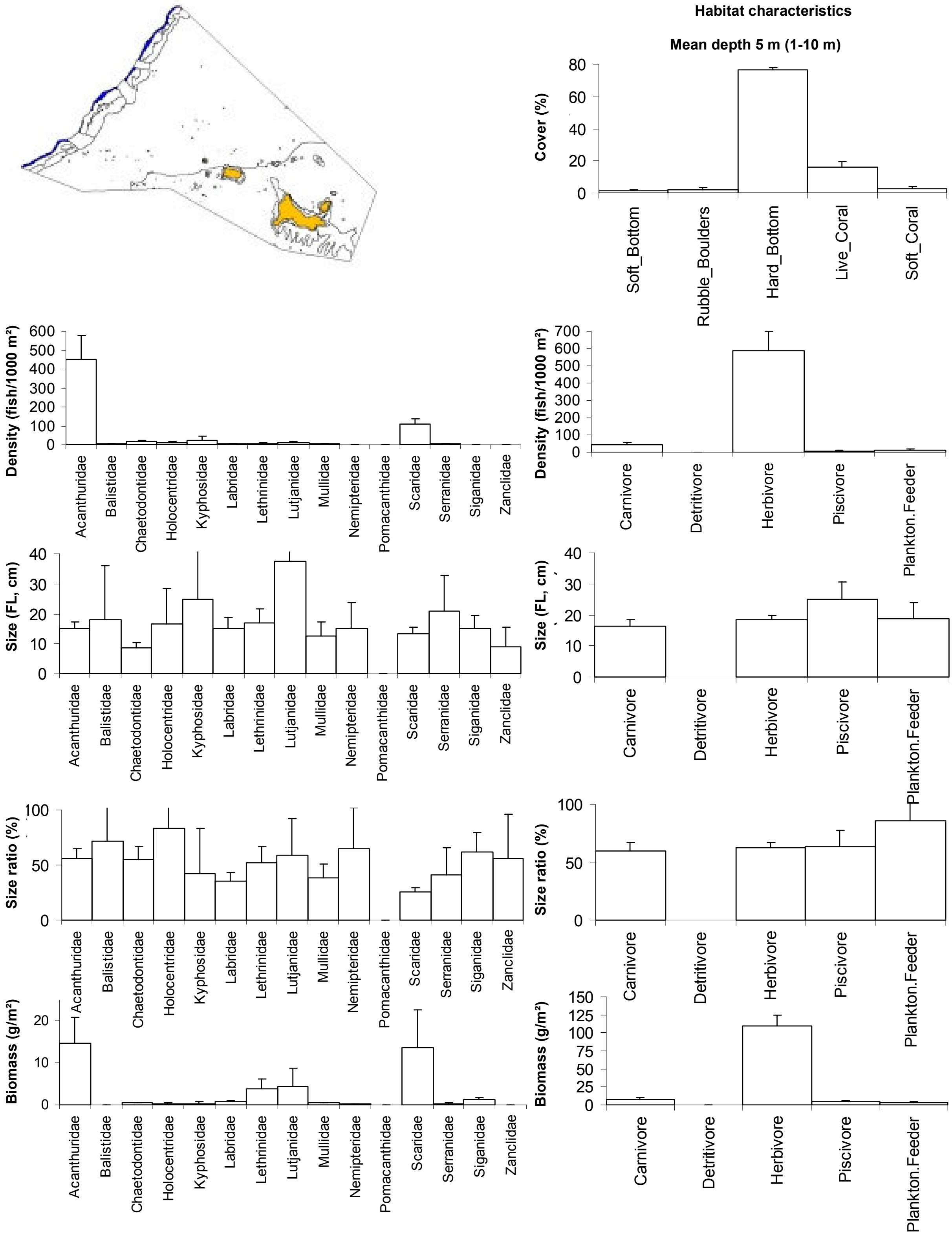

Figure 5.23: Profile of finfish resources in the outer-reef environment of Romanum.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Romanum

Overall, the fish assemblage of Romanum was strongly dominated by herbivorous Acanthuridae and Scaridae (Figure 5.24). These two families were represented by a total of 36 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus, Chlorurus sordidus, Scarus rubroviolaceus, C. microrhinos, S. rivulatus, Naso lituratus, C. bleekeri, Acanthurus nigricans* and *N. unicornis* (Table 21). The average substrate was dominated by hard bottom (42%), with rather good cover of live coral (22%), and a good proportion of mobile bottom (35%). The overall fish assemblage in Romanum shared characteristics of primarily back-reefs (68% of total habitat), then of coastal reefs (13%) and only to a lower extent outer reefs (10% of habitat) and intermediate reefs (8%).

Table 5.11: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Romanum (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.111	12.7
	Naso lituratus	Orangespine unicornfish	0.011	2.5
	Acanthurus nigricans	Whitecheek surgeonfish	0.021	1.6
	Naso unicornis	Bluespine unicornfish	0.005	1.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.050	4.7
	Scarus rubroviolaceus	Ember parrotfish	0.007	3.5
	Chlorurus microrhinos	Steephead parrotfish	0.004	3.1
	Scarus rivulatus	Rivulated parrotfish	0.031	3.1
	Chlorurus bleekeri	Bleeker's parrotfish	0.006	1.7

Overall, Romanum appeared to support a rather poor finfish resource, with the lowest density (equal value to Piis-Panewu), lowest diversity of species, lowest size, size ratio and second-lowest biomass (only higher than Piis-Panewu, Table 5.6) in the country. A detailed assessment at the family level revealed a consistent dominance of herbivores over carnivores. Herbivores were almost equally represented by Scaridae and Acanthuridae, except in the outer reefs, where Acanthuridae dominated in numbers. This trend could be partially explained by the composition of the habitat, mostly composed of hard rock and live coral, especially in the outer reef, with very little percentage of soft substrate, which normally favours most invertebrate-feeding carnivores, such as Mullidae and Lethrinidae. Overall, size ratios were below the 50% threshold for Lethrinidae and Scaridae. Scaridae, Mullidae, Acanthuridae and Siganidae were the most frequently targeted fish, mostly caught by spearfishing. The reduced size of some families could be a sign of impact from this selective fishing method.

Figure 5.24: Profile of finfish resources in the combined reef habitats of Romanum (weighted average).
FL = fork length.

5.3.2 Discussion and conclusions: finfish resources in Romanum

The assessment indicated that the status of finfish resources in this site was rather poor at the time of surveys. Similar to the reefs in Piis-Panewu, the reefs at Romanum appeared healthy and rich in live-coral cover, but had little soft bottom, which is the type of substrate associated with carnivores such as Lethrinidae and Mullidae. However, Lutjanidae, usually associated with hard substrate, were also in low abundance or absent, probably as a result of intense fishing. Lethrinidae, Scaridae and Acanthuridae, representing the bulk of the catches, had very low average size ratios, an indication of impact on these selected families. At the reef-habitat level, resources were very variable. Coastal reefs were particularly poor, with very small-sized fish. Fish in the intermediate and back-reefs had minimum density values and only slightly larger sizes, resulting in small values of biomass. Only outer reefs were richer, with biomass twice as high as that recorded in Piis-Panewu. Heavy fishing is carried out for subsistence as well as sale and a high density of fishers was recorded in the small fishing areas available. Signs of dynamite fishing were also recorded around Romanum. Therefore, fishing is imposing some changes in the resources, evident in smaller fish sizes, smaller numbers of fish and lower number of species compared to in the other sites surveyed in both Chuuk and Yap.

- Overall, Romanum finfish resources appeared to be in poor condition. The reef habitat was relatively healthy and somewhat diverse although mostly composed of coral rock and live coral. However the fish community was not very diverse and was strongly dominated by herbivores.

- The dominance of Scaridae and Acanthuridae fish families could only partially be explained by the type of environment. Some carnivores usually associated with hard-bottom habitats were also lacking or in very low numbers.

- Coastal and intermediate reefs showed clear signs of high fishing pressure: very low average fish size and size ratios, especially for Scaridae and Siganidae, resulting in very low values of biomass.

- Intermediate and back-reefs were rather poor as well, especially in terms of fish density.

5.4 Invertebrate resource surveys: Romanum, CHUUK

The diversity and abundance of invertebrate species at Romanum were independently determined using a range of survey techniques (Table 5.12): broad-scale assessment (using the 'manta tow'; locations shown in Figure 5.25) and finer-scale assessment of specific reef and benthic habitats (Figures 5.26 and 5.27).

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

Table 5.12: Number of stations and replicates completed at Romanum

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 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)	7	42 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	6	36 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	5	30 search periods
Sea cucumber night searches (Ns)	3	18 search periods

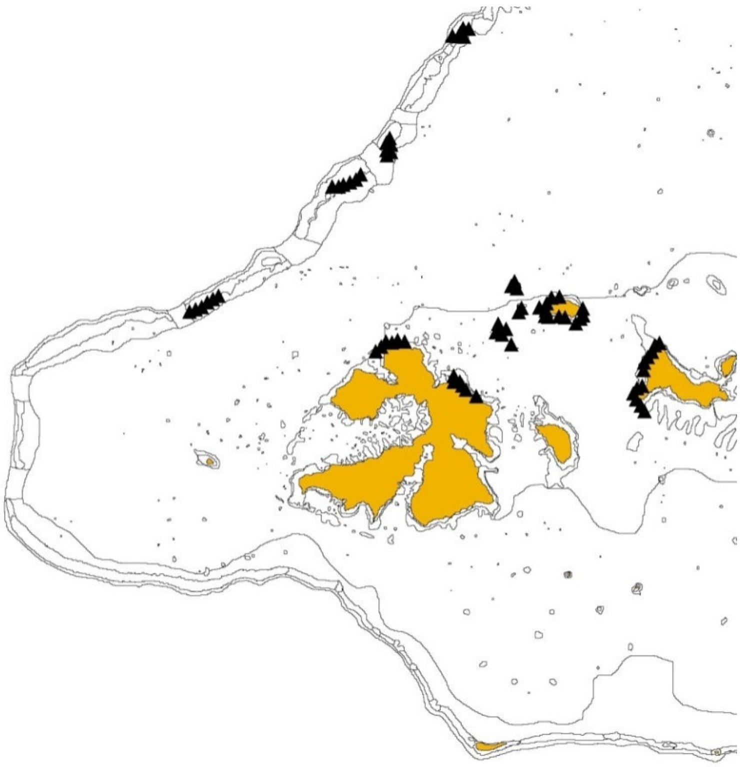

Figure 5.25: Broad-scale survey stations for invertebrates in Romanum.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

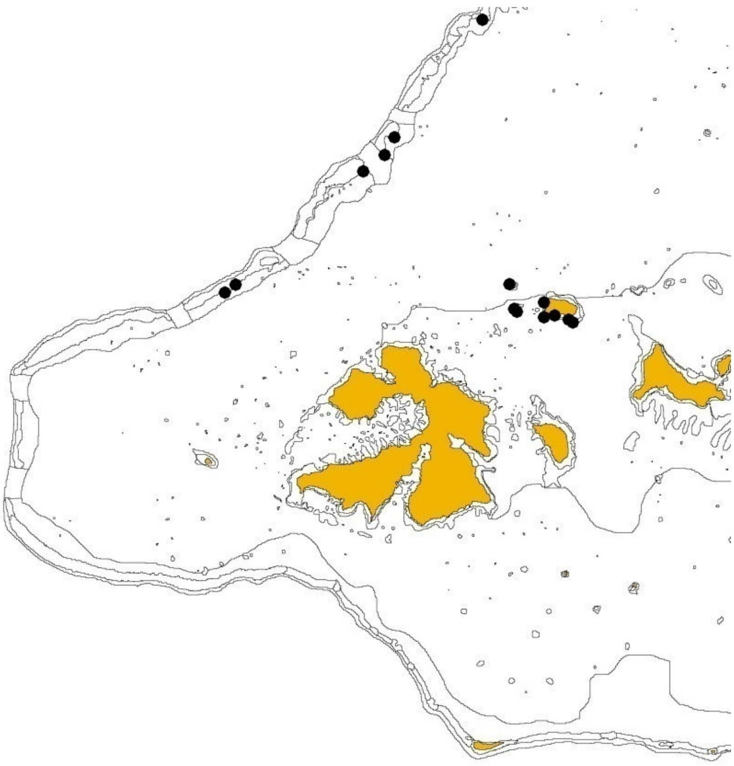

Figure 5.26: Fine-scale reef-benthos transect survey stations in Romanum.
Black circles: reef-benthos transect stations (RBt).

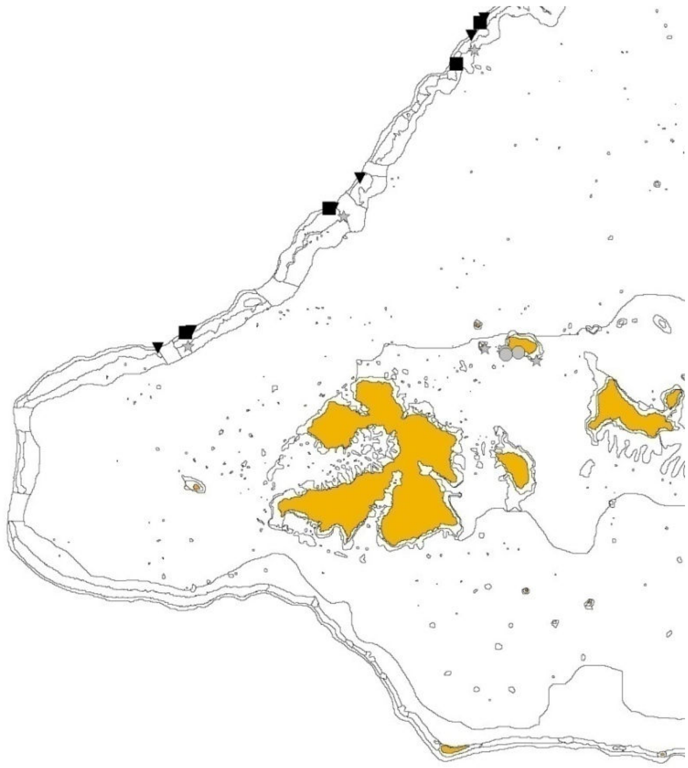

Figure 5.27: Fine-scale survey stations for invertebrates in Romanum.
Inverted black triangles: reef-front search stations (RFs);
black squares: mother-of-pearl transect stations (MOPt);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Fifty-nine species or species groupings (groups of species within a genus) were recorded in the Romanum invertebrate surveys. Among these were 9 bivalves, 19 gastropods, 20 sea cucumbers, 4 urchins, 4 sea stars, 1 cnidarian and 1 lobster (Appendix 4.4.1). Information on key families and species is detailed below.

5.4.1 Giant clams: Romanum

Shallow-reef habitat that is suitable for giant clams was extensive at Romanum (25.51 km²: ~17 km² within the lagoon and 8.5 km² on the reef front or slope of the barrier reef). The lagoon of this western section of Chuuk was extensive (~521.9 km²) and stretched west from Weno across the Faichuk Islands and intermediate-reefs to the barrier reef and Mochun Pianu (the large western pass).

Close to the island of Romanum, reef structure was characterised by fringing areas of seagrass and patch coral within a pseudo-lagoon, surrounded by more substantial banks of reef. At the barrier reef and along the passages, coral was also more developed, even along the back-reef, although the reef slope in general did not have extensive shoaling reef on the ocean side. Around Romanum, the main influence was from the land; waters became more oceanic towards the barrier reef, which had numerous passages linking the lagoon to open water.

Using all survey techniques, three species of giant clam were noted; the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the bear's paw clam *Hippopus hippopus*. Broad-scale sampling provided a good overview of giant clam distribution and density for two of the three species noted, and records reveal that *T. maxima* had the widest distribution (found in 9 stations and 33 transects), followed by *H. hippopus* (in 1 station and 1 transect, see Figure 5.28). *T. squamosa* was not recorded in broad-scale surveys.

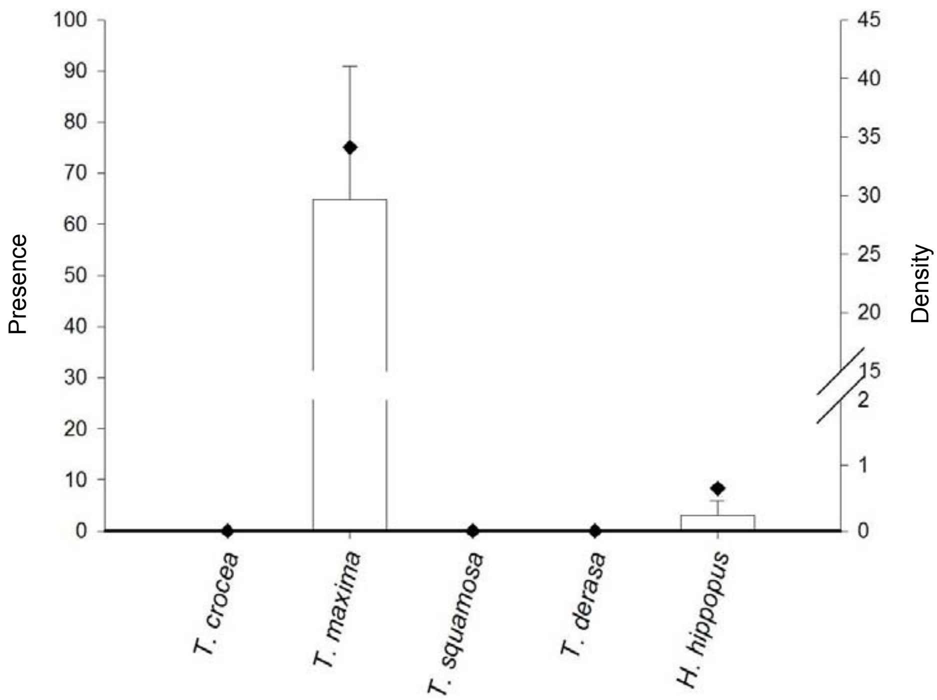

Figure 5.28: Presence and mean density of giant clam species at Romanum based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 5.29). In these reef-benthos assessments (RBt), *T. maxima* was present in 63% of stations, the highest station density being 291.7 ±163.5 clams/ha. *T. squamosa* was recorded as a single clam in two stations only and no *H. hippopus* clams were noted in RBt stations.

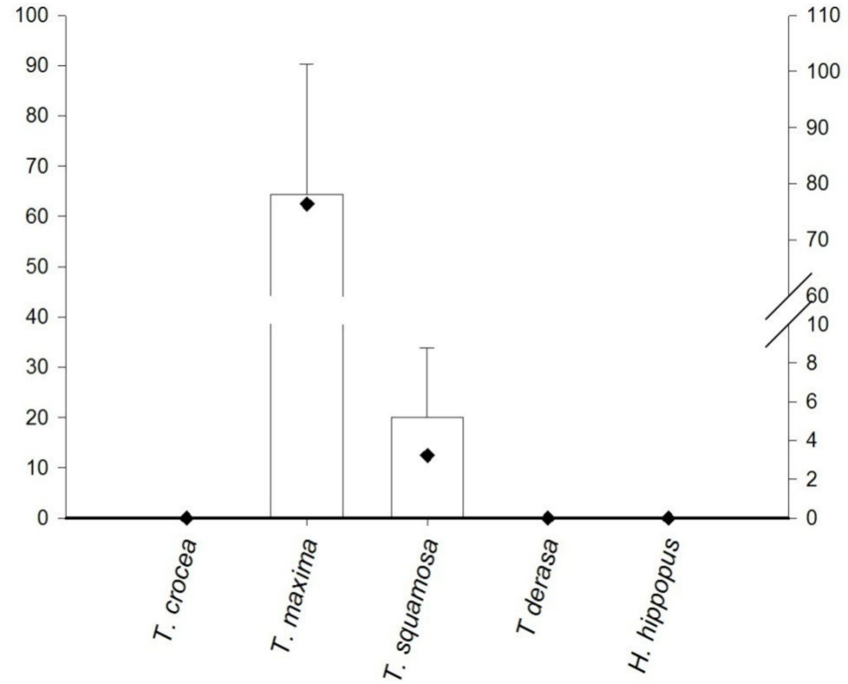

Figure 5.29: Presence and mean density of giant clam species at Romanum based on reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

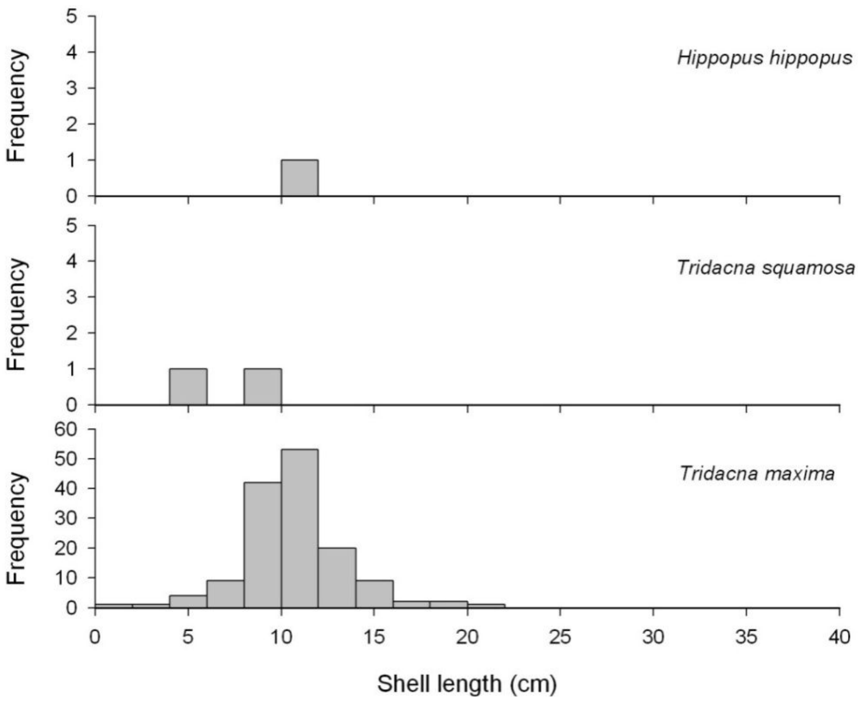

Figure 5.30: Size frequency histograms of giant clam shell length (cm) for Romanum.

The mean size of elongate clams *T. maxima* from RBt stations was 11.2 cm ±0.7, which represents a clam of ≥5 years old. A full range of *T. maxima* lengths was noted in survey, although the largest sizes (≥15 cm) were not common. Only two of the faster-growing *T. squamosa* clams (asymptotic length L_∞ of 40 cm) were recorded (4.6 and 10 cm in length). *H. hippopus* was also rare; only a single clam of 12 cm was noted (Figure 5.30).

5.4.2 Mother-of-pearl species (MOP) – trochus and pearl oysters: Romanum

Chuuk does not seem to have supported natural stocks of the commercial topshell, *Trochus niloticus*, before 1927, as there are reports of unsuccessful translocations of live shell from Palau. Despite the various early attempts to introduce trochus, a total of 6724 shells were transferred in bait wells of skipjack boats in 1927 and five years elapsed before this introduction was judged successful (Gillett 2002b). The first harvest was in 1939 and the greatest annual harvest in the early days of the fishery was in 1952 (230 t, or 233.7 t of shell). Later, trochus taken from Chuuk was used to make introductions to Jaluit and Pohnpei (Gillett 2002b).

Trochus is one of the few inshore species that is protected by Chuuk law. The Department of Marine Resources (DMR) monitors the trochus species and declares whether the species is ready for harvesting or not. However, illegal harvests are commonly noted. There was an incident in 2003 that involved a particular company buying trochus from the local people although DMR had not declared an open season for harvesting. The company bought the trochus for 25 cents per pound although it is a known fact that trochus cost a lot more when exported. During the current survey, officers noted that trochus harvests were occurring and noted the remains of trochus processing on uninhabited *motu*.

Table 5.13: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Romanum
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	6.2	1.6	9/12 = 75	16/72 = 22
RBt	122.4	40.0	13/16 = 81	32/96 = 33
RFs	12.4	6.5	5/6 = 83	12/36 = 33
MOPt	1310	28.3	6/7 = 86	24/42 = 57
Tectus pyramis				
B-S	0.2	0.2	1/12 = 8	1/72 = 1
RBt	23.4	10.0	5/16 = 31	7/96 =7
RFs	2.6	1.9	2/6 = 33	3/36 = 8
MOPt	3.0	3.0	1/7 = 14	1/42 = 2
Pinctada margaritifera				
B-S	2.3	0.8	5/12 = 42	9/72 = 13
RBt	0		0/16 = 0	0/96 = 0
RFs	0		0/6 = 0	0/36 = 0
MOPt	0		0/7 = 0	0/42 = 0

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

The survey of many different reef zones at different scales allows the determination of shell distribution and density for commercial trochus. Usually, in addition to standard broad-scale and shallow-reef surveys, trochus information is collected using reef-front searches (RFs) and mother-of-pearl transects (MOPt, see Methods, Table 5.13). Inshore, intermediate and barrier reef at Chuuk was suitable for trochus. CoFish survey work revealed that juvenile and adult *T. niloticus* shells were well distributed around reefs throughout western Chuuk, with even broad-scale surveys picking up trochus in 9 of the 12 stations surveyed (Total lineal distance of exposed reef perimeter was 34.1 km.).

The majority of the stock was on shallow reef (depth ~1.5–3 m) that was easily accessible to fishers working with a mask and snorkel. From the broad-scale and reef-benthos transect stations that held trochus, the density recorded by station was 3–667 trochus/ha.

Although *T. niloticus* was commonly recorded in northern Chuuk, the density of trochus at all stations was generally low (59% of RBt, RFs and MOPt stations recorded <100 trochus/ha). The most significant trochus aggregations were noted right at Romanum and at reefs in close proximity to the west. If we adopt the threshold of 500 shells/ha as an indication of density required before main aggregations can be considered for commercial fishing, trochus density records from Romanum generally indicate that there is significant potential for growth in overall abundance before commercial fishing can be contemplated.

A total of 125 trochus were recorded during the survey, with a mean basal width of 7.8 cm ±0.2. The range and frequency of shell sizes gives an important indication of the status of stocks by highlighting new recruitment or lack of recruitment into the fishery, and which sizes are being removed from the fishery (Figure 5.30).

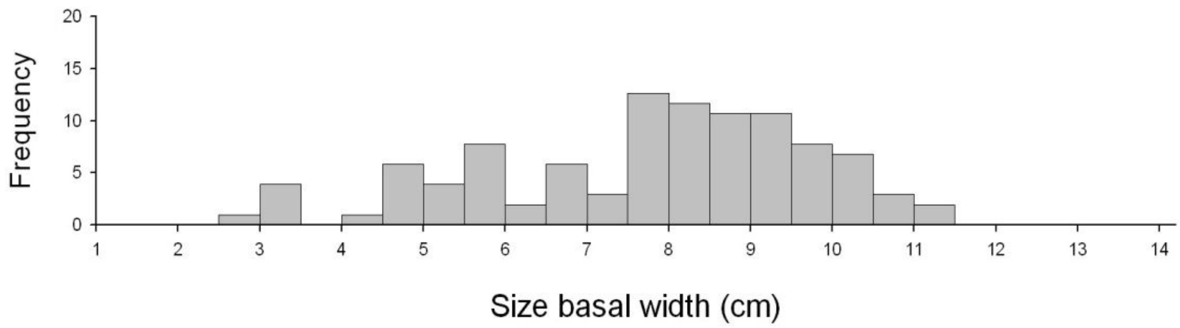

Figure 5.30: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Romanum.

The length frequency graph reveals that a full range of trochus sizes was still in the water at Romanum and that small numbers of juveniles were still entering the capture size classes (recruitment). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic phase of life and joining the main stock. As can be seen from the length frequency graph, a small recruitment pulse of younger trochus is evident from the size records collected at Romanum.

Despite the continued recruitment, there are few older, large shells in the fishery. The length frequency results can be interpreted as an indication of the level of fishing in previous harvests. In this case, only 2% of the stock was from size classes >11 cm basal width, which is low, indicating that the larger, mature proportion of the population has been actively fished. In some other trochus fisheries in the Pacific, where stock has not been fished for an extended period or where there is a maximum basal width for commercial sale (of >11 cm), this portion of the stock usually makes up ≥25% of the population.

Normally, we also look at the occurrence of the false trochus or green topshell (*Tectus pyramis*), a related but less valuable species of topshell. *T. pyramis*, an algal-grazing gastropod with a similar life history to trochus, can give an indication of the suitability of reefs for grazing gastropods. In this case, *T. pyramis* was rare and at low density (n = 15 recorded in survey).

Another mother-of-pearl species, the blacklip pearl oyster *Pinctada margaritifera*, is cryptic and normally sparsely distributed in 'open' lagoon systems such as the one around Romanum. In survey, ten blacklip were found (average length 14.1 cm).

5.4.3 Infaunal species and groups: Romanum

Soft benthos at the coastal margins of Romanum was suitable for seagrass, and small areas of seagrass were seen in the pseudo-lagoon in front of the settlement at Romanum. The area was not pristine and there were no reported concentrations of in-ground resources (shell 'beds'). No infaunal 'digging' (quadrat) surveys were completed.

5.4.4 Other gastropods and bivalves: Romanum

One individual of the large Seba's spider conch *Lambis truncata* was recorded in broad-scale surveys. Three other, smaller *Lambis* species were also noted at low density (*L. lambis*, *L. chiragra*, *L. crocata*) and the strawberry or red-lipped conch *Strombus luhuanus* was noted, but no high-density aggregations were found (Appendices 4.4.2 to 4.4.9).

Only one species of turban shell, *Turbo argyrostomus*, was noted. This large, silver-mouthed turban was recorded at moderate rates (in 71% of MOPt stations and 69% of RBt stations) and at average station densities of 68–86 /ha. Other resource species targeted by fishers (e.g. *Cassis*, *Cerithium*, *Conus*, *Cypraea*, *Pleuroploca*, *Thais*, *Tutufa* and *Vasum*) were also recorded during independent surveys (Appendices 4.4.2 to 4.4.9).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina*, *Chama*, *Hyotissa*, *Pteria*, and *Spondylus*, are also in Appendices 4.4.2 to 4.4.9. No creel survey was conducted at Romanum.

5.4.5 Lobsters: Romanum

There was no dedicated night reef-front assessment of lobsters (See Methods.), although night-time assessments for nocturnal sea cucumber species (Ns) offered a small, extra opportunity to record lobster species. Only one record for lobster (*Panulirus* sp.) was made in surveys at Romanum; no prawn killers (*Lysiosquillina maculata*) or mud lobsters (*Thalassina* spp.) were noted.

5.4.6 Sea cucumbers[10]: Romanum

Around Romanum there were extensive areas of shallow- and deep-water sheltered lagoon and barrier reef (lagoon area 521.9 km^2). Coastal areas around Romanum had greater land influence than might be expected for a large, open lagoon system, although semi-high islands at this section of western Chuuk had a total land area that was relatively significant (≥50 km^2). Land inputs (allochthonous matter) were likely to be important to the nutrient regime of the system, and reef margins and areas of shallow, mixed hard- and soft-benthos habitat (suitable for sea cucumbers) were extensive (Sea cucumbers eat detritus and other organic matter in the upper few mm of bottom substrates.). Romanum had a full range of suitable habitats for sea cucumber species.

The presence and density of sea cucumber species were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.13, Appendices 4.4.1 to 4.4.9; see also Methods). Results from the full range of assessments yielded 19 commercial species of sea cucumber (plus one indicator species, see Table 5.13).

Sea cucumber species associated with shallow-reef areas, such as the medium-value leopardfish (*Bohadschia argus*), were moderately common in distribution (recorded in 19% of broad-scale transects) but generally at low density (mean broad-scale transect density was 5.1 /ha ±1.5). The high-value black teatfish (*Holothuria nobilis*), which is easily targeted by commercial fishers, was recorded in small numbers at Romanum (n = 6 individuals, recorded in 33% of broad-scale stations). The mean density for this species was 1.4 /ha ±0.6, which is low, despite this species hardly ever being recorded at high density (>20 /ha) around the Pacific.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was quite well distributed across reefs at Romanum (recorded in 32% and 75% of broad-scale and reef-benthos transect stations). The greatest concentrations were at relatively high density, with two RBt stations returning a record close to 1500 /ha; see Appendix 4.4.3). Both these stations were on reefs bordering Romanum Island.

Surf redfish (*Actinopyga mauritiana*) were recorded in 5 of 6 reef-front search stations (RFs). As this species is mostly found, where its name suggests, on reef fronts, RFs provide a valuable indication of its status. In Romanum, the density of this medium/high-value species was low (<10 /ha) whereas, in other locations in the Pacific, this species is recorded in densities >400–500 /ha.

More protected areas of reef and soft benthos at relatively embayed areas of the lagoon also returned distribution and density records for sea cucumbers. Curryfish (*Stichopus hermanni*) and blackfish (*Actinopyga miliaris*) were rare (16 individuals in total noted in survey). The brown curryfish (*Stichopus vastus*) was recorded on seagrass close to shore at Romanum during night searches (Ns), and small numbers of brown sandfish (*Bohadschia vitiensis*) were also noted in the lagoon and close to Romanum (Ns). The high-value sandfish (*Holothuria scabra*) was not recorded but there were anecdotal reports that this species was present in small numbers.

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

Other, lower-value species of sea cucumber, such as flowerfish (*Bohadschia graeffei*), pinkfish (*Holothuria edulis*) and lollyfish (*H. atra*), were noted at reasonable coverage, but no high-density areas were located.

Deep-water assessments (30 five-minute searches, average depth 26 m, maximum depth 40 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the narrow and wide passages had suitably dynamic water movement for these species, but only five *H. fuscogilva* were recorded. At Ds stations, the average station density for *H. fuscogilva* was low (2.4 /ha ±1.3) and, in general, the density of other deep-water species was also low with greater abundance of *T. anax* (n = 19 individuals) than *T. ananas* (n = 7 individuals).

5.4.7 Other echinoderms: Romanum

At Romanum, only a single edible collector urchin (*Tripneustes gratilla*) and no slate urchins (*Heterocentrotus mammillatus*) were recorded in survey. *Diadema* sp. was also absent from the records. The stronger-spined *Echinothrix* spp. were seen. *Echinothrix diadema* was noted in 75% of RBt stations at moderate density (177.1 /ha ±44.1). Unusually, *Echinometra mathaei* was rare in surveys (recorded in 13% of RBt stations) and at low density (18.2 /ha ±13.7; see Appendices 4.4.1 to 4.4.7). Non-edible urchins, such as *Echinothrix* spp. and *Echinometra mathaei*, can be used within assessments as potential indicators of habitat condition.

