PACIFIC REGIONAL OCEANIC AND

COASTAL FISHERIES DEVELOPMENT PROGRAMME

(PROCFish/C/CoFish)

MARSHALL ISLANDS COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT LIKIEP, AILUK, ARNO AND LAURA

(August and September 2007)

by

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

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PROCFish/C and CoFish staff work (or used to work) for the Secretariat of the Pacific Community, BP D5, 98848 Noumea Cedex, New Caledonia under this EU-funded project. All PROCFish/C and CoFish staff work as a team, so even those not directly involved in fieldwork usually assist in data analysis, report writing, or reviewing drafts of site and country reports.
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[1] CoFish and PROCFish/C are part of the same programme, with CoFish covering the countries of Niue, Nauru, Federated States of Micronesia, Palau, Marshall Islands and Cook Islands (ACP countries covered under EDF 9 funding) and PROCFish/C countries covered under EDF 8 funding (the ACP countries: Fiji, Tonga, Papua New Guinea, Solomon Islands, Vanuatu, Samoa, Tuvalu and Kiribati, and French overseas countries and territories (OCTs): New Caledonia, French Polynesia, and Wallis and Futuna). Therefore, CoFish and PROCFish/C are used synonymously in all country reports.

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EXECUTIVE SUMMARY

The Pacific Regional Coastal Fisheries Development Programme (CoFish) conducted fieldwork in four locations around the Marshall Islands in August and September 2007. The Marshall Islands is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by CoFish or its associated programme PROCFish/C (Pacific Regional Oceanic and Coastal Fisheries Development Programme – 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 Marshall Islands covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with programme scientists and several local counterparts from the Marshall Islands Marine Resources Authority (MIMRA). 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 Marshall Islands, the four sites selected for the survey were Likiep Atoll, Ailuk Atoll, Arno Atoll and Laura, on Majuro Atoll. These sites were selected based on specific criteria, which included:

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

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

Results from fieldwork at Likiep

Likiep is a large atoll, much longer (45 km) than it is wide (15 km). It is located at the position 9º54' N and 169º08' E, oriented along a NW–SE axis. There is a relatively shallow lagoon encircled by islets or *motu* and exposed reef flats. Within the lagoon are patches of reef and pinnacles, which protrude from a predominantly sandy bottom. The continuous flow of oceanic water over the reefs in the north (and through passages in the south) generates a very oceanic and nutrient-poor lagoon system. Sedimentation is not an issue as there is little in the way of elevated land and run-off. The two main communities live in the southern islands. A fishing base, which was established through Japanese grants in 1993 and runs on solar power, provides the only means of commercial fishing activity for the village. The MIMRA collection vessel travels to Likiep 3–4 times per year, purchases fish and transports it back to Majuro and Ebeye for sale.

Socioeconomics: Likiep

The Likiep community is small in size and isolated on an island surrounded by large reef and lagoon fishing grounds. Fishing is done for subsistence purposes, and little is caught for sale due to the limited opportunities for selling produce outside the island. People pursue a very traditional lifestyle, reliant upon agricultural and marine produce, and supported by remittances sent from overseas. Most income is generated from handicrafts, and comparatively little is due to primary-sector activities or salaries. The amount of finfish consumed is very high (128 kg/person/year), while invertebrates are consumed much less (9.3 kg/person/year) and canned fish consumption is very low (4.1 kg/person/year). The household expenditure level is also low (USD 1248/year). Fishing mainly targets the more accessible sheltered coastal reef and lagoon, rather than the outer reef and passages.

The Likiep population is highly dependent on marine resources for home consumption. Both male and female fishers are engaged in finfish fishing and invertebrate collection. Female fishers do not target the outer reef and passages, nor do they participate in diving activities. Male fishers account for most of the catch (wet weight) of both finfish and invertebrates. The main fishing gears used for finfish are cast nets and fishing rods in the closer-to-shore areas, and spear guns, trolling and deep-bottom lines at the outer reef and passages. Invertebrates are collected exclusively for home consumption.

Finfish resources: Likiep

The status of finfish resources at Likiep at the time of surveys was found to be average to good when compared to the other three country sites. The habitat was generally healthy, with good representation of different substrate types and high cover of live coral, the highest among the four sites and the highest in the region. At the intermediate reefs, the general status of corals was fairly good. The back-reefs (49% live-coral cover) as well as the outer reef (63%) were really rich in live coral. On the outer reef, coral cover was fairly high in the shallower depths but varied widely, with areas of barren bedrock and rock boulders covered with turfs and encrusting algae mixed with areas of massive and submassive Porites corals, and tabulate, encrusting and digitate corals especially abundant below 20 m depth.

Fish density and biomass were in the average range of the four country sites. Biodiversity was the highest in the country. Size and size ratios were at the higher end of the country range. Large-sized species of parrotfish (*Chlorurus microrhinos*, *Hipposcarus longiceps* and

Scarus altipinnis) were rather common. Apex predators occurred quite frequently (41 sharks were observed along transects). However, there was a total absence of large groupers and napoleon wrasses, as well as other large carnivores. The intermediate reefs displayed low density and biomass as well as biodiversity, mainly made up by Acanthuridae, Scaridae and Serranidae, and the average size ratios were particularly low for Scaridae, Lethrinidae and Mullidae, suggesting an impact from fishing. The back-reefs displayed intermediate values of density, biomass, average size and diversity, with the average sizes of several families (Lethrinidae, Scaridae, Mullidae and Serranidae) much lower than 50% of their maximum recorded value also suggesting impact from fishing. The outer reefs displayed the best conditions of the site with biomass double that of the intermediate reefs, although the sizes of fish were low for Lethrinidae, Mullidae, Scaridae and Siganidae.

Invertebrate resources: Likiep

The reefs at Likiep were very suitable for a range of giant clams, and five species were recorded (*Tridacna maxima*, *T. squamosa*, *T. gigas* and *Hippopus hippopus*, plus *T. derasa*, which was also present as a result of translocation). Giant clam distribution and density were indicative of a moderately impacted clam fishery. Coverage across the study area was high, apart from a noticeable decline around the main settlement island of Likiep, and densities were moderately high where habitat was suitable. Although *T. maxima* displayed a 'full' range of size classes, including young clams, which indicate successful spawning and recruitment, the abundance of clams close to the main settlement and of large-sized clams was relatively low, suggesting that clam stocks are moderately impacted by fishing.

The reefs at Likiep can potentially support the commercial topshell (*Trochus niloticus*) and this species was introduced in the past. Unfortunately, no trochus were recorded at Likiep, either as live or dead shells. This was despite a wide survey, including the area where trochus were introduced. The occurrence of the false trochus or green topshell (*Tectus pyramis*) indicated that, in general, algal-grazing Trochidae might not be very successful at colonising the oceanic-influenced reefs at Likiep. Although complex reefs were present, in general, surfaces were clean of algae, and this insufficient food supply may restrict the build-up of commercial grazing gastropods. The blacklip pearl oyster (*Pinctada margaritifera*) was uncommon at Likiep.

A restricted range of sea cucumber species was present at Likiep. This is possibly due to biogeographical influences: the isolated position of Likiep in the Pacific, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system. The high-value black teatfish (*Holothuria nobilis*) which is easily targeted by fishers, was absent around Likiep, as were several other potentially commercial species. The medium-value prickly redfish (*Thelenota ananas*) was recorded, as was the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish (*Holothuria atra*); however, distribution was sparse and densities were too low to warrant any commercial interest. Assessments targeting deeper-water white teatfish (*Holothuria fuscogilva*) stocks were not successful in locating this high-value species. Overall, it is hard to tell whether overfishing of this resource occurred over a decade ago, or whether Likiep is naturally deficient in both the range and density of these commercial species.

Recommendations for Likiep

- Traditional and already established rules be continued under current fishing pressure and practices.

- Sound fisheries management planning and strategies be developed and put in place prior to any further development of commercial reef and lagoon fisheries.

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

- Controls be put in place to limit the use of spearfishing, especially at night.

- The communities be supported in their efforts to establish marine reserves, as this has been discussed and suggested for many years without action.

- Juvenile *Tridacna derasa* giant clam stocks be monitored around the lagoon to plot where recruitment is happening in regard to the hatchery where the broodstock aggregations are held.

- There is no potential for developing a commercial sea cucumber fishery based on stocks around Likiep at this time.

Results from fieldwork at Ailuk

Ailuk atoll is a typical atoll located at 10º20' N and 169º56' E, with an extensive lagoon that is about 30 km long and 13 km wide (maximum depth of 40 m) encircled by approximately 55 islets, which lie predominantly along the eastern reef. Its elongated shape is oriented north–south. The atoll has four main channels, all on the west barrier, which facilitate water exchange, but access to the ocean can be made at many locations on high tide when swell conditions allow. Water circulation inside the lagoon is high, with the main water exchange occurring over the reef from the east and escaping the lagoon through the main passages and submerged areas of the barrier. There is little in the way of elevated land, and run-off and sedimentation are not common. As in Likiep, the lagoon is predominantly oceanic-influenced and has small pinnacles and patches of live and dead corals.

Socioeconomics: Ailuk

The Ailuk community is small in size and isolated on an island surrounded by large reef and lagoon fishing grounds. Fishing is done for subsistence purposes, and little is caught for sale due to the limited opportunities to sell outside the island. People pursue a very traditional lifestyle, dependent upon agricultural and marine produce, and supported by cash revenues from handicrafts and remittances sent from overseas. Comparatively little income is due to primary-sector activities or salaries. The consumption rate of finfish is very high (119.6 kg/person/year), with low consumption rates for invertebrates (5.3 kg/person/year) and canned fish (4.1 kg/person/year).

The population of Ailuk is highly dependent on marine resources for home consumption. Both male and female fishers are engaged in finfish fishing and invertebrate collection. Female fishers do not target the outer reef and passages, nor do they participate in diving activities. Male fishers account for the most impact regarding both finfish and invertebrates.

Boat transport mainly consists of locally built canoes, a special skill of Ailuk people. Motorised boat transport is very limited. Fishing techniques and gears used vary according to the habitat targeted, and mainly include cast nets, spear diving and fishing rods in the closer-to-shore areas, and handlines and deep-bottom lines at the outer reef and passages. Invertebrates are collected exclusively for home consumption.

Finfish resources: Ailuk

The assessment indicated that the status of finfish resources in Ailuk was rather poor: the site appeared to be naturally fairly rich, as shown by the healthy substrate composition and fish biodiversity; however, it already showed declining resources (a low abundance of carnivores and small average sizes), probably due to fishing. The good general conditions were assured by the general health of the reefs, with relatively high live-coral cover. At the back-reefs, corals were alive and healthy, even very close to the surface. Less coral cover was found at the intermediate reefs, where much of the substrate was detritical or sandy, and rock and corals were covered in algae (especially Microdyction). Among the three habitats present, the outer reefs were by far the richest.