Starfish, such as the blue starfish (*Linckia laevigata*) were common in broad-scale surveys (recorded in 83% of broad-scale transects) at low-to-moderate density (20.4 /ha ±8.1). Corallivore (coral eating) starfish, such as the pincushion star, *Culcita novaeguineae,* were recorded in 50% of broad-scale stations (total number recorded, n = 30); however, the most destructive coral-eating starfish, the crown of thorns (*Acanthaster planci,* COTS), was moderately common. COTS were recorded across much of the reefs in western Chuuk (in 79% of broad-scale stations). Overall the mean density of COTS at Romanum was low (9.5 /ha ±2.2 in broad-scale transects) and they were only recorded at >50 /ha in 4% of broad-scale transects (never >100 /ha, see Figure 5.31). Most of the areas with higher densities were localised to reefs bordering Romanum itself, and the northwestern section of the barrier. All the density estimates are likely to be conservative, as COTS are not active during the day when broad-scale survey recordings were conducted.

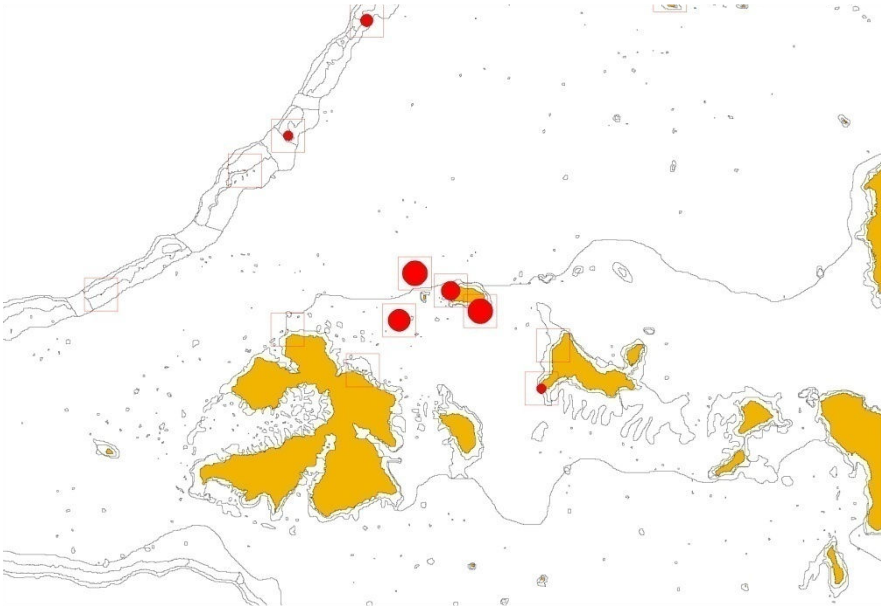

Figure 5.31: Average density of COTS recorded in broad-scale assessment stations at the study area, Romanum.
The circles highlight broad-scale survey station densities ranging from a mean of 5.5–28 /ha.

This level of colonisation can be considered an 'incipient outbreak' (0.22 adults per 2-minute manta tow; or >30 adult and subadults per hectare). CoFish broad-scale transects of 300m x 2 m swathe take about 8 minutes to complete, and therefore recordings of >1 /transect would be sufficient to qualify for an 'incipient outbreak' classification and >4 /transect for the definition of an 'active outbreak', as described by Australian scientists working on the Great Barrier Reef (GBR) (On the GBR an 'active outbreak' is when >1.0 adult is recorded per 2-minutes of manta tow, and adults are >15 cm diameter, or >30 adult only starfish per ha if SCUBA diving.). In the CoFish data for the Romanum study area, 12.5% of transects qualified for the definition of 'incipient outbreak'. Although not critically high, this is still of concern, as COTS can consume significant amounts of live coral (2–6 m^2 of coral/year), and in some areas COTS are at a density that could quickly increase to 'active outbreak' levels.

No horned or chocolate chip stars (*Protoreaster nodosus*) were recorded but eight doughboy sea stars (*Choriaster granulatus*) were noted, predominantly in one MOPt station, but also at depth in Ds stations.

Table 5.14: Sea cucumber species records for Romanum

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef-benthos stations n = 16			Other stations RFs = 6; MOPt = 7			Other stations Ds = 5; Ns = 3		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.5	16.7	3	23.4	46.9	50	7.2 11.9	8.6 27.8	83 RFs 43 MOPt			
Actinopyga miliaris	Blackfish	M/H	0.5	16.7	1	2.6	41.7	6				5.9	17.8	33 Ns
Actinopyga sp. nov.	No name as yet	M												
Bohadschia argus	Leopardfish	M	5.1	26.1	19	39.1	104.2	38				5.9 1.0	17.8 2.4	33 Ns 40 Ds
Bohadschia graeffei	Flowerfish	L	22.7	40.8	56	13.0	52.1	25	0.7 20.8	3.9 145.8	17 RFs 14 MOPt	8.9 1.0	26.7 4.8	33 Ns 20 Ds
Bohadschia vitiensis	Brown sandfish	L	1.6	58.3	3	2.6	41.7	6				11.9	17.8	66 Ns
Holothuria atra	Lollyfish	L	63.2	126.4	50	177.1	314.8	56	14.9	104.2	14 MOPt	1.4	7.1	20 Ds
Holothuria coluber	Snakefish	L				2.6	41.7	6				32.6	97.8	33 Ns
Holothuria edulis	Pinkfish	L	8.8	37.3	24	13.0	52.1	25				8.9 5.2	13.3 13.1	66 Ns 40 Ds
Holothuria flavomaculata		L												
Holothuria fuscogilva [4]	White teatfish	H										2.4	4.0	60 Ds
Holothuria fuscopunctata	Elephant trunkfish	M	0.2	16.7	1							1.4	3.6	40 Ds
Holothuria leucospilota		L				5.2	41.7	13						
Holothuria nobilis [4]	Black teatfish	H	1.4	20.0	7									
Holothuria scabra	Sandfish	H												
Stichopus chloronotus	Greenfish	H/M	73.1	229.0	32	338.5	451.4	75				47.4 3.3	71.1 16.7	66 Ns 20 Ds
Stichopus hermanni	Curryfish	H/M	0.5	16.7	3	7.8	62.5	13				3.3	8.3	40 Ds
Stichopus horrens	Dragonfish	M/L				5.2	83.3	6				77.0	115.6	66 Ns
Stichopus vastus	Brown curryfish	H/M										5.9	17.8	33 Ns
Synapta spp.	-	-	0.2	16.7	1									
Thelenota ananas	Prickly redfish	H	1.4	16.6	8							0.5	2.4	20 Ds
Thelenota anax	Amberfish	M										9.0	11.3	80 Ds

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

5.4.8 Discussion and conclusions: invertebrate resources in Romanum

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

Data collected on giant clam habitat, distribution, density and shell size at Romanum showed the following:

- There was a wide range of shallow-water reef habitats that were suitable for giant clams at Romanum. The area had a full range of land and oceanic influences, variation in depth and exposure. However, population pressures were also evident: Chuuk State has seen large population growth; currently more than half the population of FSM live on the 15 inhabited islands.

- For this part of the Pacific, a limited range of only three giant clam species was present; the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the bear's paw clam *Hippopus hippopus*.

- Giant clam distribution, density and size measures indicate that all stocks are impacted by fishing, and the larger species, which are becoming rare in other parts of the Pacific, are at critically low levels. As giant clams are broadcast spawners, they need to be at close proximity to one another for successful reproduction. In addition, as giant clams only mature to produce eggs at large sizes (which can take up to 10 years for *T. gigas* clams), it is important that aggregations of large older clams are protected from fishing, to ensure there is sufficient production of gametes (especially eggs) to create the next generation and therefore maintain sustainability of the resource. Management measures may be introduced to ensure that these life-history attributes are accounted for to ensure sustainability of this resource.

- In general, the status of giant clams at Romanum was heavily impacted, by fishing. Data on clam density and the range of clam size classes present support this assumption.

- Interestingly, a NOAA coral report (Waddell 2005) states that >USD 20,000 worth of live clams were exported from Chuuk in 2002.

A summary of the environment, distribution, density and length recordings of MOP species is given below.

- Local reef conditions at Romanum provide an extensive and suitable habitat for both juvenile and adult trochus. The surfaces here were 'richer' than those in the more oceanic-influenced system in the north of Chuuk, suggesting that food was available for these grazing gastropods. In addition, water movement was dynamic both around the barrier reef and within the lagoon.

- Trochus (*Trochus niloticus*), the commercial topshell, was relatively common across reefs at Romanum, but the density of trochus within 'core' aggregations (where trochus are typically in greatest abundance) and across reefs in general was low to moderate. This suggests that there is still significant potential for stocks to increase in number; almost no areas were noted where densities had reached 500 shells per ha, considered the minimum threshold density before commercial harvests can be recommended.

- Ongoing commercial fishing was not noted, but there were anecdotal reports that trochus could be sold in Weno, despite the current ban on commercial fishing. Reefs with the highest density of trochus were close to Romanum village, where they could be overseen (protected) by fishers in the local community.

- Information on size class reveals that most sizes are present but that previous harvests have comprehensively fished the stock, as aggregations are holding depleted levels of large old shells (>11 cm basal width). Most eggs for the production of future populations originate disproportionately from the largest individuals; a female trochus of 10 cm produces ~2 million eggs, while a 13 cm trochus produces 3 times this number. This survey shows that the larger trochus within the population were currently depleted in number. Trochus reach the larger size classes (>11 cm basal width) at ≥6 years of age. This lack of large, older shells, which have the greatest potential to fuel future populations to support the fishery, means that recovery to the commercial threshold density level might take longer than if older shells were still present.

- Results from the current assessment suggest that trochus in the Romanum study area are heavily impacted by fishing and presently well below the threshold density at which commercial fishing should be contemplated.

- The blacklip pearl oyster, *Pinctada margaritifera*, was relatively uncommon at Romanum.

A summary of the environment, distribution, and density of sea cucumbers species is given below.

- Romanum has extensive areas of shallow and deepwater sheltered lagoon and barrier reef that were suitable for a range of sea cucumber species. The environments were influenced by both land and oceanic factors but, being a small island, Romanum only had limited inshore embayments of 'rich' benthos with seagrass, which somewhat limited the potential for sea cucumber species that were characteristic of such habitats.

- Twenty species of sea cucumber were recorded at Romanum. This species complement is what might be expected for this location in the Pacific (relatively close to the centre of biodiversity), but local environmental factors play a part in limiting the abundance of species. A survey in 1988 of eight sites in Chuuk recorded 16 species overall (Richmond 1999).

- There have been a number of reports that Chuuk was the centre of a fishery for sea cucumbers between 1922 and 1936, and 5206 tonnes were removed in the 14 years preceding World War II (Richmond 1999). Bob Richmond stated that potentially almost 31 million sea cucumbers may have been taken at this time and believed that these harvests may have had a long-term affect on the productivity of local stocks. "Commercially valuable sea cucumbers have provided an example of how populations of reef organisms may be affected by reproductive and recruitment failure. In the 1930's hundreds of tons of sea cucumbers were harvested and exported from Chuuk to Japan. From interview with local residents and fishers it was apparent that stock failed to recover. It is conceivable that once stocks are reduced below a threshold value, chances of successful reproduction are low (due to gamete dilution)". This information on large harvests was supported by an article by Beardsley (1971), which stated the Japanese administration in the early 1940s had harvested as much as 454 tonnes of bêche-de-mer annually at that time. However, the article also stated that, in 1971, some recovery of stocks was underway.

- Commercial sea cucumber stocks typically taken for commercial export were often rare or only at low density at Romanum in the current survey. The general indication from presence and density data suggests that sea cucumbers have been under significant fishing or environmental pressure. If there has been no recurrent fishing at this site, then it looks as if species that are easily targeted (and depleted), such as the black teatfish (*Holothuria nobilis*), have not recovered to 'healthy' levels since earlier fishing activities.

- Sea cucumbers play an important role in 'cleaning' benthic substrates of organic matter, and mixing ('bioturbating') sands and muds. When these species are removed, there is the potential for detritus to build up and for substrates to become more compacted, creating conditions that can promote the development of non-palatable algal mats (blue-green algae) and anoxic (oxygen poor) conditions unsuitable for life. Sea cucumbers play an important role in recycling nutrients, which are usually not abundant in coral-reef systems. The wholesale export of these species depletes reefs of an important source of 'raw materials' for a system based on efficient cycling, and degrades the functionality of the cleaning and bioturbating role that they usually maintain.

5.5 Overall recommendations for Romanum, CHUUK

- Baseline studies be undertaken to identify possible problem areas so that a fisheries management strategy that addresses major problem areas can be developed to stop and preferably reverse detrimental fisheries exploitation and, at the same time, to secure the community's livelihood.

- All communities and community members (male and female) on Romanum and other nearby islands be involved in the development of the fisheries management strategy covering both finfish and invertebrates, in order to ensure cooperation and compliance with management measures.

- State and national partners, in close cooperation with the Romanum community and all male and female fishers concerned, develop and enforce standards to control the commercial exploitation of bêche-de-mer, trochus, and giant clams as part of the fisheries management strategy.

- As a first step, the fishing of commercial species of sea cucumbers for export be strictly controlled through a moratorium until stocks recover.

- Consideration be given to establishing an MPA, where adult sea cucumbers and other species could be placed for protection in viable spawning aggregations (20–50 individuals placed within one section of their normal reef habitat – 5 m apart for sea cucumbers); however, strict enforcement would be needed to protect these potential spawning groups.

- The Fisheries Department monitor developments in hatchery-based rearing and re-stocking activities for sea cucumbers, as this technique, once refined, may be used to re-create spawning populations at a number of locations in the future.

- Gillnetting and spear diving be limited and night spear diving be banned; fishers should comply with these regulations.

- Careful attention be given to the location of sand mining, in order to avoid impacting fishing grounds.

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APPENDIX 1: SURVEY METHODS

1.1 Socioeconomic surveys, questionnaires and average invertebrate wet weights

1.1.1 Socioeconomic survey methods

Preparation

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

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

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

Approach

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

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

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

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

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

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

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

Sampling

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

Data collection and analysis

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

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

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

The questionnaires are designed to allow a minimum dataset to be developed for each site, one that allows:

- the community's dependency on marine resources to be characterised;
- assessment of the community's engagement in and the possible impact of finfish and invertebrate harvesting; and
- comparison of socioeconomic information with data collected through PROCFish/C resource surveys.

Household survey

The major objectives of the household survey are to:

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

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

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

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

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

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

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

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

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

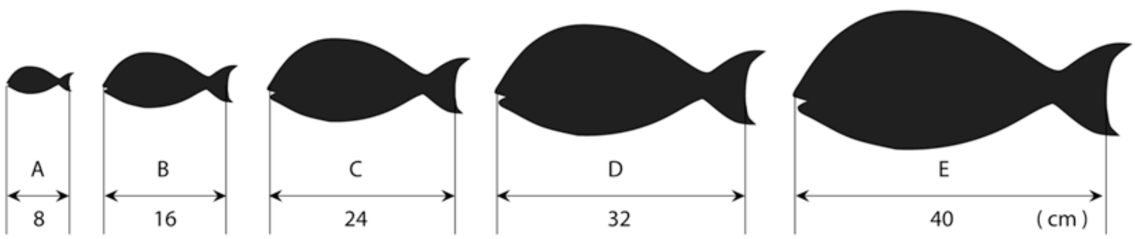

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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

Equation for fresh finfish:

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

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

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

Equation for invertebrates:

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

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

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

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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
Socioeconomics

Invertebrate per capita consumption:

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

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

Canned fish per capita consumption:

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

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

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

Total finfish consumption:

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

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

Total invertebrate consumption:

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

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

Total canned fish consumption:

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

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

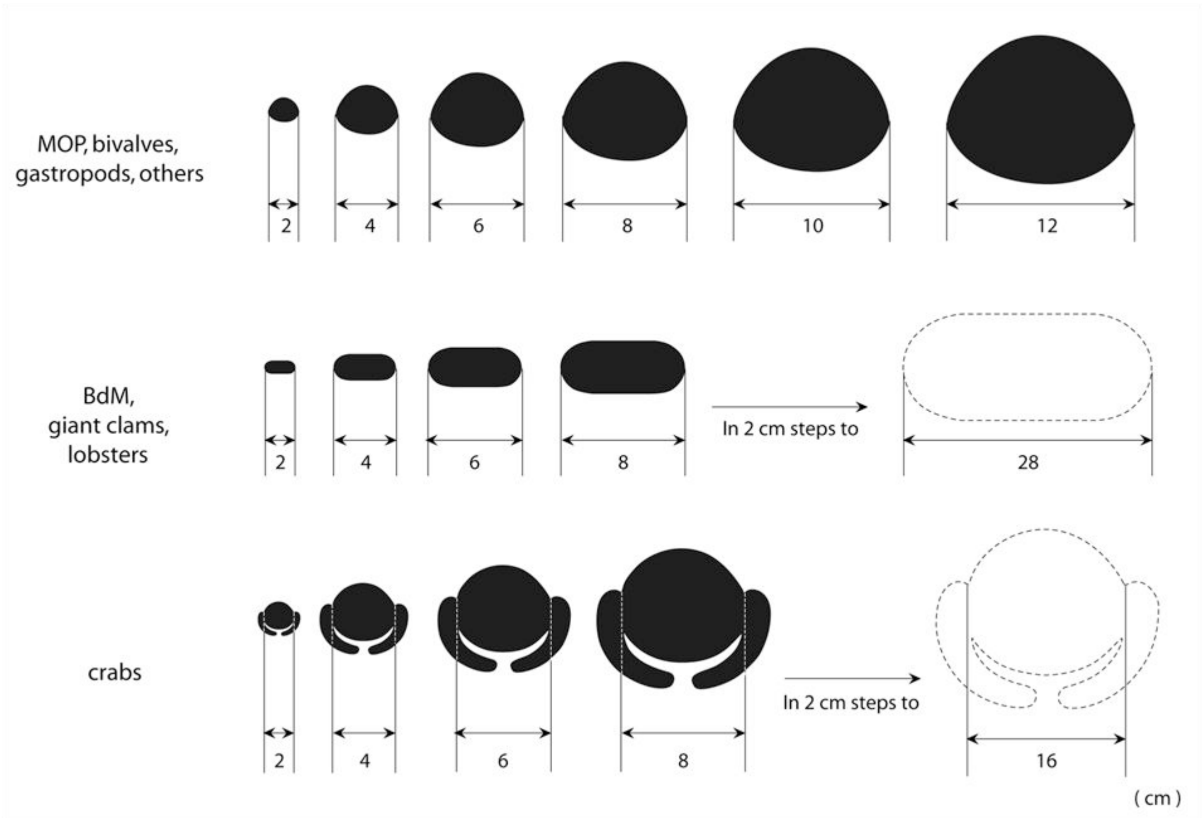

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

Appendix 1: Survey methods
Socioeconomics

Finfish fisher survey

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

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

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

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

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

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

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

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

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

Determination of <u>fishing strategies</u> includes:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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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.

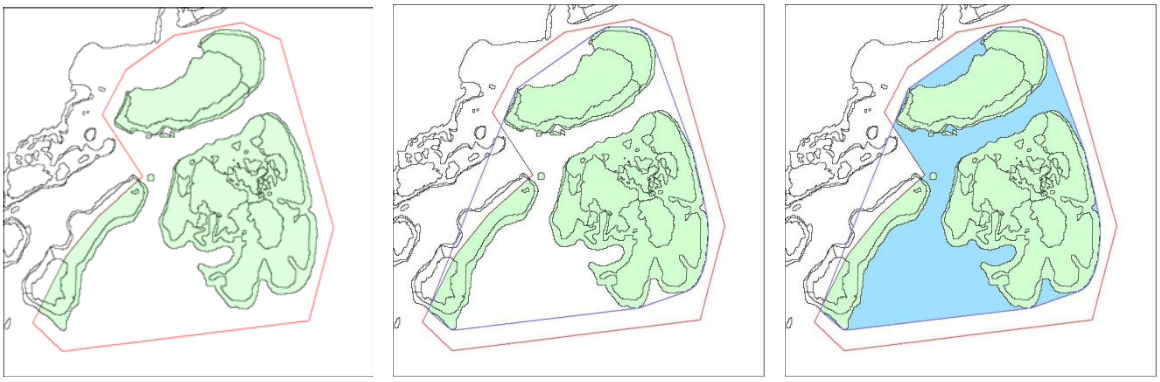

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as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

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ______________________________________

Gender: ☐ female ☐ male Age: ☐

Village: ______________________________________

Date: ________________ Surveyor's name: ___________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

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

☐ lobster diving ☐ other, such as clams, octopus

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

☐ one only ☐ several

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

----

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

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

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

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

yes ☐ no ☐

If yes, where? ____

5. Do you finfish? yes ☐ no ☐

for: ☐ consumption? ☐ sale?

at the same time? yes ☐ no ☐

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

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

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

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

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

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

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

Appendix 1: Survey methods
Socioeconomics

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

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

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

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

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

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

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

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

FISHERIES (FINFISH AND INVERTEBRATE AND SOCIOECONOMICS) GENERAL INFORMATION SURVEY

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

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

a) legal/Ministry of Fisheries

b) traditional/community/village determined:

2. What do you think – do people obey:

traditional/village management rules?

mostly ☐ sometimes ☐ hardly ☐

legal/Ministry of Fisheries management rules?

mostly ☐ sometimes ☐ hardly ☐

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

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

a) finfishing

gillnets – most-used mesh sizes:

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

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

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

Seasonality of species

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

Vernacular name	Scientific name(s)	Months NOT fished

Seasonality of species

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

Vernacular name	Scientific name(s)	Months NOT fished

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

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

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

GLEANING (soft bottom = seagrass)

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

GLEANING (soft bottom = mangrove & mud)

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

GLEANING (soft bottom = sand & beach)

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

GLEANING (hard bottom = reeftop)

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

DIVING (bêche-de-mer)

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

DIVING (lobster)

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

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

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

DIVING (other, such as clams, octopus)

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

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

☐ snorkel ☐ fins ☐ weight belt

☐ air tanks ☐ hookah ☐ other ___________

Any traditional/customary/village fisheries?

Name:

Season/occasion:

Frequency:

Quantification of marine resources caught:

Species name	Size	Quantity (unit?)

1.1.3 Average wet weight applied for selected invertebrate species groups

Unit weights used in conversions for invertebrates.

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

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

Unit weights used in conversions for invertebrates.

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

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

Unit weights used in conversions for invertebrates.

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

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

1.2 Methods used to assess the status of finfish resources

Fish counts

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

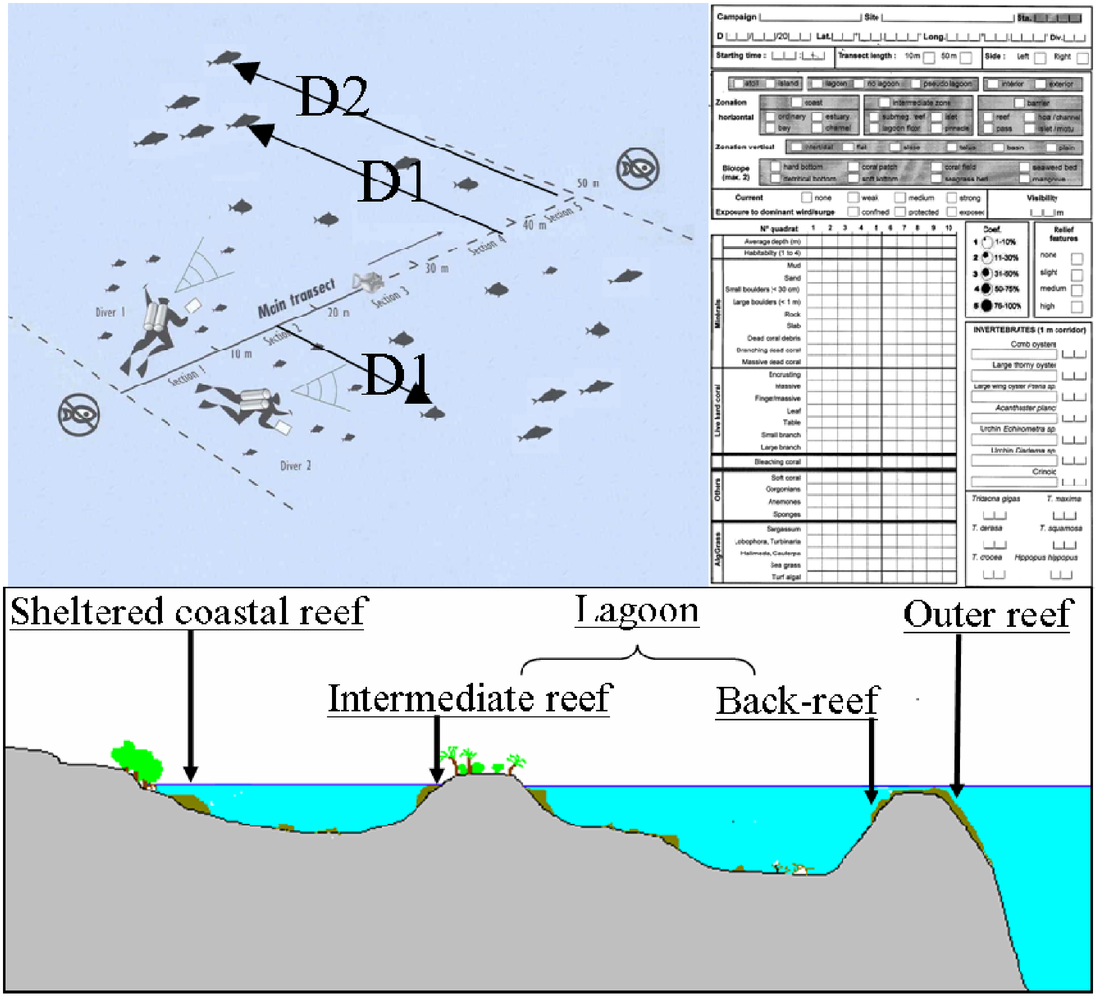


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

Species selection

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

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

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

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

Appendix 1: Survey methods
Finfish

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

These are:

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

Substrate

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

Parameters of interest

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

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

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

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

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

Sampling design

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

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

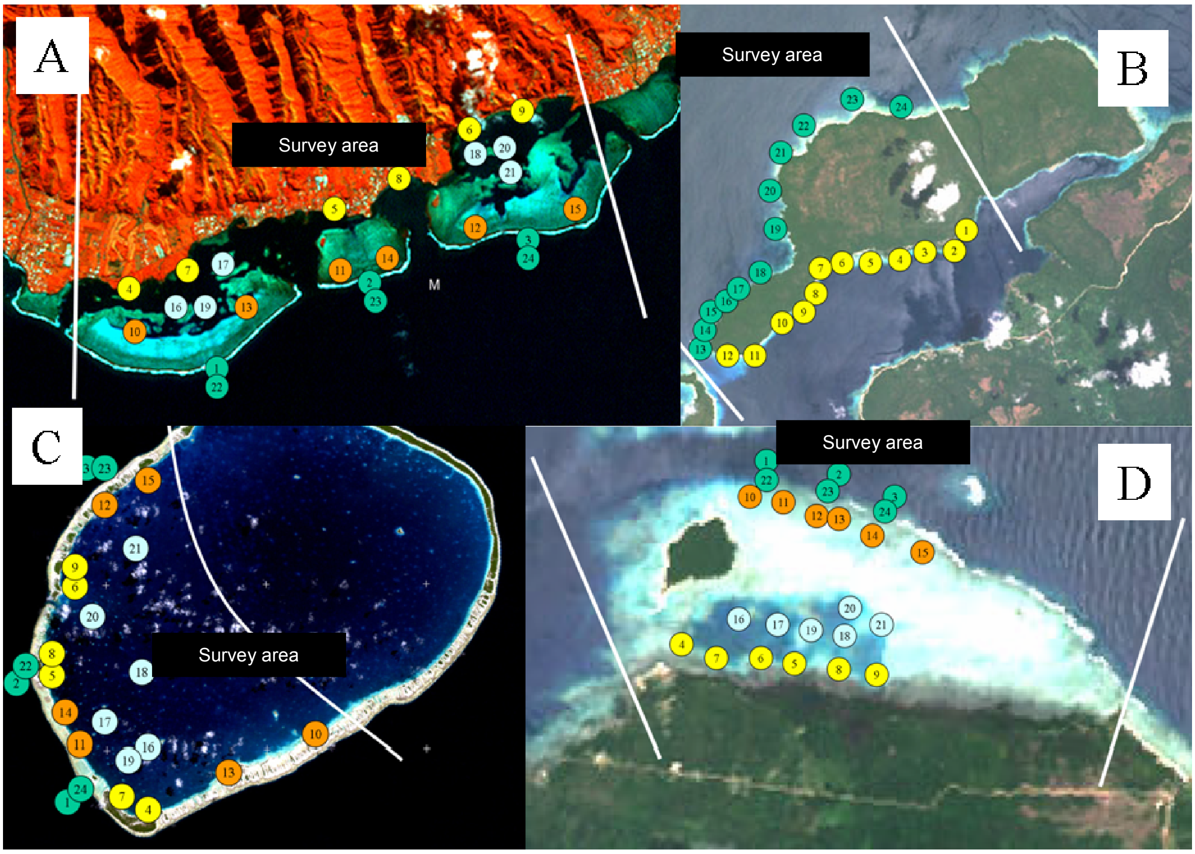


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon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

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

Scaling

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

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

Where:

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

A comparative approach only

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

Appendix 1: Survey methods
Finfish

Campaign |________________| Site |____________________________| Diver |__|__| Transect |__|__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|' Long.|__|__|__|°|__|__|,|__|__|__|' WT |__|__|__|

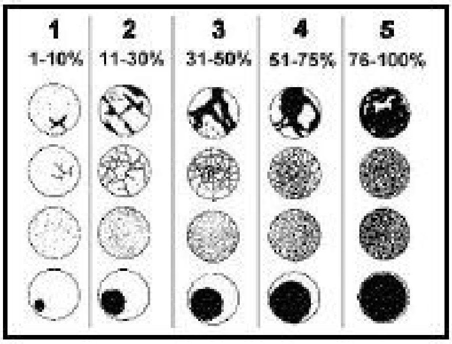
Starting time : |__|__| :|__|__| | Visibility |__|__| m | Side : Left ☐ Right ☐

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

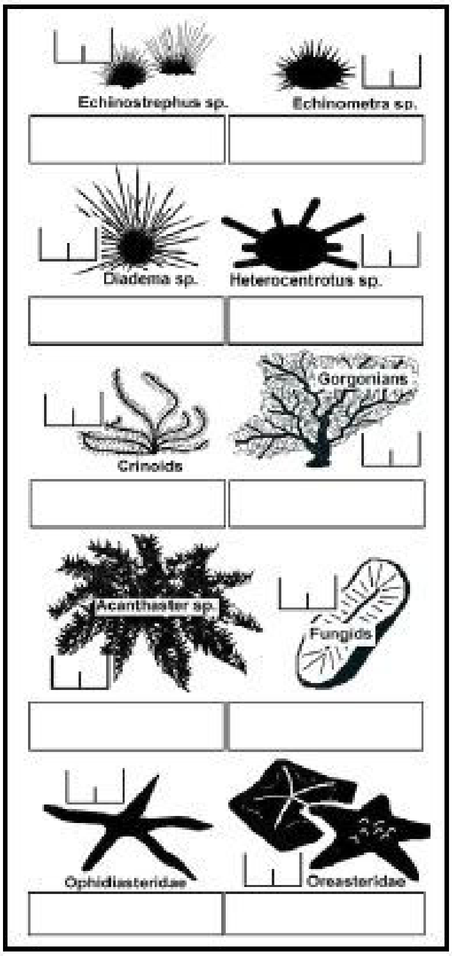
☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

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

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



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



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.

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

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

Generic terminology used for surveys: site, station and replicates

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

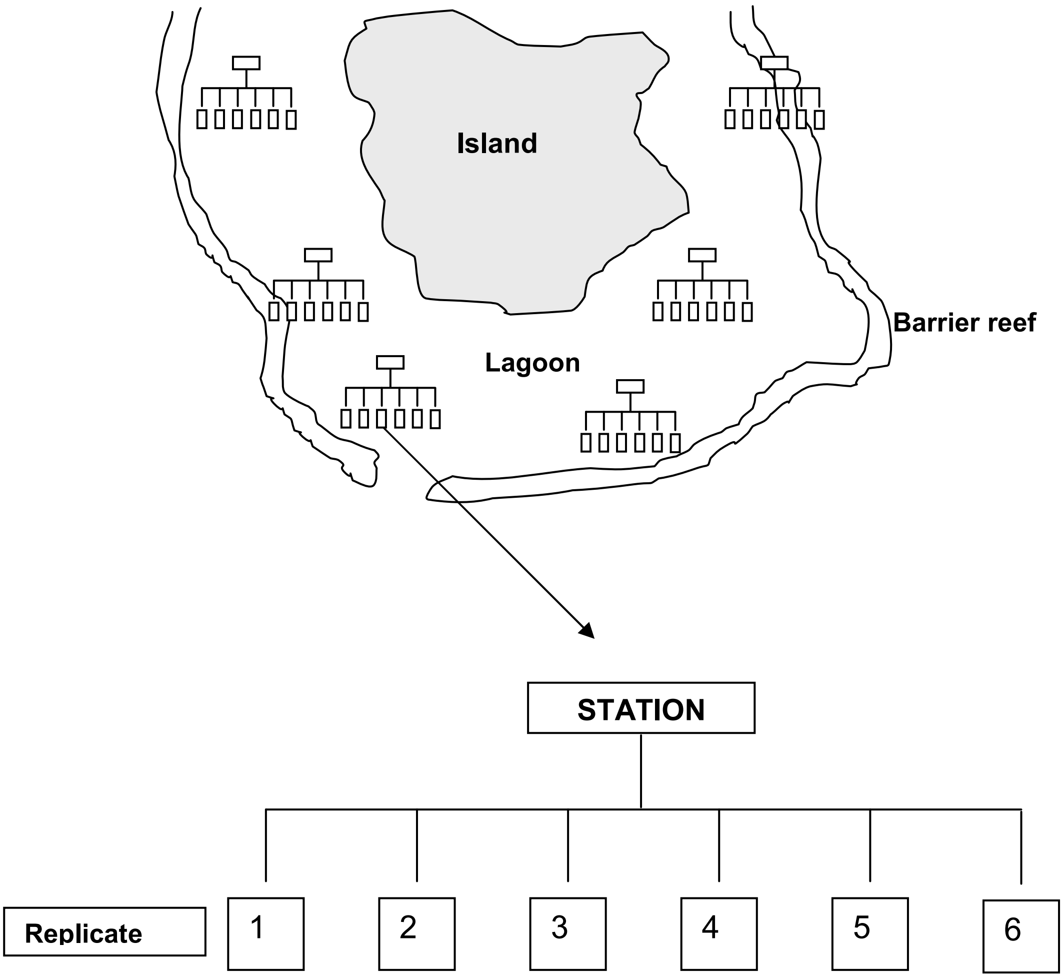


Figure A1.3.1: Stations and replicate measures at a given site.
A replicate measure could be a transect, search period or quadrat group.