The average biodiversity of fish at the site was the second-highest recorded at the four sites (43 species/transect versus 46 recorded in Likiep). However, density and biomass were the lowest among the four sites, with fish sizes smaller in the intermediate reef and back-reef in comparison to the other sites. In general, fish were wary of the presence of divers and few large-sized species of Scaridae (*Scarus altipinnis*, *Chlorurus microrhinos*, *Hipposcarus longiceps*, *Cetoscarus bicolor* and *S. frenatus*) were recorded, and these were smaller than expected (size ratio <45% of maximum size). No *Bolbometopon muricatum* was recorded, large-sized carnivores (Serranidae and Lutjanidae) were rare or absent, and apex predators were present but not in exceptional numbers.

Invertebrate resources: Ailuk

The reefs at Ailuk, both inside and outside the atoll lagoon, were suitable for a range of giant clams, with three species recorded (*Tridacna maxima*, *T. squamosa* and *Hippopus hippopus*). The true giant clam (*T. gigas*) was noted in significant numbers as dead shell, particularly on the platforms formed by intermediate reefs in the lagoon. Giant clam distribution and density was indicative of a marginally impacted clam fishery, although clam stocks near to the main village were exhausted. The coverage and density of *T. maxima* clams were moderately high. *H. hippopus* was less common and at lower density but still recorded in reasonable numbers; however, the larger *T. squamosa* was rare. This was despite one station near the main island of Ailuk recording a number of *T. squamosa* clams that were likely to have been relocated and stockpiled for later use.

The reefs at Ailuk can potentially support the commercial topshell (*Trochus niloticus*) but none were recorded in this survey. The occurrence of the false trochus or green topshell (*Tectus pyramis*) indicated that, in general, algal-grazing Trochidae may not be very successful at colonising the oceanic-influenced reefs at Ailuk. Although complex reefs were present, in general, surfaces were clean of algae, and this lack of food supply may restrict the build-up of commercial grazing gastropod stocks. The blacklip pearl oyster (*Pinctada margaritifera*) was relatively common.

A restricted range of commercial sea cucumber species was present at Ailuk, possibly due to biogeographical influences: the isolated position of Ailuk in the Pacific, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system. The high-value black teatfish (*Holothuria nobilis*) which is easily targeted by fishers, was present at Ailuk, although the abundance recorded was very low. The medium-value prickly redfish (*Thelenota ananas*) was recorded, as was the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish (*H. atra*). Surveys targeting deeper-water white teatfish (*Holothuria fuscogilva*) stocks only located one small aggregation of this species from the four passages and one lagoon site sampled. All species noted were below the threshold recommended before commercialisation can be considered.

Recommendations for Ailuk

- The ongoing community-based fisheries management projects and activities be further developed and strengthened.

- The community committees be supported in their efforts to establish four marine reserves and observe the relative restrictions as well as the species catch restrictions in the whole atoll, as proposed in the fishery management plan.

- A monitoring system be set in place to follow any further changes in finfish resources, especially in marine reserves.

- Controls be put in place to limit the use of spearfishing, especially in the lagoon and at night.

- Some larger clams be placed in the newly devised ‘no-fishing zones’ in Ailuk to ensure that clam stocks remain protected from fishing.

- Restocking of the true giant clam, *Tridacna gigas*, be considered for the intermediate reeftops, if a successful breeding programme of *T. gigas* can be achieved at nearby Likiep atoll. A local hatchery would need to be set up to enable juvenile-only clams to be moved from Likiep to Ailuk for breeding purposes. Translocating adult clams is not recommended.

- There is no potential for developing a commercial sea cucumber fishery based on stocks at Ailuk at this time.

Results from fieldwork at Arno

Arno atoll is located about 20 km east of Majuro at 07°05' N and 171°42' E. It includes 133 islands around its rim, covering an area of only 13 km² and enclosing three different lagoons: a large central one, and two smaller ones in the north and east. Its main lagoon encloses an area of 339 km². The most populous islands are Ajeltokrok, Kobjeltak, Rearlaplap, Langor and Tutu. A fish base was established on Arno in 1989, financed by Japanese aid. The fish base purchased fish from local fishers and then transported the product to Majuro for marketing. Although this has now been operating for 20 years, many operators now land their fish direct to markets in Majuro and not to the Arno fish base.

Socioeconomics: Arno

The Arno community is relatively small in size, but in close proximity to Majuro. The community benefits from the establishment of the fish base, which has drastically changed the community, as well as from participation in the MIMRA outer island development project activities. Fishing is now the primary income source and serves both commercial and subsistence interests. In addition, copra production and handicrafts supply complementary income. Dependency on marine resources for food is high, and external financial input (remittances) is relatively small. Consumption of fresh fish is relatively high (82.5 kg/person/year); however, invertebrates (6.6 kg/person/year) and canned fish (6 kg/person/year) are consumed to a much lesser extent.

Both male and female fishers engage in finfish fishing and invertebrate collection. Female fishers do not target the outer reef, nor do they participate in diving activities. Male fishers account for most of the impact regarding the catch of both finfish and invertebrates (wet weight). Techniques and gears used vary according to the habitat targeted and mainly include gillnets, handlines and spear diving in the sheltered coastal reef and lagoon but may also include deep-bottom lines if the lagoon is fished in combination with the outer reef. Invertebrates, mostly clams and octopus, are almost exclusively collected for home consumption.

Finfish resources: Arno

The status of finfish resources at Arno was found to be rather poor at the time of surveys. Fishing in Arno was mostly conducted for commercial purposes (67% of catches were for export). The reefs appeared generally quite healthy but poorer in live coral than reefs at the other sites, in all habitats. The intermediate and back-reefs displayed very low live-coral cover, while hard rock and soft substrate were dominant. The back-reef habitats were mostly covered by rubble and sand, with patches of massive, submassive and digitate corals. The outer reefs were much richer in live corals, which were also quite diverse, with submassive and massive corals dominating at all six stations.

Fish density and biomass were comparable to values at the other sites, but in the lower half of the range on a regional scale. Biodiversity was also quite low and the lowest among the four sites. Some signs of fishing impact were detectable as low average size ratios for certain families, especially Scaridae, Mullidae, Lethrinidae, Acanthuridae and Siganidae, which were recorded among the families mostly targeted by fishers. Large carnivores as well as top predators were rather rare except in the back-reef area on the north side of the atoll (some large Lutjanidae and some white tip reef sharks), possibly indicating a first sign of deteriorating conditions.

Invertebrate resources: Arno

Parts of the barrier reef and areas within the lagoon at Arno were suitable for the full range of giant clams found in Marshall Islands. Three species of giant clam were noted; *Tridacna maxima*, *T. squamosa* and *Hippopus hippopus*. No true giant clam, *T. gigas*, was recorded, even though this icon species naturally occurs in Marshall Islands. Giant clam distribution and density indicated a moderately impacted clam fishery. Clam stocks near to the main settlement areas were the most depleted. Coverage and densities of *T. maxima* clams were moderately high, with *H. hippopus* being less common and at lower density and the larger *T. squamosa* rare.

There was no apparent reason why the reefs at Arno would not support commercial populations of the topshell, *Trochus niloticus*, but the slow spread of colonisation over the last 15 years away from the place of release suggests that the system is in some way not ideal. Some unidentified parameter, such as periodic shortages of grazing matter or active fishing of the newly colonised stock, may be negatively affecting establishment. Trochus density was very low across the site at Arno, even at the most dense aggregations that were recorded. Despite the low numbers, the trochus population held a range of sizes, including juveniles and large mature adults, showing that density was sufficient to maintain ongoing reproduction and recruitment. The blacklip pearl oyster, *Pinctada margaritifera*, was rare at Arno.

The number of commercial sea cucumber species noted at Arno was limited to seven species only due to biogeographical influences: the isolated position of Arno in the Pacific, the poverty of the primary production and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system. The high-value black teatfish (*Holothuria nobilis*) was absent. The high-value white teatfish (*H. fuscogilva*) and the medium-value prickly redfish (*Thelenota ananas*) were recorded, as were the lower-value leopard or tigerfish (*Bohadschia argus*) and the lollyfish (*H. atra*); however, distribution was sparse and densities were too low to warrant any commercial interest. The medium-to-low value amberfish (*T. anax*) was recorded at reasonably high density on the sandy bottom of the lagoon.

Recommendations for Arno

- The legalisation of the 23 marine reserves that have been approved by the Arno community be strongly supported and assisted by MIMRA.
- The ongoing community-based fisheries management projects and activities be further developed and strengthened, especially in regard to the 23 marine reserves.
- Care be taken to ensure that only reserves that can be actively patrolled be implemented to avoid ineffective management as well as the setting up of negative examples.
- More awareness be provided at the village levels to heighten the understanding of the functions of MPAs and to alleviate concerns among landowners.
- Continued support of the Coastal Management Advisory Committee be required to ensure that any recommendations from scientists are fully considered in future management plans and measures for Arno.
- A monitoring system be designed and set in place to follow any further changes in finfish resources, especially in marine reserves.
- Controls be put in place to limit the use of spearfishing, especially at the frequently fished outer reef, and at night.

- Consideration be given to imposing a fee on tourist divers visiting Arno, in order to provide financial support to sustain the management of the marine reserves.

- Some larger clams be placed in the marine reserves at Arno to ensure that clam stocks remain protected from fishing.

- No commercial harvest of the trochus resource be undertaken or even considered in the coming years.

- Any future introduction of trochus to Arno take place in the area to the north of the atoll, where water flow is greater; an alternative release site could be the outer reef northeast of the site and locations east of the study site.

- There is no potential for developing a commercial sea cucumber fishery based on existing stocks at Ailuk at this time.

Results from fieldwork at Laura

Laura is a village situated at the western tip of Majuro Atoll, at 07°08' N, 171°01' E. The lagoon is relatively shallow (30–40 m) and houses several pinnacles and patch reefs, mostly found in the extreme western side and in the central area. As in the other three sites, there are no coastal reefs in Laura. Laura is a large, peri-urban community, with more than 200 households.

Socioeconomics: Laura

The Laura community is large and in close proximity to Majuro. The community benefits from access to salary-based income but is still dependent on marine resources for both subsistence and income generation. In addition, about one-third of the Laura population benefits from external financial input (remittances) and the basic household expenditure levels are high (USD 4209 /year). Consumption of fresh fish is relatively high (89.5 kg/person/year); however, invertebrates (4.9 kg/person/year) and canned fish (6.8 kg/person/year) are consumed to a much lesser extent.

Males are responsible for all types of fishing; females are not expected to engage in finfish fishing or invertebrate fishing, and any involvement is hardly acknowledged or mentioned. In fact, males are responsible for all commercial fishing activities (finfish and invertebrates), and female invertebrate fishers only collect for home consumption. Techniques and gears vary according to the habitat targeted and mainly include gillnets, handlines and spear guns in the sheltered coastal reef and lagoon, but may also include deep-bottom lines if the outer reef and passages are fished. Half of the reported annual catch of invertebrates (wet weight) is for home consumption, and the other half for commercial purposes, with clams, octopus and lobster the main species targeted.