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

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

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

Broad-scale survey

Manta 'tow-board' transect surveys

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

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

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

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

Targeted surveys

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

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

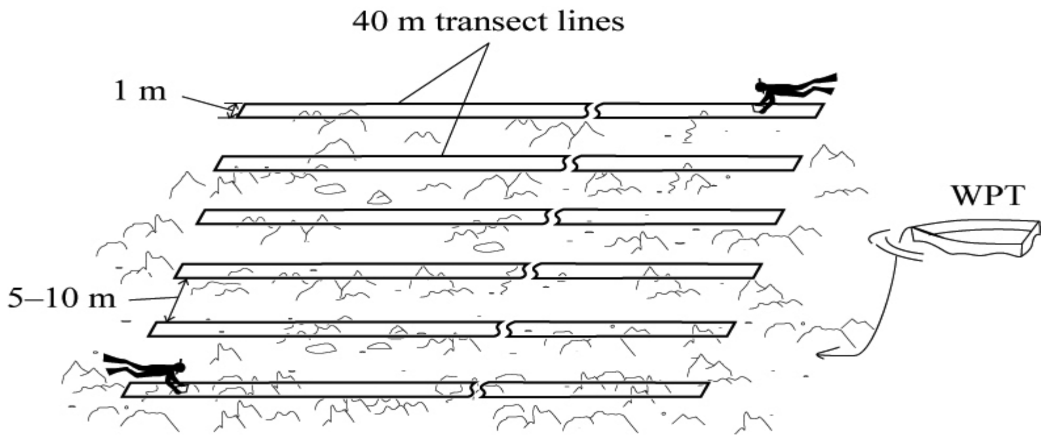


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

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

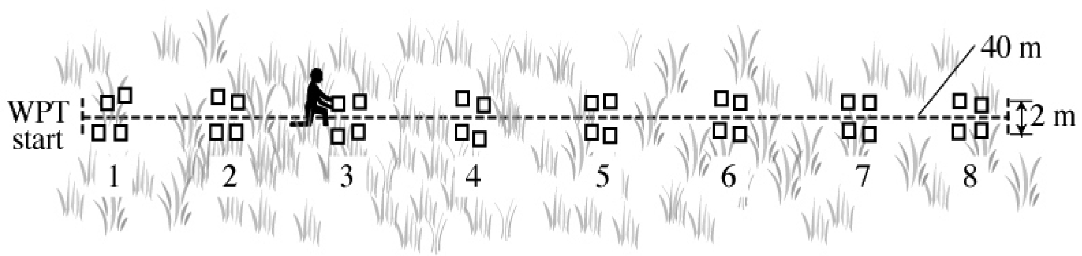


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

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

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

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

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

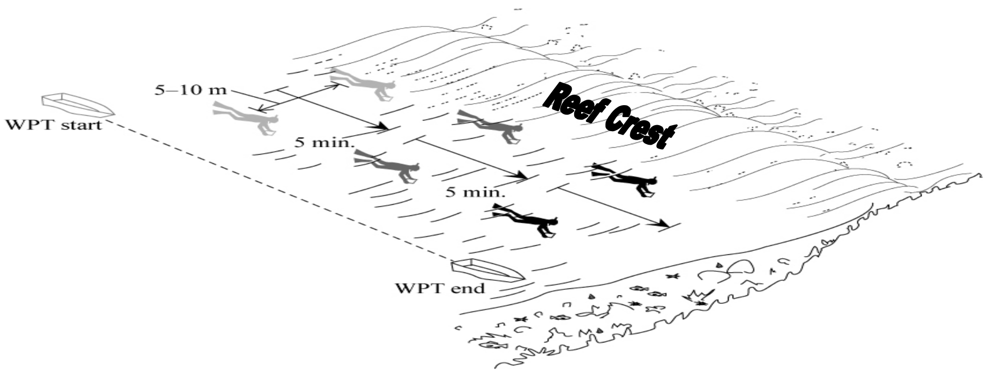


Figure A1.3.4: Reef-front search (RFs) station.

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

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

Mother-of-pearl search (MOPs)

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

Mother-of-pearl transects (MOPt)

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

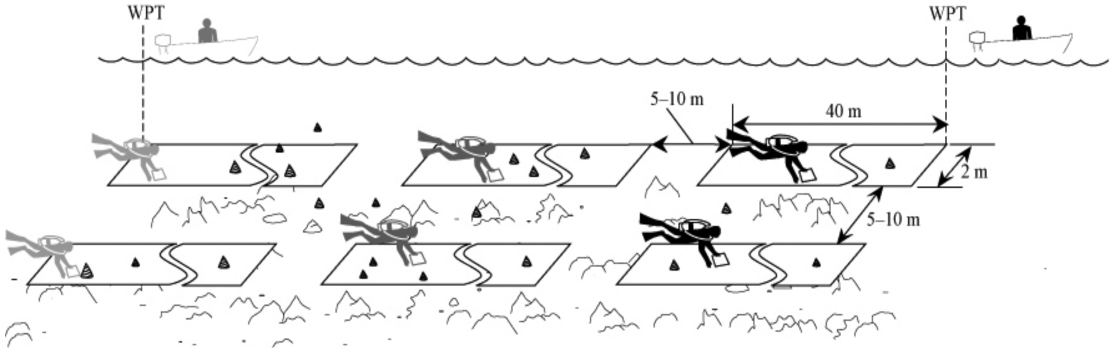


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

Sea cucumber day search (Ds)

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

Sea cucumber night search (Ns)

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

Reporting style

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

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

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

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

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

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

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

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

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

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

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

1.3.2 General fauna invertebrate recording sheet with instructions to users

DATE		**RECORDER**		**Pg No**	

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

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

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

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

1.3.3 Habitat section of invertebrate recording sheet with instructions to users

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

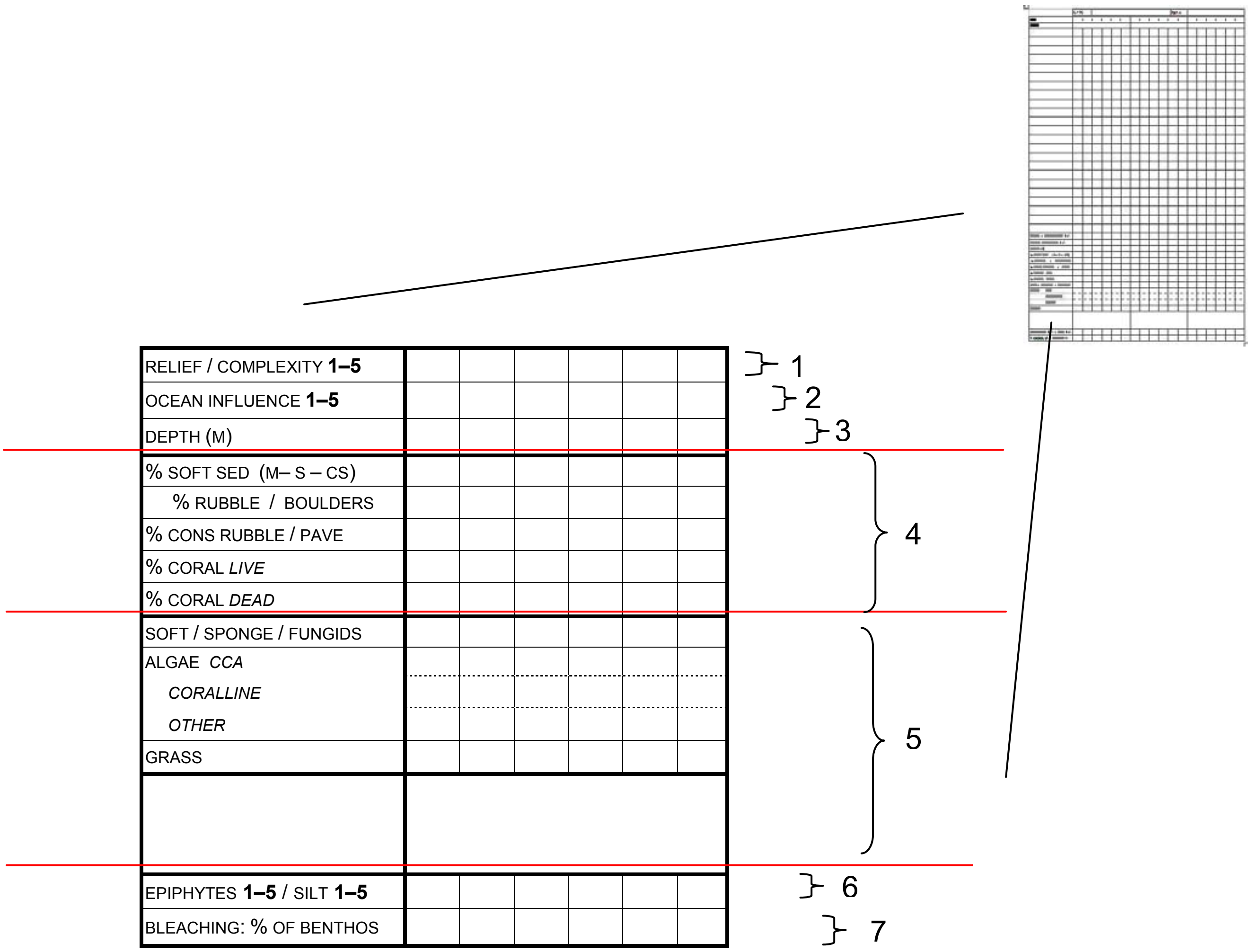


Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

Relief and complexity (section 1 of form)

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

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

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

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

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

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

Ocean influence (section 2 of form)

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

Depth (section 3 of form)

Average depth in metres

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

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

Elements to consider:

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

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

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

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

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

Appendix 1: Survey methods
Invertebrates

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

Coral live is any live hard coral.

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

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

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

Elements to consider:

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

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

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

Fungids are fungids.

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

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

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

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

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

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

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

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

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

Bleaching (section 7 of form)

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

APPENDIX 2: SOCIOECONOMIC SURVEY DATA

2.1 Yyin socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat – Yyin

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Galunglung	Scaridae	*Scarus* spp.	520	11.79
Ngarar	Acanthuridae	*Ctenochaetus striatus*	496	11.24
Nguwee	Scaridae	*Chlorurus* spp.	489	11.08
Abuyuwol	Gerreidae	*Gerres erythrurum*	489	11.08
Erngal	Acanthuridae	*Naso lituratus*	398	9.02
Druy	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	380	8.62
Wul	Lethrinidae	*Lethrinus amboinensis*, *Lethrinus rubrioperculatus*, *Lethrinus harak*	380	8.62
Garmiy	Siganidae	*Siganus lineatus*	380	8.62
Biywod	Siganidae	*Siganus argenteus*	380	8.62
Ayit	Siganidae	*Siganus guttatus*, *Siganus punctatus*	380	8.62
Machagwog	Acanthuridae	*Acanthurus xanthopterus*	32	0.72
Ngol	Carangidae	*Caranx melampygus*	31	0.70
Um	Acanthuridae	*Naso unicornis*	31	0.70
Match	Acanthuridae	*Naso tuberosus*	15	0.35
Sabkuw	Serranidae	*Epinephelus* spp.	11	0.24
Total:			**4410**	**100**
Sheltered coastal reef & lagoon				
Ngol	Carangidae	*Caranx melampygus*	472	12.93
Um	Acanthuridae	*Naso unicornis*	435	11.93
Nguwee	Scaridae	*Chlorurus* spp.	367	10.07
Garmiy	Siganidae	*Siganus lineatus*	362	9.93
Galunglung	Scaridae	*Scarus* spp.	304	8.33
Machagwog	Acanthuridae	*Acanthurus xanthopterus*	303	8.32
Druy	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	250	6.86
Ayit	Siganidae	*Siganus guttatus*, *Siganus punctatus*	235	6.45
Tobemerged			155	4.25
Wul	Lethrinidae	*Lethrinus amboinensis*, *Lethrinus rubrioperculatus*, *Lethrinus harak*	152	4.17
Ngarar	Acanthuridae	*Ctenochaetus striatus*	144	3.94
Manguch	Mullidae	*Parupeneus heptacanthus*, *Parupeneus pleurostigma*	126	3.46
Mbing	Mullidae	*Parupeneus ciliatus*, *Parupeneus cyclostomus*, *Parupeneus barberinus*	77	2.11
Biywod	Siganidae	*Siganus argenteus*	42	1.15
Dak	Pomacentridae	*Pomacentrus* spp.	38	1.03
Dagarwoch	Lethrinidae	*Gnathodentex aureolineatus*	38	1.03

2.1.1 Annual catch (kg) of fish groups per habitat – Yyin (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon (continued)				
Abuyuwol	Gerreidae	*Gerres erythrurum*	29	0.79
Buy	Belonidae	*Tylosurus crocodilus crocodilus*, *Tylosurus acus melanotus*	29	0.79
Taokfon			29	0.79
Achthul			29	0.79
Blaw	Acanthuridae	*Acanthurus nigricauda*, *Acanthurus leucocheilus*	26	0.72
Song	Mullidae	*Parupeneus* spp.	2	0.07
Lab	Haemulidae	*Plectorhinchus diagrammus*, *Plectorhinchus goldmanni*, *Plectorhinchus lineatus*	2	0.07
Sabkuw	Serranidae	*Epinephelus* spp.	1	0.02
Total:			**3646**	**100**
Sheltered coastal reef & outer reef				
Ngol	Carangidae	*Caranx melampygus*	2.36	39.30
Lupo			2.36	39.30
Barracuda	Sphyraenidae	*Sphyraena* spp.	1.18	19.65
Total:			**6**	**100**

2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Yyin

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Other	Fasu	*Hippopus hippopus*	80.0	13.3	6.7	39.2	19.6
	Tow	*Tridacna maxima*	20.0	3.3	1.7	9.8	4.9
Reeftop	Fasu	*Hippopus hippopus*	53.3	80.0	40.0	235.3	117.6
	Tow	*Tridacna maxima*	46.7	70.0	35.0	205.8	102.9
Soft benthos	Mire	*Nerita albicilla*	100.0	666.3	3.3	2613.9	13.1
Soft benthos & Intertidal	Goy	*Anadara* spp.	75.9	10.0	0.2	29.4	0.6
	Mire	*Nerita albicilla*	24.1	13.3	0.1	42.5	0.2

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Yyin

Vernacular name	Scientific name	Size class	% of total catch (weight)
Fasu	*Hippopus hippopus*	10-16 cm	53.6
		14-18 cm	32.1
		20-22 cm	3.6
		26 cm	10.7
Goy	*Anadara* spp.	06 cm	100.0
Mire	*Nerita albicilla*	04 cm	100.0
Tow	*Tridacna maxima*	10-16 cm	68.2
		14-18 cm	27.3
		20-22 cm	4.5

2.2 Riiken socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat – Riiken

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Um	Acanthuridae	*Naso unicornis*	1080	14.17
Blaw	Acanthuridae	*Acanthurus nigricauda*, *Acanthurus leucocheilus*	923	12.11
Nguwee	Scaridae	*Chlorurus* spp.	922	12.09
Galunglung	Scaridae	*Scarus* spp.	606	7.94
Ngol	Carangidae	*Caranx melampygus*	474	6.22
Nguwod	Acanthuridae	*Acanthurus triostegus*	455	5.96
Garmiy	Siganidae	*Siganus lineatus*	367	4.82
Druy	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	319	4.18
Wul	Lethrinidae	*Lethrinus amboinensis*, *Lethrinus rubrioperculatus*, *Lethrinus harak*	274	3.60
Galuf	Platycephalidae	*Platycephalus indicus*	211	2.77
Tobemerged			211	2.77
Match	Acanthuridae	*Naso tuberosus*	204	2.67
Machagwog	Acanthuridae	*Acanthurus xanthopterus*	203	2.67
Erngal	Acanthuridae	*Naso lituratus*	203	2.66
Biywod	Siganidae	*Siganus argenteus*	172	2.25
Ngarar	Acanthuridae	*Ctenochaetus striatus*	159	2.08
Chep	Carangidae	*Caranx* spp.	133	1.74
Ngun	Mugilidae	*Mugil cephalus*	131	1.72
Mbing	Mullidae	*Parupeneus ciliatus*, *Parupeneus cyclostomus*, *Parupeneus barberinus*	112	1.47
Buy	Belonidae	*Tylosurus crocodilus crocodilus*, *Tylosurus acus melanotus*	107	1.41
Marib			106	1.39
Gadaw	Lutjanidae	*Lutjanus gibbus*	101	1.33
Ayit	Siganidae	*Siganus guttatus*, *Siganus punctatus*	58	0.76
Yoch	Holocentridae	*Ostichthys kaianus*, *Sargocentron* spp.	53	0.69
Gochuch	Ostraciidae	*Ostracion meleagris*	32	0.42
Song	Mullidae	*Parupeneus* spp.	3	0.05
Oye	Lethrinidae	*Gymnocranius grandoculis*	2	0.02
Rawal			2	0.02
Numen			1	0.01
Total:			**7624**	**100**

2.2.1 Annual catch (kg) of fish groups per habitat – Riiken (continued)

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & passage				
Nguwee	Scaridae	*Chlorurus* spp.	246	36.27
Um	Acanthuridae	*Naso unicornis*	142	21.01
Blaw	Acanthuridae	*Acanthurus nigricauda*, *Acanthurus leucocheilus*	64	9.50
Galunglung	Scaridae	*Scarus* spp.	64	9.50
Erngal	Acanthuridae	*Naso lituratus*	64	9.50
Mbing	Mullidae	*Parupeneus ciliatus*, *Parupeneus cyclostomus*, *Parupeneus barberinus*	64	9.50
Ngol	Carangidae	*Caranx melampygus*	32	4.75
Total:			677	100
Passage				
Ngol	Carangidae	*Caranx melampygus*	136	37.49
Match	Acanthuridae	*Naso tuberosus*	136	37.49
Um	Acanthuridae	*Naso unicornis*	45	12.50
Nguwee	Scaridae	*Chlorurus* spp.	45	12.50
Total:			**362**	**100**
Mangrove				
Ngol	Carangidae	*Caranx melampygus*	177	33.87
Ngarar	Acanthuridae	*Ctenochaetus striatus*	152	29.03
Garmiy	Siganidae	*Siganus lineatus*	123	23.42
Wul	Lethrinidae	*Lethrinus amboinensis*, *Lethrinus rubrioperculatus*, *Lethrinus harak*	51	9.64
Druy	Siganidae	*Siganus canaliculatus*, *Siganus fuscescens*	21	4.07
Total:			**524**	**66**
Outer reef				
Machagwog	Acanthuridae	*Acanthurus xanthopterus*	42	33.32
Chep	Carangidae	*Caranx* spp.	42	33.32
Um	Acanthuridae	*Naso unicornis*	21	16.66
Galunglung	Scaridae	*Scarus* spp.	21	16.66
Total:			**125**	**100**

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Riiken

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Other	Tow	*Tridacna maxima*	85.9	455.7	227.9	1082.3	541.1
	Arangiong (lil)	*Panulirus penicillatus*	7.8	20.8	20.8	49.5	49.5
	Dalrowal	*Parribacus antarcticus*	4.7	16.7	12.5	39.6	29.7
	Fasu	*Hippopus hippopus*	1.6	8.3	4.2	19.8	9.9

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Riiken (continued)

Fishery	Vernacular name	Scientific name	% annual catch (weight)	Recorded		Extrapolated	
				no/year	kg/year	no/year	kg/year
Soft benthos	Arangiong (lil)	*Panulirus penicillatus*	94.0	2642.5	2642.5	5379.5	5379.5
	Dab	*Gafrarium* spp.	1.8	2417.8	50.8	4922.0	103.4
	Ligarich	*Nerita polita*	1.8	10,008.6	50.0	20,816.6	104.1
	Tow	*Tridacna maxima*	1.8	99.9	50.0	203.5	101.7
	Tuntheth	*Donax cuneatus*	0.4	3654.4	10.0	7439.2	20.5
	Mire	*Nerita albicilla*	0.2	1302.9	6.5	3094.3	15.5
	Wol			237.1		482.7	

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Riiken

Vernacular name	Scientific name	Size class	% of total catch (weight)
Arangiong (lil)	*Panulirus penicillatus*	06-08 cm	42.2
		08 cm	29.3
		10 cm	16.5
		12-14 cm	11.3
		24 cm	0.8
Dab	*Gafrarium* spp.	02-04 cm	85.5
		04 cm	14.5
Dalrowal	*Parribacus antarcticus*	16 cm	100.0
Fasu	*Hippopus hippopus*	28 cm	100.0
Ligarich	*Nerita polita*	02-04 cm	0.2
		04 cm	99.8
Mire	*Nerita albicilla*	04 cm	100.0
Tow	*Tridacna maxima*	10 cm	18.0
		16-18 cm	18.0
		24 cm	62.5
		28 cm	1.5
Tuntheth	*Donax cuneatus*	02 cm	0.5
		02-04 cm	99.5
Wol		06 cm	
		06-08 cm	

2.3 Piis-Panewu socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat – Piis-Panewu
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef				
Feinisi	Mullidae	*Parupeneus* spp.	164.01	28.54
Aar	Scaridae	*Scarus* spp.	146.70	25.53
Eni	Serranidae	*Cephalopholis* spp.	131.93	22.96
Fita	Siganidae	*Siganus* spp.	131.93	22.96
Total:			**574.57**	**100.00**
Sheltered coastal reef & lagoon				
Aar	Scaridae	*Scarus* spp.	521.19	25.56
Ruu	Scaridae	*Scarus* spp.	488.84	23.98
Sewi	Serranidae	*Epinephelus* spp.	353.84	17.36
Ikekkar	Serranidae	*Epinephelus maculatus*	220.29	10.80
Puna	Acanthuridae	*Naso lituratus*	149.12	7.31
Fitichu	Acanthuridae	*Acanthurus* spp.	125.88	6.17
Niopwoopo	Acanthuridae	*Naso* spp.	59.87	2.94
Appo	Scaridae	*Scarus* spp.	59.87	2.94
Pweeas	Acanthuridae	*Naso* spp.	59.87	2.94
Total:			**2038.78**	**100.00**
Sheltered coastal reef & outer reef				
Nguwod	Acanthuridae	*Acanthurus triostegus*	237.48	32.86
Mwon	Serranidae	*Cephalopholis* spp.	177.93	24.62
Pwene	Acanthuridae	*Naso* spp.	136.53	18.89
Sewi	Serranidae	*Epinephelus* spp.	135.81	18.79
Umwune	Siganidae	*Siganus* spp.	34.86	4.82
Total:			**722.60**	**100.00**
Lagoon & outer reef				
Aar	Scaridae	*Scarus* spp.	1067.58	20.12
Fitichu	Acanthuridae	*Acanthurus* spp.	589.71	11.11
Sewi	Serranidae	*Epinephelus* spp.	581.30	10.96
Ruu	Scaridae	*Scarus* spp.	460.66	8.68
Tinipu	Lethrinidae	*Gymnocranius microdon*	450.99	8.50
Marraw	Scaridae	*Scarus* spp.	382.49	7.21
Pweetut	Acanthuridae	*Naso* spp.	279.85	5.27
Puna	Acanthuridae	*Naso lituratus*	248.61	4.69
Ikekkar	Serranidae	*Epinephelus maculatus*	237.48	4.48
Niopwoopo	Acanthuridae	*Naso* spp.	217.69	4.10
Eni	Serranidae	*Cephalopholis* spp.	153.96	2.90
Pou	Lutjanidae	*Lutjanus monostigma*	109.48	2.06
Fita	Siganidae	*Siganus* spp.	97.80	1.84
Mbing	Mullidae	*Parupeneus ciliatus*, *Parupeneus cyclostomus*, *Parupeneus barberinus*	92.95	1.75
Feinisi	Mullidae	*Parupeneus* spp.	83.76	1.58
Maam	Labridae	*Cheilinus* spp.	83.76	1.58
Mwoch	Acanthuridae	*Zebrasoma* spp.	83.76	1.58
Unuun	Lethrinidae	*Lethrinus miniatus*	83.76	1.58
Total:			**5305.60**	**100.00**

2.3.1 Annual catch (kg) of fish groups per habitat – Piis-Panewu (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon & outer reef & passage				
Eni	Serranidae	*Cephalopholis* spp.	293.40	34.99
Puna	Acanthuridae	*Naso lituratus*	270.16	32.22
Aar	Scaridae	*Scarus* spp.	149.12	17.78
Appo	Scaridae	*Scarus* spp.	125.88	15.01
Total:			**838.56**	**100.00**
Outer reef				
Noot	Lethrinidae	*Lethrinus* spp.	345.69	43.04
Pou	Lutjanidae	*Lutjanus monostigma*	254.91	31.74
Umwune	Siganidae	*Siganus* spp.	202.62	25.23
Total:			**803.22**	**100.00**

2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Piis-Panewu

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Reeftop	Arangiong (lil)	*Panulirus penicillatus*	32.1
	Asia	*Holothuria* spp.	19.3
	To	*Tridacna* spp.	16.0
	Nipak	*Octopus* spp.	15.3
	Amwe	*Tridacna* spp.	4.8
	Tomun	*Holothuria scabra*, *Holothuria* spp.	4.3
	Ammot	*Trochus* spp.	3.9
	Fasu	*Hippopus hippopus*	1.6
	Penichon	*Holothuria nobilis*, *Holothuria* spp.	1.0
	Purek	*Stichopus* spp.	0.8
	Anipwi	*Serpulorbis* spp.	0.5
	Ongi	*Nerita polita*	0.2
	Onon	*Saccostrea* spp.	0.2
	Neangepar	*Turbo* spp.	0.1
Intertidal & reeftop	Purek	*Stichopus* spp.	50.6
	Nipak	*Octopus* spp.	34.2
	Onon	*Saccostrea* spp.	13.0
	Anipwi	*Serpulorbis* spp.	2.2
Soft benthos	Purek	*Stichopus* spp.	71.9
	Ammot	*Trochus* spp.	19.9
	Penichon	*Holothuria nobilis*, *Holothuria* spp.	8.3
Mangrove	Nippwei	*Cardisoma* spp.	100.0
Bêche-de-mer	Pwenimarang	*Holothuria* spp.	59.7
	Purek	*Stichopus* spp.	32.4
	Penichon	*Holothuria nobilis*, *Holothuria* spp.	8.0
Lobster	Uur	*Panulirus* spp.	100.0
Trochus	Ammot	*Trochus* spp.	55.7
	Penik	*Bohadschia* spp.	26.9
	To	*Tridacna* spp.	17.4

2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Piis-Panewu

Vernacular name	Scientific name	Size class	% of total catch (weight)
Ammot	*Trochus* spp.	08-14 cm	38.9
		10-14 cm	33.8
		12-14 cm	27.2
Amwe	*Tridacna* spp.	06-08 cm	100.0
To	*Tridacna* spp.	08-12 cm	37.1
		10-12 cm	10.0
		12-14 cm	21.3
		12-16 cm	9.9
		14-16 cm	21.6
Anipwi	*Serpulorbis* spp.	04-06 cm	32.1
		04-08 cm	37.3
		06-08 cm	15.3
		08-10 cm	15.3
Arangiong (lil)	*Panulirus penicillatus*	04-06 cm	100.0
Asia	*Holothuria* spp.	10-14 cm	66.7
		12-14 cm	33.3
Pwenimarang	*Holothuria* spp.	12-14 cm	100.0
Fasu	*Hippopus hippopus*	06-08 cm	100.0
Kinnen	*Cardisoma* spp.	12-14 cm	100.0
Nippwei	*Cardisoma* spp.	08-12 cm	9.9
		10-14 cm	47.1
		12-14 cm	43.0
Neangepar	*Turbo* spp.	04-06 cm	16.9
		04-08 cm	83.1
Nipak	*Octopus* spp.	12-14 cm	25.9
		12-16 cm	28.5
		14-16 cm	11.1
		14-18 cm	12.9
		16-18 cm	21.6
Ongi	*Nerita polita*	04-08 cm	100.0
Onon	*Saccostrea* spp.	04-08 cm	33.3
		08-10 cm	66.7
Penichon	*Holothuria nobilis (Holothuria* spp.*)*	08-14 cm	35.7
		10-14 cm	42.9
		12-14 cm	21.4
Penik	*Bohadschia* spp.	12-14 cm	100.0
Purek	*Stichopus* spp.	12-14 cm	100.0

2.4 Romanum socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat – Romanum
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% total catch
Sheltered coastal reef				
Umwune	Siganidae	*Siganus* spp.	222.08	28.51
Mettin			155.92	20.02
Sewi	Serranidae	*Epinephelus* spp.	135.42	17.38
Tonokar	Siganidae	*Siganus doliatus*	135.42	17.38
Urupin			130.15	16.71
Total:			779.00	100.00
Sheltered coastal reef & lagoon				
Aar	Scaridae	*Scarus* spp.	1512.39	20.67
Fitichu	Acanthuridae	*Acanthurus* spp.	926.97	12.67
Ruu	Scaridae	*Scarus* spp.	707.43	9.67
Fita	Siganidae	*Siganus* spp.	508.63	6.95
Puna	Acanthuridae	*Naso lituratus*	446.44	6.10
Umwune	Siganidae	*Siganus* spp.	390.94	5.34
Puu	Scaridae	*Scarus* spp.	365.48	5.00
Nimwaspitik	Acanthuridae	*Naso unicornis*	357.42	4.89
Feinisi	Mullidae	*Parupeneus* spp.	329.65	4.51
Appo	Scaridae	*Scarus* spp.	324.38	4.43
Pweeas	Acanthuridae	*Naso* spp.	316.03	4.32
Sewi	Serranidae	*Epinephelus* spp.	254.69	3.48
Niopwoopo	Acanthuridae	*Naso* spp.	231.52	3.16
Eni	Serranidae	*Cephalopholis* spp.	155.92	2.13
Mettin			140.60	1.92
Mwon	Serranidae	*Cephalopholis* spp.	91.93	1.26
Urupin			86.98	1.19
Tinipu	Lethrinidae	*Gymnocranius microdon*	71.50	0.98
Poko	Carcharhinidae	*Negaprion* spp.	53.63	0.73
Unuun etik	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus miniatus*	43.49	0.59
Total:			**7316.04**	**100.00**
Lagoon & outer reef				
Ruu	Scaridae	*Scarus* spp.	379.79	12.29
Aar	Scaridae	*Scarus* spp.	324.38	10.49
Maam	Labridae	*Cheilinus* spp.	303.79	9.83
Marraw	Scaridae	*Scarus* spp.	303.79	9.83
Pweeas	Acanthuridae	*Naso* spp.	270.65	8.75
Mwarafach	Acanthuridae	*Naso* spp.	252.88	8.18
Sewi	Serranidae	*Epinephelus* spp.	212.11	6.86
Fitichu	Acanthuridae	*Acanthurus* spp.	183.78	5.94
Ikekkar	Serranidae	*Epinephelus maculatus*	173.54	5.61
Feinisi	Mullidae	*Parupeneus* spp.	132.87	4.30
Etik	Lethrinidae	*Monotaxis grandoculis*, *Monotaxis* spp.	130.46	4.22
Poko	Carcharhinidae	*Negaprion* spp.	106.46	3.44
Noot	Lethrinidae	*Lethrinus* spp.	97.12	3.14
Appo	Scaridae	*Scarus* spp.	61.36	1.98
Tonokar	Siganidae	*Siganus doliatus*	61.36	1.98

2.4.1 Annual catch (kg) of fish groups per habitat – Romanum (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon & outer reef (continued)				
Unuun etik	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus miniatus*	43.49	1.41
Umwune	Siganidae	*Siganus* spp.	35.75	1.16
Puna	Acanthuridae	*Naso lituratus*	17.88	0.58
Total:			**3091.46**	**100.00**
Outer reef				
Eni	Serranidae	*Cephalopholis* spp.	289.09	17.74
Poko	Carcharhinidae	*Negaprion* spp.	238.55	14.64
Pweeas	Acanthuridae	*Naso* spp.	194.23	11.92
Marraw	Scaridae	*Scarus* spp.	173.54	10.65
Pwene	Acanthuridae	*Naso* spp.	153.32	9.41
Sewi	Serranidae	*Epinephelus* spp.	127.78	7.84
Fitichu	Acanthuridae	*Acanthurus* spp.	119.27	7.32
Etik	Lethrinidae	*Monotaxis grandoculis*, *Monotaxis* spp.	115.76	7.10
Tinipu	Lethrinidae	*Gymnocranius microdon*	81.82	5.02
Appo	Scaridae	*Scarus* spp.	64.74	3.97
Feinisi	Mullidae	*Parupeneus* spp.	35.75	2.19
Mettin			35.75	2.19
Total:			**1629.61**	**100.00**
Outer reef & passage				
Pweeas	Acanthuridae	*Naso* spp.	390.45	30.02
Marraw	Scaridae	*Scarus* spp.	303.79	23.36
Noot	Lethrinidae	*Lethrinus* spp.	180.30	13.86
Tinipu	Lethrinidae	*Gymnocranius microdon*	134.44	10.34
Etik	Lethrinidae	*Monotaxis grandoculis*, *Monotaxis* spp.	130.46	10.03
Fita	Siganidae	*Siganus* spp.	76.66	5.89
Puna	Acanthuridae	*Naso lituratus*	43.49	3.34
Niopwoopo	Acanthuridae	*Naso* spp.	40.91	3.15
Total:			**1300.50**	**100.00**