Finfish resources: Laura

The assessment indicated that the status of finfish resources in Laura was rather meagre. The habitat was not rich everywhere and fish resources were scarce, displaying parameters lower than the regional average although comparable to those at the other three country sites. Corals were less abundant compared to corals in the other sites, especially in the lagoon and back-reef; they were slightly better on the outer reefs but still lower than at Likiep and Arno. At the intermediate reefs the coral coverage was slightly better than at the back-reef, but still lower than at Ailuk and Likiep, and dominated by digitate, submassive, table and branching corals with local high coral coverage (40–60%). In some stations, dead table corals covered with algae were very frequent, suggesting that massive bleaching of such forms in this area a few years ago. The back-reef system of Laura displayed a low live-coral cover (22%) compared to the other sites, and was dominated by submassive and massive corals. Soft bottom was present in a good amount (36%). The outer reef of Laura had a much richer live-coral coverage (41%), with some areas showing high peaks of percentage cover (80–100%).

Fish density, biomass and size were comparable to values at the other country sites but biodiversity was low and comparable to the low value recorded at Arno. However, these values ranked average to low in the regional range. The finfish community was almost everywhere dominated by herbivores; only in the back-reefs was biomass composed almost equally of herbivores and carnivores. Fishing is probably one of the causes of the poverty of the fish community, and especially of the shortage of large carnivores (Serranidae, Lutjanidae, Lethrinidae and Labridae). Apex predators were also rare and sharks were less common than at the other atolls (Eight sharks were sighted during surveys in Laura compared to 41 in Likiep, 17 in Arno and 48 in Ailuk.). Average fish sizes were rather small, especially in the outer reefs, and large-sized fish were almost absent. Size ratios of carnivores (Serranidae, Lutjanidae and Holocentridae) were low. These observations, along with the overall analysis of the data, suggest that Laura is a relatively impacted site.

Invertebrate resources: Laura

The lagoon and part of the barrier reef were suitable for the full range of giant clams found in Marshall Islands. Three species of giant clam were recorded at Laura (*Tridacna maxima*, *T. squamosa* and *Hippopus hippopus*). No true giant clam, *T. gigas*, was recorded, although this species naturally occurs in Marshall Islands. Giant clam distribution and density indicated an impacted clam fishery, and clam stocks near to the main settlement were depleted. Coverage and densities of *T. maxima* were low to moderate. *H. hippopus* was less common and at lower density but still recorded in reasonable numbers. The larger *T. squamosa* was the most rare, but was still receiving recruitment, possibly from adults protected by living at greater depth.

Marshall Islands is outside the normal range of the commercial topshell, *Trochus niloticus*, but reefs at Laura do hold trochus, which were initially introduced by the Japanese in the 1930s. The local reefs provide excellent habitat for both juvenile and adult trochus. Juveniles have extensive, suitable back-reef habitat, especially north of the site, while the main adult habitat (barrier and outer-reef slope) occurs predominantly in the north. Trochus was well distributed but recorded at low density within the lagoon. The false trochus or green topshell (*Tectus pyramis*) is present at low density, and the blacklip pearl oyster (*Pinctada margaritifera*) was relatively common at Laura.

A restricted range of seven commercial sea cucumber species was present at Laura. This is possibly due to biogeographical influences: the isolated, easterly position of Laura in the Pacific, the poverty of the primary production, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system. The easily accessed, high-value black teatfish (*Holothuria nobilis*) and the medium-value prickly redfish (*Thelenota ananas*) were recorded, as was the lower-value leopard or tigerfish (*Bohadschia* *argus*); however, distribution was sparse and densities were low. In more protected areas, no blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*) were recorded, but the low-value lollyfish (*H. atra*) was common. In deeper-water surveys, the high-value white teatfish (*H. fuscogilva*) was not recorded, although the low-to-medium value amberfish (*T. anax*) was recorded at good density on the sandy bottom of the lagoon.

Recommendations for Laura

- The community-based fisheries management projects and activities be further developed and strengthened in Laura.

- The use of community-managed conservation areas (marine reserves) be applied, and sites selected in accordance with the communities' requirements, along with the recommendations issued by scientists.

- More awareness be provided at the village level to increase the understanding of the functions of MPAs and to alleviate concerns among landowners.

- The continued support of the Coastal Management Advisory Committee be required to ensure that any recommendations from scientists are fully considered in future management plans and measures for Laura and Majuro.

- A monitoring system be set in place to follow any further changes in finfish resources and monitor any other land and marine sources of impact affecting the reefs, in particular, dredging, lagoon pollution, garbage disposal, etc.

- Controls be put in place to limit the use of spearfishing, especially in the lagoon and at night, and gillnetting, mostly in the lagoon.

- Some larger clams be placed in marine reserves, if these are established in Laura, to ensure that clam stocks remain protected from fishing.

- There is no potential for commercial fishing of trochus at this time, and stocks are in need of ongoing protection to build until the main aggregations reach a minimum of 500–600 shells/ha.

- There is no potential for developing a commercial sea cucumber fishery based on the existing stocks at Ailuk at this time.

RÉSUMÉ

Les agents du projet régional océanien de développement de la pêche côtière CoFish ont effectué des travaux sur le terrain, sur quatre sites des Îles Marshall, en août et septembre 2007. Les Îles Marshall sont l'un des 17 pays insulaires océaniens dans lesquels les agents de CoFish et du programme associé PROCFish/C (Programme régional de développement de la pêche océanique et côtière dans les PTOM et pays ACP du Pacifique (PROCFish, composante côtière) ont conduit des enquêtes[3].

L'objet de ce travail d'enquête était de recueillir des informations de référence sur l'état des pêcheries récifales et de contribuer à remédier à l'énorme manque d'informations qui entrave la gestion efficace de ces ressources récifales.

Les autres résultats escomptés du programme étaient les suivants :

- réalisation de la première évaluation exhaustive des ressources récifales dans plusieurs pays (poissons, invertébrés, aspects socioéconomiques) jamais entreprise dans la région du Pacifique suivant des méthodes identiques sur chaque site ;
- diffusion de rapports nationaux comprenant un ensemble de « descriptifs des ressources halieutiques récifales » pour les sites étudiés dans chaque pays, servant de base au développement de la pêche côtière et à la planification de sa gestion ;
- élaboration d'un jeu d'indicateurs (ou points de référence pour l'évaluation de l'état des stocks), qui serviront de guide à l'élaboration de plans de gestion des ressources récifales à l'échelon local et national, et de programmes de suivi ; et
- élaboration de systèmes de gestion des données et de l'information, dont des bases de données régionales et nationales.

Les enquêtes conduites aux Îles Marshall comprenaient trois volets (poissons, invertébrés et paramètres socioéconomiques) pour chaque site. L'équipe était composée de chargés de recherche et de plusieurs homologues locaux détachés par le Service des ressources marines des Îles Marshall (MIMRA). Les travaux de terrain visaient à renforcer les capacités des homologues locaux qui se sont familiarisés avec les méthodes d'enquête et d'inventaire suivies dans les domaines précités, en particulier la collecte de données et 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, Wallis et Futuna). C'est pourquoi les termes CoFish et PROCFish/C sont employés indifféremment dans tous les rapports de pays.

Aux Îles Marshall, les quatre sites sélectionnés pour l'enquête étaient : les atolls de Likiep, d'Ailuk, d'Arno, ainsi que Laura sur l'atoll de Majuro. Chacun devait satisfaire aux critères énoncés ci-après :

- 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 déjà avoir fait l'objet d'une étude auparavant, et
- il devait présenter un intérêt particulier pour le Service national des ressources marines des Îles Marshall.

Résultats des travaux de terrain à Likiep

Likiep est un grand atoll, beaucoup plus long (45 km) que large (15 km). Il est situé par 9º54' de latitude nord et 169º08' de longitude est, et orienté selon un axe NO-SE. Le lagon est relativement peu profond, entouré d'îlots (*motu*) et de platiers récifaux émergés. À l'intérieur du lagon, on observe des pâtés récifaux et des pinacles qui émergent d'un fond sablonneux. La circulation continue d'eau de l'océan sur les récifs, au nord (et dans des passes, au sud) crée un système lagonaire très marqué par les influences océaniques et pauvre en nutriments. La sédimentation ne pose pas de problème car peu d'obstacles s'opposent au ruissellement et aux terres surélevées. Les deux villages se trouvent sur les îles du sud. Une base de pêche, aménagée grâce à des subventions japonaises en 1993 et alimentée en électricité par l'énergie solaire, fournit les seuls moyens pour les villageois d'exercer une activité halieutique commerciale. Le navire de desserte inter-îles du MIMRA se rend à Likiep trois à quatre fois par an, achète le poisson et l'emporte aux marchés de Majuro et Ebeye.

Aspects socioéconomiques : Likiep

La population de Likiep est peu nombreuse, isolée sur une île entourée de vastes zones de pêche récifo-lagonaires. La pêche est pratiquée à des fins de subsistance, une faible proportion des prises étant destinée à la vente en raison des possibilités limitées de vendre les produits de la pêche à l'extérieur de l'île. Les habitants ont un mode de vie tout à fait traditionnel ; ils sont tributaires des produits de l'agriculture et des ressources marines et vivent des virements de fonds de l'étranger. La majeure partie de leurs revenus est tirée de l'artisanat, et une part relativement faible d'activités exercées dans le secteur primaire ou des salaires. La quantité de poissons consommée est très élevée (128 kg par personne et par an), celle d'invertébrés bien moindre (9,3 kg par personne et par an). Celle de poisson en conserve est très faible (41 kg/personne/an). Le niveau de dépenses des ménages est également très bas (1 248 dollars É.-U par an). Les pêcheurs ciblent principalement le récif côtier abrité et le lagon, plus accessibles, de préférence au récif extérieur et aux passes.

La population de Likiep est fortement tributaire des ressources marines dont elle tire sa nourriture. Les pêcheurs, hommes et femmes, pêchent des poissons et ramassent des invertébrés. Les femmes ne ciblent pas le récif extérieur ni les passes et ne plongent pas. Ce sont les hommes qui réalisent la majeure partie des prises (en poids humide) de poissons et d'invertébrés. Les principaux engins utilisés pour les poissons sont l'épervier et la canne à pêche dans les zones proches du rivage, le fusil-harpon, la ligne de traîne et la ligne de pêche profonde sur le récif extérieur et dans les passes. Les invertébrés sont exclusivement récoltés en vue de la consommation domestique.