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Romanum

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Reeftop	Ammot	*Trochus* spp.	27.76
	Nipak	*Octopus* spp.	26.30
	Purek	*Stichopus* spp.	25.13
	Tota	*Etisus splendidus*	12.15
	Nippwei	*Cardisoma* spp.	7.03
	Neangepar	*Turbo* spp.	1.39
	Anipwi	*Serpulorbis* spp.	0.25
Intertidal & reeftop	Arangiong (lil)	*Panulirus penicillatus*	30.38
	Asia	*Holothuria* spp.	23.63
	Purek	*Stichopus* spp.	14.66
	Amwe	*Tridacna* spp.	12.70

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Romanum (continued)

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Intertidal & reeftop (continued)	Penichon	*Holothuria nobilis*, *Holothuria* spp.	6.33
	Tota	*Etisus splendidus*	5.08
	To	*Tridacna* spp.	2.87
	Kinnen	*Cardisoma* spp.	2.69
	Nipak	*Octopus* spp.	1.39
	Ongi	*Nerita polita*	0.19
	Anipwi	*Serpulorbis* spp.	0.07
Soft benthos & intertidal	Ammot	*Trochus* spp.	54.70
	Purek	*Stichopus* spp.	27.84
	Nipak	*Octopus* spp.	16.92
	Anipwi	*Serpulorbis* spp.	0.54

2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Romanum

Vernacular name	Scientific name	Size class	% of total catch (weight)
Ammot	*Trochus* spp.	08-12 cm	64.0
		12-14 cm	36.0
Amwe	*Tridacna* spp.	12-16 cm	8.3
		16-20 cm	91.7
To	*Tridacna* spp.	12-14 cm	82.4
		12-16 cm	17.6
Anipwi	*Serpulorbis* spp.	04-08 cm	23.7
		06-08 cm	44.4
		06-12 cm	17.0
		10-12 cm	14.8
Arangiong (lil)	*Panulirus penicillatus*	06-08 cm	100.0
Asia	*Holothuria* spp.	12-16 cm	100.0
Kinnen	*Cardisoma* spp.	12-14 cm	100.0
Nippwei	*Cardisoma* spp.	12-16 cm	100.0
Neangepar	*Turbo* spp.	06-08 cm	100.0
Nipak	*Octopus* spp.	10-14 cm	13.3
		12-14 cm	58.4
		12-16 cm	28.3
Ongi	*Nerita polita*	08-14 cm	100.0
Penichon	*Holothuria nobilis* (*Holothuria* spp.)	08-14 cm	100.0
Purek	*Stichopus* spp.	08-12 cm	21.4
		08-14 cm	78.6
Tota	*Etisus splendidus*	10-14 cm	22.9
		12-14 cm	34.4
		12-16 cm	42.7

APPENDIX 3: FINFISH SURVEY DATA

3.1 Yyin finfish survey data

3.1.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Yyin

Station name	Habitat	Latitude	Longitude
TRA01	Back-reef	9º35'52.5588" N	138º07'28.4988" E
TRA02	Outer reef	9º34'45.5412" N	138º06'02.88" E
TRA03	Outer reef	9º34'53.6988" N	138º06'12.4812" E
TRA04	Back-reef	9º34'30.9612" N	138º06'22.5" E
TRA05	Outer reef	9º34'38.7588" N	138º06'13.2012" E
TRA06	Outer reef	9º35'01.68" N	38º06'20.9988" E
TRA07	Back-reef	9º34'46.8588" N	138º06'29.16" E
TRA08	Back-reef	9º34'39.1188" N	138º06'31.9788" E
TRA09	Outer reef	9º35'07.08" N	138º06'32.04" E
TRA10	Outer reef	9º35'13.8012" N	138º06'34.9812" E
TRA11	Outer reef	9º35'23.1" N	138º06'39.78" E
TRA12	Back-reef	9º34'58.1412"	138º06'33.7788" E
TRA13	Back-reef	9º35'06"13 N	8º06'42.3612" E
TRA14	Outer reef	9º36'17.9388" N	138º07'22.8612" E
TRA15	Outer reef	9º36'07.6788" N	138º07'12.0612" E
TRA16	Back-reef	9º35'12.7788" N	138º06'51.48" E
TRA17	Back-reef	9º35'25.44" N	138º06'57.42" E
TRA18	Back-reef	9º35'29.1588" N	138º07'15.78" E
TRA19	Outer reef	9º35'58.92" N	138º07'06.96" E
TRA20	Back-reef	9º35'44.0988" N	138º07'18.1812" E
TRA21	Back-reef	9º36'07.8012" N	138º07'32.8188" E
TRA22	Back-reef	9º35'44.4588" N	138º07'51.6612" E
TRA23	Outer reef	9º35'35.6388" N	138º06'46.44" E
TRA24	Outer reef	9º35'50.0388" N	138º06'57.6612" E

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0035	0.595
Back-reef	Acanthuridae	*Acanthurus guttatus*	0.0005	0.029
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0015	0.320
Back-reef	Acanthuridae	*Acanthurus maculiceps*	0.0002	0.012
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0020	0.122
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0003	0.036
Back-reef	Acanthuridae	*Acanthurus nigroris*	0.0035	0.178
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0007	0.376
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0010	0.093
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0250	0.936
Back-reef	Acanthuridae	*Acanthurus xanthopterus*	0.0073	5.412
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.0735	4.911
Back-reef	Acanthuridae	*Ctenochaetus tominiensis*	0.0033	0.200
Back-reef	Acanthuridae	*Naso lituratus*	0.0015	0.690
Back-reef	Acanthuridae	*Naso unicornis*	0.0002	0.059

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0097	0.348
Back-reef	Acanthuridae	*Zebrasoma veliferum*	0.0007	0.015
Back-reef	Balistidae	*Balistapus undulatus*	0.0012	0.272
Back-reef	Balistidae	*Melichthys vidua*	0.0003	0.092
Back-reef	Balistidae	*Rhinecanthus aculeatus*	0.0002	0.009
Back-reef	Balistidae	*Rhinecanthus rectangulus*	0.0002	0.003
Back-reef	Balistidae	*Rhinecanthus verrucosus*	0.0003	0.020
Back-reef	Balistidae	*Sufflamen chrysopterus*	0.0003	0.036
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0087	0.184
Back-reef	Chaetodontidae	*Chaetodon bennetti*	0.0002	0.006
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0045	0.067
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0033	0.091
Back-reef	Chaetodontidae	*Chaetodon kleinii*	0.0022	0.046
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0003	0.010
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0058	0.153
Back-reef	Chaetodontidae	*Chaetodon melannotus*	0.0030	0.076
Back-reef	Chaetodontidae	*Chaetodon mertensii*	0.0005	0.017
Back-reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0003	0.016
Back-reef	Chaetodontidae	*Chaetodon pelewensis*	0.0005	0.007
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0002	0.006
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0015	0.047
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0037	0.077
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0017	0.059
Back-reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0005	0.020
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0020	0.054
Back-reef	Chaetodontidae	*Heniochus chrysostomus*	0.0012	0.090
Back-reef	Chaetodontidae	*Heniochus varius*	0.0008	0.025
Back-reef	Holocentridae	*Myripristis adusta*	0.0025	0.467
Back-reef	Holocentridae	*Myripristis berndti*	0.0007	0.194
Back-reef	Holocentridae	*Myripristis kuntee*	0.0003	0.090
Back-reef	Holocentridae	*Myripristis murdjan*	0.0007	0.055
Back-reef	Holocentridae	*Myripristis violacea*	0.0013	0.196
Back-reef	Holocentridae	*Neoniphon sammara*	0.0017	0.203
Back-reef	Holocentridae	*Sargocentron spiniferum*	0.0012	0.403
Back-reef	Kyphosidae	*Kyphosus cinerascens*	0.0002	0.157
Back-reef	Kyphosidae	*Kyphosus vaigiensis*	0.0010	1.254
Back-reef	Labridae	*Cheilinus chlorourus*	0.0017	0.200
Back-reef	Labridae	*Cheilinus fasciatus*	0.0013	0.133
Back-reef	Labridae	*Cheilinus trilobatus*	0.0002	0.011
Back-reef	Labridae	*Cheilinus undulatus*	0.0028	0.733
Back-reef	Labridae	*Choerodon anchorago*	0.0008	0.035
Back-reef	Labridae	*Hemigymnus fasciatus*	0.0003	0.013
Back-reef	Labridae	*Hemigymnus melapterus*	0.0047	0.232
Back-reef	Labridae	*Oxycheilinus diagrammus*	0.0007	0.077
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0458	13.557
Back-reef	Lethrinidae	*Lethrinus harak*	0.0055	1.034
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0002	0.126

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0185	12.678
Back-reef	Lutjanidae	*Aphareus furca*	0.0008	0.564
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0072	3.656
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0303	16.088
Back-reef	Lutjanidae	*Lutjanus monostigma*	0.0070	3.864
Back-reef	Lutjanidae	*Macolor macularis*	0.0005	0.269
Back-reef	Lutjanidae	*Macolor niger*	0.0023	0.986
Back-reef	Mullidae	*Mulloidichthys flavolineatus*	0.0032	0.142
Back-reef	Mullidae	*Mulloidichthys vanicolensis*	0.0043	0.705
Back-reef	Mullidae	*Parupeneus barberinus*	0.0013	0.251
Back-reef	Mullidae	*Parupeneus bifasciatus*	0.0018	0.188
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0005	0.253
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0048	0.114
Back-reef	Mullidae	*Parupeneus spilurus*	0.0002	0.068
Back-reef	Mullidae	*Upeneus moluccensis*	0.0085	1.230
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0205	2.806
Back-reef	Nemipteridae	*Scolopsis lineatus*	0.0020	0.053
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0003	0.148
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0002	0.192
Back-reef	Scaridae	*Chlorurus sordidus*	0.0542	9.682
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0018	0.629
Back-reef	Scaridae	*Scarus dimidiatus*	0.0145	2.360
Back-reef	Scaridae	*Scarus flavipectoralis*	0.0008	0.209
Back-reef	Scaridae	*Scarus ghobban*	0.0023	1.494
Back-reef	Scaridae	*Scarus globiceps*	0.0017	0.664
Back-reef	Scaridae	*Scarus niger*	0.0007	0.202
Back-reef	Scaridae	*Scarus oviceps*	0.0137	4.670
Back-reef	Scaridae	*Scarus psittacus*	0.0220	1.694
Back-reef	Scaridae	*Scarus schlegeli*	0.0035	0.417
Back-reef	Scaridae	*Scarus spinus*	0.0008	0.306
Back-reef	Serranidae	*Aethaloperca rogaa*	0.0013	0.085
Back-reef	Serranidae	*Epinephelus merra*	0.0018	0.115
Back-reef	Siganidae	*Siganus doliatus*	0.0018	0.275
Back-reef	Siganidae	*Siganus fuscescens*	0.0005	0.067
Back-reef	Siganidae	*Siganus puellus*	0.0010	0.152
Back-reef	Zanclidae	*Zanclus cornutus*	0.0062	0.527
Outer reef	Acanthuridae	*Acanthurus guttatus*	0.0035	0.452
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0572	19.209
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.1103	11.726
Outer reef	Acanthuridae	*Acanthurus nigricauda*	0.0017	0.446
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0007	0.153
Outer reef	Acanthuridae	*Acanthurus nigroris*	0.0045	0.243
Outer reef	Acanthuridae	*Acanthurus pyroferus*	0.0002	0.030
Outer reef	Acanthuridae	*Acanthurus triostegus*	0.0628	4.792
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.3131	27.833
Outer reef	Acanthuridae	*Naso annulatus*	0.0028	1.229
Outer reef	Acanthuridae	*Naso brevirostris*	0.0033	0.811

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Acanthuridae	*Naso lituratus*	0.0532	30.133
Outer reef	Acanthuridae	*Naso unicornis*	0.0043	2.801
Outer reef	Acanthuridae	*Naso vlamingii*	0.0145	10.211
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0070	0.355
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0045	0.347
Outer reef	Balistidae	*Balistapus undulatus*	0.0080	2.214
Outer reef	Balistidae	*Balistoides viridescens*	0.0003	0.497
Outer reef	Balistidae	*Melichthys niger*	0.0085	1.525
Outer reef	Balistidae	*Melichthys vidua*	0.0398	6.068
Outer reef	Balistidae	*Rhinecanthus rectangulus*	0.0003	0.012
Outer reef	Balistidae	*Sufflamen bursa*	0.0002	0.012
Outer reef	Balistidae	*Sufflamen chrysopterus*	0.0010	0.138
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0058	0.185
Outer reef	Chaetodontidae	*Chaetodon bennetti*	0.0010	0.039
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0070	0.139
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0015	0.048
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0037	0.081
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0040	0.164
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0058	0.183
Outer reef	Chaetodontidae	*Chaetodon melannotus*	0.0003	0.010
Outer reef	Chaetodontidae	*Chaetodon meyeri*	0.0010	0.032
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0020	0.081
Outer reef	Chaetodontidae	*Chaetodon pelewensis*	0.0028	0.074
Outer reef	Chaetodontidae	*Chaetodon plebeius*	0.0003	0.009
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0018	0.062
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0063	0.262
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0040	0.090
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0023	0.057
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0030	0.087
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0052	0.252
Outer reef	Chaetodontidae	*Hemitaurichthys polylepis*	0.0002	0.016
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0017	0.138
Outer reef	Chaetodontidae	*Heniochus varius*	0.0003	0.023
Outer reef	Holocentridae	*Myripristis adusta*	0.0045	1.278
Outer reef	Holocentridae	*Myripristis berndti*	0.0012	0.337
Outer reef	Holocentridae	*Myripristis kuntee*	0.0013	0.359
Outer reef	Holocentridae	*Myripristis murdjan*	0.0020	0.437
Outer reef	Holocentridae	*Myripristis violacea*	0.0002	0.041
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0037	0.405
Outer reef	Holocentridae	*Sargocentron* spp.	0.0002	0.014
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0007	0.405
Outer reef	Kyphosidae	*Kyphosus cinerascens*	0.0038	3.179
Outer reef	Kyphosidae	*Kyphosus vaigiensis*	0.0023	1.577
Outer reef	Labridae	*Cheilinus chlorourus*	0.0015	0.386
Outer reef	Labridae	*Cheilinus fasciatus*	0.0007	0.152
Outer reef	Labridae	*Cheilinus undulatus*	0.0003	0.313
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0008	0.158

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Labridae	*Hemigymnus melapterus*	0.0030	0.546
Outer reef	Labridae	*Oxycheilinus diagrammus*	0.0002	0.017
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0140	7.332
Outer reef	Lethrinidae	*Lethrinus olivaceus*	0.0002	0.104
Outer reef	Lethrinidae	*Lethrinus xanthochilus*	0.0002	0.137
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0072	5.741
Outer reef	Lutjanidae	*Aphareus furca*	0.0027	1.505
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0047	5.279
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0050	2.185
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0396	33.400
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0035	2.117
Outer reef	Lutjanidae	*Macolor macularis*	0.0008	0.205
Outer reef	Lutjanidae	*Macolor niger*	0.0028	2.481
Outer reef	Mullidae	*Mulloidichthys vanicolensis*	0.0048	0.711
Outer reef	Mullidae	*Parupeneus barberinus*	0.0018	0.312
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0025	0.657
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0045	0.541
Outer reef	Mullidae	*Parupeneus spilurus*	0.0002	0.047
Outer reef	Mullidae	*Upeneus moluccensis*	0.0058	0.849
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0015	0.167
Outer reef	Scaridae	*Bolbometopon muricatum*	0.0068	9.145
Outer reef	Scaridae	*Calotomus carolinus*	0.0002	0.156
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0002	0.059
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0077	6.478
Outer reef	Scaridae	*Chlorurus sordidus*	0.0970	23.015
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0030	1.585
Outer reef	Scaridae	*Scarus altipinnis*	0.0002	0.122
Outer reef	Scaridae	*Scarus dimidiatus*	0.0063	2.241
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0003	0.165
Outer reef	Scaridae	*Scarus forsteni*	0.0035	1.630
Outer reef	Scaridae	*Scarus frenatus*	0.0018	0.734
Outer reef	Scaridae	*Scarus ghobban*	0.0030	2.210
Outer reef	Scaridae	*Scarus globiceps*	0.0028	1.036
Outer reef	Scaridae	*Scarus longipinnis*	0.0003	0.219
Outer reef	Scaridae	*Scarus niger*	0.0023	1.706
Outer reef	Scaridae	*Scarus oviceps*	0.0303	12.234
Outer reef	Scaridae	*Scarus psittacus*	0.0723	7.201
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0010	1.018
Outer reef	Scaridae	*Scarus schlegeli*	0.0013	0.359
Outer reef	Scaridae	*Scarus* spp.	0.0002	0.110
Outer reef	Scaridae	*Scarus spinus*	0.0025	0.896
Outer reef	Scaridae	*Scarus tricolor*	0.0010	0.754
Outer reef	Serranidae	*Aethaloperca rogaa*	0.0012	0.163
Outer reef	Serranidae	*Cephalopholis argus*	0.0047	2.455
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0093	0.986
Outer reef	Serranidae	*Epinephelus areolatus*	0.0003	0.123
Outer reef	Serranidae	*Epinephelus howlandi*	0.0002	0.031

3.1.2 Weighted average density and biomass of all finfish species recorded in Yyin (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Serranidae	*Epinephelus merra*	0.0003	0.038
Outer reef	Serranidae	*Epinephelus polyphekadion*	0.0002	0.117
Outer reef	Serranidae	*Epinephelus spilotoceps*	0.0002	0.026
Outer reef	Serranidae	*Plectropomus maculatus*	0.0002	0.113
Outer reef	Siganidae	*Siganus argenteus*	0.0005	0.165
Outer reef	Siganidae	*Siganus spinus*	0.0002	0.019
Outer reef	Zanclidae	*Zanclus cornutus*	0.0068	0.625

3.2 Riiken finfish survey data

3.2.1 Coordinates (WGS84) of the 25 D-UVC transects used to assess finfish resource status in Riiken

Station name	Habitat	Latitude	Longitude
TRA01	Back-reef	9º33'55.26" N	138º12'12.1212" E
TRA02	Outer reef	9º35'00.42" N	138º12'16.8588" E
TRA03	Back-reef	9º34'23.8188" N	138º12'07.38" E
TRA04	Outer reef	9º34'43.9788" N	138º12'27.4212" E
TRA05	Back-reef	9º34'45.5412" N	138º11'58.4412" E
TRA06	Lagoon	9º33'58.0212" N	138º10'59.7612" E
TRA07	Coastal reef	9º33'50.8212" N	138º11'06.2412" E
TRA08	Outer reef	9º34'12.0612" N	138º12'42.1812" E
TRA09	Outer reef	9º33'31.68" N	138º12'53.28" E
TRA10	Back-reef	9º33'13.2588" N	138º12'00.2412" E
TRA11	Back-reef	9º32'35.8188" N	138º11'43.08" E
TRA12	Back-reef	9º33'49.9788" N	138º12'25.4412" E
TRA13	Lagoon	9º34'08.58" N	138º11'03.0588" E
TRA14	Coastal reef	9º34'03.7812" N	138º11'05.82" E
TRA15	Outer reef	9º32'30.0012" N	138º12'22.9212" E
TRA16	Outer reef	9º33'03.5388" N	138º12'41.8212" E
TRA17	Lagoon	9º34'14.9412" N	138º11'30.5412" E
TRA18	Lagoon	9º34'09.3" N	138º11'27.06" E
TRA19	Coastal reef	9º34'02.7012" N	138º11'12.0012" E
TRA20	Coastal reef	9º34'00.2388" N	138º11'20.1012" E
TRA21	Coastal reef	9º34'07.2012" N	138º11'30.9588" E
TRA22	Coastal reef	9º34'08.3388" N	138º11'45.42" E
TRA23	Back-reef	9º32'36.6" N	138º12'14.04" E
TRA24	Back-reef	9º32'53.2788" N	138º12'24.7212" E
TRA25	Back-reef	9º33'20.0412" N	138º12'30.06" E

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0076	3.011
Back-reef	Acanthuridae	*Acanthurus guttatus*	0.0004	0.026
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0127	4.585
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0344	3.095
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0007	0.264
Back-reef	Acanthuridae	*Acanthurus nigroris*	0.0058	0.638
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0047	0.343
Back-reef	Acanthuridae	*Acanthurus thompsoni*	0.0011	0.076
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0539	3.486
Back-reef	Acanthuridae	*Acanthurus xanthopterus*	0.0067	6.432
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.1856	14.518
Back-reef	Acanthuridae	*Naso lituratus*	0.0122	4.574
Back-reef	Acanthuridae	*Naso unicornis*	0.0002	0.030
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0404	1.863
Back-reef	Acanthuridae	*Zebrasoma veliferum*	0.0018	0.103
Back-reef	Balistidae	*Balistapus undulatus*	0.0011	0.207

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Back-reef	Balistidae	*Rhinecanthus rectangulus*	0.0002	0.023
Back-reef	Balistidae	*Sufflamen chrysopterus*	0.0002	0.034
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0089	0.252
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0113	0.172
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0047	0.145
Back-reef	Chaetodontidae	*Chaetodon kleinii*	0.0029	0.061
Back-reef	Chaetodontidae	*Chaetodon lunula*	0.0031	0.112
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0082	0.207
Back-reef	Chaetodontidae	*Chaetodon melannotus*	0.0033	0.089
Back-reef	Chaetodontidae	*Chaetodon meyeri*	0.0009	0.034
Back-reef	Chaetodontidae	*Chaetodon pelewensis*	0.0007	0.010
Back-reef	Chaetodontidae	*Chaetodon rafflesii*	0.0009	0.024
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0076	0.225
Back-reef	Chaetodontidae	*Chaetodon semeion*	0.0002	0.011
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0084	0.139
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0031	0.061
Back-reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0013	0.033
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0009	0.020
Back-reef	Chaetodontidae	*Heniochus chrysostomus*	0.0022	0.125
Back-reef	Holocentridae	*Myripristis berndti*	0.0016	0.397
Back-reef	Holocentridae	*Myripristis kuntee*	0.0009	0.106
Back-reef	Holocentridae	*Myripristis murdjan*	0.0009	0.073
Back-reef	Holocentridae	*Myripristis pralinia*	0.0009	0.108
Back-reef	Holocentridae	*Myripristis* spp.	0.0007	0.094
Back-reef	Holocentridae	*Myripristis violacea*	0.0018	0.381
Back-reef	Holocentridae	*Neoniphon sammara*	0.0078	0.509
Back-reef	Holocentridae	*Sargocentron caudimaculatum*	0.0002	0.045
Back-reef	Holocentridae	*Sargocentron diadema*	0.0009	0.096
Back-reef	Holocentridae	*Sargocentron spiniferum*	0.0027	0.851
Back-reef	Kyphosidae	*Kyphosus vaigiensis*	0.0038	1.741
Back-reef	Labridae	*Cheilinus chlorourus*	0.0024	0.251
Back-reef	Labridae	*Cheilinus fasciatus*	0.0009	0.070
Back-reef	Labridae	*Cheilinus undulatus*	0.0018	0.743
Back-reef	Labridae	*Coris aygula*	0.0004	0.059
Back-reef	Labridae	*Hemigymnus fasciatus*	0.0002	0.015
Back-reef	Labridae	*Hemigymnus melapterus*	0.0062	0.793
Back-reef	Labridae	*Oxycheilinus diagrammus*	0.0002	0.032
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0178	4.604
Back-reef	Lethrinidae	*Lethrinus harak*	0.0031	1.463
Back-reef	Lethrinidae	*Lethrinus xanthochilus*	0.0004	0.248
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0058	1.875
Back-reef	Lutjanidae	*Lutjanus bohar*	0.0009	0.411
Back-reef	Lutjanidae	*Lutjanus fulviflammus*	0.0002	0.155
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0107	4.265
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0029	1.082
Back-reef	Lutjanidae	*Lutjanus monostigma*	0.0004	0.339
Back-reef	Mullidae	*Mulloidichthys flavolineatus*	0.0136	1.064

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Mullidae	*Mulloidichthys vanicolensis*	0.0024	0.229
Back-reef	Mullidae	*Parupeneus barberinus*	0.0051	1.042
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0002	0.027
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0011	0.039
Back-reef	Nemipteridae	*Scolopsis bilineata*	0.0076	1.741
Back-reef	Nemipteridae	*Scolopsis lineatus*	0.0004	0.033
Back-reef	Nemipteridae	*Scolopsis temporalis*	0.0002	0.068
Back-reef	Scaridae	*Cetoscarus bicolor*	0.0007	0.558
Back-reef	Scaridae	*Chlorurus bleekeri*	0.0004	0.242
Back-reef	Scaridae	*Chlorurus microrhinos*	0.0022	1.696
Back-reef	Scaridae	*Chlorurus sordidus*	0.0798	16.252
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0020	0.917
Back-reef	Scaridae	*Scarus dimidiatus*	0.0236	6.260
Back-reef	Scaridae	*Scarus ghobban*	0.0020	0.317
Back-reef	Scaridae	*Scarus globiceps*	0.0009	0.354
Back-reef	Scaridae	*Scarus niger*	0.0018	0.861
Back-reef	Scaridae	*Scarus oviceps*	0.0213	6.889
Back-reef	Scaridae	*Scarus psittacus*	0.0541	3.770
Back-reef	Scaridae	*Scarus rubroviolaceus*	0.0013	0.517
Back-reef	Scaridae	*Scarus schlegeli*	0.0131	2.023
Back-reef	Scaridae	*Scarus spinus*	0.0002	0.048
Back-reef	Serranidae	*Aethaloperca rogaa*	0.0004	0.098
Back-reef	Serranidae	*Anyperodon leucogrammicus*	0.0002	0.055
Back-reef	Serranidae	*Cephalopholis argus*	0.0004	0.338
Back-reef	Serranidae	*Epinephelus merra*	0.0013	0.175
Back-reef	Serranidae	*Plectropomus maculatus*	0.0002	0.151
Back-reef	Siganidae	*Siganus argenteus*	0.0020	0.340
Back-reef	Siganidae	*Siganus doliatus*	0.0060	1.373
Back-reef	Siganidae	*Siganus puellus*	0.0033	0.775
Back-reef	Siganidae	*Siganus spinus*	0.0002	0.014
Back-reef	Zanclidae	*Zanclus cornutus*	0.0222	1.755
Coastal reef	Acanthuridae	*Acanthurus blochii*	0.0047	0.494
Coastal reef	Acanthuridae	*Acanthurus guttatus*	0.0027	0.131
Coastal reef	Acanthuridae	*Acanthurus lineatus*	0.0070	1.377
Coastal reef	Acanthuridae	*Acanthurus nigricans*	0.0017	0.102
Coastal reef	Acanthuridae	*Acanthurus nigricauda*	0.0050	1.696
Coastal reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0007	0.153
Coastal reef	Acanthuridae	*Acanthurus nigroris*	0.0027	0.399
Coastal reef	Acanthuridae	*Acanthurus thompsoni*	0.0007	0.104
Coastal reef	Acanthuridae	*Acanthurus triostegus*	0.0037	0.187
Coastal reef	Acanthuridae	*Acanthurus xanthopterus*	0.0037	1.850
Coastal reef	Acanthuridae	*Ctenochaetus striatus*	0.0909	6.342
Coastal reef	Acanthuridae	*Naso annulatus*	0.0003	0.174
Coastal reef	Acanthuridae	*Naso brevirostris*	0.0007	0.057
Coastal reef	Acanthuridae	*Naso lituratus*	0.0047	1.818
Coastal reef	Acanthuridae	*Zebrasoma scopas*	0.0110	0.401
Coastal reef	Acanthuridae	*Zebrasoma veliferum*	0.0040	0.225

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Balistidae	*Balistapus undulatus*	0.0007	0.091
Coastal reef	Balistidae	*Rhinecanthus aculeatus*	0.0007	0.078
Coastal reef	Balistidae	*Sufflamen chrysopterus*	0.0010	0.104
Coastal reef	Chaetodontidae	*Chaetodon auriga*	0.0070	0.204
Coastal reef	Chaetodontidae	*Chaetodon bennetti*	0.0027	0.107
Coastal reef	Chaetodontidae	*Chaetodon citrinellus*	0.0050	0.112
Coastal reef	Chaetodontidae	*Chaetodon ephippium*	0.0067	0.245
Coastal reef	Chaetodontidae	*Chaetodon kleinii*	0.0017	0.039
Coastal reef	Chaetodontidae	*Chaetodon lunula*	0.0063	0.219
Coastal reef	Chaetodontidae	*Chaetodon lunulatus*	0.0197	0.588
Coastal reef	Chaetodontidae	*Chaetodon mertensii*	0.0003	0.009
Coastal reef	Chaetodontidae	*Chaetodon reticulatus*	0.0020	0.078
Coastal reef	Chaetodontidae	*Chaetodon trifascialis*	0.0027	0.064
Coastal reef	Chaetodontidae	*Chaetodon ulietensis*	0.0013	0.024
Coastal reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0010	0.061
Coastal reef	Chaetodontidae	*Chaetodon vagabundus*	0.0013	0.047
Coastal reef	Chaetodontidae	*Heniochus acuminatus*	0.0010	0.070
Coastal reef	Chaetodontidae	*Heniochus chrysostomus*	0.0027	0.262
Coastal reef	Holocentridae	*Myripristis adusta*	0.0050	1.011
Coastal reef	Holocentridae	*Myripristis berndti*	0.0010	0.273
Coastal reef	Holocentridae	*Myripristis botche*	0.0007	0.167
Coastal reef	Holocentridae	*Myripristis kuntee*	0.0003	0.049
Coastal reef	Holocentridae	*Myripristis murdjan*	0.0020	0.164
Coastal reef	Holocentridae	*Neoniphon sammara*	0.0030	0.235
Coastal reef	Holocentridae	*Sargocentron spiniferum*	0.0007	0.313
Coastal reef	Labridae	*Cheilinus chlorourus*	0.0003	0.032
Coastal reef	Labridae	*Cheilinus fasciatus*	0.0030	0.410
Coastal reef	Labridae	*Cheilinus undulatus*	0.0003	0.012
Coastal reef	Labridae	*Choerodon anchorago*	0.0027	0.747
Coastal reef	Labridae	*Coris aygula*	0.0003	0.043
Coastal reef	Labridae	*Hemigymnus melapterus*	0.0040	0.367
Coastal reef	Labridae	*Oxycheilinus diagrammus*	0.0007	0.173
Coastal reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0013	0.168
Coastal reef	Lethrinidae	*Lethrinus harak*	0.0117	2.851
Coastal reef	Lethrinidae	*Monotaxis grandoculis*	0.0020	1.177
Coastal reef	Lutjanidae	*Aphareus furca*	0.0017	0.754
Coastal reef	Lutjanidae	*Lutjanus fulvus*	0.0023	0.970
Coastal reef	Lutjanidae	*Lutjanus gibbus*	0.0087	3.402
Coastal reef	Lutjanidae	*Lutjanus monostigma*	0.0007	0.362
Coastal reef	Mullidae	*Parupeneus barberinus*	0.0043	0.698
Coastal reef	Mullidae	*Parupeneus cyclostomus*	0.0010	0.258
Coastal reef	Mullidae	*Parupeneus multifasciatus*	0.0033	0.300
Coastal reef	Nemipteridae	*Scolopsis bilineata*	0.0067	1.113
Coastal reef	Nemipteridae	*Scolopsis ciliatus*	0.0003	0.042
Coastal reef	Nemipteridae	*Scolopsis lineatus*	0.0003	0.006
Coastal reef	Pomacanthidae	*Pomacanthus sexstriatus*	0.0010	0.447
Coastal reef	Scaridae	*Chlorurus bleekeri*	0.0007	0.362

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Coastal reef	Scaridae	*Chlorurus sordidus*	0.0557	10.913
Coastal reef	Scaridae	*Hipposcarus longiceps*	0.0013	0.054
Coastal reef	Scaridae	*Scarus dimidiatus*	0.0153	3.149
Coastal reef	Scaridae	*Scarus frenatus*	0.0020	0.496
Coastal reef	Scaridae	*Scarus ghobban*	0.0017	0.659
Coastal reef	Scaridae	*Scarus globiceps*	0.0010	0.372
Coastal reef	Scaridae	*Scarus niger*	0.0007	0.311
Coastal reef	Scaridae	*Scarus oviceps*	0.0067	3.387
Coastal reef	Scaridae	*Scarus psittacus*	0.0073	0.166
Coastal reef	Scaridae	*Scarus rubroviolaceus*	0.0007	0.363
Coastal reef	Scaridae	*Scarus schlegeli*	0.0007	0.283
Coastal reef	Serranidae	*Aethaloperca rogaa*	0.0007	0.045
Coastal reef	Serranidae	*Epinephelus merra*	0.0007	0.058
Coastal reef	Siganidae	*Siganus doliatus*	0.0027	0.350
Coastal reef	Siganidae	*Siganus puellus*	0.0027	1.089
Coastal reef	Zanclidae	*Zanclus cornutus*	0.0160	1.574
Lagoon	Acanthuridae	*Acanthurus blochii*	0.0015	0.288
Lagoon	Acanthuridae	*Acanthurus guttatus*	0.0030	0.353
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0005	0.107
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0035	0.228
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0005	0.045
Lagoon	Acanthuridae	*Acanthurus nigroris*	0.0060	0.446
Lagoon	Acanthuridae	*Acanthurus xanthopterus*	0.0025	1.513
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.0520	3.779
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0465	2.055
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0040	0.188
Lagoon	Balistidae	*Balistapus undulatus*	0.0005	0.102
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0075	0.227
Lagoon	Chaetodontidae	*Chaetodon bennetti*	0.0005	0.019
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.0090	0.128
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0020	0.084
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0085	0.256
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0030	0.083
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0135	0.463
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0105	0.230
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0040	0.104
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0025	0.093
Lagoon	Chaetodontidae	*Heniochus acuminatus*	0.0015	0.099
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0010	0.243
Lagoon	Kyphosidae	*Kyphosus vaigiensis*	0.0040	1.585
Lagoon	Labridae	*Cheilinus chlorourus*	0.0005	0.033
Lagoon	Labridae	*Cheilinus fasciatus*	0.0020	0.310
Lagoon	Labridae	*Cheilinus undulatus*	0.0005	0.509
Lagoon	Labridae	*Choerodon anchorago*	0.0005	0.223
Lagoon	Labridae	*Coris aygula*	0.0015	0.138
Lagoon	Labridae	*Hemigymnus melapterus*	0.0005	0.131
Lagoon	Labridae	*Oxycheilinus diagrammus*	0.0025	0.185