Ressources en poissons : Likiep

L'état des ressources en poissons à Likiep, à l'époque des enquêtes, était moyen à bon par rapport à celui des trois autres sites. L'habitat était généralement en bonne santé, avec une bonne représentation des différents types de substrats et une forte couverture de coraux vivants, la plus grande des quatre sites et la plus grande de la région. Sur les récifs intermédiaires, l'état général des coraux était assez bon. Les arrière-récifs (49 % de couverture de coraux vivants) et le récif extérieur (63 %) étaient très riches en coraux vivants. Sur le récif extérieur, la couverture corallienne était assez élevée à faible profondeur, mais aussi très variée, avec des zones de fonds rocheux stériles parsemés de blocs rocheux recouverts de turf et d'algues encroûtantes, auxquels se mêlaient divers porites massifs et submassifs et des coraux tabulaires, encroûtants et digités très abondants, surtout à plus de 20 m de profondeur.

La densité et la biomasse des poissons étaient dans la fourchette moyenne des quatre sites du pays. La biodiversité était la plus grande du pays. La taille et les rapports de tailles étaient à la limite supérieure de la fourchette du pays. Des espèces de perroquets de grande taille (*Chlorurus microrhinos*, *Hipposcarus longiceps* et *Scarus altipinnis*) étaient assez courantes. Des prédateurs de niveau trophique supérieur ont été observés très fréquemment (41 requins observés le long des transects). On a toutefois noté une absence totale de mérous et de napoléons de grande taille, ainsi que d'autres grands carnivores. Les récifs intermédiaires se caractérisaient par de faibles densité, biomasse et biodiversité. Celle-ci était surtout composée d'acanthuridés, de scaridés et de serranidés, et les rapports de tailles moyens étaient particulièrement faibles pour les scaridés, les lethrinidés et les mullidés, ce qui laisse supposer un impact de la pêche. Les arrière-récifs affichaient des valeurs intermédiaires de densité, biomasse, taille moyenne et diversité ; les tailles moyennes de plusieurs familles (lethrinidés, scaridés, mullidés et serranidés) étaient bien inférieures aux 50 pour cent maximum enregistrés, ce qui suggère aussi un impact de la pêche. Les récifs extérieurs présentaient les meilleures conditions du site, la biomasse étant le double de celle des récifs intermédiaires, bien que les tailles des poissons soient faibles pour les lethrinidés, mullidés, scaridés et siganidés.

Ressources en invertébrés : Likiep

Les récifs de Likiep conviennent bien à divers bénitiers ; cinq espèces ont été observées (*Tridacna maxima*, *T. squamosa*, *T. gigas* et *Hippopus hippopus*, plus *T. derasa*, présent après un transfert). La répartition et la densité des bénitiers traduisent un impact modéré de la pêche sur les espèces. Dans toute la zone inspectée, la couverture était élevée, hormis un déclin remarquable autour de la principale île habitée de Likiep, et les densités étaient modérément élevées là où l'habitat était approprié. Bien que l'on observe toute la gamme de classes de taille chez *T. maxima*, y compris de jeunes bénitiers, ce qui traduit le succès du frai et du recrutement, l'abondance des bénitiers près de l'établissement humain principal et de bénitiers de grande taille est relativement faible, ce qui confirme l'hypothèse que les stocks de bénitiers sont modérément affectés par la pêche.

Le troca d'intérêt commercial (*Trochus niloticus*), espèce introduite dans le passé, pourrait trouver des conditions favorables sur les récifs de Likiep. Malheureusement, on n'a observé aucun troca à Likiep, vivant ou mort, malgré une enquête étendue, menée notamment dans la zone d'introduction passée des trocas. La présence de faux troca ou troca vert (*Tectus pyramis*) indiquait que, en général, les trochidés brouteurs d'algues ne réussissent pas bien à coloniser les récifs de Likiep soumis à des influences océaniques. Malgré la complexité des récifs, en général, les surfaces étaient exemptes d'algues, et cette insuffisance de nutriments peut limiter l'accumulation de gastropodes brouteurs d'intérêt commercial. L'huître à lèvres noires (*Pinctada margaritifera*) n'était pas très répandue à Likiep.

Un nombre limité d'espèces d'holothuries était présent à Likiep. Cela s'explique peut-être par des influences biogéographiques : la position isolée de Likiep dans le Pacifique, et la gamme limitée d'habitats protégés, en eaux peu profondes, dans ce système atoll-lagon soumis à de fortes influences océaniques. L'holothurie noire à mamelles, de grande valeur marchande ((*Holothuria nobilis*), facilement ciblée par les pêcheurs n'a pas été observée autour de Likiep, de même que plusieurs autres espèces présentant un intérêt commercial potentiel. Des holothuries ananas (*Thelenota ananas*) de valeur marchande moyenne ont été relevées, ainsi que des holothuries léopards (*Bohadschia argus*) et *Holothuria atra* ; toutefois, elles étaient clairsemées, et leur densité trop faible pour susciter un quelconque intérêt commercial. On a essayé d'évaluer des stocks d'holothuries blanches à mamelles *Holothuria fuscogilva* vivant dans des eaux plus profondes, mais on n'a pas réussi à repérer cette espèce de grande valeur marchande. Dans l'ensemble, il est difficile de dire si la surpêche de cette ressource s'est produite il y a dix ans, ou si la gamme et la densité de ces espèces commerciales sont déficientes pour des causes naturelles à Likiep.

Recommandations pour Likiep

- Il faut continuer d'appliquer les règles traditionnelles et déjà édictées, vu la pression de pêche et les pratiques actuelles.

- Il faut commencer par élaborer des plans et stratégies rationnels de gestion des pêcheries et les mettre en place avant de développer la pêche récifo-lagonaire commerciale.

- Un système de suivi doit être mis en place pour observer l'évolution des ressources en poissons.

- Il faut prendre des dispositions pour limiter la pêche au harpon, en particulier de nuit.

- Il faut appuyer les efforts des communautés pour aménager des réserves marines, comme cela a été débattu et suggéré il y a de nombreuses années sans qu'aucune suite ne soit donnée.

- Il faut surveiller les stocks de bénitiers *Tridacna derasa* juvéniles tout autour du lagon, pour voir à quel endroit le recrutement se produit par rapport à l'écloserie où se trouvent les concentrations de reproducteurs.

- Pour le moment, il n'existe pas de potentiel de développement d'une pêcherie d'holothuries d'intérêt commercial fondée sur des stocks autour de Likiep.

Résultats des travaux de terrain à Ailuk

L'atoll d'Ailuk est un atoll typique situé par 10º20' N and 169º56' E. Il possède un vaste lagon de 30 km de long pour 13 km de large (profondeur maximum de 40 m), entouré d'environ 55 îlots situés principalement le long du récif oriental. De forme allongée, il est orienté nord-sud. L'atoll présente quatre grands chenaux, tous situés sur la barrière ouest, ce qui facilite les échanges d'eau, mais on peut accéder à l'océan en de nombreux endroits à marée haute, lorsque les conditions de houle le permettent. La circulation de l'eau à l'intérieur du lagon est forte, les principaux échanges se produisant sur le récif depuis l'est et sortant du lagon par les principales passes et zones submergées de la barrière. Peu d'obstacles s'opposent à la terre élevée ; le ruissellement et la sédimentation ne sont pas courants. Comme à Likiep, le lagon est surtout soumis aux influences océaniques et comporte de petits pinacles et pâtés de coraux morts et vivants.

Aspects socioéconomiques : Ailuk

La population d'Ailuk est peu nombreuse, isolée sur une île entourée de vastes zones de pêche récifo-lagonaires. La pêche est pratiquée à des fins de subsistance, et une faible proportion est destinée à la vente, faute de possibilités de vendre les prises à l'extérieur de l'île. Les habitants ont un mode de vie tout à fait traditionnel ; ils sont tributaires des produits de l'agriculture et des ressources marines, et bénéficient des recettes tirées de l'artisanat et de virements de fonds de l'étranger. Une part relativement faible des revenus provient d'activités relevant du secteur primaire ou des salaires. La consommation de poissons est très élevée (119,6 kg par personne et par an), celle d'invertébrés est faible (5,3 kg/personne/an), de même que celle de poissons en conserve (4,1 kg/personne/an).

La population d'Ailuk est fortement tributaire des ressources marines, dont elle tire sa nourriture. Les hommes et les femmes pêchent des poissons et ramassent des invertébrés. Les femmes ne ciblent pas le récif extérieur ni les passes, et ne plongent pas. Ce sont les hommes qui exercent le plus fort impact sur les poissons et invertébrés. Le transport se fait surtout par pirogue de fabrication locale, savoir-faire spécial des habitants d'Ailuk, et rarement par bateau à moteur. Les techniques et engins de pêche varient selon l'habitat ciblé : l'épervier, le fusil-harpon en plongée et la canne à pêche sont utilisés dans les zones proches du littoral, et les lignes à main et lignes de pêche profonde sur le récif extérieur et dans les passes. Les invertébrés ramassés sont exclusivement destinés à la consommation domestique.

Ressources en poissons : Ailuk

D'après l'évaluation, l'état des ressources en poissons à Ailuk est plutôt médiocre : le site semblait assez riche à l'état naturel, comme le montrent la composition saine du substrat et la biodiversité des poissons ; toutefois, il présente déjà un déclin des ressources (une faible abondance de carnivores et des tailles moyennes réduites), ce qui s'explique probablement par la pêche. Le bon état général est confirmé par la santé générale des récifs, qui présentent une couverture de coraux vivants relativement élevée. Sur les arrière-récifs, les coraux sont vivants et sains, même ceux qui se trouvent très près de la surface. On a observé une couverture corallienne moindre sur les récifs intermédiaires, où le substrat est en grande partie détritique ou sablonneux, et où les roches et coraux sont couverts d'algues (en particulier *Microdyction*). Des trois habitats présents, ce sont les récifs extérieurs qui sont de loin les plus riches.

La biodiversité moyenne des poissons sur le site venait au second rang de celles enregistrées sur les quatre sites (43 espèces/transect, contre 46 observées à Likiep). Toutefois, la densité et la biomasse sont les plus faibles des quatre sites ; les tailles des poissons sont plus petites sur le récif intermédiaire et l'arrière-récif que sur les autres sites. En général, les poissons se méfiaient de la présence des plongeurs, et peu d'espèces de scaridés de grande taille (*Scarus altipinnis*, *Chlorurus microrhinos*, *Hipposcarus longiceps*, *Cetoscarus bicolor* et *S. frenatus*) ont été enregistrées ; en outre, elles étaient plus petites que prévu (rapport de tailles <45 % de la taille maximum). Aucun *Bolbometopon muricatum* n'a été observé ; les carnivores de grande taille (serranidés et lutjanidés) étaient rares ou absents, et des prédateurs de niveau trophique supérieur étaient présents mais pas en nombre exceptionnel.