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0005	0.071
Lagoon	Lutjanidae	*Lutjanus fulvus*	0.0005	0.170
Lagoon	Lutjanidae	*Lutjanus monostigma*	0.0030	1.326
Lagoon	Lutjanidae	*Macolor niger*	0.0005	0.044
Lagoon	Mullidae	*Mulloidichthys flavolineatus*	0.0255	1.827
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0030	0.347
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0005	0.005
Lagoon	Nemipteridae	*Scolopsis bilineata*	0.0010	0.290
Lagoon	Nemipteridae	*Scolopsis ciliatus*	0.0010	0.101
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0015	0.362
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0010	0.467
Lagoon	Scaridae	*Chlorurus sordidus*	0.0295	8.204
Lagoon	Scaridae	*Scarus altipinnis*	0.0010	0.608
Lagoon	Scaridae	*Scarus dimidiatus*	0.0080	1.159
Lagoon	Scaridae	*Scarus ghobban*	0.0015	0.442
Lagoon	Scaridae	*Scarus globiceps*	0.0025	0.645
Lagoon	Scaridae	*Scarus niger*	0.0050	2.877
Lagoon	Scaridae	*Scarus oviceps*	0.0005	0.272
Lagoon	Scaridae	*Scarus psittacus*	0.0180	1.787
Lagoon	Scaridae	*Scarus schlegeli*	0.0020	0.135
Lagoon	Serranidae	*Cephalopholis argus*	0.0005	0.232
Lagoon	Serranidae	*Epinephelus merra*	0.0045	0.360
Lagoon	Serranidae	*Plectropomus maculatus*	0.0005	0.470
Lagoon	Siganidae	*Siganus argenteus*	0.0050	1.230
Lagoon	Siganidae	*Siganus doliatus*	0.0090	0.703
Lagoon	Siganidae	*Siganus lineatus*	0.0010	0.588
Lagoon	Siganidae	*Siganus puellus*	0.0010	0.094
Lagoon	Zanclidae	*Zanclus cornutus*	0.0050	0.427
Outer reef	Acanthuridae	*Acanthurus albipectoralis*	0.0027	0.905
Outer reef	Acanthuridae	*Acanthurus blochii*	0.0007	0.075
Outer reef	Acanthuridae	*Acanthurus guttatus*	0.0067	0.949
Outer reef	Acanthuridae	*Acanthurus leucocheilus*	0.0020	0.778
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0542	11.107
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.1207	12.656
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0027	0.483
Outer reef	Acanthuridae	*Acanthurus nigroris*	0.0040	0.469
Outer reef	Acanthuridae	*Acanthurus olivaceus*	0.0020	0.494
Outer reef	Acanthuridae	*Acanthurus pyroferus*	0.0010	0.171
Outer reef	Acanthuridae	*Acanthurus triostegus*	0.0310	2.119
Outer reef	Acanthuridae	*Acanthurus xanthopterus*	0.0007	0.579
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.2243	16.897
Outer reef	Acanthuridae	*Naso annulatus*	0.0003	0.159
Outer reef	Acanthuridae	*Naso brevirostris*	0.0030	1.068
Outer reef	Acanthuridae	*Naso lituratus*	0.0267	11.649
Outer reef	Acanthuridae	*Naso unicornis*	0.0007	0.401
Outer reef	Acanthuridae	*Naso vlamingii*	0.0003	0.143
Outer reef	Acanthuridae	*Zebrasoma scopas*	0.0180	0.741

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m²)	Biomass (g/m²)
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0057	0.417
Outer reef	Balistidae	*Balistapus undulatus*	0.0080	1.288
Outer reef	Balistidae	*Balistoides viridescens*	0.0003	0.406
Outer reef	Balistidae	*Melichthys niger*	0.0073	2.346
Outer reef	Balistidae	*Melichthys vidua*	0.0306	3.167
Outer reef	Balistidae	*Pseudobalistes flavimarginatus*	0.0003	0.478
Outer reef	Balistidae	*Rhinecanthus rectangulus*	0.0027	0.438
Outer reef	Balistidae	*Sufflamen chrysopterus*	0.0062	0.598
Outer reef	Chaetodontidae	*Chaetodon auriga*	0.0003	0.009
Outer reef	Chaetodontidae	*Chaetodon bennetti*	0.0013	0.039
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0100	0.131
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0013	0.040
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0077	0.194
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0007	0.026
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0110	0.349
Outer reef	Chaetodontidae	*Chaetodon melannotus*	0.0017	0.042
Outer reef	Chaetodontidae	*Chaetodon ornatissimus*	0.0007	0.033
Outer reef	Chaetodontidae	*Chaetodon pelewensis*	0.0073	0.157
Outer reef	Chaetodontidae	*Chaetodon rafflesii*	0.0007	0.026
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0160	0.717
Outer reef	Chaetodontidae	*Chaetodon speculum*	0.0007	0.028
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0007	0.016
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0013	0.031
Outer reef	Chaetodontidae	*Chaetodon unimaculatus*	0.0017	0.076
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0053	0.156
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0020	0.101
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0033	0.171
Outer reef	Chaetodontidae	*Heniochus varius*	0.0007	0.057
Outer reef	Holocentridae	*Myripristis adusta*	0.0050	1.259
Outer reef	Holocentridae	*Myripristis berndti*	0.0020	0.294
Outer reef	Holocentridae	*Myripristis kuntee*	0.0047	0.671
Outer reef	Holocentridae	*Myripristis murdjan*	0.0080	1.096
Outer reef	Holocentridae	*Myripristis pralinia*	0.0013	0.107
Outer reef	Holocentridae	*Myripristis violacea*	0.0043	1.055
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0003	0.049
Outer reef	Holocentridae	*Sargocentron spiniferum*	0.0007	0.335
Outer reef	Labridae	*Cheilinus chlorourus*	0.0010	0.206
Outer reef	Labridae	*Cheilinus undulatus*	0.0010	0.788
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0007	0.077
Outer reef	Labridae	*Hemigymnus melapterus*	0.0010	0.188
Outer reef	Labridae	*Oxycheilinus diagrammus*	0.0003	0.024
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0100	4.548
Outer reef	Lethrinidae	*Lethrinus atkinsoni*	0.0003	0.086
Outer reef	Lethrinidae	*Lethrinus olivaceus*	0.0003	0.267
Outer reef	Lethrinidae	*Lethrinus xanthochilus*	0.0003	0.231
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0010	0.976
Outer reef	Lutjanidae	*Aphareus furca*	0.0080	4.029

3.2.2 Weighted average density and biomass of all finfish species recorded in Riiken (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Lutjanidae	*Aprion virescens*	0.0003	0.219
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0030	1.833
Outer reef	Lutjanidae	*Lutjanus fulviflammus*	0.0003	0.254
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0003	0.174
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0197	10.001
Outer reef	Lutjanidae	*Lutjanus monostigma*	0.0003	0.179
Outer reef	Lutjanidae	*Macolor macularis*	0.0030	2.444
Outer reef	Lutjanidae	*Macolor niger*	0.0003	0.035
Outer reef	Mullidae	*Parupeneus barberinus*	0.0003	0.218
Outer reef	Mullidae	*Parupeneus bifasciatus*	0.0003	0.023
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0003	0.129
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0010	0.053
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0013	0.140
Outer reef	Scaridae	*Bolbometopon muricatum*	0.0090	18.811
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0007	0.444
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0020	2.156
Outer reef	Scaridae	*Chlorurus sordidus*	0.0813	14.342
Outer reef	Scaridae	*Scarus altipinnis*	0.0003	0.292
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0003	0.181
Outer reef	Scaridae	*Scarus forsteni*	0.0007	0.296
Outer reef	Scaridae	*Scarus frenatus*	0.0013	0.592
Outer reef	Scaridae	*Scarus ghobban*	0.0003	0.050
Outer reef	Scaridae	*Scarus globiceps*	0.0030	1.196
Outer reef	Scaridae	*Scarus niger*	0.0010	0.344
Outer reef	Scaridae	*Scarus oviceps*	0.0163	5.514
Outer reef	Scaridae	*Scarus psittacus*	0.0413	2.349
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0087	4.825
Outer reef	Scaridae	*Scarus schlegeli*	0.0013	0.465
Outer reef	Scaridae	*Scarus* spp.	0.0010	0.164
Outer reef	Scaridae	*Scarus spinus*	0.0017	0.573
Outer reef	Scaridae	*Scarus tricolor*	0.0010	0.766
Outer reef	Serranidae	*Aethaloperca rogaa*	0.0007	0.033
Outer reef	Serranidae	*Cephalopholis argus*	0.0030	1.313
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0043	0.336
Outer reef	Serranidae	*Plectropomus maculatus*	0.0003	0.226
Outer reef	Serranidae	*Variola louti*	0.0003	0.144
Outer reef	Siganidae	*Siganus doliatus*	0.0020	0.338
Outer reef	Siganidae	*Siganus puellus*	0.0027	0.432
Outer reef	Siganidae	*Siganus vulpinus*	0.0013	0.393
Outer reef	Zanclidae	*Zanclus cornutus*	0.0070	0.530

3.3 Piis-Panewu finfish survey data

3.3.1 Coordinates (WGS84) of the 16 D-UVC transects used to assess finfish resource status in Piis-Panewu

Station name	Habitat	Latitude	Longitude
TRA01	Lagoon	7º39'40.0788" N	151º46'08.22" E
TRA02	Lagoon	7º39'15.9588" N	151º47'01.0212" E
TRA03	Back-reef	7º40'28.8588" N	151º45'52.2612" E
TRA04	Back-reef	7º40'12.6588" N	151º44'42" E
TRA05	Outer reef	7º40'19.38" N	51º44'04.56" E
TRA06	Outer reef	7º40'19.38" N	151º44'04.56" E
TRA07	Back-reef	7º39'54.4788" N	151º43'08.22" E
TRA08	Back-reef	7º40'34.7412" N	151º46'25.68" E
TRA09	Outer reef	7º41'04.74" N	151º46'03.4788" E
TRA10	Outer reef	7º41'04.74" N	151º46'03.4788" E
TRA11	Back-reef	7º40'22.3212" N	151º49'00.48" E
TRA12	Back-reef	7º40'34.2012" N	151º48'06.48" E
TRA15	Lagoon	7º35'10.68" N	151º46'13.0188" E
TRA16	Lagoon	7º37'05.7612" N	151º49'06.6" E

3.3.2 Weighted average density and biomass of all finfish species recorded in Piis-Panewu

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Scaridae	*Scarus psittacus*	0.0112	1.436
Back-reef	Siganidae	*Siganus* spp.	0.0007	0.029
Back-reef	Lethrinidae	*Lethrinus erythropterus*	0.0007	0.124
Back-reef	Monacanthidae	*Aluterus scriptus*	0.0003	0.252
Back-reef	Labridae	*Bodianus loxozonus*	0.0003	0.048
Back-reef	Scaridae	*Chlorurus bleekeri*	0.0010	0.211
Back-reef	Zanclidae	*Zanclus cornutus*	0.0013	0.143
Back-reef	Mullidae	*Parupeneus cyclostomus*	0.0020	0.341
Back-reef	Scaridae	*Scarus spinus*	0.0003	0.063
Back-reef	Acanthuridae	*Naso lituratus*	0.0047	0.823
Back-reef	Labridae	*Cheilinus chlorourus*	0.0013	0.143
Back-reef	Pomacanthidae	*Pygoplites diacanthus*	0.0020	0.253
Back-reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0077	0.326
Back-reef	Balistidae	*Sufflamen chrysopterum*	0.0010	0.065
Back-reef	Holocentridae	*Myripristis violacea*	0.0010	0.081
Back-reef	Scaridae	*Scarus schlegeli*	0.0037	0.569
Back-reef	Chaetodontidae	*Chaetodon auriga*	0.0010	0.078
Back-reef	Serranidae	*Epinephelus merra*	0.0003	0.011
Back-reef	Acanthuridae	*Acanthurus lineatus*	0.0003	0.044
Back-reef	Serranidae	*Epinephelus areolatus*	0.0003	0.018
Back-reef	Lethrinidae	*Monotaxis grandoculis*	0.0030	0.547
Back-reef	Scaridae	*Scarus globiceps*	0.0063	1.019
Back-reef	Acanthuridae	*Acanthurus blochii*	0.0003	0.112
Back-reef	Scaridae	*Scarus frenatus*	0.0023	0.566
Back-reef	Labridae	*Epibulus insidiator*	0.0003	0.074
Back-reef	Siganidae	*Siganus argenteus*	0.0007	0.066

3.3.2 Weighted average density and biomass of all finfish species recorded in Piis-Panewu (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Scaridae	*Scarus rivulatus*	0.0017	0.060
Back-reef	Kyphosidae	*Kyphosus vaigiensis*	0.0027	1.100
Back-reef	Mullidae	*Parupeneus barberinus*	0.0007	0.194
Back-reef	Acanthuridae	*Zebrasoma veliferum*	0.0017	0.282
Back-reef	Scaridae	*Scarus rubroviolaceus*	0.0003	0.094
Back-reef	Chaetodontidae	*Chaetodon reticulatus*	0.0027	0.096
Back-reef	Holocentridae	*Myripristis* spp.	0.0027	0.315
Back-reef	Siganidae	*Siganus vulpinus*	0.0033	0.201
Back-reef	Chaetodontidae	*Heniochus chrysostomus*	0.0003	0.023
Back-reef	Caesionidae	*Pterocaesio trilineata*	0.0133	0.776
Back-reef	Serranidae	*Epinephelus fasciatus*	0.0003	0.021
Back-reef	Chaetodontidae	*Chaetodon citrinellus*	0.0037	0.038
Back-reef	Holocentridae	*Neoniphon sammara*	0.0007	0.072
Back-reef	Labridae	*Cheilinus undulatus*	0.0003	0.803
Back-reef	Lutjanidae	*Lutjanus semicinctus*	0.0007	0.176
Back-reef	Lutjanidae	*Lutjanus gibbus*	0.0007	0.152
Back-reef	Chaetodontidae	*Chaetodon melannotus*	0.0020	0.081
Back-reef	Scaridae	*Scarus niger*	0.0003	0.089
Back-reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0280	2.045
Back-reef	Chaetodontidae	*Chaetodon lunulatus*	0.0093	0.261
Back-reef	Lutjanidae	*Lutjanus fulvus*	0.0006	0.131
Back-reef	Carcharhinidae	*Carcharhinus melanopterus*	0.0003	8.501
Back-reef	Scaridae	*Chlorurus sordidus*	0.0427	3.551
Back-reef	Scaridae	*Scarus oviceps*	0.0017	0.241
Back-reef	Chaetodontidae	*Heniochus varius*	0.0013	0.066
Back-reef	Chaetodontidae	*Chaetodon ulietensis*	0.0007	0.020
Back-reef	Lutjanidae	*Lutjanus monostigma*	0.0003	0.087
Back-reef	Acanthuridae	*Zebrasoma scopas*	0.0142	0.486
Back-reef	Mullidae	*Parupeneus trifasciatus*	0.0020	0.604
Back-reef	Serranidae	*Cephalopholis argus*	0.0010	0.191
Back-reef	Chaetodontidae	*Chaetodon vagabundus*	0.0007	0.030
Back-reef	Lutjanidae	*Macolor niger*	0.0003	0.048
Back-reef	Kyphosidae	*Kyphosus cinerascens*	0.0003	0.096
Back-reef	Acanthuridae	*Acanthurus pyroferus*	0.0013	0.100
Back-reef	Scaridae	*Hipposcarus longiceps*	0.0040	1.284
Back-reef	Mullidae	*Parupeneus multifasciatus*	0.0037	0.358
Back-reef	Acanthuridae	*Acanthurus olivaceus*	0.0010	0.195
Back-reef	Scaridae	*Scarus dimidiatus*	0.0023	0.399
Back-reef	Acanthuridae	*Ctenochaetus striatus*	0.0888	11.325
Back-reef	Chaetodontidae	*Chaetodon trifascialis*	0.0023	0.082
Back-reef	Chaetodontidae	*Chaetodon ephippium*	0.0007	0.073
Back-reef	Balistidae	*Balistapus undulatus*	0.0047	0.462
Back-reef	Labridae	*Cheilinus fasciatus*	0.0020	0.277
Back-reef	Balistidae	*Melichthys vidua*	0.0003	0.023
Back-reef	Labridae	*Hemigymnus melapterus*	0.0013	0.230
Back-reef	Caesionidae	*Pterocaesio tile*	0.0003	0.029
Back-reef	Lutjanidae	*Aprion virescens*	0.0003	0.219

3.3.2 Weighted average density and biomass of all finfish species recorded in Piis-Panewu (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Back-reef	Labridae	*Hemigymnus fasciatus*	0.0003	0.004
Back-reef	Serranidae	*Cephalopholis urodeta*	0.0047	0.387
Back-reef	Siganidae	*Siganus puellus*	0.0007	0.074
Back-reef	Acanthuridae	*Acanthurus triostegus*	0.0003	0.016
Back-reef	Acanthuridae	*Acanthurus nigricauda*	0.0030	0.785
Back-reef	Acanthuridae	*Acanthurus nigricans*	0.0003	0.025
Back-reef	Scaridae	*Scarus* spp.	0.0003	0.073
Back-reef	Scaridae	*Scarus altipinnis*	0.0017	0.444
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0005	0.023
Lagoon	Siganidae	*Siganus argenteus*	0.0100	0.648
Lagoon	Siganidae	*Siganus vulpinus*	0.0113	0.959
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0050	1.082
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0065	1.882
Lagoon	Siganidae	*Siganus spinus*	0.0005	0.079
Lagoon	Chaetodontidae	*Chaetodon reticulatus*	0.0035	0.196
Lagoon	Pomacanthidae	*Pygoplites diacanthus*	0.0035	0.317
Lagoon	Aulostomidae	*Aulostomus chinensis*	0.0005	0.100
Lagoon	Scaridae	*Chlorurus sordidus*	0.0611	7.929
Lagoon	Chaetodontidae	*Chaetodon pelewensis*	0.0005	0.007
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0005	0.026
Lagoon	Lutjanidae	*Macolor macularis*	0.0010	0.281
Lagoon	Chaetodontidae	*Chaetodon ornatissimus*	0.0010	0.061
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0300	7.489
Lagoon	Scaridae	*Scarus rubroviolaceus*	0.0081	1.404
Lagoon	Holocentridae	*Myripristis murdjan*	0.0020	0.202
Lagoon	Labridae	*Hemigymnus melapterus*	0.0005	0.206
Lagoon	Lutjanidae	*Macolor niger*	0.0010	0.316
Lagoon	Scaridae	*Scarus globiceps*	0.0075	1.234
Lagoon	Serranidae	*Cephalopholis urodeta*	0.0060	0.470
Lagoon	Caesionidae	*Pterocaesio tile*	0.0083	1.040
Lagoon	Scaridae	*Scarus frenatus*	0.0052	1.188
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0050	0.158
Lagoon	Nemipteridae	*Scolopsis lineata*	0.0010	0.075
Lagoon	Scaridae	*Chlorurus microrhinos*	0.0080	4.175
Lagoon	Scaridae	*Scarus flavipectoralis*	0.0005	0.051
Lagoon	Lutjanidae	*Lutjanus gibbus*	0.0018	0.762
Lagoon	Acanthuridae	*Acanthurus thompsoni*	0.0271	1.722
Lagoon	Scaridae	*Scarus niger*	0.0045	1.127
Lagoon	Labridae	*Cheilinus chlorourus*	0.0005	0.056
Lagoon	Acanthuridae	*Naso lituratus*	0.0387	8.738
Lagoon	Labridae	*Cheilinus undulatus*	0.0005	0.195
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0006	0.537
Lagoon	Scaridae	*Scarus* spp.	0.0025	0.496
Lagoon	Serranidae	*Plectropomus leopardus*	0.0005	0.157
Lagoon	Balistidae	*Odonus niger*	0.0026	0.370
Lagoon	Acanthuridae	*Acanthurus olivaceus*	0.0212	6.719
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1971	26.621

3.3.2 Weighted average density and biomass of all finfish species recorded in Piis-Panewu (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Carcharhinidae	*Triaenodon obesus*	0.0005	4.380
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0010	0.058
Lagoon	Mullidae	*Parupeneus trifasciatus*	0.0015	0.127
Lagoon	Acanthuridae	*Acanthurus nigricauda*	0.0005	0.287
Lagoon	Scaridae	*Scarus forsteni*	0.0010	0.164
Lagoon	Scaridae	*Cetoscarus bicolor*	0.0045	3.279
Lagoon	Holocentridae	*Sargocentron spiniferum*	0.0015	0.385
Lagoon	Acanthuridae	*Zebrasoma scopas*	0.0093	0.384
Lagoon	Scaridae	*Chlorurus japanensis*	0.0005	0.221
Lagoon	Labridae	*Coris aygula*	0.0005	0.087
Lagoon	Siganidae	*Siganus doliatus*	0.0010	0.187
Lagoon	Scaridae	*Scarus schlegeli*	0.0046	0.733
Lagoon	Acanthuridae	*Naso brevirostris*	0.0030	0.674
Lagoon	Kyphosidae	*Kyphosus vaigiensis*	0.0020	0.546
Lagoon	Acanthuridae	*Acanthurus nigricans*	0.0430	3.084
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0005	0.022
Lagoon	Nemipteridae	*Scolopsis trilineata*	0.0005	0.054
Lagoon	Balistidae	*Balistapus undulatus*	0.0040	0.289
Lagoon	Siganidae	*Siganus punctatus*	0.0010	0.237
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0060	1.280
Lagoon	Labridae	*Cheilinus fasciatus*	0.0020	0.776
Lagoon	Acanthuridae	*Naso thynnoides*	0.0184	2.693
Lagoon	Mullidae	*Parupeneus barberinus*	0.0005	0.045
Lagoon	Siganidae	*Siganus puellus*	0.0050	0.648
Lagoon	Holocentridae	*Myripristis* spp.	0.0005	0.033
Lagoon	Zanclidae	*Zanclus cornutus*	0.0035	0.279
Lagoon	Serranidae	*Plectropomus laevis*	0.0005	0.143
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0060	0.203
Lagoon	Lethrinidae	*Lethrinus erythropterus*	0.0010	0.298
Lagoon	Serranidae	*Epinephelus polyphekadion*	0.0005	0.352
Lagoon	Chaetodontidae	*Hemitaurichthys polylepis*	0.0015	0.061
Lagoon	Balistidae	*Melichthys vidua*	0.0015	0.091
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0005	0.038
Lagoon	Serranidae	*Cephalopholis argus*	0.0005	0.064
Lagoon	Chaetodontidae	*Chaetodon trifascialis*	0.0040	0.131
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.0040	0.054
Lagoon	Scaridae	*Scarus psittacus*	0.0454	3.470
Lagoon	Scaridae	*Scarus spinus*	0.0005	0.051
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0095	1.945
Outer reef	Lutjanidae	*Lutjanus semicinctus*	0.0005	0.123
Outer reef	Lutjanidae	*Aphareus furca*	0.0010	0.249
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0035	0.376
Outer reef	Balistidae	*Odonus niger*	0.0261	3.095
Outer reef	Chaetodontidae	*Chaetodon ephippium*	0.0005	0.023
Outer reef	Scaridae	*Scarus altipinnis*	0.0010	0.445
Outer reef	Chaetodontidae	*Chaetodon trifascialis*	0.0050	0.128
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0005	0.334

3.3.2 Weighted average density and biomass of all finfish species recorded in Piis-Panewu (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	**Family**	**Species**	**Density (fish/m^2)**	**Biomass (g/m^2)**
Outer reef	Scaridae	*Scarus psittacus*	0.0091	1.179
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0005	0.621
Outer reef	Labridae	*Cheilinus chlorourus*	0.0005	0.056
Outer reef	Balistidae	*Sufflamen bursa*	0.0050	0.301
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0010	0.904
Outer reef	Zanclidae	*Zanclus cornutus*	0.0060	0.550
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0010	0.016
Outer reef	Chaetodontidae	*Heniochus monoceros*	0.0010	0.103
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0015	0.046
Outer reef	Scaridae	*Scarus globiceps*	0.0060	1.004
Outer reef	Acanthuridae	*Acanthurus olivaceus*	0.0010	0.219
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0005	0.218
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.2844	26.867
Outer reef	Labridae	*Hemigymnus melapterus*	0.0020	0.403
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0045	0.556
Outer reef	Siganidae	*Siganus argenteus*	0.0005	0.050
Outer reef	Scaridae	*Scarus* spp.	0.0005	0.082
Outer reef	Acanthuridae	*Naso lituratus*	0.0087	1.885
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0065	0.314
Outer reef	Scaridae	*Chlorurus sordidus*	0.0765	7.167
Outer reef	Serranidae	*Cephalopholis argus*	0.0015	0.214
Outer reef	Scaridae	*Scarus oviceps*	0.0045	0.673
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0015	0.044
Outer reef	Scaridae	*Scarus frenatus*	0.0026	0.695
Outer reef	Lethrinidae	*Lethrinus xanthochilus*	0.0025	1.198
Outer reef	Acanthuridae	*Zebrasoma veliferum*	0.0010	0.347
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0020	0.121
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0085	0.088
Outer reef	Carangidae	*Carangoides ferdau*	0.0010	0.720
Outer reef	Balistidae	*Balistapus undulatus*	0.0060	0.569
Outer reef	Balistidae	*Sufflamen chrysopterum*	0.0005	0.007
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0015	0.052
Outer reef	Balistidae	*Melichthys niger*	0.0005	0.074
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.0065	0.458
Outer reef	Scaridae	*Scarus forsteni*	0.0030	0.673
Outer reef	Scaridae	*Scarus schlegeli*	0.0005	0.052
Outer reef	Carangidae	*Caranx* spp.	0.0010	0.152
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0030	1.363
Outer reef	Balistidae	*Melichthys vidua*	0.0436	4.788

3.4 Romanum finfish survey data

3.4.1 Coordinates (WGS84) of the 23 D-UVC transects used to assess finfish resource status in Romanum

Station name	Habitat	Latitude	Longitude
TRA01	Coastal reef	7º24'24.3612" N	151º39'47.52" E
TRA02	Lagoon	7º25'09.2388" N	151º38'52.08" E
TRA03	Lagoon	7º24'36.7812" N	151º38'58.56" E
TRA04	Coastal reef	7º24'20.4012" N	151º40'26.4" E
TRA05	Back-reef	7º24'51.9012" N	151º31'10.6788" E
TRA06	Back-reef	7º25'32.4012" N	151º32'18.6612" E
TRA07	Back-reef	7º26'53.2212" N	151º33'40.2012" E
TRA08	Back-reef	7º27'49.9212" N	151º34'40.08" E
TRA09	Lagoon	7º25'04.3788" N	151º42'02.0988" E
TRA10	Coastal reef	7º23'21.3" N	151º42'18.18" E
TRA11	Coastal reef	7º23'09.78" N	151º44'06.9612" E
TRA12	Lagoon	7º25'13.3212" N	151º44'03.4188" E
TRA15	Coastal reef	7º24'46.8" N	151º40'33.6612" E
TRA16	Coastal reef	7º24'57.7188" N	151º39'56.88" E
TRA19	Outer reef	7º27'34.74" N	151º33'51.5412" E
TRA20	Outer reef	7º28'05.9412" N	151º34'20.2188" E
TRA21	Outer reef	7º25'50.16" N	151º32'14.1" E
TRA22	Outer reef	7º25'50.16" N	151º32'14.1" E
TRA23	Outer reef	7º30'09.2988" N	151º36'11.9412" E

3.4.2 Weighted average density and biomass of all finfish species recorded in Romanum (using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Acanthuridae	*Naso brevirostris*	0.0005	0.043
Lagoon	Acanthuridae	*Naso lituratus*	0.0005	0.061
Lagoon	Acanthuridae	*Acanthurus triostegus*	0.0010	0.031
Lagoon	Acanthuridae	*Ctenochaetus flavicauda*	0.0005	0.002
Lagoon	Acanthuridae	*Zebrasoma veliferum*	0.0005	0.013
Lagoon	Acanthuridae	*Ctenochaetus striatus*	0.1154	13.656
Lagoon	Acanthuridae	*Acanthurus pyroferus*	0.0005	0.029
Lagoon	Acanthuridae	*Acanthurus lineatus*	0.0180	0.973
Lagoon	Aulostomidae	*Aulostomus chinensis*	0.0005	0.100
Lagoon	Balistidae	*Rhinecanthus rectangulus*	0.0005	0.052
Lagoon	Caesionidae	*Pterocaesio trilineata*	0.0250	0.923
Lagoon	Carangidae	*Caranx melampygus*	0.0005	0.553
Lagoon	Carcharhinidae	*Carcharhinus melanopterus*	0.0015	35.680
Lagoon	Chaetodontidae	*Chaetodon lunula*	0.0010	0.049
Lagoon	Chaetodontidae	*Chaetodon kleinii*	0.0025	0.055
Lagoon	Chaetodontidae	*Chaetodon citrinellus*	0.0085	0.071
Lagoon	Chaetodontidae	*Chaetodon vagabundus*	0.0020	0.080
Lagoon	Chaetodontidae	*Chaetodon auriga*	0.0005	0.043
Lagoon	Chaetodontidae	*Chaetodon ephippium*	0.0015	0.068
Lagoon	Chaetodontidae	*Chaetodon lunulatus*	0.0005	0.015
Lagoon	Chaetodontidae	*Heniochus chrysostomus*	0.0005	0.035
Lagoon	Chaetodontidae	*Chaetodon unimaculatus*	0.0005	0.018

3.4.2 Weighted average density and biomass of all finfish species recorded in Romanum (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lagoon	Chaetodontidae	*Chaetodon ulietensis*	0.0005	0.006
Lagoon	Holocentridae	*Myripristis violacea*	0.0020	0.302
Lagoon	Kyphosidae	*Kyphosus vaigiensis*	0.0010	0.352
Lagoon	Labridae	*Hemigymnus melapterus*	0.0045	0.291
Lagoon	Labridae	*Cheilinus fasciatus*	0.0010	0.065
Lagoon	Labridae	*Cheilinus chlorourus*	0.0040	0.440
Lagoon	Lethrinidae	*Lethrinus harak*	0.0030	1.294
Lagoon	Lethrinidae	*Monotaxis grandoculis*	0.0010	0.042
Lagoon	Lethrinidae	*Gnathodentex aureolineatus*	0.0295	2.555
Lagoon	Lutjanidae	*Lutjanus bohar*	0.0010	4.321
Lagoon	Lutjanidae	*Lutjanus semicinctus*	0.0005	0.033
Lagoon	Mullidae	*Mulloidichthys vanicolensis*	0.0005	0.020
Lagoon	Mullidae	*Parupeneus multifasciatus*	0.0070	0.271
Lagoon	Mullidae	*Parupeneus barberinus*	0.0020	0.123
Lagoon	Nemipteridae	*Scolopsis trilineata*	0.0015	0.060
Lagoon	Nemipteridae	*Scolopsis lineata*	0.0015	0.135
Lagoon	Scaridae	*Chlorurus bleekeri*	0.0015	0.117
Lagoon	Scaridae	*Scarus niger*	0.0013	0.230
Lagoon	Scaridae	*Scarus ghobban*	0.0005	0.016
Lagoon	Scaridae	*Hipposcarus longiceps*	0.0005	0.060
Lagoon	Scaridae	*Scarus psittacus*	0.0030	0.156
Lagoon	Scaridae	*Scarus rivulatus*	0.0225	7.992
Lagoon	Scaridae	*Chlorurus sordidus*	0.0260	1.767
Lagoon	Scaridae	*Scarus flavipectoralis*	0.0276	1.968
Lagoon	Scaridae	*Scarus* spp.	0.0660	1.315
Lagoon	Serranidae	*Epinephelus polyphekadion*	0.0005	0.242
Lagoon	Serranidae	*Epinephelus areolatus*	0.0015	0.099
Lagoon	Siganidae	*Siganus vulpinus*	0.0070	0.670
Lagoon	Siganidae	*Siganus doliatus*	0.0090	0.621
Lagoon	Zanclidae	*Zanclus cornutus*	0.0010	0.025
Outer reef	Acanthuridae	*Acanthurus guttatus*	0.0004	0.044
Outer reef	Acanthuridae	*Acanthurus lineatus*	0.0131	3.522
Outer reef	Acanthuridae	*Acanthurus nigrofuscus*	0.0032	0.090
Outer reef	Acanthuridae	*Naso unicornis*	0.0020	0.883
Outer reef	Acanthuridae	*Ctenochaetus striatus*	0.2653	38.221
Outer reef	Acanthuridae	*Acanthurus triostegus*	0.0075	0.656
Outer reef	Acanthuridae	*Naso lituratus*	0.0315	8.544
Outer reef	Acanthuridae	*Acanthurus nigricans*	0.1268	11.279
Outer reef	Balistidae	*Sufflamen bursa*	0.0004	0.024
Outer reef	Balistidae	*Balistapus undulatus*	0.0012	0.079
Outer reef	Balistidae	*Melichthys niger*	0.0004	0.126
Outer reef	Balistidae	*Melichthys vidua*	0.0026	0.279
Outer reef	Carcharhinidae	*Carcharhinus melanopterus*	0.0004	7.518
Outer reef	Carcharhinidae	*Triaenodon obesus*	0.0004	4.819
Outer reef	Chaetodontidae	*Chaetodon ulietensis*	0.0004	0.009
Outer reef	Chaetodontidae	*Chaetodon lunula*	0.0004	0.025
Outer reef	Chaetodontidae	*Chaetodon semeion*	0.0004	0.025