Ressources en invertébrés : Ailuk

Les récifs d'Ailuk, à l'intérieur et à l'extérieur du lagon de l'atoll, sont appropriés à divers bénitiers, dont trois espèces ont été observées : *Tridacna maxima*, *T. squamosa* et *Hippopus hippopus*. Le bénitier *T. gigas* a été observé en grandes quantités, sous forme de coquilles mortes, notamment sur les plateformes formées par les récifs intermédiaires dans le lagon. La distribution et la densité de bénitiers dénotaient un impact marginal de la pêche, mais les stocks près du village principal étaient épuisés. La couverture et la densité de *T. maxima* étaient modérément élevées. *H. hippopus* était moins courant et à moindre densité, mais observé en quantités raisonnables ; toutefois le grand *T. squamosa* était rare. Sur une station proche de l'île principale d'Ailuk, on a enregistré un certain nombre de *T. squamosa* qui ont probablement dû être transférés et stockés en vue d'une exploitation ultérieure.

Les récifs d'Ailuk ont la capacité d'abriter le troca d'intérêt commercial *Trochus niloticus*, mais aucun individu n'a été observé au cours de cette enquête. La présence du faux troca, ou troca vert *Tectus pyramis* indique que, en général, les trochidés brouteurs d'algues ne réussissent pas bien à coloniser les récifs d'Ailuk, exposés aux influences océaniques. Malgré la présence de récifs complexes, en général, les surfaces étaient exemptes d'algues, et cette absence de nutriments pourrait limiter l'accumulation de gastropodes brouteurs d'intérêt commercial. L'huître perlière à lèvres noires *Pinctada margaritifera* était relativement courante.

Une gamme limitée d'espèces d'holothuries d'intérêt commercial était présente à Ailuk, probablement en raison d'influences biogéographiques : isolement d'Ailuk dans le Pacifique, et gamme limitée d'habitats protégés, en eaux peu profondes, dans ce système atoll-lagon fortement exposé aux influences océaniques. L'holothurie noire à mamelles, de grande valeur commerciale (*Holothuria nobilis*), facilement ciblée par les pêcheurs, était présente à Ailuk, bien que l'abondance enregistrée ait été très faible. Des holothuries ananas *Thelenota ananas* de valeur moyenne ont été observées, de même que des holothuries léopards (*Bohadschia argus*) et *H. atra*. Au cours d'enquêtes ciblant l'holothurie blanche à mamelles *Holothuria fuscogilva* qui vit à plus grande profondeur, on n'a trouvé qu'une petite concentration de cette espèce dans les quatre passes et un site du lagon échantillonné. Toutes les espèces étaient inférieures au seuil qu'il est recommandé d'atteindre avant que leur commercialisation ne puisse être envisagée.

Recommandations pour Ailuk

- Il faut développer et renforcer les projets de gestion communautaire des ressources halieutiques et poursuivre les activités en cours.

- Il faut aider les comités locaux qui s'efforcent d'aménager quatre réserves marines et d'observer les restrictions relatives et les limitations des prises dans l'ensemble de l'atoll, ainsi qu'il est proposé dans le plan de gestion de la pêcherie.

- Un système de suivi devrait être mis en place pour observer l'évolution des ressources en poissons, notamment dans les réserves marines.

- Il faudrait prendre des dispositions pour limiter l'utilisation du fusil-harpon, surtout dans le lagon et la nuit.

- Certains grands bénitiers devraient être placés dans les nouvelles zones de pêche interdite à Ailuk, pour faire en sorte que les stocks de bénitiers restent à l'abri de la pêche.

- On devrait envisager de reconstituer le stock de vrais bénitiers *Tridacna gigas* sur les crêtes récifales, à condition de pouvoir mener à bien un programme de reproduction de *T. gigas* sur l'atoll voisin de Likiep. Une écloserie locale devrait être aménagée pour pouvoir transférer les juvéniles de bénitiers de Likiep à Ailuk à des fins de reproduction. Il n'est pas recommandé de transférer des adultes.

- Il n'existe pas de potentiel de développement d'une pêcherie commerciale d'holothuries sur la base des stocks présents à Ailuk pour l'instant.

Résultats des travaux de terrain à Arno

L'atoll d'Arno est situé à 20 km à l'est de Majuro, par 07°05' N et 171°42' E. Il regroupe 133 îles couvrant une superficie de 13 km² seulement, et englobe trois lagons différents : un grand lagon central et deux plus petits au nord et à l'est. Son lagon principal a une superficie de 339 km². Les îles les plus peuplées sont Ajeltokrok, Kobjeltak, Rearlaplap, Langor et Tutu. Une base de pêche a été créée à Arno en 1989, financé grâce à une subvention japonaise. Cette base achetait le poisson aux pêcheurs locaux, puis le transportait à Majuro où il était commercialisé. Bien que ce centre fonctionne depuis 20 ans, de nombreux opérateurs débarquent désormais leur poisson directement sur les marchés de Majuro, et non au centre d'Arno.

Aspects socioéconomiques : Arno

La population d'Arno est relativement peu nombreuse, mais vit à proximité de Majuro. Elle bénéficie de la création de la base de pêche qui a représenté un changement spectaculaire pour la communauté, et de la participation aux activités menées par le MIMRA dans le cadre du projet de développement des îles périphériques. La pêche, pratiquée à des fins commerciales et vivrières, est maintenant la première source de revenus. La production de coprah et l'artisanat sont des sources complémentaires. La population est fortement tributaire des ressources marines dont elle tire sa nourriture, et les sources financières extérieures (virements de fonds) sont relativement modestes. La consommation de poisson frais est relativement élevée (82,5 kg par personne et par an) ; toutefois, des invertébrés

(6,6 kg/personne/an) et du poisson en conserve (6 kg/personne/an) sont consommés en bien moindres quantités.

Les femmes et les hommes pratiquent la pêche de poissons et la collecte d'invertébrés. Les femmes ne ciblent pas le récif extérieur et ne plongent pas pour pêcher. Les hommes sont responsables de la majeure partie des impacts de la pêche sur les prises de poissons et d'invertébrés (poids humide). Les techniques et engins utilisés varient selon l'habitat ciblé : filet maillant, ligne à main et fusil-harpon sur le récif côtier abrité et dans le lagon, mais aussi ligne de pêche profonde quand on pêche à la fois dans le lagon et sur le récif extérieur. Les invertébrés – bénitiers et poulpes surtout – sont presque uniquement collectés en vue de la consommation domestique.

Ressources en poissons : Arno

L'état des ressources en poissons à Arno était assez médiocre au moment de l'enquête. La pêche est surtout pratiquée à des fins commerciales (67 % des prises sont destinées à l'exportation). Les récifs semblent généralement en bonne santé, mais moins riches en coraux vivants que les récifs d'autres sites, et ce, dans tous les habitats. Les récifs intermédiaires et les arrière-récifs présentaient une très faible couverture de coraux vivants, tandis que des roches dures et des substrats meubles prédominaient. Les habitats de l'arrière-récif étaient principalement couverts de débris, de sable et de patates de coraux massifs, submassifs et digités. Les récifs extérieurs étaient beaucoup plus riches en coraux vivants, très diversifiés ; les coraux massifs et submassifs prédominaient sur les six stations.

La densité et la biomasse des poissons étaient comparables aux valeurs des autres sites, mais dans la moitié inférieure de la fourchette à l'échelle régionale. La biodiversité était très faible, et la plus faible des quatre sites. Certains éléments révélaient cependant une incidence de la pêche : ainsi les rapports de tailles moyens étaient particulièrement faibles chez les scaridés, les mullidés, les lethrinidés, les acanthuridés et les siganidés, familles présentées par les pêcheurs comme faisant partie des plus ciblées. Des carnivores de grande taille et des prédateurs de niveau trophique supérieur étaient rares, sauf dans l'arrière-récif, au nord de l'atoll (quelques gros lutjanidés et quelques requins de récif à pointe blanche), ce qui pourrait dénoter un premier signe de détérioration.

Ressources en invertébrés : Arno

Certaines parties du récif-barrière et zones à l'intérieur du lagon d'Arno convenaient à toutes les espèces de bénitiers que l'on trouve aux Îles Marshall. On a répertorié trois espèces de bénitiers : *Tridacna maxima*, *T. squamosa* et *Hippopus hippopus*, mais aucun *T. gigas* bien que cette espèce prestigieuse vive en milieu naturel aux Îles Marshall. La distribution et la densité des bénitiers dénotent un impact modéré de la pêche. Les stocks situés près des zones d'habitation principales étaient les plus appauvris. La couverture et la densité de *T. maxima* étaient modérément élevées, *H. hippopus* étant moins courant et en moins grande densité, et *T. squamosa* de grande taille plus rare.

Il n'y avait aucune raison apparente pour laquelle les récifs d'Arno n'abriteraient pas de populations de troca *Trochus niloticus* d'intérêt commercial, mais la lenteur de la dispersion de la colonisation, au cours des quinze dernières années, à partir du point de lâcher, laisse à penser que le système n'est pas idéal, d'une manière ou d'une autre. Certains paramètres non identifiés, par exemple les pénuries périodiques de nourriture à brouter ou la pêche active du stock nouvellement installé, peuvent affecter la fixation. La densité des trocas était très faible sur l'ensemble du site d'Arno, même aux concentrations les plus denses enregistrées. Malgré leur nombre limité, la population de trocas recouvrait tout un éventail de tailles, des juvéniles aux gros adultes matures, ce qui montre que la densité était suffisante pour que soient assurés en permanence la reproduction et le recrutement. L'huître perlière à lèvres noires *Pinctada margaritifera* était rare à Arno.

Le nombre d'espèces d'holothuries d'intérêt commercial relevé à Arno se limitait à sept, ce qui s'explique uniquement par des influences biogéographiques : l'isolement d'Arno dans le Pacifique, la pauvreté de la production primaire et la gamme limitée d'habitats protégés, en eaux peu profondes existant dans ce système atoll-lagon en grande partie exposé à des influences océaniques. L'holothurie noire à mamelles (*Holothuria nobilis*), de grande valeur marchande, était absente. Des holothuries blanches à mamelles (*H. fuscogilva*) et des holothuries ananas (*Thelenota ananas*) ont été observées, ainsi que l'holothurie léopard (*Bohadschia argus*) et *H. atra*, mais de manière clairsemée et à des densités trop faibles pour susciter un quelconque intérêt commercial. *Thelenota anax*, de moyenne à faible valeur marchande, a été observée à une densité modérée sur le fond sablonneux du lagon.

Recommandations pour Arno

- La légalisation des 23 réserves marines, approuvée par la population d'Arno, devrait faire l'objet d'une promotion active et d'une assistance de la part du MIMRA.

- Les projets et activités en cours en matière de gestion communautaire des ressources halieutiques devraient être développés et renforcés, notamment pour ce qui concerne les 23 réserves marines.

- Il convient de procéder avec prudence, de sorte que, seules, des réserves pouvant être surveillées par des patrouilles, soient aménagées pour éviter une gestion inefficace et les mauvais exemples.

- Il faut renforcer les campagnes de sensibilisation à l'échelon des villages pour faire mieux comprendre les fonctions des aires marines protégées et lever les doutes des propriétaires fonciers.

- Il faut continuer de soutenir le comité consultatif de gestion côtière pour faire en sorte que toute recommandation émanant des scientifiques soit prise en considération dans les plans de gestion et les mesures qui seront prises pour Arno.