3.4.2 Weighted average density and biomass of all finfish species recorded in Romanum (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Chaetodontidae	*Chaetodon kleinii*	0.0016	0.047
Outer reef	Chaetodontidae	*Chaetodon bennetti*	0.0004	0.025
Outer reef	Chaetodontidae	*Forcipiger longirostris*	0.0032	0.098
Outer reef	Chaetodontidae	*Heniochus varius*	0.0024	0.126
Outer reef	Chaetodontidae	*Heniochus chrysostomus*	0.0012	0.083
Outer reef	Chaetodontidae	*Chaetodon reticulatus*	0.0024	0.101
Outer reef	Chaetodontidae	*Chaetodon lunulatus*	0.0016	0.047
Outer reef	Chaetodontidae	*Chaetodon vagabundus*	0.0008	0.028
Outer reef	Chaetodontidae	*Chaetodon citrinellus*	0.0044	0.052
Outer reef	Holocentridae	*Myripristis violacea*	0.0108	2.232
Outer reef	Holocentridae	*Sargocentron tiere*	0.0004	0.141
Outer reef	Holocentridae	*Sargocentron caudimaculatum*	0.0004	0.059
Outer reef	Kyphosidae	*Kyphosus cinerascens*	0.0155	5.021
Outer reef	Kyphosidae	*Kyphosus vaigiensis*	0.0095	6.084
Outer reef	Labridae	*Cheilinus chlorourus*	0.0008	0.117
Outer reef	Labridae	*Hemigymnus fasciatus*	0.0004	0.081
Outer reef	Labridae	*Cheilinus fasciatus*	0.0012	0.275
Outer reef	Labridae	*Cheilinus trilobatus*	0.0009	0.737
Outer reef	Lethrinidae	*Monotaxis grandoculis*	0.0011	0.331
Outer reef	Lethrinidae	*Gnathodentex aureolineatus*	0.0040	0.352
Outer reef	Lutjanidae	*Aphareus furca*	0.0012	0.554
Outer reef	Lutjanidae	*Lutjanus bohar*	0.0008	1.966
Outer reef	Lutjanidae	*Lutjanus semicinctus*	0.0004	0.146
Outer reef	Lutjanidae	*Lutjanus gibbus*	0.0049	2.422
Outer reef	Lutjanidae	*Lutjanus fulvus*	0.0040	1.417
Outer reef	Mullidae	*Parupeneus cyclostomus*	0.0004	0.068
Outer reef	Mullidae	*Parupeneus multifasciatus*	0.0012	0.126
Outer reef	Mullidae	*Parupeneus trifasciatus*	0.0020	0.334
Outer reef	Pomacanthidae	*Pygoplites diacanthus*	0.0012	0.081
Outer reef	Scaridae	*Chlorurus frontalis*	0.0038	2.038
Outer reef	Scaridae	*Scarus flavipectoralis*	0.0004	0.218
Outer reef	Scaridae	*Scarus niger*	0.0051	1.862
Outer reef	Scaridae	*Chlorurus sordidus*	0.0415	4.766
Outer reef	Scaridae	*Scarus psittacus*	0.0012	0.398
Outer reef	Scaridae	*Chlorurus bleekeri*	0.0048	0.964
Outer reef	Scaridae	*Scarus globiceps*	0.0089	1.876
Outer reef	Scaridae	*Chlorurus microrhinos*	0.0180	15.504
Outer reef	Scaridae	*Cetoscarus bicolor*	0.0004	0.065
Outer reef	Scaridae	*Chlorurus japanensis*	0.0024	0.791
Outer reef	Scaridae	*Scarus oviceps*	0.0016	0.360
Outer reef	Scaridae	*Scarus spinus*	0.0044	1.066
Outer reef	Scaridae	*Scarus frenatus*	0.0046	1.077
Outer reef	Scaridae	*Hipposcarus longiceps*	0.0004	0.217
Outer reef	Scaridae	*Scarus rubroviolaceus*	0.0051	1.864
Outer reef	Scaridae	*Scarus forsteni*	0.0024	0.525
Outer reef	Scaridae	*Scarus schlegeli*	0.0038	0.880
Outer reef	Serranidae	*Cephalopholis urodeta*	0.0040	0.331

3.4.2 Weighted average density and biomass of all finfish species recorded in Romanum (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Habitat	Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Outer reef	Serranidae	*Plectropomus areolatus*	0.0004	0.749
Outer reef	Serranidae	*Cephalopholis argus*	0.0012	0.391
Outer reef	Siganidae	*Siganus vulpinus*	0.0012	0.228
Outer reef	Zanclidae	*Zanclus cornutus*	0.0016	0.114

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Yyin invertebrate survey data

4.1.1 Invertebrate species recorded in different assessments in Yyin

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*				+
Bêche-de-mer	*Actinopyga miliaris*				+
Bêche-de-mer	*Actinopyga* spp.	+	+	+	+
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Bohadschia vitiensis*			+	+
Bêche-de-mer	*Holothuria atra*	+	+	+	+
Bêche-de-mer	*Holothuria coluber*	+		+	+
Bêche-de-mer	*Holothuria edulis*	+	+	+	+
Bêche-de-mer	*Holothuria flavomaculata*				+
Bêche-de-mer	*Holothuria fuscopunctata*	+			
Bêche-de-mer	*Holothuria nobilis*	+	+		
Bêche-de-mer	*Stichopus chloronotus*				+
Bêche-de-mer	*Stichopus horrens*			+	
Bêche-de-mer	*Stichopus* spp.				+
Bêche-de-mer	*Stichopus vastus*		+		
Bêche-de-mer	*Synapta* spp.			+	+
Bêche-de-mer	*Thelenota ananas*	+	+		+
Bivalve	*Hippopus hippopus*	+	+		
Bivalve	*Isognomon* spp.		+		
Bivalve	*Modiolus* spp.			+	
Bivalve	*Pteria* spp.				+
Bivalve	*Spondylus* spp.		+		+
Bivalve	*Tellina palatum*			+	
Bivalve	*Tridacna maxima*	+	+		+
Cnidarian	*Cassiopea andromeda*	+		+	
Cnidarian	*Cassiopea* spp.	+			
Cnidarian	*Stichodactyla* spp.	+	+	+	+
Crustacean	*Atergatis floridus*				+
Crustacean	*Etisus splendidus*				+
Crustacean	*Lysiosquillina maculata*			+	
Crustacean	*Panulirus versicolor*	+			+
Crustacean	*Periclimenes brevicarpalis*			+	
Crustacean	*Portunus* spp.			+	+
Crustacean	*Stenopus hispidus*			+	
Crustacean	*Thor amboinensis*			+	
Gastropod	*Cantharus* spp.			+	
Gastropod	*Cerithium aluco*	+			
Gastropod	*Cerithium* spp.			+	
Gastropod	*Charonia tritonis*	+			
Gastropod	*Conus coronatus*			+	
Gastropod	*Conus distans*	+	+		+
Gastropod	*Conus ebraeus*			+	
Gastropod	*Conus frigidus*		+		
Gastropod	*Conus leopardus*	+			

+ = presence of the species.

4.1.1 Invertebrate species recorded in different assessments in Yyin (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Conus litteratus*		+	+	
Gastropod	*Conus marmoreus*	+	+		
Gastropod	*Conus* spp.			+	
Gastropod	*Conus virgo*	+	+		
Gastropod	*Cypraea annulus*	+	+		
Gastropod	*Cypraea carneola*		+		
Gastropod	*Cypraea isabella*		+		
Gastropod	*Cypraea moneta*		+	+	
Gastropod	*Cypraea tigris*	+	+		+
Gastropod	*Cypraea vitellus*				+
Gastropod	*Drupa morum*				+
Gastropod	*Lambis lambis*	+	+	+	
Gastropod	*Lambis truncata*		+		+
Gastropod	*Mitra mitra*				+
Gastropod	*Morula* spp.			+	
Gastropod	*Oliva* spp.			+	
Gastropod	*Pyrene* spp.			+	
Gastropod	*Rhinoclavis aspera*		+		
Gastropod	*Strombus gibberulus gibbosus*			+	
Gastropod	*Strombus luhuanus*	+	+		+
Gastropod	*Tectus pyramis*	+			+
Gastropod	*Terebra dimidiata*				+
Gastropod	*Thais* spp.				+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.			+	
Gastropod	*Turbo argyrostomus*				+
Gastropod	*Turbo* spp.				+
Star	*Acanthaster planci*	+	+		+
Star	*Culcita novaeguineae*	+	+		+
Star	*Leiaster speciosus*				+
Star	*Linckia laevigata*	+	+		
Star	*Protoreaster nodosus*			+	
Urchin	*Echinometra mathaei*		+	+	+
Urchin	*Echinothrix diadema*	+			
Urchin	*Echinothrix* spp.	+			
Urchin	*Mespilia globulus*	+			

+ = presence of the species.

4.1.2 Yyin broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.2	0.2	72	16.1		1	0.2	0.2	12	2.7		1
Actinopyga spp.	47.2	20.4	72	485.7	122.3	7	47.0	35.0	12	282.0	120.8	2
Bohadschia argus	9.3	2.4	72	39.6	5.8	17	9.3	4.2	12	22.3	6.8	5
Cassiopea spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Cassiopea andromeda	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Cerithium aluco	0.9	0.4	72	16.5	0.1	4	0.9	0.5	12	3.7	0.9	3
Charonia tritonis	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Conus distans	2.5	1.1	72	25.9	7.0	7	2.5	1.5	12	10.0	3.2	3
Conus leopardus	1.2	0.8	72	27.8	11.1	3	1.1	0.9	12	6.9	4.1	2
Conus marmoreus	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Conus virgo	1.6	0.7	72	19.4	2.7	6	1.6	0.9	12	6.4	1.9	3
Culcita novaeguineae	1.5	0.7	72	18.5	3.1	6	1.6	1.0	12	6.2	2.4	3
Cypraea annulus	0.4	0.3	72	15.9	0.8	2	0.5	0.3	12	2.7	0.0	2
Cypraea tigris	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Echinothrix diadema	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.5		1
Echinothrix spp.	1.3	0.9	72	32.3	16.1	3	1.4	1.4	12	16.3		1
Hippopus hippopus	3.7	1.0	72	22.0	2.4	12	3.6	1.5	12	8.6	2.0	5
Holothuria atra	95.8	30.1	72	181.5	53.6	38	96.1	55.2	12	104.8	59.7	11
Holothuria coluber	0.2	0.2	72	16.7		1	0.2	0.2	12	2.7		1
Holothuria edulis	1.4	0.7	72	24.5	5.1	4	1.4	0.6	12	4.1	0.8	4
Holothuria fuscopunctata	1.9	1.3	72	44.4	20.0	3	1.8	1.8	12	22.1		1
Holothuria nobilis	0.7	0.5	72	24.7	8.1	2	0.7	0.5	12	4.1	1.3	2
Lambis lambis	1.1	0.6	72	20.6	4.2	4	1.1	0.5	12	3.4	0.7	4
Linckia laevigata	39.2	9.2	72	117.6	19.6	24	39.2	17.2	12	117.6	13.2	4
Mespilia globulus	4.6	4.6	72	333.3		1	4.6	4.6	12	54.6		1
Panulirus versicolor	0.7	0.5	72	24.5	7.8	2	0.7	0.7	12	8.1		1
Stichodactyla spp.	1.8	1.1	72	33.1	11.8	4	1.8	1.0	12	5.5	2.0	4
Strombus luhuanus	0.9	0.7	72	32.4	17.6	2	0.9	0.7	12	5.5	2.8	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.

4.1.2 Yyin broad-scale assessment data review (continued)

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
Tectus pyramis	0.2	0.2	72	16.1		1	0.2	0.2	12	2.7		1
Thelenota ananas	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tridacna maxima	4.1	1.4	72	24.8	5.5	12	4.1	1.9	12	7.1	2.7	7
Trochus niloticus	2.3	0.7	72	18.3	1.7	9	2.3	1.2	12	5.4	2.1	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.

4.1.3 Yyin 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	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Actinopyga spp.	6.9	4.9	72	250.0	0.0	2	6.9	6.9	12	83.3		1
Bohadschia argus	27.8	11.7	72	333.3	52.7	6	27.8	16.5	12	111.1	36.7	3
Conus distans	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Conus frigidus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus litteratus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus marmoreus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus virgo	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Culcita novaeguineae	66.0	28.8	72	593.8	176.4	8	66.0	58.6	12	263.9	222.2	3
Cypraea annulus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cypraea carneola	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cypraea isabella	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cypraea moneta	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Cypraea tigris	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Echinometra mathaei	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Hippopus hippopus	17.4	7.5	72	250.0	0.0	5	17.4	8.0	12	52.1	10.4	4
Holothuria atra	125.0	33.2	72	600.0	80.2	15	125.0	63.9	12	375.0	116.6	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3 Yyin reef-benthos transect (RBt) assessment data review (continued)
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria edulis	69.4	26.7	72	625.0	125.0	8	69.4	59.0	12	416.7	291.7	2
Holothuria nobilis	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Isognomon spp.	6.9	4.9	72	250.0	0.0	2	6.9	6.9	12	83.3		1
Lambis lambis	13.9	8.4	72	333.3	83.3	3	13.9	13.9	12	166.7		1
Lambis truncata	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Linckia laevigata	20.8	11.9	72	375.0	125.0	4	20.8	10.9	12	62.5	20.8	4
Rhinoclavis aspera	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Spondylus spp.	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Stichodactyla spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Stichopus vastus	6.9	4.9	72	250.0	0.0	2	6.9	6.9	12	83.3		1
Strombus luhuanus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Thelenota ananas	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Tridacna maxima	79.9	17.0	72	287.5	27.4	20	79.9	29.2	12	119.8	36.5	8
Trochus niloticus	10.4	5.9	72	250.0	0.0	3	10.4	5.4	12	41.7	0.0	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.4 Yyin soft-benthos transect (SBt) 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 spp.	520.8	191.1	72	3 125.0	820.8	12	520.8	367.3	12	3 125.0	875.0	2
Bohadschia vitiensis	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cantharus spp.	13.9	8.4	72	333.3	83.3	3	13.9	7.8	12	55.6	13.9	3
Cassiopea andromeda	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cerithium spp.	34.7	15.9	72	416.7	105.4	6	34.7	24.0	12	104.2	62.5	4
Conus coronatus	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Conus ebraeus	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.4 Yyin soft-benthos transect (SBt) assessment data review (continued)

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
Conus litteratus	13.9	6.8	72	250.0	0.0	4	13.9	10.7	12	83.3	41.7	2
Conus spp.	41.7	25.7	72	600.0	291.5	5	41.7	25.1	12	125.0	58.9	4
Cypraea moneta	13.9	8.4	72	333.3	83.3	3	13.9	10.7	12	83.3	41.7	2
Echinometra mathaei	10.4	7.7	72	375.0	125.0	2	10.4	10.4	12	125.0		1
Holothuria atra	149.3	40.1	72	565.8	104.4	19	149.3	72.4	12	224.0	99.9	8
Holothuria coluber	48.6	18.3	72	388.9	84.5	9	48.6	35.1	12	194.4	113.7	3
Holothuria edulis	10.4	7.7	72	375.0	125.0	2	10.4	10.4	12	125.0		1
Lambis lambis	10.4	5.9	72	250.0	0.0	3	10.4	7.5	12	62.5	20.8	2
Lysiosquillina maculata	10.4	5.9	72	250.0	0.0	3	10.4	7.5	12	62.5	20.8	2
Modiolus spp.	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Morula spp.	10.4	5.9	72	250.0	0.0	3	10.4	7.5	12	62.5	20.8	2
Oliva spp.	13.9	9.8	72	500.0	0.0	2	13.9	9.4	12	83.3	0.0	2
Periclimenes brevicarpalis	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Portunus spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Protoreaster nodosus	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Pyrene spp.	316.0	122.2	72	2275.0	594.5	10	316.0	207.5	12	947.9	523.6	4
Stenopus hispidus	10.4	7.7	72	375.0	125.0	2	10.4	7.5	12	62.5	20.8	2
Stichodactyla spp.	24.3	11.2	72	350.0	61.2	5	24.3	14.9	12	97.2	36.7	3
Stichopus horrens	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Strombus gibberulus gibbosus	27.8	10.6	72	285.7	35.7	7	27.8	12.9	12	83.3	17.0	4
Synapta spp.	10.4	7.7	72	375.0	125.0	2	10.4	10.4	12	125.0		1
Tellina palatum	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Thor amboinensis	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Trochus spp.	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.

4.1.5 Yyin 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	4.9	2.0	24	23.5	0.0	5	4.9	1.9	4	6.5	1.3	3
Conus distans	3.9	2.3	24	31.4	7.8	3	3.9	2.8	4	7.8	3.9	2
Culcita novaeguineae	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Drupa morum	5.9	5.9	24	141.2		1	5.9	5.9	4	23.5		1
Lambis truncata	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Stichodactyla spp.	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Thais spp.	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Tridacna maxima	25.5	6.2	24	43.7	7.3	14	25.5	4.7	4	25.5	4.7	4
Trochus niloticus	352.9	48.7	24	368.3	48.3	23	352.9	62.7	4	352.9	62.7	4
Turbo argyrostomus	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Turbo spp.	5.9	2.9	24	35.3	6.8	4	5.9	2.5	4	7.8	2.3	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.

4.1.6 Yyin 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
Acanthaster planci	12.5	7.0	30	125.0	0.0	3	12.5	8.3	5	31.3	10.4	2
Actinopyga mauritiana	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Conus distans	4.2	4.2	30	125.0		1	4.2	4.2	5	20.8		1
Culcita novaeguineae	20.8	10.5	30	156.3	31.3	4	20.8	9.3	5	34.7	6.9	3
Tectus pyramis	12.5	7.0	30	125.0	0.0	3	12.5	5.1	5	20.8	0.0	3
Tridacna maxima	87.5	24.8	30	218.8	38.1	12	87.5	41.4	5	109.4	45.3	4
Trochus niloticus	983.3	113.2	30	983.3	113.2	30	983.3	111.3	5	983.3	111.3	5
Turbo argyrostomus	54.2	22.2	30	270.8	50.2	6	54.2	34.6	5	135.4	31.3	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.7 Yyin sea cucumber night search (Ns) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga miliaris	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Actinopyga spp.	195.6	157.3	12	391.1	306.0	6	195.6	195.6	2	391.1		1
Atergatis floridus	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Bohadschia argus	22.2	15.3	12	133.3	26.7	2	22.2	22.2	2	44.4		1
Bohadschia vitiensis	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Culcita novaeguineae	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Cypraea tigris	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Cypraea vitellus	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Echinometra mathaei	688.9	665.0	12	4133.3	3866.7	2	688.9	688.9	2	1377.8		1
Etisus splendidus	26.7	15.4	12	106.7	30.8	3	26.7	26.7	2	53.3		1
Holothuria atra	31.1	13.9	12	93.3	13.3	4	31.1	13.3	2	31.1	13.3	2
Holothuria coluber	462.2	186.3	12	924.4	259.3	6	462.2	462.2	2	924.4		1
Holothuria edulis	226.7	56.1	12	226.7	56.1	12	226.7	102.2	2	226.7	102.2	2
Holothuria flavomaculata	71.1	50.1	12	284.4	158.0	3	71.1	71.1	2	142.2		1
Leiaster speciosus	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Portunus spp.	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Stichopus chloronotus	88.9	40.6	12	177.8	64.1	6	88.9	88.9	2	177.8		1
Stichopus spp.	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Strombus luhuanus	13.3	13.3	12	160.0		1	13.3	13.3	2	26.7		1
Synapta spp.	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Tridacna maxima	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Trochus niloticus	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.

4.1.8 Yyin sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Culcita novaeguineae	1.6	1.1	18	14.3	0.0	2	1.6	0.8	3	2.4	0.0	2
Holothuria atra	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Mitra mitra	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Panulirus versicolor	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Pteria spp.	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Spondylus spp.	1.6	1.1	18	14.3	0.0	2	1.6	1.6	3	4.8		1
Stichodactyla spp.	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Terebra dimidiata	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Thelenota ananas	2.4	1.3	18	14.3	0.0	3	2.4	1.4	3	3.6	1.2	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

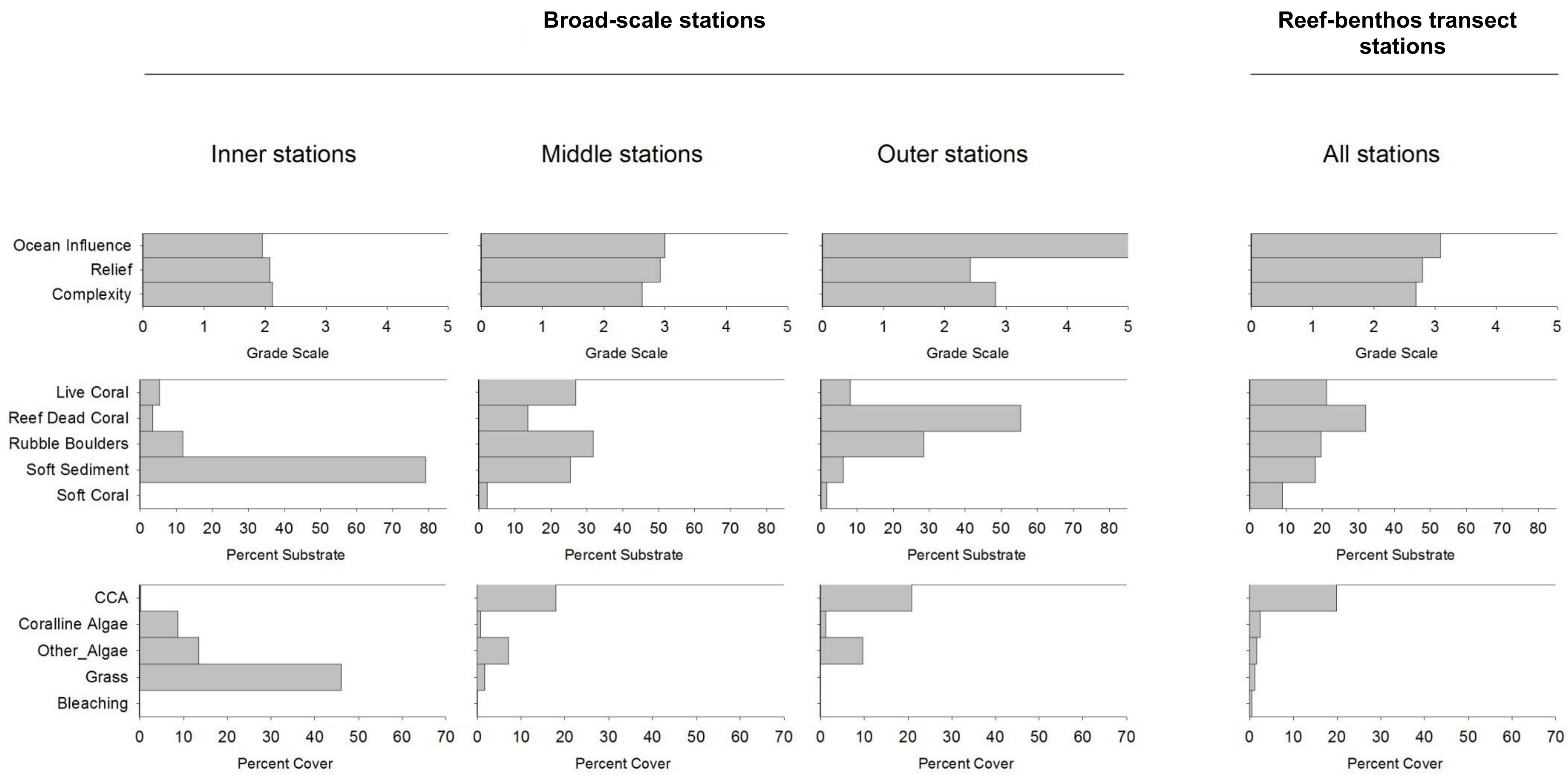
4.1.9 Yyin species size review – all survey methods

Species	Mean length (cm)	SE	n
Trochus niloticus	10.5	0.1	610
Holothuria atra	20.2	0.6	505
Actinopyga spp.	12.0	0.3	400
Tridacna maxima	15.8	0.6	89
Holothuria edulis	20.9	1.0	80
Bohadschia argus	30.1	0.6	54
Hippopus hippopus	15.6	1.5	21
Stichopus chloronotus	21.5	0.5	20
Conus distans	7.3	0.3	18
Turbo argyrostomus	6.6	0.1	14
Holothuria fuscopunctata	40.1	0.5	8
Conus virgo	8.8	0.4	8
Actinopyga mauritiana	17.1	1.1	7
Thelenota ananas	42.0	2.6	5
Conus litteratus	8.6	0.6	5
Holothuria nobilis	26.8	2.8	4
Tectus pyramis	7.0	2.0	4
Lambis truncata	24.0	0.6	3
Bohadschia vitiensis	20.0	0.0	2
Conus marmoreus	8.8	0.3	2
Charonia tritonis	40.0	10.0	2
Stichopus vastus	26.8	1.8	2
Conus spp.	10.0	0.0	12
Lambis lambis	13.0	0.0	12
Strombus luhuanus	5.0	0.0	8
Cypraea tigris	8.0	0.0	4
Trochus spp.	1.1	0.0	1
Cypraea carneola	4.5	0.0	1
Leiaster speciosus	60.0	0.0	1
Actinopyga miliaris	19.0	0.0	1
Stichopus horrens	5.0	0.0	1
Linckia laevigata			178
Echinometra mathaei			159
Holothuria coluber			119
Pyrene spp.			91
Culcita novaeguineae			36
Mespilia globulus			20
Stichodactyla spp.			18
Holothuria flavomaculata			16
Cerithium spp.			10
Strombus gibberulus gibbosus			8
Etisus splendidus			6
Turbo spp.			6
Echinothrix spp.			6
Drupa morum			6
Cypraea moneta			6
Conus leopardus			5
Acanthaster planci			5
Spondylus spp.			4
Synapta spp.			4

4.1.9 Yyin species size review – all survey methods (continued)

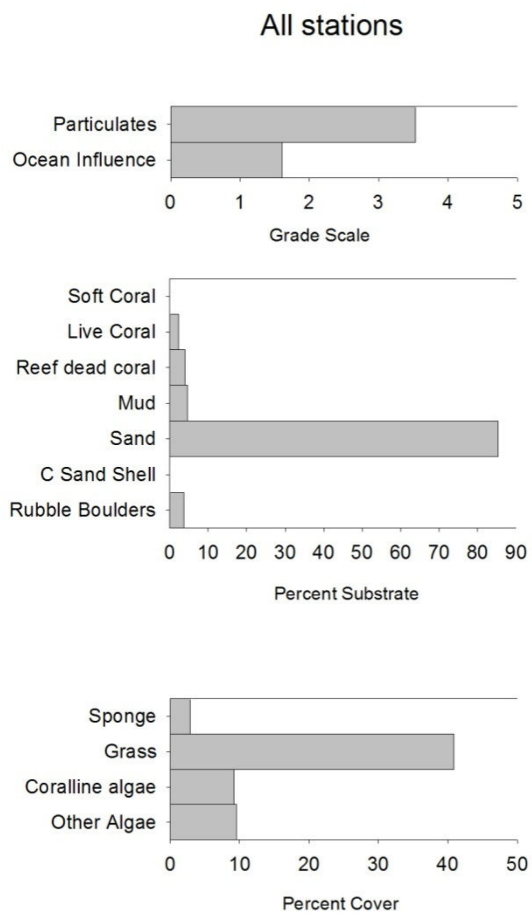
Species	Mean length (cm)	SE	n
Panulirus versicolor			4
Cantharus spp.			4
Cerithium aluco			4
Oliva spp.			4
Lysiosquillina maculata			3
Cypraea annulus			3
Morula spp.			3
Stenopus hispidus			3
Echinothrix diadema			2
Modiolus spp.			2
Portunus spp.			2
Stichopus spp.			2
Protoreaster nodosus			2
Conus ebraeus			2
Isognomon spp.			2
Periclimenes brevicarpalis			2
Thor amboinensis			2
Cassiopea andromeda			2
Mitra mitra			1
Thais spp.			1
Conus coronatus			1
Conus frigidus			1
Tellina palatum			1
Pteria spp.			1
Cypraea isabella			1
Rhinoclavis aspera			1
Terebra dimidiata			1
Atergatis floridus			1
Cassiopea spp.			1
Cypraea vitellus			1

4.1.10 Habitat descriptors for independent assessment – Yyin



4.1.10 Habitat descriptors for independent assessment – Yyin (continued)

Soft-benthos transect stations



4.2 Riiken invertebrate survey data

4.2.1 Invertebrate species recorded in different assessments in Riiken

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*		+		+
Bêche-de-mer	*Actinopyga* spp.			+	
Bêche-de-mer	*Bohadschia argus*	+	+		
Bêche-de-mer	*Bohadschia graeffei*				+
Bêche-de-mer	*Bohadschia vitiensis*	+		+	+
Bêche-de-mer	*Holothuria atra*	+	+	+	+
Bêche-de-mer	*Holothuria coluber*		+		+
Bêche-de-mer	*Holothuria edulis*	+	+		+
Bêche-de-mer	*Holothuria nobilis*	+	+		+
Bêche-de-mer	*Holothuria scabra*			+	
Bêche-de-mer	*Holothuria* spp.		+		
Bêche-de-mer	*Stichopus chloronotus*	+	+	+	+
Bêche-de-mer	*Stichopus vastus*			+	
Bêche-de-mer	*Synapta* spp.	+		+	
Bêche-de-mer	*Thelenota ananas*	+			
Bivalve	*Anadara antiquata*	+			
Bivalve	*Chama* spp.	+			
Bivalve	*Hippopus hippopus*	+	+		
Bivalve	*Hyotissa* spp.	+			
Bivalve	*Pinctada margaritifera*		+		
Bivalve	*Pinna* spp.			+	
Bivalve	*Tridacna derasa*	+			
Bivalve	*Tridacna maxima*	+	+		+
Cnidarians	*Cassiopea andromeda*			+	
Cnidarians	*Cassiopea* spp.	+		+	
Cnidarians	*Stichodactyla* spp.	+	+	+	+
Crustacean	*Eriphia sebana*				+
Crustacean	*Gonodactylus* spp.			+	
Crustacean	*Periclimenes* spp.			+	
Gastropod	*Astralium* spp.		+		+
Gastropod	*Bursa rhodostoma*		+		
Gastropod	*Cerithium aluco*		+		
Gastropod	*Cerithium* spp.			+	
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Clanculus* spp.			+	
Gastropod	*Conus distans*	+	+		+
Gastropod	*Conus ebraeus*		+		
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus leopardus*			+	+
Gastropod	*Conus litteratus*	+			
Gastropod	*Conus lividus*		+		
Gastropod	*Conus marmoreus*	+	+		+
Gastropod	*Conus miliaris*				+
Gastropod	*Conus rattus*		+		
Gastropod	*Conus* spp.	+	+		
Gastropod	*Conus virgo*			+	+

+ = presence of the species.

4.2.1 Invertebrate species recorded in different assessments in Riiken (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Cypraea annulus*	+			
Gastropod	*Cypraea carneola*		+		
Gastropod	*Cypraea erosa*		+		
Gastropod	*Cypraea isabella*		+		
Gastropod	*Cypraea lynx*		+		
Gastropod	*Cypraea moneta*		+	+	
Gastropod	*Cypraea* spp.	+			
Gastropod	*Cypraea tigris*	+	+	+	+
Gastropod	*Drupa morum*				+
Gastropod	*Drupa* spp.				+
Gastropod	*Drupella cornus*		+		
Gastropod	*Haliotis asinina*		+		
Gastropod	*Haliotis* spp.		+		
Gastropod	*Lambis chiragra*	+			
Gastropod	*Lambis lambis*		+	+	
Gastropod	*Lambis* spp.	+			
Gastropod	*Lambis truncata*		+		
Gastropod	*Mitra stictica*	+			
Gastropod	*Morula* spp.				+
Gastropod	*Ovula ovum*		+		
Gastropod	*Pleuroploca filamentosa*		+		+
Gastropod	*Strombus luhuanus*	+	+		
Gastropod	*Tectus pyramis*	+	+		+
Gastropod	*Trochus maculata*	+	+	+	
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.			+	
Gastropod	*Turbo argyrostomus*		+		+
Gastropod	*Turbo chrysostomus*		+		
Gastropod	*Turbo* spp.		+		
Gastropod	*Vasum ceramicum*	+			+
Nudibranch	*Phyllidia* spp.			+	
Star	*Acanthaster planci*		+		+
Star	*Culcita novaeguineae*	+	+		+
Star	*Culcita* spp.				+
Star	*Fromia* spp.	+			
Star	*Linckia laevigata*	+	+		+
Urchin	*Diadema* spp.		+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix calamaris*		+		
Urchin	*Echinothrix diadema*	+	+		
Urchin	*Echinothrix* spp.				+
Urchin	*Mespilia globulus*	+			
Urchin	*Tripneustes gratilla*	+			+

+ = presence of the species.

4.2.2 Riiken 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
Anadara antiquata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Bohadschia argus	6.2	2.0	72	29.9	6.7	15	6.2	2.5	12	9.4	3.3	8
Bohadschia vitiensis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Cassiopea spp.	0.5	0.5	72	33.3		1	0.5	0.5	12	5.6		1
Chama spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus distans	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus litteratus	1.4	0.5	72	16.7	0.0	6	1.4	0.8	12	5.6	1.6	3
Conus marmoreus	0.5	0.5	72	33.3		1	0.5	0.5	12	5.5		1
Conus spp.	0.9	0.6	72	22.2	5.6	3	0.9	0.9	12	11.1		1
Culcita novaeguineae	4.2	1.5	72	27.2	6.1	11	4.2	1.7	12	7.1	2.4	7
Cypraea annulus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Cypraea spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Cypraea tigris	0.9	0.5	72	16.7	0.0	4	0.9	0.5	12	3.7	0.9	3
Echinothrix diadema	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Fromia spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Hippopus hippopus	1.4	0.6	72	20.0	3.3	5	1.4	0.7	12	4.2	1.4	4
Holothuria atra	31.2	10.7	72	132.3	36.2	17	31.2	13.2	12	53.5	18.6	7
Holothuria edulis	7.2	4.9	72	64.5	40.9	8	7.2	5.9	12	21.5	16.9	4
Holothuria nobilis	4.4	1.2	72	24.4	3.1	13	4.4	1.8	12	8.8	2.6	6
Hyotissa spp.	0.7	0.4	72	16.7	0.0	3	0.7	0.5	12	4.2	1.4	2
Lambis chiragra	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Lambis spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Linckia laevigata	18.3	5.4	72	65.7	14.9	20	18.3	8.7	12	27.4	11.9	8
Mespilia globulus	115.7	82.9	72	4166.7	833.3	2	115.1	115.1	12	1381.2		1
Mitra stictica	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Stichodactyla spp.	1.9	0.8	72	26.7	4.1	5	1.9	1.4	12	11.1	5.6	2
Stichopus chloronotus	90.0	57.3	72	270.0	168.3	24	89.8	57.0	12	119.8	74.2	9
Strombus luhuanus	1.4	0.9	72	33.3	9.6	3	1.4	0.8	12	5.6	1.6	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.