- Un système de suivi devrait être conçu et mis en place, afin de surveiller l'évolution future des ressources en poissons, notamment dans les réserves marines.

- Des mesures devraient être prises pour limiter la pêche au harpon, surtout sur le récif extérieur fréquemment ciblé, et la nuit.

- Il faudrait envisager d'imposer une taxe aux plongeurs amateurs qui se rendent à Arno afin de recueillir des fonds à l'appui de la gestion durable des réserves marines.

- Certains bénitiers de grande taille devraient être placés dans les réserves marines d'Arno, de manière que les stocks restent à l'abri de la pêche.

- Aucune récolte commerciale de trocas ne devrait être effectuée, ni même envisagée, au cours des prochaines années.

- Toute introduction de trocas à Arno devrait avoir lieu, à l'avenir, dans la zone située au nord de l'atoll, où le flux d'eau est plus grand ; un autre site de lâche pourrait être le récif extérieur au nord-est du site, et des lieux situés à l'est du site d'étude.

- Il n'y a pas, pour l'instant, de potentiel de développement d'une pêcherie commerciale d'holothuries, appuyée sur les stocks existant à Ailuk.

Résultats des travaux de terrain à Laura

Le village de Laura est situé à la pointe occidentale de l'atoll de Majuro, par 07°08' N, 171°01' E. Le lagon est relativement peu profond (30-40 m), et comporte plusieurs pinacles et pâtés récifaux, qui se trouvent surtout à l'extrémité ouest et dans la partie centrale. Comme aux trois autres sites, celui de Laura ne possède pas de récifs côtiers. Le village abrite une grande communauté périurbaine qui compte plus de 200 ménages

Aspects socioéconomiques : Laura

La grande communauté de Laura vit à proximité de Majuro. Tout en bénéficiant d'un accès aux revenus des salaires, elle demeure fortement tributaire des ressources marines dont elle tire nourriture et revenus. En outre, près d'un tiers de la population reçoit des virements de fonds de l'extérieur, et le niveau des dépenses des ménages est élevé (4 209 dollars É.-U. par an). La consommation de poisson frais est relativement élevée (89,5 kg/personne/an), contrairement à celle d'invertébrés (4,9 kg/personne/an) et de poisson en conserve (6,8 kg/personne/an).

Les hommes pratiquent tous types de pêche ; les femmes ne sont pas censées pratiquer la pêche de poissons ni d'invertébrés, et toute participation est à peine reconnue ou mentionnée. De fait, les hommes se livrent à toutes les activités de pêche commerciale (poissons et invertébrés), tandis que les femmes ne collectent des invertébrés qu'aux fins de la consommation domestique. Techniques et engins varient selon l'habitat ciblé : filet maillant, ligne à main et fusil-harpon sur le récif côtier abrité et dans le lagon, mais aussi ligne de pêche profonde si le récif extérieur et les passes sont ciblés. La moitié des prises annuelles déclarées d'invertébrés (poids humide) est destinée à la consommation des ménages, et l'autre moitié est commercialisée. Bénitiers, poulpes et langoustes sont les principales espèces ciblées.

Ressources en poissons : Laura

D'après l'évaluation, l'état des ressources en poissons à Laura était assez médiocre. L'habitat n'était pas riche partout, et les ressources étaient rares. Les paramètres étaient inférieurs à la moyenne régionale, mais comparables à ceux des trois autres sites du pays. Les coraux étaient moins abondants que sur les autres sites, surtout dans le lagon et sur l'arrière-récif, ils étaient légèrement en meilleur état sur les récifs extérieurs, mais moins qu'à Likiep et Arno. Sur les récifs intermédiaires, la couverture corallienne était légèrement meilleure que sur l'arrière-récif, mais moins bonne qu'à Ailuk et Likiep, et elle était surtout constituée de coraux digités, submassifs, tabulaires et branchus, avec une couverture corallienne localement élevée (40–60 %). Sur certaines stations, les coraux tabulaires morts, couverts d'algues, étaient très fréquents, ce qui laisse à penser qu'un blanchissement massif des coraux de cette forme a eu lieu dans cette zone il y a quelques années. Le système de l'arrière-récif de Laura présentait une faible couverture de coraux vivants (22 %) par rapport aux autres sites, et était dominé par des coraux massifs et submassifs. Le fond était principalement meuble (36 %). Le récif extérieur de Laura présentait une couverture de coraux vivants beaucoup plus riche (41 %), avec des pics de couverture de 80 à 100 %.

La densité, la biomasse et la taille des poissons étaient comparables aux valeurs des autres sites du pays, mais la biodiversité était faible ou comparable à la valeur enregistrée à Arno. Toutefois, ces valeurs se rapprochaient de la moyenne ou de la moitié inférieure de la fourchette régionale. La population de poissons était, presque, partout, dominée par les herbivores ; ce n'est que sur les arrière-récifs que la biomasse se composait, en quantités presque égales, d'herbivores et de carnivores. La pêche est probablement l'une des causes de la pauvreté de la population de poissons, en particulier du manque de gros carnivores (serranidés, lutjanidés, lethrinidés et labridés). Les prédateurs de niveau trophique supérieur étaient également rares, et les requins moins courants que sur les autres atolls (on a observé huit requins au cours des enquêtes menées à Laura, contre 41 à Likiep, 17 à Arno et 48 à Ailuk). La taille moyenne des poissons était plus petite, surtout sur les récifs extérieurs, et les poissons de grande taille étaient pratiquement absents. Les rapports de tailles des carnivores (serranidés, lutjanidés et holocentridés) étaient faibles. Ces observations, ainsi que l'analyse globale des données, laisse à penser que Laura est un site relativement abîmé.

Ressources en invertébrés : Laura

Le lagon et une partie du récif-barrière conviennent à tout l'éventail d'espèces de bénitiers que l'on trouve aux Marshall. Trois espèces ont été observées à Laura (*Tridacna maxima*, *T. squamosa* et *Hippopus hippopus*). Aucun *T. gigas* n'a été relevé, bien que cette espèce soit présente dans le milieu naturel aux Îles Marshall. La distribution et la densité des bénitiers indiquent que la pêcherie subit un impact, et les stocks proches du principal établissement humain étaient épuisés. La couverture et la densité de *T. maxima* étaient faibles à modérées. *H. hippopus* était moins courant et à densité plus faible, mais a été observé en quantités raisonnables. *T. squamosa*, l'espèce la plus grosse, était aussi la plus rare, mais le recrutement était encore assuré, sans doute par des adultes protégés par le fait qu'ils vivent à plus grande profondeur.

Les Îles Marshall sont en dehors de l'aire normale de distribution du troca d'intérêt commercial, *Trochus niloticus*, mais les récifs de Laura abritent des trocas, introduits par les Japonais au cours des années 30. Les récifs locaux fournissent un excellent habitat aux juvéniles et aux adultes. Les juvéniles ont un vaste habitat approprié sur l'arrière-récif, en particulier au nord du site, tandis que l'habitat principal des adultes (barrière et tombant du récif extérieur) est surtout situé au nord. Les trocas sont bien répartis dans le lagon, mais à faible densité. Le faux troca, ou troca vert (*Tectus pyramis*) est présent à faible densité, et l'huître perlière à lèvres noires (*Pinctada margaritifera*) était relativement courante à Laura.

Une gamme limitée de sept espèces d'holothuries d'intérêt commercial a été observée à Laura. Cela s'explique probablement par des influences biogéographiques : isolement de Laura, à l'est du Pacifique, pauvreté de la production primaire, et gamme limitée d'habitats protégés, en eaux peu profondes dans ce système atoll-lagon fortement exposé à des influences océaniques. L'holothurie noire à mamelles *Holothuria nobilis,* de grande valeur marchande et facile à pêcher, et l'holothurie ananas *Thelenota ananas* de moyenne valeur ont été observées, de même que l'holothurie léopard de faible valeur *Bohadschia argus*. Toutefois, leur distribution et leur densité étaient faibles. Dans des zones plus abritées, on n'a vu aucune holothurie noire *Actinopyga miliaris*, holothurie caillou *A. lecanora*, holothurie trompe d'éléphant *H. fuscopunctata* ni trépang curry *Stichopus hermanni*, mais *H. atra* était courante. Au cours des enquêtes en eaux plus profondes, on n'a pas observé d'holothurie blanche à mamelles de grande valeur (*H. fuscogilva*), mais *Thelenota anax* a été relevée à une bonne densité sur le fond sablonneux du lagon.

Recommandations pour Laura

- Il faut poursuivre et renforcer les activités et projets de gestion communautaire des ressources halieutiques à Laura.

- Des zones de conservation (réserves marines) gérées par la communauté devraient être aménagées, et des sites choisis en fonction des exigences des communautés et des recommandations formulées par les scientifiques.

- Il faut renforcer les campagnes de sensibilisation à l'échelon du village pour faire mieux comprendre les fonctions des aires marines protégées et lever les doutes des propriétaires fonciers.

- Il faut continuer de soutenir le comité consultatif de gestion côtière pour faire en sorte que toute recommandation émanant des scientifiques soit prise en considération dans les plans de gestion et les mesures qui seront prises pour Laura et Majuro.

- Un système de suivi devrait être mis en place pour surveiller l'évolution future des ressources en poissons, ainsi que toute autre source terrestre ou marine de pollution des récifs, en particulier le dragage, la pollution du lagon, le déversement d'ordures, etc.

- Il faut prendre des dispositions pour limiter la pêche au harpon, surtout dans le lagon et la nuit, ainsi que la pêche au filet maillant, principalement dans le lagon.

- Certains bénitiers de grande taille devraient être placés dans les réserves marines, s'il en est aménagé à Laura, de manière que les stocks restent à l'abri de la pêche

- Pour l'instant, il n'y a pas de possibilité de pratiquer la pêche commerciale de trocas, et les stocks ont besoin d'une protection permanente pour se reconstituer, jusqu'à ce que les concentrations principales atteignent une densité minimale de 500 à 600 coquilles par hectare.

- Pour l'instant, il n'existe pas de potentiel de développement d'une pêcherie commerciale d'holothuries fondée sur les stocks existant à Ailuk.

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)
CBFM	community-based fisheries management
CMAC	Coastal Management Advisory Council
CMI	College of the Marshall Islands
CMT	customary marine tenure
CoFish	Pacific Regional Coastal Fisheries Development Programme
COTS	crown-of-thorns starfish
CPUE	catch per unit effort
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
GDP	gross domestic product
GIS	geographic information systems
GPS	global positioning system
GRT	gross registered tonnage
ha	hectare
HH	household
JICA	Japan International Cooperation Association
MCRMP	Millennium Coral Reef Mapping Project
MIDA	Marshall Islands Development Authority
MIFV	Marshall Islands Fishing Venture
MIMRA	Marshall Islands Marine Resources Authority
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MIOD	Marshall Islands Ocean Development
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
MSP	Marine Science Programme
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
NRAS	Natural Resource Assessment Surveys
Ns	night search
OCT	Overseas Countries and Territories
OFCF	Overseas Fisheries Cooperation Foundation
OIFMC	Outer Island Fish Market Center
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
RMI	Republic of the Marshall Islands
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
WCPFC	Western and Central Pacific Fisheries Commission
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).