4.2.2 Riiken broad-scale assessment data review (continued)
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
Synapta spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tectus pyramis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Thelenota ananas	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tridacna derasa	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Tridacna maxima	3.7	1.1	72	22.2	3.1	12	3.7	1.9	12	11.1	3.6	4
Tripneustes gratilla	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Trochus maculata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Trochus niloticus	0.7	0.4	72	16.6	0.1	3	0.7	0.4	12	2.8	0.0	3
Vasum ceramicum	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	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.

4.2.3 Riiken 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	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Actinopyga mauritiana	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Astralium spp.	8.9	6.6	84	375.0	125.0	2	8.9	8.9	14	125.0		1
Bohadschia argus	47.6	15.0	84	363.6	51.8	11	47.6	27.9	14	166.7	72.2	4
Bursa rhodostoma	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cerithium aluco	32.7	12.5	84	343.8	65.8	8	32.7	14.6	14	91.7	24.3	5
Chicoreus brunneus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Conus distans	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Conus ebraeus	8.9	6.6	84	375.0	125.0	2	8.9	6.4	14	62.5	20.8	2
Conus flavidus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Conus lividus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Conus marmoreus	3.0	3.0	84	250.0		1	3.0	3.0	14	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.

4.2.3 Riiken 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
Conus rattus	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Conus spp.	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Culcita novaeguineae	8.9	5.1	84	250.0	0.0	3	8.9	6.4	14	62.5	20.8	2
Cypraea carneola	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cypraea erosa	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cypraea isabella	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cypraea lynx	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Cypraea moneta	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Cypraea tigris	29.8	9.8	84	277.8	27.8	9	29.8	10.2	14	59.5	12.4	7
Diadema spp.	11.9	5.8	84	250.0	0.0	4	11.9	6.8	14	55.6	13.9	3
Drupella cornus	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Echinometra mathaei	6.0	6.0	84	500.0		1	6.0	6.0	14	83.3		1
Echinothrix calamaris	6.0	6.0	84	500.0		1	6.0	6.0	14	83.3		1
Echinothrix diadema	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Haliotis asinina	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Haliotis spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Hippopus hippopus	29.8	8.9	84	250.0	0.0	10	29.8	11.9	14	83.3	13.2	5
Holothuria atra	131.0	33.7	84	647.1	91.1	17	131.0	55.6	14	305.6	89.8	6
Holothuria coluber	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Holothuria edulis	20.8	9.7	84	350.0	61.2	5	20.8	20.8	14	291.7		1
Holothuria nobilis	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Holothuria spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Lambis lambis	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Lambis truncata	8.9	6.6	84	375.0	125.0	2	8.9	6.4	14	62.5	20.8	2
Linckia laevigata	50.6	13.2	84	303.6	28.5	14	50.6	21.5	14	101.2	33.8	7
Ovula ovum	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Pinctada margaritifera	3.0	3.0	84	250.0		1	3.0	3.0	14	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.

4.2.3 Riiken 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
Pleuroploca filamentosa	3.0	3.0	84	250.0		1	3.0	3.0	14	41.7		1
Stichodactyla spp.	11.9	9.4	84	500.0	250.0	2	11.9	11.9	14	166.7		1
Stichopus chloronotus	333.3	73.5	84	933.3	154.9	30	333.3	155.8	14	583.3	240.9	8
Strombus luhuanus	56.5	20.9	84	475.0	108.3	10	56.5	39.2	14	197.9	118.3	4
Tectus pyramis	11.9	5.8	84	250.0	0.0	4	11.9	8.1	14	83.3	0.0	2
Tridacna maxima	68.5	14.9	84	302.6	24.0	19	68.5	19.8	14	95.8	22.4	10
Trochus maculata	8.9	6.6	84	375.0	125.0	2	8.9	6.4	14	62.5	20.8	2
Trochus niloticus	83.3	32.3	84	700.0	181.8	10	83.3	52.8	14	291.7	148.3	4
Turbo argyrostomus	6.0	4.2	84	250.0	0.0	2	6.0	4.0	14	41.7	0.0	2
Turbo chrysostomus	6.0	6.0	84	500.0		1	6.0	6.0	14	83.3		1
Turbo spp.	3.0	3.0	84	250.0		1	3.0	3.0	14	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.

4.2.4 Riiken soft-benthos transect (SBt) 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 spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Bohadschia vitiensis	10.4	5.9	72	250.0	0.0	3	10.4	5.4	12	41.7	0.0	3
Cassiopea spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Cassiopea andromeda	59.0	18.8	72	354.2	65.0	12	59.0	29.7	12	177.1	52.1	4
Cerithium spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Clanculus spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus leopardus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus virgo	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Cypraea moneta	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1
Cypraea tigris	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Gonodactylus spp.	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Holothuria atra	173.6	40.1	72	416.7	77.1	30	173.6	51.0	12	208.3	54.9	10
Holothuria scabra	55.6	28.9	72	800.0	255.0	5	55.6	55.6	12	666.7		1
Lambis lambis	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Periclimenes spp.	10.4	7.7	72	375.0	125.0	2	10.4	7.5	12	62.5	20.8	2
Phyllidia spp.	10.4	10.4	72	750.0		1	10.4	10.4	12	125.0		1
Pinna spp.	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Stichodactyla spp.	31.3	13.0	72	321.4	71.4	7	31.3	13.7	12	62.5	20.8	6
Stichopus chloronotus	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Stichopus vastus	13.9	8.4	72	333.3	83.3	3	13.9	9.4	12	83.3	0.0	2
Synapta spp.	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Trochus maculata	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Trochus spp.	6.9	6.9	72	500.0		1	6.9	6.9	12	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.5 Riiken 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	0.5	0.5	24	11.1		1	0.5	0.5	4	1.9		1
Conus distans	1.9	1.4	24	22.2	11.1	2	1.9	1.3	4	3.7	1.9	2
Conus miliaris	0.5	0.5	24	11.1		1	0.5	0.5	4	1.9		1
Drupa morum	1.4	1.0	24	16.7	5.6	2	1.4	0.9	4	2.8	0.9	2
Drupa spp.	0.5	0.5	24	11.1		1	0.5	0.5	4	1.9		1
Echinothrix spp.	0.5	0.5	24	11.1		1	0.5	0.5	4	1.9		1
Eriphia sebana	0.5	0.5	24	11.1		1	0.5	0.5	4	1.9		1
Holothuria atra	78.7	11.5	24	89.9	11.1	21	78.7	17.7	4	78.7	17.7	4
Holothuria nobilis	1.9	0.9	24	11.1	0.0	4	1.9	0.8	4	2.5	0.6	3
Linckia laevigata	30.6	10.9	24	73.3	19.6	10	30.6	11.8	4	40.7	8.6	3
Morula spp.	2.8	1.9	24	33.3	0.0	2	2.8	1.6	4	5.6	0.0	2
Stichopus chloronotus	2.8	2.8	24	66.7		1	2.8	2.8	4	11.1		1
Trochus niloticus	1.4	1.4	24	33.3		1	1.4	1.4	4	5.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.6 Riiken 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
Acanthaster planci	27.8	19.1	18	250.0	0.0	2	27.8	27.8	3	83.3		1
Astralium spp.	27.8	19.1	18	250.0	0.0	2	27.8	27.8	3	83.3		1
Conus distans	111.1	36.3	18	285.7	35.7	7	111.1	27.8	3	111.1	27.8	3
Conus marmoreus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Pleuroploca filamentosa	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Stichodactyla spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Stichopus chloronotus	250.0	67.0	18	409.1	77.4	11	250.0	41.7	3	250.0	41.7	3
Tectus pyramis	375.0	83.9	18	519.2	87.1	13	375.0	133.9	3	375.0	133.9	3
Tridacna maxima	41.7	22.6	18	250.0	0.0	3	41.7	24.1	3	62.5	20.8	2
Trochus niloticus	736.1	89.2	18	736.1	89.2	18	736.1	84.5	3	736.1	84.5	3
Turbo argyrostomus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Vasum ceramicum	27.8	19.1	18	250.0	0.0	2	27.8	13.9	3	41.7	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.

4.2.7 Riiken 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 vitiensis	48.9	20.2	12	117.3	26.1	5	48.9	48.9	2	97.8		1
Culcita novaeguineae	22.2	13.9	12	88.9	35.6	3	22.2	22.2	2	44.4		1
Culcita spp.	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Cypraea tigris	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Echinometra mathaei	8.9	8.9	12	106.7		1	8.9	8.9	2	17.8		1
Holothuria atra	168.9	36.5	12	184.2	36.2	11	168.9	17.8	2	168.9	17.8	2
Holothuria coluber	435.6	152.2	12	871.1	161.6	6	435.6	435.6	2	871.1		1
Holothuria edulis	102.2	34.4	12	204.4	32.0	6	102.2	102.2	2	204.4		1
Linckia laevigata	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Stichopus chloronotus	44.4	18.4	12	106.7	23.9	5	44.4	44.4	2	88.9		1
Tripneustes gratilla	8.9	6.0	12	53.3	0.0	2	8.9	0.0	2	8.9	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.

4.2.8 Riiken 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 graeffei	3.6	3.6	12	42.9		1	3.6	3.6	2	7.1		1
Conus leopardus	1.2	1.2	12	14.3		1	1.2	1.2	2	2.4		1
Conus virgo	1.2	1.2	12	14.3		1	1.2	1.2	2	2.4		1
Holothuria nobilis	1.2	1.2	12	14.3		1	1.2	1.2	2	2.4		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.

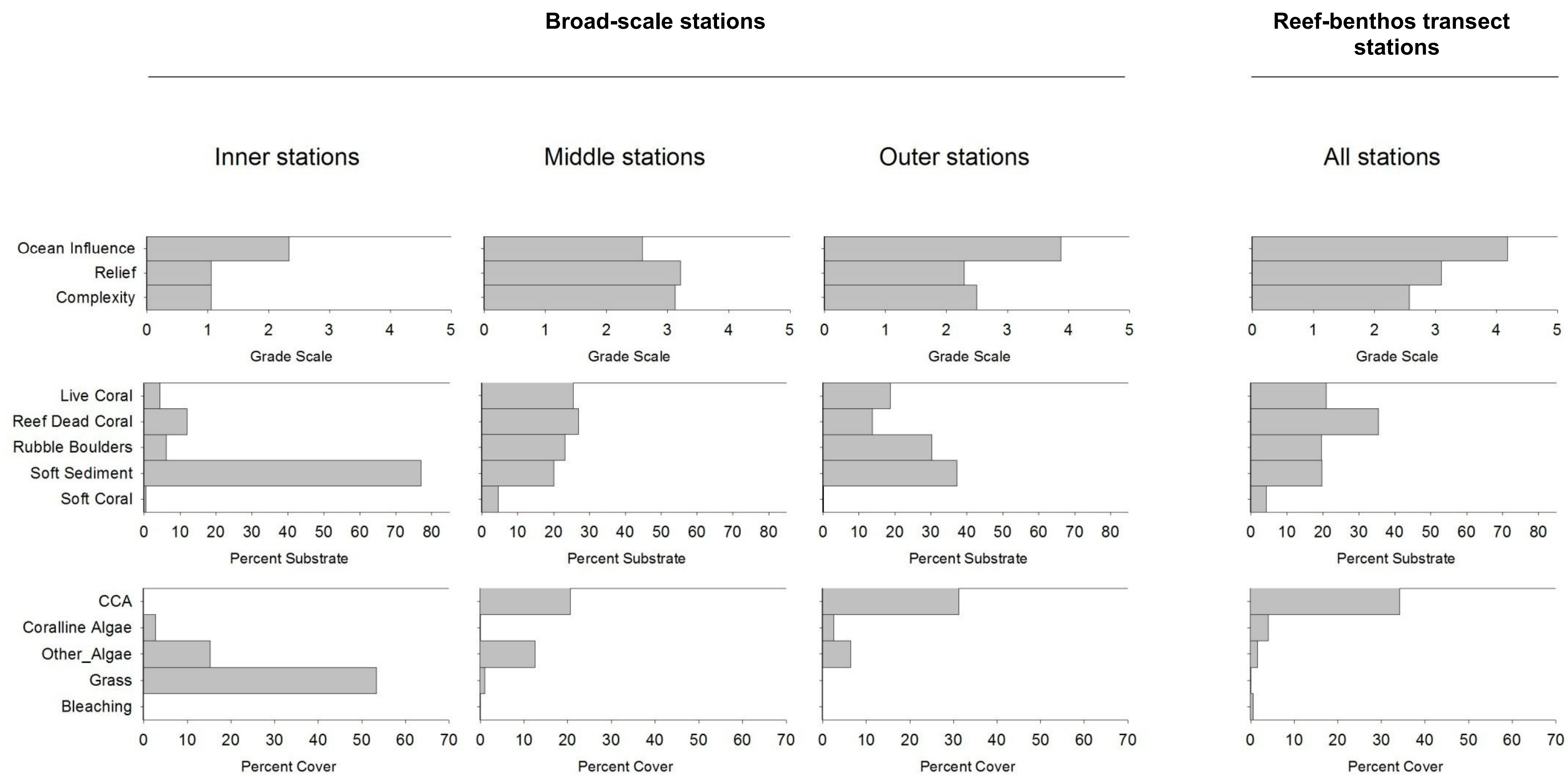
4.2.9 Riiken species size review – all survey methods

Species	Mean length (cm)	SE	n
Stichopus chloronotus	17.1	0.5	537
Holothuria atra	17.7	0.4	437
Trochus niloticus	9.7	0.3	101
Holothuria edulis	19.1	2.1	61
Bohadschia argus	33.9	1.1	43
Tridacna maxima	15.3	0.9	42
Holothuria nobilis	28.3	1.1	26
Strombus luhuanus	5.3	0.5	25
Cypraea tigris	7.6	0.5	17
Tectus pyramis	6.8	0.6	17
Holothuria scabra	18.1	0.8	16
Hippopus hippopus	17.1	1.5	16
Conus distans	8.5	0.2	15
Bohadschia vitiensis	22.8	2.8	15
Cerithium aluco	8.5	0.3	11
Conus spp.	6.5	1.0	6
Conus litteratus	11.0	1.0	6
Stichopus vastus	21.0	2.3	4
Lambis lambis	14.0	1.0	4
Vasum ceramicum	10.5	1.5	4
Conus virgo	7.7	0.3	3
Trochus spp.	1.7	0.2	2
Actinopyga mauritiana	19.0	7.0	2
Turbo chrysostomus	4.0	0.0	2
Tridacna derasa	27.5	12.5	2
Conus leopardus	9.7	0.2	2
Conus marmoreus	8.5	0.0	4
Turbo argyrostomus	6.5	0.0	3
Gonodactylus spp.	10.0	0.0	2
Pleuroploca filamentosa	10.6	0.0	2
Cypraea carneola	5.0	0.0	1
Ovula ovum	9.0	0.0	1
Pinctada margaritifera	12.0	0.0	1
Clanculus spp.	1.4	0.0	1
Anadara antiquata	2.5	0.0	1
Actinopyga spp.	20.0	0.0	1
Cypraea isabella	1.9	0.0	1
Conus lividus	2.5	0.0	1
Thelenota ananas	30.0	0.0	1
Mespilia globulus			500
Linckia laevigata			163
Holothuria coluber			99
Culcita novaeguineae			26
Stichodactyla spp.			22
Cassiopea andromeda			17
Morula spp.			6
Astralium spp.			5
Trochus maculata			5

4.2.9 Riiken species size review – all survey methods (continued)

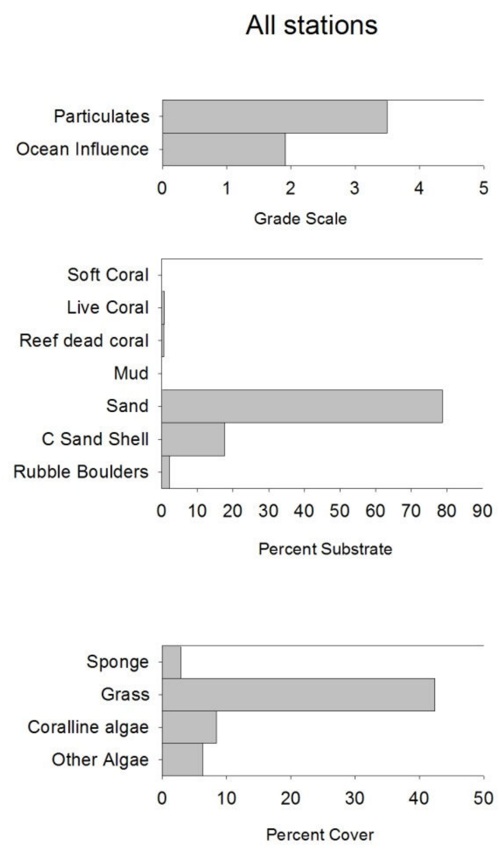
Species	Mean length (cm)	SE	n
Cypraea moneta			4
Echinometra mathaei			4
Diadema spp.			4
Acanthaster planci			3
Hyotissa spp.			3
Lambis truncata			3
Synapta spp.			3
Cassiopea spp.			3
Echinothrix diadema			3
Tripneustes gratilla			3
Drupa morum			3
Periclimenes spp.			3
Conus ebraeus			3
Phyllidia spp.			3
Bohadschia graeffei			3
Conus rattus			2
Echinothrix calamaris			2
Fromia spp.			2
Holothuria spp.			1
Cerithium spp.			1
Eriphia sebana			1
Drupella cornus			1
Haliotis asinina			1
Drupa spp.			1
Haliotis spp.			1
Lambis spp.			1
Cypraea erosa			1
Echinothrix spp.			1
Cypraea lynx			1
Cypraea spp.			1
Chicoreus brunneus			1
Conus miliaris			1
Culcita spp.			1
Cypraea annulus			1
Conus flavidus			1
Chama spp.			1
Bursa rhodostoma			1
Pinna spp.			1
Turbo spp.			1
Mitra stictica			1
Lambis chiragra			1

4.2.10 Habitat descriptors for independent assessment – Riiken



4.2.10 Habitat descriptors for independent assessment – Riiken (continued)

Soft-benthos transect stations



4.3 Piis-Panewu invertebrate survey data

4.3.1 Invertebrate species recorded in different assessments in Piis-Panewu

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+	+
Bêche-de-mer	*Actinopyga miliaris*			+
Bêche-de-mer	*Bohadschia argus*	+	+	+
Bêche-de-mer	*Bohadschia graeffei*	+	+	+
Bêche-de-mer	*Bohadschia vitiensis*			+
Bêche-de-mer	*Holothuria atra*	+	+	+
Bêche-de-mer	*Holothuria edulis*	+	+	+
Bêche-de-mer	*Holothuria fuscogilva*			+
Bêche-de-mer	*Holothuria fuscopunctata*			+
Bêche-de-mer	*Stichopus chloronotus*	+	+	+
Bêche-de-mer	*Stichopus hermanni*	+		
Bêche-de-mer	*Synapta* spp.		+	
Bêche-de-mer	*Thelenota ananas*			+
Bêche-de-mer	*Thelenota anax*	+		+
Bivalve	*Chama* spp.	+		+
Bivalve	*Hippopus hippopus*	+	+	
Bivalve	*Hyotissa* spp.	+		
Bivalve	*Pinctada margaritifera*	+		+
Bivalve	*Spondylus* spp.	+	+	
Bivalve	*Tridacna crocea*		+	
Bivalve	*Tridacna maxima*	+	+	+
Bivalve	*Tridacna squamosa*	+		
Cnidarian	*Stichodactyla* spp.	+	+	+
Crustacean	*Carpilius maculatus*			+
Crustacean	*Panulirus* spp.	+		
Gastropod	*Astralium* spp.		+	+
Gastropod	*Cerithium nodulosum*		+	+
Gastropod	*Chicoreus* spp.	+		
Gastropod	*Conus ebraeus*		+	
Gastropod	*Conus flavidus*		+	
Gastropod	*Conus* spp.	+	+	+
Gastropod	*Conus vexillum*		+	+
Gastropod	*Cypraea annulus*		+	
Gastropod	*Cypraea caputserpensis*		+	
Gastropod	*Cypraea moneta*		+	
Gastropod	*Cypraea* spp.	+		
Gastropod	*Cypraea tigris*		+	
Gastropod	*Lambis chiragra*		+	
Gastropod	*Lambis crocata*		+	
Gastropod	*Lambis lambis*	+	+	
Gastropod	*Lambis scorpius*	+		
Gastropod	*Lambis truncata*	+		+
Gastropod	*Ovula ovum*	+		
Gastropod	*Pleuroploca* spp.			+
Gastropod	*Strombus luhuanus*		+	
Gastropod	*Strombus* spp.			+

+ = presence of the species.

4.3.1 Invertebrate species recorded in different assessments in Piis-Panewu (continued)

Group	Species	Broad scale	Reef benthos	Others
Gastropod	*Tectus conus*		+	+
Gastropod	*Tectus pyramis*	+	+	+
Gastropod	*Thais aculeata*		+	
Gastropod	*Thais* spp.		+	
Gastropod	*Trochus maculata*		+	+
Gastropod	*Trochus niloticus*	+	+	+
Gastropod	*Trochus* spp.	+	+	
Gastropod	*Turbo argyrostomus*	+	+	+
Gastropod	*Vasum ceramicum*		+	
Octopus	*Octopus* spp.		+	
Star	*Acanthaster planci*	+	+	+
Star	*Culcita novaeguineae*	+	+	+
Star	*Linckia laevigata*	+	+	+
Urchin	*Echinometra mathaei*		+	
Urchin	*Echinothrix diadema*	+	+	+
Urchin	*Heterocentrotus mammillatus*	+	+	+
Urchin	*Tripneustes gratilla*		+	

+ = presence of the species.

4.3.2 Piis-Panewu 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	28.6	7.1	81	68.1	14.3	34	28.3	12.4	14	36.1	15.0	11
Actinopyga mauritiana	0.8	0.4	81	16.7	0.0	4	0.8	0.5	14	3.7	0.9	3
Bohadschia argus	2.2	0.9	81	26.0	4.8	7	2.2	1.0	14	6.1	1.6	5
Bohadschia graeffei	12.7	4.8	81	46.9	15.8	22	12.7	6.2	14	17.7	8.2	10
Chama spp.	1.2	0.6	81	20.0	3.3	5	1.2	0.5	14	4.1	0.7	4
Chicoreus spp.	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Conus spp.	0.4	0.3	81	16.7	0.0	2	0.4	0.3	14	2.8	0.0	2
Culcita novaeguineae	3.1	0.9	81	19.0	2.5	13	2.9	1.2	14	5.1	1.7	8
Cypraea spp.	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Echinothrix diadema	0.4	0.3	81	16.5	0.1	2	0.4	0.3	14	2.7	0.0	2
Heterocentrotus mammillatus	0.4	0.3	81	16.5	0.1	2	0.4	0.4	14	5.4		1
Hippopus hippopus	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Holothuria atra	89.8	42.7	81	316.1	141.9	23	87.8	71.6	14	175.6	140.1	7
Holothuria edulis	0.6	0.4	81	16.7	0.0	3	0.6	0.3	14	2.7	0.1	3
Hyotissa spp.	2.5	1.2	81	40.0	11.3	5	2.4	1.1	14	6.7	1.9	5
Lambis lambis	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Lambis scorpius	0.2	0.2	81	16.7		1	0.4	0.4	14	5.6		1
Lambis truncata	0.6	0.5	81	24.7	8.1	2	0.6	0.6	14	8.3		1
Linckia laevigata	5.7	1.2	81	22.0	1.8	21	5.5	1.9	14	9.6	2.5	8
Ovula ovum	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Panulirus spp.	0.2	0.2	81	16.7		1	0.4	0.4	14	5.6		1
Pinctada margaritifera	1.2	0.5	81	16.7	0.0	6	1.2	0.5	14	4.1	0.7	4
Spondylus spp.	0.6	0.3	81	16.6	0.1	3	0.6	0.3	14	2.8	0.0	3
Stichodactyla spp.	6.1	1.2	81	20.7	1.8	24	6.9	1.9	14	8.0	2.0	12
Stichopus chloronotus	4.5	1.9	81	45.7	12.1	8	5.5	2.6	14	12.9	4.8	6
Stichopus hermanni	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Tectus pyramis	1.0	0.4	81	16.4	0.2	5	1.0	0.5	14	3.4	0.7	4
Thelenota anax	0.4	0.3	81	16.5	0.1	2	0.4	0.3	14	2.8	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.

4.3.2 Piis-Panewu broad-scale assessment data review (continued)
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
Tridacna maxima	33.9	5.3	81	67.0	7.6	41	33.9	9.9	14	47.5	11.2	10
Tridacna squamosa	0.4	0.3	81	16.3	0.4	2	0.6	0.4	14	4.1	1.4	2
Trochus niloticus	8.1	1.3	81	21.2	1.4	31	8.3	1.0	14	8.3	1.0	14
Trochus spp.	0.2	0.2	81	16.7		1	0.2	0.2	14	2.8		1
Turbo argyrostomus	1.4	0.7	81	23.3	4.1	5	1.4	0.7	14	4.8	1.3	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 Piis-Panewu 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	7.8	5.8	96	375.0	125.0	2	7.8	5.7	16	62.5	20.8	2
Actinopyga mauritiana	15.6	8.1	96	375.0	72.2	4	15.6	9.2	16	83.3	24.1	3
Astralium spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Bohadschia argus	13.0	5.7	96	250.0	0.0	5	13.0	5.0	16	41.7	0.0	5
Bohadschia graeffei	18.2	11.8	96	583.3	220.5	3	18.2	15.7	16	145.8	104.2	2
Cerithium nodulosum	28.6	10.4	96	343.8	45.7	8	28.6	13.0	16	91.7	24.3	5
Conus ebraeus	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Conus flavidus	5.2	5.2	96	500.0		1	5.2	5.2	16	83.3		1
Conus spp.	112.0	18.5	96	325.8	27.7	33	112.0	25.1	16	128.0	26.0	14
Conus vexillum	18.2	13.0	96	875.0	125.0	2	18.2	12.6	16	145.8	20.8	2
Culcita novaeguineae	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	2
Cypraea annulus	20.8	14.2	96	666.7	300.5	3	20.8	20.8	16	333.3		1
Cypraea caputserpensis	7.8	4.5	96	250.0	0.0	3	7.8	4.2	16	41.7	0.0	3
Cypraea moneta	20.8	9.6	96	400.0	61.2	5	20.8	11.4	16	83.3	29.5	4
Cypraea tigris	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Echinometra mathaei	36.5	11.7	96	350.0	40.8	10	36.5	14.7	16	97.2	23.2	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.

4.3.3 Piis-Panewu 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
Echinothrix diadema	109.4	22.8	96	437.5	48.2	24	109.4	40.6	16	175.0	55.8	10
Heterocentrotus mammillatus	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Hippopus hippopus	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Holothuria atra	138.0	37.4	96	576.1	117.0	23	138.0	72.1	16	315.5	142.9	7
Holothuria edulis	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Lambis chiragra	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	2
Lambis crocata	5.2	3.7	96	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Lambis lambis	18.2	9.3	96	350.0	100.0	5	18.2	13.2	16	97.2	55.6	3
Linckia laevigata	101.6	17.6	96	325.0	27.2	30	101.6	21.2	16	135.4	19.9	12
Octopus spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Spondylus spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Stichodactyla spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Stichopus chloronotus	41.7	16.0	96	400.0	100.0	10	41.7	24.1	16	133.3	62.4	5
Strombus luhuanus	28.6	13.3	96	458.3	119.3	6	28.6	14.1	16	91.7	30.6	5
Synapta spp.	5.2	3.7	96	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Tectus conus	23.4	9.8	96	321.4	71.4	7	23.4	11.4	16	75.0	24.3	5
Tectus pyramis	39.1	13.0	96	312.5	62.5	12	39.1	14.5	16	78.1	21.5	8
Thais aculeata	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Thais spp.	5.2	3.7	96	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Tridacna crocea	7.8	7.8	96	750.0		1	7.8	7.8	16	125.0		1
Tridacna maxima	164.1	26.4	96	393.8	41.9	40	164.1	33.5	16	187.5	33.8	14
Tripneustes gratilla	23.4	16.6	96	1125.0	125.0	2	23.4	23.4	16	375.0		1
Trochus maculata	7.8	5.8	96	375.0	125.0	2	7.8	5.7	16	62.5	20.8	2
Trochus niloticus	59.9	12.7	96	287.5	20.5	20	59.9	15.2	16	95.8	15.3	10
Trochus spp.	13.0	5.7	96	250.0	0.0	5	13.0	5.0	16	41.7	0.0	5
Turbo argyrostomus	52.1	15.7	96	357.1	62.6	14	52.1	22.0	16	104.2	36.1	8
Vasum ceramicum	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	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 Piis-Panewu 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	13.1	3.6	36	39.2	5.3	12	13.1	6.8	6	19.6	8.5	4
Conus spp.	1.3	0.9	36	23.5	0.0	2	1.3	0.8	6	3.9	0.0	2
Culcita novaeguineae	3.3	1.4	36	23.5	0.0	5	3.3	1.6	6	6.5	1.3	3
Echinothrix diadema	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Heterocentrotus mammillatus	1.3	1.3	36	47.1		1	1.3	1.3	6	7.8		1
Linckia laevigata	2.0	1.1	36	23.5	0.0	3	2.0	2.0	6	11.8		1
Pleuroploca spp.	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Stichodactyla spp.	3.9	1.8	36	28.2	4.7	5	3.9	2.5	6	7.8	3.9	3
Stichopus chloronotus	4.6	1.8	36	27.5	3.9	6	4.6	2.9	6	13.7	2.0	2
Tectus conus	1.3	0.9	36	23.5	0.0	2	1.3	0.8	6	3.9	0.0	2
Tectus pyramis	3.3	1.7	36	29.4	5.9	4	3.3	1.9	6	6.5	2.6	3
Tridacna maxima	17.0	4.3	36	38.2	6.4	16	17.0	4.0	6	17.0	4.0	6
Trochus niloticus	9.2	2.7	36	29.9	4.6	11	9.2	3.0	6	11.0	2.9	5
Turbo argyrostomus	3.3	1.7	36	29.4	5.9	4	3.3	2.6	6	9.8	5.9	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.

4.3.5 Piis-Panewu 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	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Astralium spp.	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Culcita novaeguineae	20.8	7.9	36	125.0	0.0	6	20.8	7.6	6	31.3	6.0	4
Stichodactyla spp.	6.9	4.8	36	125.0	0.0	2	6.9	4.4	6	20.8	0.0	2
Stichopus chloronotus	10.4	5.8	36	125.0	0.0	3	10.4	10.4	6	62.5		1
Tectus pyramis	72.9	15.2	36	164.1	15.0	16	72.9	10.4	6	72.9	10.4	6
Tridacna maxima	34.7	12.8	36	178.6	25.3	7	34.7	6.9	6	34.7	6.9	6
Trochus maculata	3.5	3.5	36	125.0		1	3.5	3.5	6	20.8		1
Trochus niloticus	107.6	29.9	36	276.8	51.1	14	107.6	59.8	6	129.2	68.3	5
Turbo argyrostomus	118.1	26.8	36	236.1	36.3	18	118.1	40.1	6	118.1	40.1	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.

4.3.6 Piis-Panewu 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
Acanthaster planci	17.8	12.0	12	106.7	0.0	2	17.8	17.8	2	35.6		1
Actinopyga miliaris	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Bohadschia argus	22.2	7.9	12	53.3	0.0	5	22.2	4.4	2	22.2	4.4	2
Bohadschia graeffei	22.2	12.2	12	88.9	17.8	3	22.2	22.2	2	44.4		1
Bohadschia vitiensis	13.3	7.0	12	53.3	0.0	3	13.3	13.3	2	26.7		1
Carpilius maculatus	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Cerithium nodulosum	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Conus vexillum	8.9	8.9	12	106.7		1	8.9	8.9	2	17.8		1
Holothuria atra	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Holothuria edulis	13.3	9.6	12	80.0	26.7	2	13.3	13.3	2	26.7		1
Linckia laevigata	4.4	4.4	12	53.3		1	4.4	4.4	2	8.9		1
Trochus niloticus	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		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.

4.3.7 Piis-Panewu sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Chama spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Culcita novaeguineae	1.4	0.8	30	14.3	0.0	3	1.4	1.0	5	3.6	1.2	2
Holothuria atra	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Holothuria fuscogilva	1.9	0.9	30	14.3	0.0	4	1.9	0.9	5	3.2	0.8	3
Holothuria fuscopunctata	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Lambis truncata	1.4	1.1	30	21.4	7.1	2	1.4	1.0	5	3.6	1.2	2
Pinctada margaritifera	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Strombus spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Thelenota ananas	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Thelenota anax	3.3	1.3	30	16.7	2.4	6	3.3	1.2	5	4.2	1.1	4
Tridacna maxima	1.9	1.1	30	19.0	4.8	3	1.9	0.9	5	3.2	0.8	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.