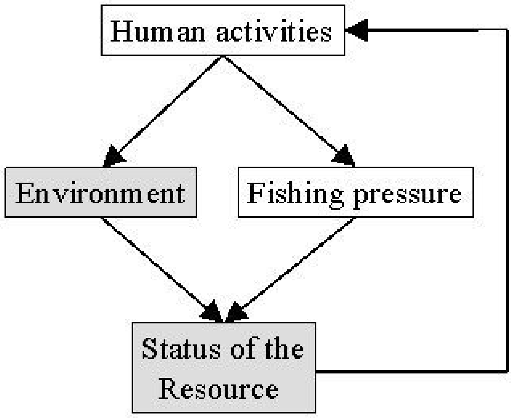

Figure 1.1: Synopsis of the CoFish multidisciplinary approach.
CoFish conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the basis for 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).

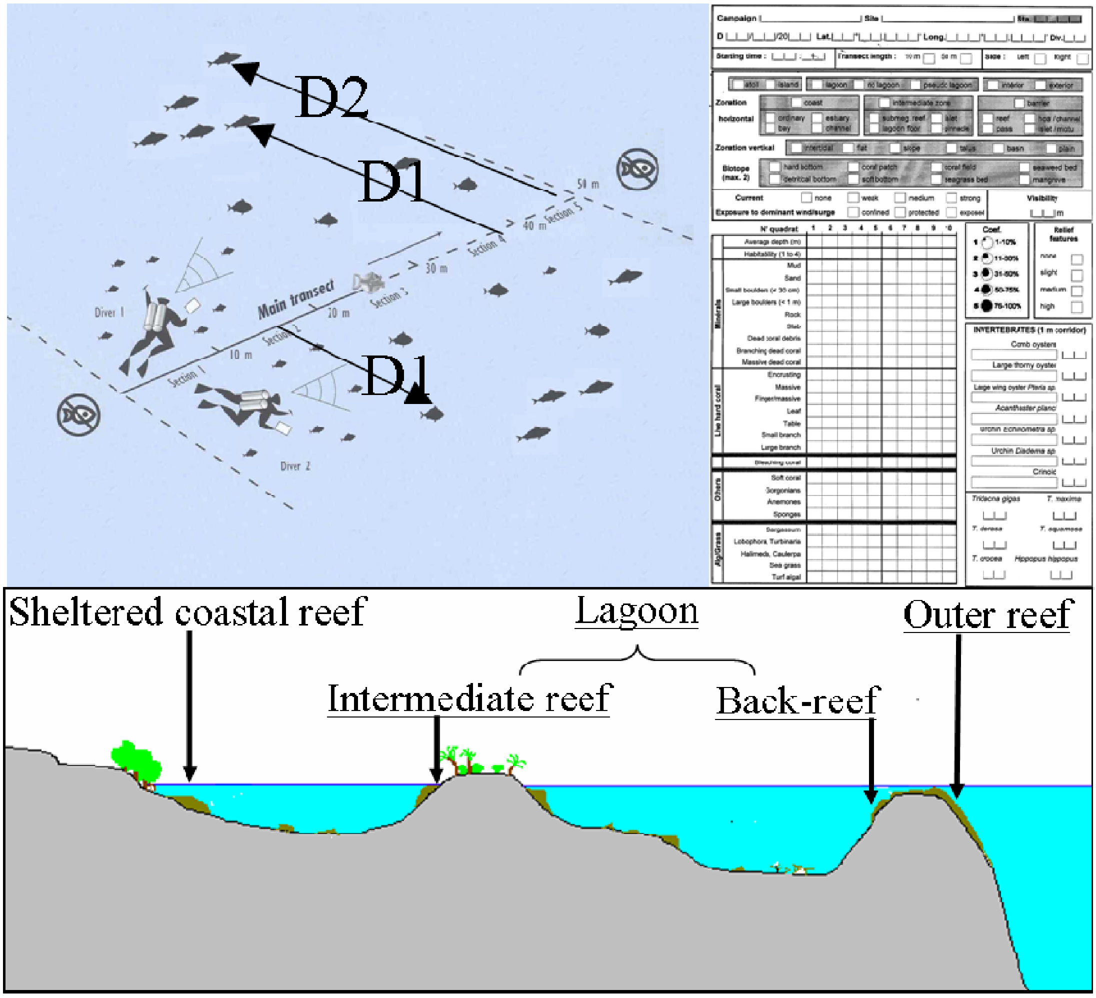

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

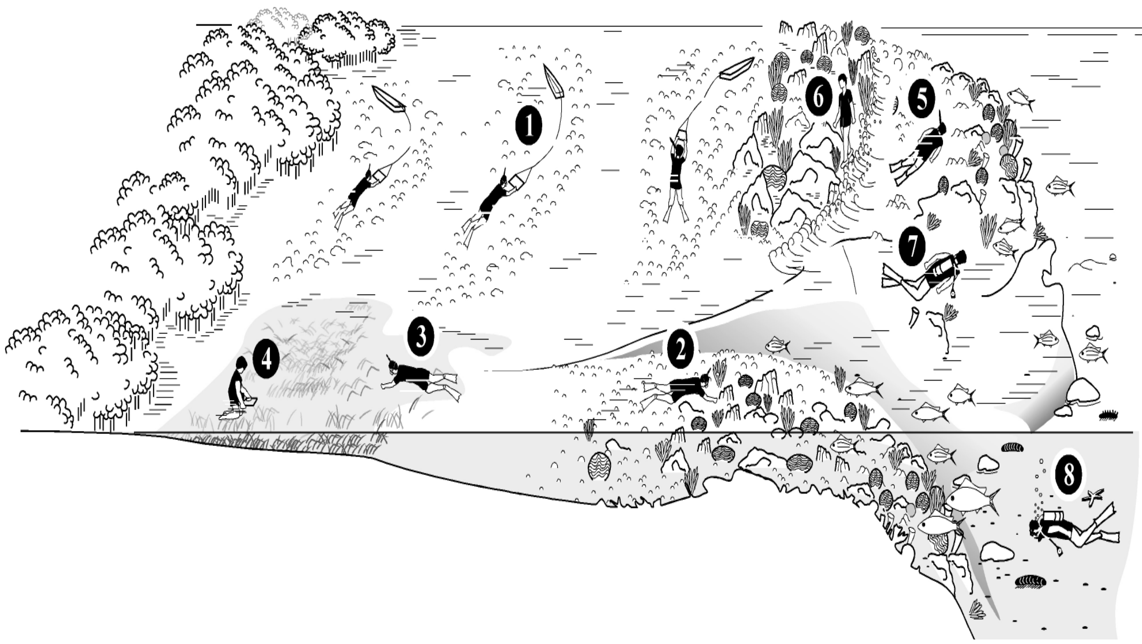

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal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

1.3.1 General

The Republic of the Marshall Islands (RMI) lies just north of the equator in the central Pacific Ocean, at 4–14° N latitude and 160–173° E longitude (Figure 1.4). The country consists of 29 atolls and five low-lying, solitary coral islands distributed between two roughly parallel archipelagos running NNW/SSE: the Ratak Chain to the east and the Ralik Chain to the west. The total number of islands and islets is estimated to be 1225. The exclusive economic zone (EEZ) of RMI is 2.131 million km², 11,770 times larger than its land area (181 km²). It is bounded on the west by the Federated States of Micronesia, on the south by Nauru and Kiribati, and on the north by the United States territory of Wake Island (Hart 2005, McCoy 2004 and Gillett 2002). The combination of small land areas and low land elevations contributes to the ecological vulnerability of the RMI, making the islands particularly vulnerable to sea level rise and the destructive forces of tropical storms (RMI Government 2002, Smith 1992, Sisifa 2002). The climate is warm and humid, with temperatures ranging from 24.7 to 29.9°C, a humidity of 78–83% and an annual rainfall of approximately 4034 mm. The wet season is from May to November (Sisifa 2002, Turner 2008).

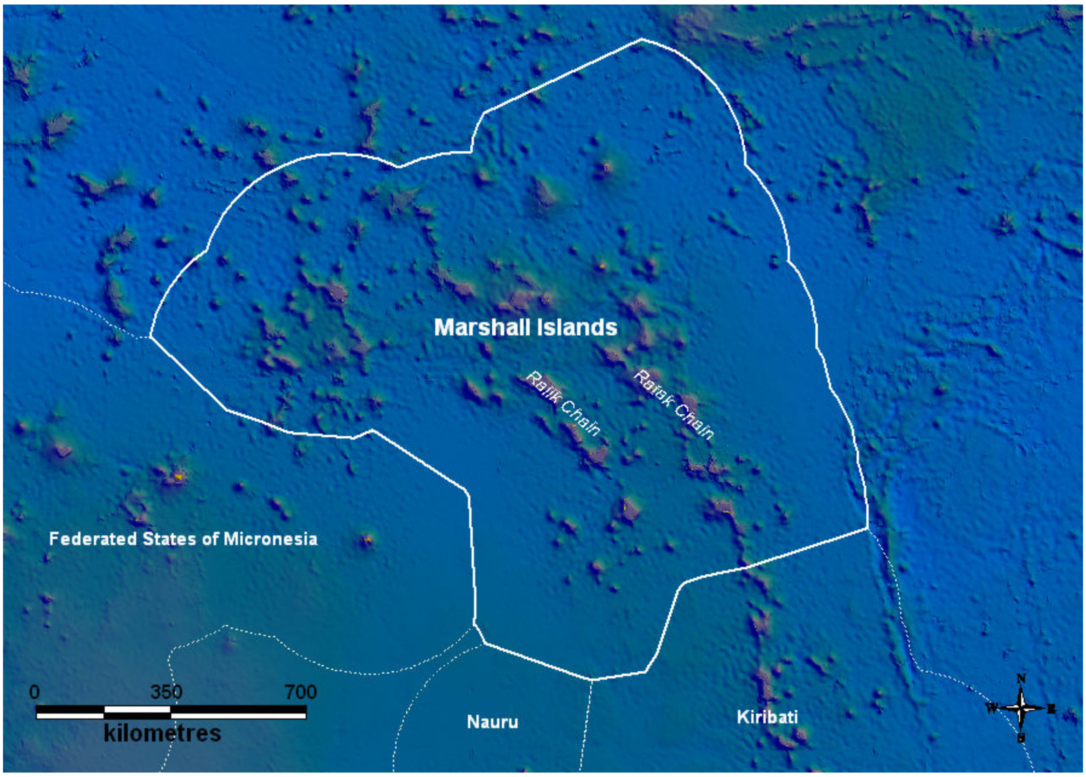

Figure 1.4: Map of Marshall Islands.