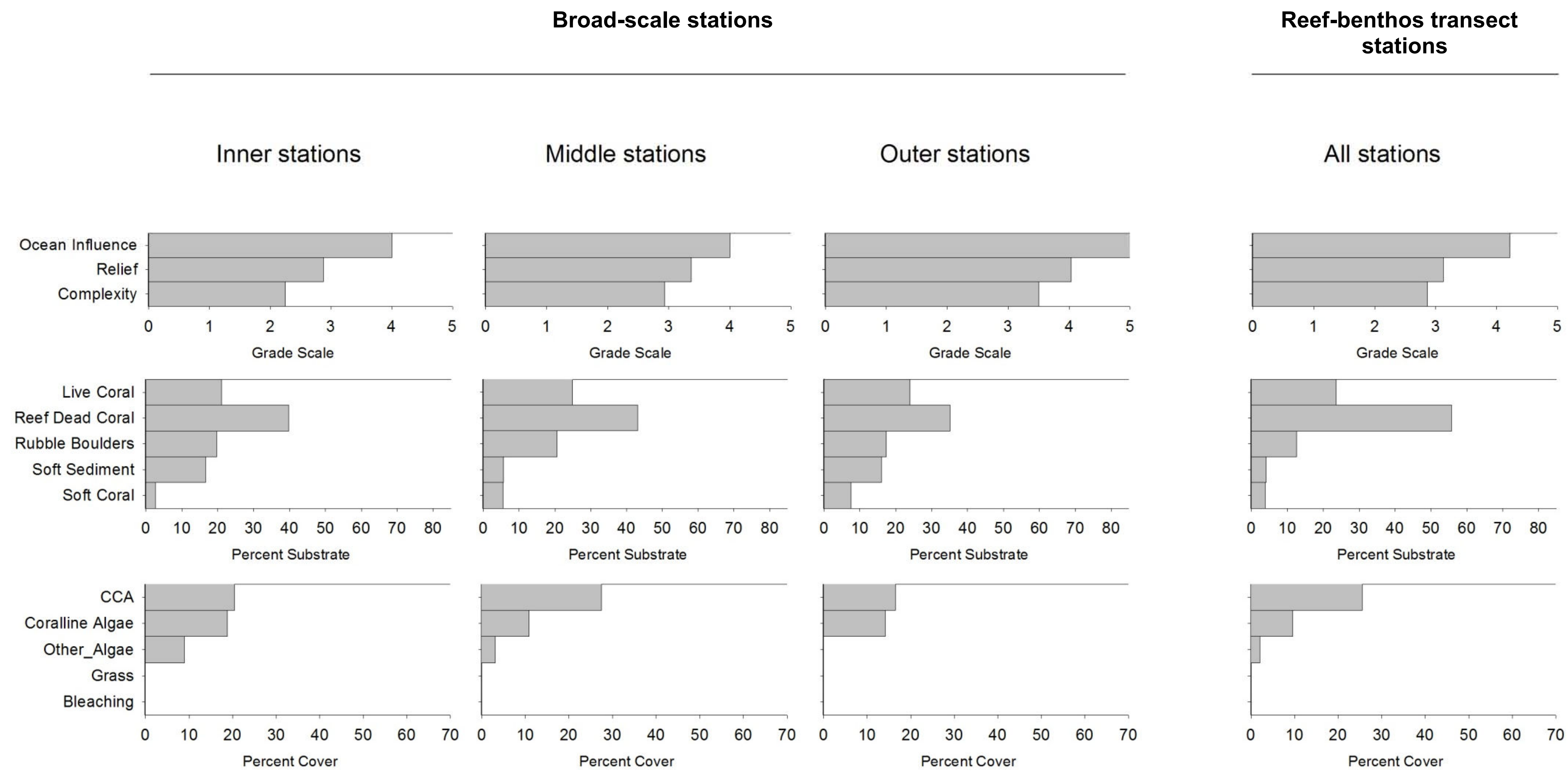
4.3.8 Piis-Panewu species size review – all survey methods

Species	Mean length (cm)	SE	n
Holothuria atra	17.4	0.7	502
Tridacna maxima	11.0	0.3	269
Trochus niloticus	9.4	0.2	110
Bohadschia graeffei	30.4	1.0	74
Turbo argyrostomus	5.7	0.3	66
Stichopus chloronotus	17.9	1.1	48
Conus spp.	5.4	0.7	47
Tectus pyramis	5.5	0.2	46
Actinopyga mauritiana	18.9	0.6	31
Bohadschia argus	31.9	1.5	23
Cerithium nodulosum	9.1	0.2	12
Strombus luhuanus	4.2	0.1	11
Tectus conus	4.7	0.4	11
Tripneustes gratilla	8.6	0.1	9
Conus vexillum	8.5	0.2	9
Thelenota anax	46.8	4.4	9
Lambis lambis	15.3	0.5	8
Pinctada margaritifera	13.5	0.7	7
Holothuria edulis	24.5	4.5	7
Trochus spp.	3.5	0.5	6
Lambis truncata	30.0	2.5	6
Holothuria fuscogilva	35.5	2.3	4
Trochus maculata	3.5	0.4	4
Vasum ceramicum	12.7	1.1	3
Tridacna crocea	5.3	0.7	3
Lambis chiragra	15.3	1.2	3
Lambis crocata	12.0	0.0	2
Astralium spp.	3.3	0.3	2
Conus flavidus	4.0	0.2	2
Thais spp.	4.8	1.0	2
Hippopus hippopus	21.5	3.5	2
Linckia laevigata	35.0	0.0	71
Spondylus spp.	5.0	0.0	4
Bohadschia vitiensis	18.0	0.0	3
Tridacna squamosa	18.0	0.0	2
Cypraea tigris	7.2	0.0	1
Thelenota ananas	40.0	0.0	1
Stichopus hermanni	38.0	0.0	1
Acanthaster planci			146
Echinothrix diadema			45
Stichodactyla spp.			39
Culcita novaeguineae			32
Echinometra mathaei			14
Hyotissa spp.			12
Cypraea annulus			8
Cypraea moneta			8
Chama spp.			7
Heterocentrotus mammillatus			5

4.3.8 Piis-Panewu species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n
Cypraea caputserpensis			3
Carpilius maculatus			2
Synapta spp.			2
Thais aculeata			1
Panulirus spp.			1
Holothuria fuscopunctata			1
Chicoreus spp.			1
Conus ebraeus			1
Strombus spp.			1
Lambis scorpius			1
Cypraea spp.			1
Actinopyga miliaris			1
Ovula ovum			1
Octopus spp.			1
Pleuroploca spp.			1

4.3.9 Habitat descriptors for independent assessment – Piis-Panewu



4.4 Romanum invertebrate survey data

4.4.1 Invertebrate species recorded in different assessments in Romanum

Group	Species	Broad scale	Reef benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+	+
Bêche-de-mer	*Actinopyga miliaris*	+	+	+
Bêche-de-mer	*Bohadschia argus*	+	+	+
Bêche-de-mer	*Bohadschia graeffei*	+	+	+
Bêche-de-mer	*Bohadschia similis*			+
Bêche-de-mer	*Bohadschia vitiensis*	+	+	+
Bêche-de-mer	*Holothuria atra*	+	+	+
Bêche-de-mer	*Holothuria coluber*		+	+
Bêche-de-mer	*Holothuria edulis*	+	+	+
Bêche-de-mer	*Holothuria fuscogilva*			+
Bêche-de-mer	*Holothuria fuscopunctata*	+		+
Bêche-de-mer	*Holothuria leucospilota*		+	
Bêche-de-mer	*Holothuria nobilis*	+		
Bêche-de-mer	*Holothuria* spp.			+
Bêche-de-mer	*Stichopus chloronotus*	+	+	+
Bêche-de-mer	*Stichopus hermanni*	+	+	+
Bêche-de-mer	*Stichopus horrens*		+	+
Bêche-de-mer	*Stichopus vastus*			+
Bêche-de-mer	*Synapta* spp.	+		
Bêche-de-mer	*Thelenota ananas*	+		+
Bêche-de-mer	*Thelenota anax*			+
Bivalve	*Atrina* spp.	+		
Bivalve	*Chama* spp.	+	+	
Bivalve	*Hippopus hippopus*	+		
Bivalve	*Hyotissa* spp.	+		+
Bivalve	*Pinctada margaritifera*	+		
Bivalve	*Pteria* spp.			+
Bivalve	*Spondylus* spp.	+		+
Bivalve	*Tridacna maxima*	+	+	+
Bivalve	*Tridacna squamosa*		+	
Cnidarians	*Stichodactyla* spp.	+	+	+
Crustacean	*Panulirus* spp.	+		
Gastropod	*Cantharus* spp.		+	
Gastropod	*Cassis cornuta*	+		+
Gastropod	*Cerithium nodulosum*		+	
Gastropod	*Conus ebraeus*		+	
Gastropod	*Conus miles*		+	
Gastropod	*Conus* spp.	+	+	+
Gastropod	*Conus vexillum*		+	
Gastropod	*Cypraea annulus*		+	
Gastropod	*Cypraea caputserpensis*		+	
Gastropod	*Cypraea isabella*		+	
Gastropod	*Cypraea lynx*		+	
Gastropod	*Cypraea moneta*		+	
Gastropod	*Cypraea tigris*	+		
Gastropod	*Drupa* spp.		+	

+ = presence of the species.

4.4.1 Invertebrate species recorded in different assessments in Romanum (continued)

Group	Species	Broad scale	Reef benthos	Others
Gastropod	*Drupella* spp.		+	
Gastropod	*Lambis chiragra*		+	
Gastropod	*Lambis crocata*		+	+
Gastropod	*Lambis lambis*	+	+	
Gastropod	*Lambis truncata*	+		
Gastropod	*Pleuroploca* spp.		+	
Gastropod	*Strombus luhuanus*	+		
Gastropod	*Tectus conus*		+	
Gastropod	*Tectus pyramis*	+	+	+
Gastropod	*Tectus* spp.		+	
Gastropod	*Thais aculeata*		+	
Gastropod	*Thais* spp.		+	
Gastropod	*Trochus maculata*		+	+
Gastropod	*Trochus niloticus*	+	+	+
Gastropod	*Trochus* spp.		+	+
Gastropod	*Turbo argyrostomus*		+	+
Gastropod	*Tutufa rubeta*		+	
Gastropod	*Vasum ceramicum*		+	+
Gastropod	*Vasum* spp.		+	
Octopus	*Octopus* spp.		+	+
Star	*Acanthaster planci*	+	+	+
Star	*Choriaster granulatus*			+
Star	*Culcita novaeguineae*	+	+	+
Star	*Linckia laevigata*	+	+	
Urchin	*Echinometra mathaei*	+	+	+
Urchin	*Echinothrix calamaris*		+	
Urchin	*Echinothrix diadema*		+	+
Urchin	*Tripneustes gratilla*		+	

+ = presence of the species.

4.4.2 Romanum 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	9.5	2.2	72	31.0	4.8	22	9.5	3.2	12	16.3	3.8	7
Actinopyga mauritiana	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Actinopyga miliaris	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Atrina spp.	0.9	0.6	72	22.2	5.6	3	0.9	0.5	12	3.7	0.9	3
Bohadschia argus	5.1	1.5	72	26.1	4.2	14	5.1	2.6	12	10.2	4.4	6
Bohadschia graeffei	22.7	4.6	72	40.8	7.1	40	22.7	8.9	12	24.7	9.5	11
Bohadschia vitiensis	1.6	1.4	72	58.3	41.7	2	1.6	1.4	12	9.7	7.0	2
Cassis cornuta	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Chama spp.	1.2	0.6	72	20.8	4.2	4	1.2	0.6	12	4.6	0.9	3
Conus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Culcita novaeguineae	3.2	1.1	72	23.3	3.7	10	3.2	1.4	12	6.5	2.2	6
Cypraea tigris	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Echinometra mathaei	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Hippopus hippopus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Holothuria atra	63.2	16.3	72	126.4	29.1	36	63.2	25.8	12	84.3	31.6	9
Holothuria edulis	8.8	2.6	72	37.3	7.6	17	8.8	3.1	12	15.1	3.9	7
Holothuria fuscopunctata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Holothuria nobilis	1.4	0.6	72	20.0	3.3	5	1.4	0.6	12	4.2	0.8	4
Hyotissa spp.	10.2	3.9	72	61.1	17.4	12	10.2	4.9	12	20.4	8.1	6
Lambis lambis	1.4	0.6	72	19.9	3.4	5	1.4	0.8	12	5.5	1.6	3
Lambis truncata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Linckia laevigata	20.4	4.8	72	48.9	9.2	30	20.4	8.1	12	24.4	9.3	10
Panulirus spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Pinctada margaritifera	2.3	0.8	72	18.5	1.9	9	2.3	1.0	12	5.5	1.5	5
Spondylus spp.	2.1	0.8	72	21.4	3.1	7	2.1	1.1	12	6.2	2.1	4
Stichodactyla spp.	25.9	2.9	72	36.6	3.1	51	25.9	4.1	12	28.3	3.7	11
Stichopus chloronotus	73.1	60.1	72	229.0	186.8	23	73.1	59.9	12	109.7	88.8	8
Stichopus hermanni	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	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.

4.4.2 Romanum broad-scale assessment data review (continued)
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
Strombus luhuanus	0.5	0.5	72	33.3		1	0.5	0.5	12	5.6		1
Synapta spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Tectus pyramis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Thelenota ananas	1.4	0.5	72	16.6	0.1	6	1.4	1.0	12	8.3	2.7	2
Tridacna maxima	29.6	5.7	72	64.6	9.3	33	29.6	11.4	12	39.5	13.8	9
Trochus niloticus	6.2	1.6	72	28.1	3.6	16	6.2	1.7	12	8.3	1.7	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.

4.4.3 Romanum 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	15.6	6.2	96	250.0	0.0	6	15.6	6.4	16	50.0	8.3	5
Actinopyga mauritiana	23.4	7.5	96	250.0	0.0	9	23.4	6.6	16	46.9	5.2	8
Actinopyga miliaris	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Bohadschia argus	39.1	11.3	96	312.5	32.6	12	39.1	15.0	16	104.2	20.8	6
Bohadschia graeffei	13.0	6.8	96	312.5	62.5	4	13.0	6.3	16	52.1	10.4	4
Bohadschia vitiensis	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Cantharus spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Cerithium nodulosum	5.2	5.2	96	500.0		1	5.2	5.2	16	83.3		1
Chama spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Conus ebraeus	10.4	8.2	96	500.0	250.0	2	10.4	8.1	16	83.3	41.7	2
Conus miles	13.0	6.8	96	312.5	62.5	4	13.0	6.3	16	52.1	10.4	4
Conus spp.	182.3	25.2	96	407.0	32.2	43	182.3	30.6	16	208.3	28.6	14
Conus vexillum	18.2	7.6	96	291.7	41.7	6	18.2	7.6	16	58.3	10.2	5
Culcita novaeguineae	7.8	4.5	96	250.0	0.0	3	7.8	4.2	16	41.7	0.0	3
Cypraea annulus	5.2	5.2	96	500.0		1	5.2	5.2	16	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.3 Romanum 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
Cypraea caputserpensis	10.4	5.1	96	250.0	0.0	4	10.4	10.4	16	166.7		1
Cypraea isabella	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Cypraea lynx	7.8	4.5	96	250.0	0.0	3	7.8	4.2	16	41.7	0.0	3
Cypraea moneta	28.6	9.7	96	305.6	36.7	9	28.6	13.6	16	76.4	27.3	6
Drupa spp.	23.4	8.3	96	281.3	31.3	8	23.4	12.0	16	93.8	26.2	4
Drupella spp.	5.2	5.2	96	500.0		1	5.2	5.2	16	83.3		1
Echinometra mathaei	18.2	8.5	96	350.0	61.2	5	18.2	13.7	16	145.8	62.5	2
Echinothrix calamaris	26.0	10.8	96	357.1	74.3	7	26.0	15.2	16	138.9	36.7	3
Echinothrix diadema	177.1	29.1	96	500.0	44.8	34	177.1	44.1	16	236.1	47.7	12
Holothuria atra	177.1	29.6	96	500.0	47.2	34	177.1	57.7	16	314.8	75.5	9
Holothuria coluber	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Holothuria edulis	13.0	5.7	96	250.0	0.0	5	13.0	6.3	16	52.1	10.4	4
Holothuria leucospilota	5.2	3.7	96	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Lambis chiragra	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Lambis crocata	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	2
Lambis lambis	5.2	5.2	96	500.0		1	5.2	5.2	16	83.3		1
Linckia laevigata	390.6	39.5	96	568.2	42.0	66	390.6	58.4	16	416.7	55.9	15
Octopus spp.	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	2
Pleuroploca spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Stichodactyla spp.	20.8	8.0	96	285.7	35.7	7	20.8	8.5	16	66.7	10.2	5
Stichopus chloronotus	338.5	57.2	96	738.6	94.4	44	338.5	109.5	16	451.4	131.0	12
Stichopus hermanni	7.8	4.5	96	250.0	0.0	3	7.8	5.7	16	62.5	20.8	2
Stichopus horrens	5.2	3.7	96	250.0	0.0	2	5.2	5.2	16	83.3		1
Tectus conus	5.2	3.7	96	250.0	0.0	2	5.2	5.2	16	83.3		1
Tectus pyramis	23.4	9.1	96	321.4	46.1	7	23.4	10.0	16	75.0	15.6	5
Tectus spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Thais aculeata	28.6	11.6	96	392.9	74.3	7	28.6	11.2	16	76.4	16.7	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.

4.4.3 Romanum 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
Thais spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Tridacna maxima	78.1	17.5	96	357.1	40.7	21	78.1	23.1	16	125.0	27.8	10
Tridacna squamosa	5.2	3.7	96	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Tripneustes gratilla	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Trochus maculata	13.0	6.8	96	312.5	62.5	4	13.0	8.3	16	69.4	27.8	3
Trochus niloticus	122.4	24.0	96	367.2	48.9	32	122.4	40.0	16	150.6	45.9	13
Trochus spp.	72.9	19.2	96	388.9	61.4	18	72.9	21.7	16	106.1	26.0	11
Turbo argyrostomus	85.9	18.8	96	358.7	44.0	23	85.9	25.6	16	125.0	30.8	11
Tutufa rubeta	2.6	2.6	96	250.0		1	2.6	2.6	16	41.7		1
Vasum ceramicum	26.0	13.1	96	500.0	136.9	5	26.0	17.0	16	138.9	60.5	3
Vasum spp.	2.6	2.6	96	250.0		1	2.6	2.6	16	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 Romanum 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	7.2	2.3	36	28.8	3.5	9	7.2	2.4	6	8.6	2.3	5
Bohadschia graeffei	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Conus spp.	1.3	0.9	36	23.5	0.0	2	1.3	0.8	6	3.9	0.0	2
Culcita novaeguineae	1.3	0.9	36	23.5	0.0	2	1.3	0.8	6	3.9	0.0	2
Echinometra mathaei	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Echinothrix diadema	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Stichodactyla spp.	8.5	2.7	36	30.6	5.0	10	8.5	2.1	6	8.5	2.1	6
Tectus pyramis	2.6	1.6	36	31.4	7.8	3	2.6	1.9	6	7.8	3.9	2
Tridacna maxima	3.3	1.7	36	29.4	5.9	4	3.3	2.1	6	9.8	2.0	2
Trochus maculata	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Trochus niloticus	12.4	3.4	36	37.3	5.4	12	12.4	6.5	6	14.9	7.4	5
Trochus spp.	0.7	0.7	36	23.5		1	0.7	0.7	6	3.9		1
Turbo argyrostomus	9.2	3.3	36	36.6	8.0	9	9.2	4.1	6	13.7	4.7	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.5 Romanum 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
Acanthaster planci	8.9	6.6	42	187.5	62.5	2	8.9	6.2	7	31.3	10.4	2
Actinopyga mauritiana	11.9	5.7	42	125.0	0.0	4	11.9	6.2	7	27.8	6.9	3
Bohadschia graeffei	20.8	11.2	42	218.8	59.8	4	20.8	20.8	7	145.8		1
Choriaster granulatus	17.9	13.2	42	375.0	125.0	2	17.9	17.9	7	125.0		1
Conus spp.	11.9	5.7	42	125.0	0.0	4	11.9	4.2	7	20.8	0.0	4
Culcita novaeguineae	8.9	5.0	42	125.0	0.0	3	8.9	4.2	7	20.8	0.0	3
Echinothrix diadema	62.5	59.5	42	1312.5	1187.5	2	62.5	62.5	7	437.5		1
Holothuria atra	14.9	10.6	42	312.5	62.5	2	14.9	14.9	7	104.2		1
Stichodactyla spp.	6.0	4.2	42	125.0	0.0	2	6.0	3.8	7	20.8	0.0	2
Tectus pyramis	3.0	3.0	42	125.0		1	3.0	3.0	7	20.8		1
Tridacna maxima	29.8	9.3	42	138.9	13.9	9	29.8	7.7	7	34.7	6.9	6
Trochus niloticus	131.0	24.8	42	229.2	30.7	24	131.0	28.3	7	152.8	21.3	6
Trochus spp.	17.9	8.1	42	150.0	25.0	5	17.9	12.4	7	62.5	20.8	2
Turbo argyrostomus	68.5	18.7	42	221.2	32.1	13	68.5	21.2	7	79.9	21.1	6
Vasum ceramicum	3.0	3.0	42	125.0		1	3.0	3.0	7	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.

4.4.6 Romanum 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
Acanthaster planci	11.9	9.2	18	106.7	53.3	2	11.9	11.9	3	35.6		1
Actinopyga miliaris	5.9	4.1	18	53.3	0.0	2	5.9	5.9	3	17.8		1
Bohadschia argus	5.9	4.1	18	53.3	0.0	2	5.9	5.9	3	17.8		1
Bohadschia graeffei	8.9	4.8	18	53.3	0.0	3	8.9	8.9	3	26.7		1
Bohadschia similis	97.8	49.8	18	352.0	124.6	5	97.8	93.4	3	146.7	137.8	2
Bohadschia vitiensis	11.9	6.9	18	71.1	17.8	3	11.9	7.8	3	17.8	8.9	2
Holothuria coluber	32.6	15.6	18	146.7	25.5	4	32.6	32.6	3	97.8		1
Holothuria edulis	8.9	4.8	18	53.3	0.0	3	8.9	5.1	3	13.3	4.4	2
Holothuria spp.	3.0	3.0	18	53.3		1	3.0	3.0	3	8.9		1
Lambis crocata	3.0	3.0	18	53.3		1	3.0	3.0	3	8.9		1
Octopus spp.	3.0	3.0	18	53.3		1	3.0	3.0	3	8.9		1
Stichopus chloronotus	47.4	22.8	18	170.7	51.7	5	47.4	38.9	3	71.1	53.3	2
Stichopus horrens	77.0	39.6	18	198.1	86.1	7	77.0	72.6	3	115.6	106.7	2
Stichopus vastus	5.9	4.1	18	53.3	0.0	2	5.9	5.9	3	17.8		1
Tridacna maxima	3.0	3.0	18	53.3		1	3.0	3.0	3	8.9		1
Trochus niloticus	11.9	9.2	18	106.7	53.3	2	11.9	7.8	3	17.8	8.9	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.

4.4.7 Romanum sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Bohadschia argus	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Bohadschia graeffei	1.0	0.7	30	14.3	0.0	2	1.0	1.0	5	4.8		1
Cassis cornuta	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Choriaster granulatus	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Conus spp.	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Culcita novaeguineae	3.8	1.7	30	22.9	3.5	5	3.8	3.2	5	9.5	7.1	2
Holothuria atra	1.4	1.1	30	21.4	7.1	2	1.4	1.4	5	7.1		1
Holothuria edulis	5.2	2.0	30	22.4	4.2	7	5.2	3.4	5	13.1	3.6	2
Holothuria fuscogilva	2.4	1.0	30	14.3	0.0	5	2.4	1.3	5	4.0	1.6	3
Holothuria fuscopunctata	1.4	0.8	30	14.3	0.0	3	1.4	1.0	5	3.6	1.2	2
Hyotissa spp.	1.4	1.1	30	21.4	7.1	2	1.4	1.4	5	7.1		1
Pteria spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Spondylus spp.	2.9	1.6	30	28.6	0.0	3	2.9	1.9	5	7.1	2.4	2
Stichodactyla spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Stichopus chloronotus	3.3	2.9	30	50.0	35.7	2	3.3	3.3	5	16.7		1
Stichopus hermanni	3.3	1.6	30	20.0	5.7	5	3.3	2.8	5	8.3	6.0	2
Thelenota ananas	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Thelenota anax	9.0	2.2	30	20.9	2.6	13	9.0	2.5	5	11.3	1.5	4
Tridacna maxima	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		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.

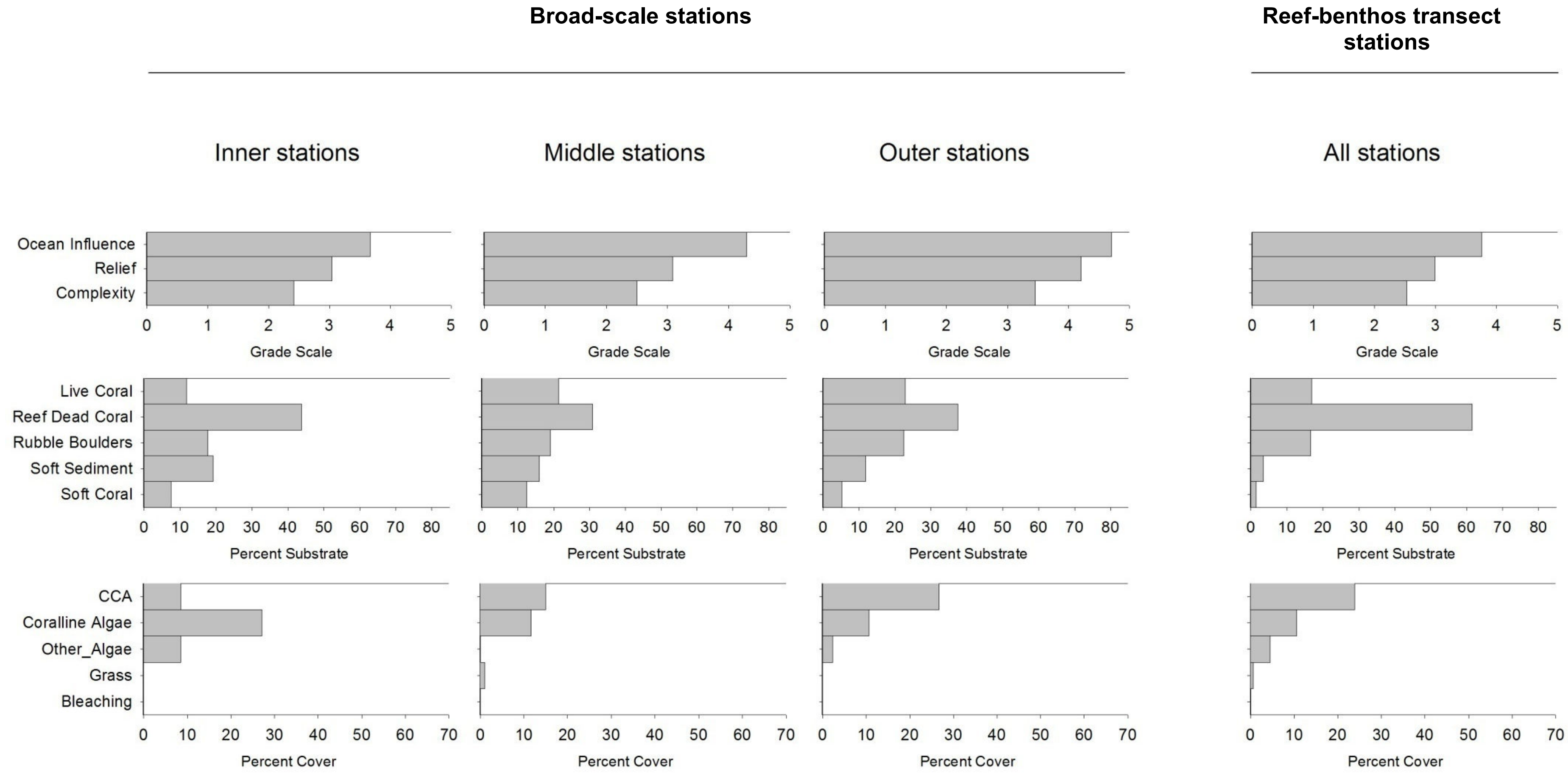
4.4.8 Romanum species size review – all survey methods

Species	Mean length (cm)	SE	n
Stichopus chloronotus	17.8	0.6	469
Holothuria atra	20.2	1.3	349
Tridacna maxima	11.2	0.2	174
Trochus niloticus	7.7	0.2	131
Bohadschia graeffei	27.0	1.8	116
Conus spp.	4.0	0.3	78
Turbo argyrostomus	6.2	0.2	58
Holothuria edulis	22.4	2.9	57
Bohadschia argus	26.9	0.8	41
Trochus spp.	3.2	0.1	33
Bohadschia similis	15.3	0.6	33
Stichopus horrens	15.2	2.2	28
Actinopyga mauritiana	19.7	1.2	26
Thelenota anax	53.4	3.5	19
Stichopus hermanni	38.6	1.6	12
Bohadschia vitiensis	24.3	5.2	12
Vasum ceramicum	9.6	1.1	11
Pinctada margaritifera	14.1	0.5	10
Lambis lambis	13.0	3.0	8
Conus vexillum	7.9	0.3	7
Thelenota ananas	48.8	4.3	7
Holothuria nobilis	29.2	1.5	6
Holothuria fuscogilva	36.1	1.1	5
Conus miles	3.7	0.1	5
Holothuria fuscopunctata	41.7	10.3	4
Lambis crocata	15.0	1.2	4
Actinopyga miliaris	16.5	4.5	4
Cypraea lynx	3.5	0.3	3
Stichopus vastus	13.3	4.8	2
Holothuria leucospilota	17.5	0.5	2
Cerithium nodulosum	9.8	0.2	2
Tectus conus	2.7	0.1	2
Tridacna squamosa	7.3	2.7	2
Acanthaster planci	50.0	0.0	56
Tectus pyramis	3.3	0.0	15
Trochus maculata	4.2	0.0	6
Cassis cornuta	9.6	0.0	2
Cypraea isabella	2.8	0.0	1
Hippopus hippopus	12.0	0.0	1
Tectus spp.	3.6	0.0	1
Pleuroploca spp.	4.6	0.0	1
Holothuria spp.	12.0	0.0	1
Tutufa rubeta	15.0	0.0	1
Cantharus spp.	3.0	0.0	1
Lambis chiragra	20.0	0.0	1
Vasum spp.	3.2	0.0	1
Thais spp.	5.5	0.0	1
Lambis truncata	28.0	0.0	1

4.4.8 Romanum species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n
Linckia laevigata			238
Stichodactyla spp.			135
Echinothrix diadema			90
Hyotissa spp.			47
Culcita novaeguineae			29
Spondylus spp.			15
Holothuria coluber			12
Cypraea moneta			11
Thais aculeata			11
Echinothrix calamaris			10
Drupa spp.			9
Echinometra mathaei			9
Choriaster granulatus			8
Chama spp.			6
Octopus spp.			4
Cypraea caputserpensis			4
Atrina spp.			4
Conus ebraeus			4
Drupella spp.			2
Cypraea annulus			2
Strombus luhuanus			2
Cypraea tigris			2
Pteria spp.			1
Panulirus spp.			1
Synapta spp.			1
Tripneustes gratilla			1

4.4.9 Habitat descriptors for independent assessment – Romanum

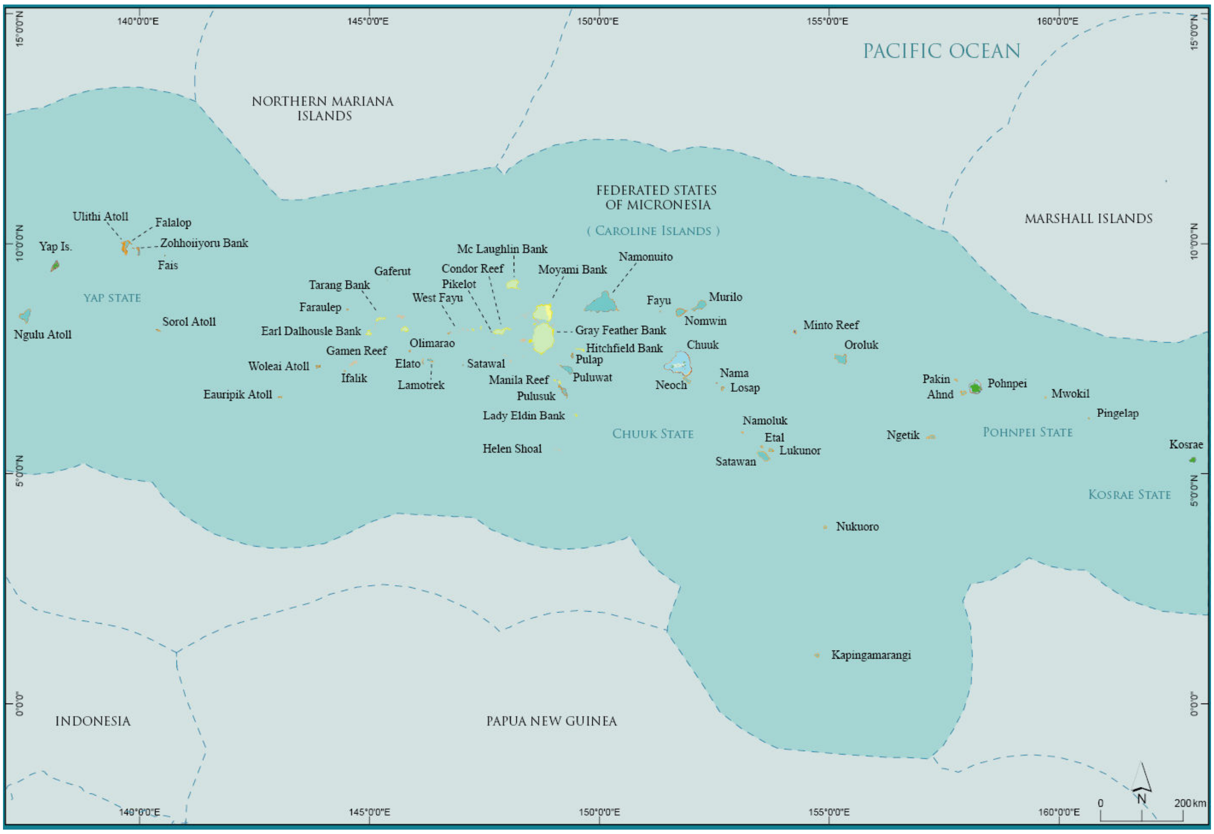


APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – FEDERATED STATES OF MICRONESIA

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 Federated States of Micronesia

(May 2009)



The Institute for Marine Remote Sensing (IMaRS) of University of South Florida (USF) was funded in 2002 by the Oceanography Program of the National Aeronautics and Space Administration (NASA) to characterize, map and estimate the extent of shallow coral reef ecosystems worldwide using high-resolution satellite imagery (Landsat 7 images at 30 meters resolution). Since mid-2003, the project is a partnership between Institut de Recherche Pour le Développement (IRD, France) and USF. The program aims to highlight similarities and differences between reef structures at a scale never considered so far by traditional work based on field studies. It provides a reliable, spatially well constrained data set for biogeochemical budgets, biodiversity assessment, coral reef conservation programs and fisheries. The PROCFish/Coastal project has been using Millennium products in the last four years to optimize sampling strategy, access reliable reef maps, and further help in fishery data interpretation for all targeted countries. PROCFish/C is using Millennium maps only for the fishery grounds surveyed for the project.

For further inquiries regarding the status of the coral reef mapping of the Federated States of Micronesia and data availability, please contact:

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Reference: Andréfouët S *et al.* (2006), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th Int. Coral Reef Symposium, Okinawa 2004, Japan: pp. 1732-1745.