The total population of RMI, according to the 1999 census, is estimated at 50,840 (RMI Government 2002). Over half the population is under the age of 15 years, the highest ratio in the Pacific (Canadian High Commission 2001). About 30,000 of the population live in Majuro and 11,500 in Kwajalein, mainly in Ebeye, giving a combined urban population of approximately two-thirds of the total population of RMI (Sisifa 2002).

In October 1986, RMI became a sovereign, independent country, ending over 125 years of foreign control. A Compact of Free Association with the USA, which came into force at the time, was extended by 20 years in May 2004 (Turner 2008). The treaty gives RMI sovereignty in domestic and foreign affairs in return for granting the United States defence rights in the islands. More importantly, through the Compact agreement, RMI receives financial assistance from USA that amounts to about 70% of the country's revenue (SPREP 1992).

The country's main industries are fisheries, copra, tourism, handicrafts, mining, manufacturing, construction and power. Imports (mainly oil) in 2000 totalled USD 54.7 million, mainly coming from USA (56.7%), Australia (10%), Japan (9.3%), and Hong Kong (5.9%). Approximately 71% of the exports, comprising coconut oil, copra cake, chilled and frozen fish, pet fish, shells, and handicrafts, are destined for USA (Turner 2008).

1.3.2 The fisheries sector

The fisheries of RMI comprise the offshore fishery for tuna and other pelagic species, the gamefish and 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, RMI has a number of aquaculture projects.

Offshore tuna and shark fisheries

Prior to 1962 there was no catch data on fishing activity, although Japanese pole-and-line vessels fished in the EEZ of RMI in the mid-1930s (SPC 1984, Barclay and Cartwright 2006). A small tuna cannery was established at Jaluit Atoll in the early 1940s (Anon. 1943). Commercial tuna fishing activities ceased in this area during World War II (SPC 1984). Pole-and-line fishing activities did not commence again until the 1960s, when Japanese distant-water fishing vessels began operation (SPC 1984). The SPC Skipjack Survey and Assessment Programme conducted tagging activities in the waters around RMI, with 286 skipjack and eight yellowfin tagged in 1978 (Kearney *et al.* 1979) and 41 skipjack and 84 yellowfin tagged in one day in 1979 (Kearney and Hallier 1980).

Tuna longlining has been conducted in the waters around RMI since the early 1950s, with Taiwanese longliners also fishing this area from 1967 to 1977, but at lower levels of effort (SPC 1984). Since 1981, most of the longline activity has been undertaken by vessels from Japan, Taiwan and China. According to SPC data, the longline fishery catch ranged from 3199 to 6426 mt during the period 1991–1996 and was composed of equal quantities of yellowfin (*Thunnus albacores*) and bigeye (*T. obesus*). The purse-seine fishery commenced in 1981, with modest catches of up to 2100 mt annually in the first 10 years. In 1992, catches improved but fluctuated, ranging from 11,800 mt (1992) to 1600 mt (1996), with most of the catch (70%) being skipjack (Bigelow 1998). In 1998 and 1999, purse-seiners from Korea, Taiwan, Japan, USA, Federated States of Micronesia (FSM), Vanuatu, Solomon Islands and Papua New Guinea (PNG) either fished in the waters of RMI or transhipped fish. These transhipments totalled 86,560 mt in 1998 and 96,693 mt in 1999 (Joseph 2000).

In 1985, to support the domestic development of tuna fishing in the RMI EEZ, the Japan International Cooperation Association (JICA) established a fish base facility with freezers, cold stores and ice machines in Majuro for the government. This facility was initially managed by the government's Marshall Islands Development Authority (MIDA) until 1990, when the facility was leased out to a Hawaii-based tuna longline company (Chapman 2004a, 2004b). This operation was short-lived, with the company closing operations in 1994 and MIDA again leasing the facility to a Taiwanese-based company in January 1995 (Gillett 2002, Chapman 2004a). The company had 70 longline vessels licensed to fish for the facility, with good catches and fresh export of the product. The lease of the fish base was cancelled in 1998 as the company was not maintaining the equipment. In 2000/2001, the fish base was leased out again to a Hong Kong-based company, which established the Marshall Islands Fishing Venture (MIFV), with their first task being to recondition most of the equipment. MIFV started operation with eight vessels in 2001, increasing to 28 in 2003, with the vessels considered as locally-based foreign vessels. The MIFV landed catch was 1250 mt in 2003, with 80% of the catch being exported fresh to Japan and US markets (Chapman 2004a).

MIDA was also involved in fishing operations, which included a joint venture involving two purse-seine vessels in 1990/1991, with the vessels fishing in areas other than the RMI, and both vessels sold off (Gillett 2002). MIDA was also involved in bringing in five tuna longline vessels in the early-to-mid 1990s to encourage domestic development of the tuna fishery. Each vessel was managed as a separate business enterprise. Unfortunately, low catch rates, a lack of working capital and a lack of fishing experience caused these ventures to fail within a few years (Chapman 2004b). One of these vessels was taken over by the Marshall Islands Fisheries and Nautical Training Center, with equipment purchased; however, no training eventuated. In 2002, SPC was approached to provide technical assistance in training local longline crew. Training was provided in 2003, with 23 people trained to conduct sea fishing trials using a 200-hook tuna longline (Sokimi and Chapman 2003).

In 1999, a tuna-loining plant was established in Majuro by the Philippines, Micronesia and Orient Line. This facility employed 400 people and had a throughput of ~10,000 mt/year (raw product). An additional processing table was started up in 2003, increasing the employment to 500 staff and the throughput to 12,500 mt/year (Chapman 2004a, 2004b). Unfortunately, the facility closed in 2005 as the operation had become uneconomical because the fish being landed for loining were too small.

In October 2001, a shark fishing company was established in Majuro. The company started with two Chinese vessels that were licensed to fish outside the 12 nm limit to avoid catching reef-shark species. By 2003, the company had five vessels fishing for sharks. The company processed the sharks for liver, meat, skins and fins, etc., with most of the shark being used. The company was charged with some illegal fishing practices in 2003 and ceased operation until this was resolved (Chapman 2004b). The company reopened in late 2003, but was closed by the mid-2000s.

In August 2007, there were five Marshall Island-flagged purse-seine vessels fishing both inside and outside the RMI EEZ. The remainder of the fleet licensed to fish in the EEZ consists of distant-water longline, domestically-based foreign longline, and Japanese pole-and-line vessels. In 2006, the overall number of vessels operating in RMI declined from 283 vessels (2005) to 228 vessels (MIMRA 2007). With the exception of the domestically based foreign longline fleet, whose catch remained relatively stable, there was significant reduction in overall catch by all fleets in the RMI EEZ in 2006 compared to 2005. Similarly, the catch by the Marshall Islands purse-seine fleet decreased by ~27% (MIMRA 2007).

Small-scale tuna fishery and game fishing, including fishing around FADs

Traditionally, tuna and other pelagic species were originally trolled for from outrigger sailing canoes. From the 1980s, these canoes were replaced with outboard-powered fibreglass or aluminium vessels (Hart 2005). The first FADs were deployed in RMI in 1989 off Arno as part of the rural fishing project. These were lost within three months and another four were deployed in 1991. After six months, three of the FADs were lost in a cyclone, and the last unit lasted 18 months. From 2000 to 2003 there were four FADs deployed off Majuro, with the last two funded by the Visitors Authority in support of the game fishing club (Chapman 2004a, Barclay and Cartwright 2006).

It was estimated that, in 2002, the small-scale fleet took about 3 mt of tuna per week in Majuro, and about 444 mt of fish annually in Marshall Islands, of which 5–10% were tuna (Gillett 2003). In 2003, there were ten full-time and 25–30 part-time vessels trolling for tuna and other pelagic species around Majuro, using FADs and bird patches, while an unknown number were trolling around reefs and bird patches in the outer islands (Chapman 2004a).

Sport or game fishing is another component of the Marshall Islands tuna industry. It is popular among locals as well as tourists. Since 1983 the biggest club has been the Billfish Club. A trolling tournament held in 1988 with 40 local teams landed 17 billfish (10,000lbs) and 934 bottomfish (Anon. 1988). In 2000, there were 25 charter vessels 6–15 m in length and another 8 vessels in the 16–60 m range (Whitelaw 2001). In 2003 there were about 25 charter vessels operating on Majuro, and 10 between Kwajalein and Arno. There are two big annual tournaments around Majuro (All Micronesian and Majuro Billfish Tournament) with 15–20 vessels participating in each. In addition, the Billfish Club holds monthly club tournaments off Majuro (Chapman 2004, Barclay and Cartwright 2006).

Deep-water snapper

The deep-water resources of RMI are dominated by the family Lutjanidae (snappers) as documented in the Marshall Islands' marine resource profile (Smith 1992). Apart from the deep-water fishing trials carried out by the SPC Deep Sea Fisheries Development Project at Majuro and Arno Atolls in 1985 (Mead n.d., Dalzell and Preston 1992), the Arno Fisheries Project between 1989 and 1990 (OFCF 1993), and the OFCF fishing trials around Jaluit and Aur Atolls in 1999–2001 (MIMRA 2002, Adams and Chapman 2004), no other deep-water fishing trials have been conducted.

The SPC trials in 1985 recorded catch rates of 5.6 kg per line-hour for teleosts only, and found that the deep-water Eteline snappers comprised only 8.5% of the catch by weight. The fact that the fish harvested were from virgin stocks suggested that subsequent catch rates would be less (Dalzell and Preston 1992). In addition, McCoy and Hart (2002) reported that RMI does not have the ideal habitat for deep-water snapper; it lacks the gradual slope (found in Samoa), and any significant offshore banks or seamounts (found in Fiji and Solomon Islands where the species are more prevalent). Despite these findings, MIMRA supports the development of the fishery. There currently is an *ad hoc* fishery using small local boats, which sell their catch on the local market (Adams and Chapman 2004, Chapman 2004a).

Infrastructure in support of coastal fisheries development

The Government of the Marshall Islands has received substantial aid and assistance from the Government of Japan to develop its coastal fisheries. This started in the late 1980s, with the establishment of a fish-processing, storage and ice-making facility with a wharf area in Majuro. This was in support of the rural fish base that was established on Arno in 1989 to develop a small-scale lagoon, bottom and troll fishery in the area, so that the fresh fish from the rural fish base could be transported to Majuro for marketing (Chapman 2004b). The project included vessels being made available for local fishers on a 'rent with the option to buy' system, as well as a transport vessel for carrying the chilled fish from Arno to Majuro for marketing. This project proved successful; therefore, the model was transferred to other locations.

From 1991 to 1999, five rural fish base facilities were established, some along the lines of the Arno facility, with cold-storage and ice-making facilities, and others with chest freezers powered by batteries and solar panels. The seventh and final facility was established in 2002, again with freezers and ice-maker. All of these centres focus mainly on harvesting lagoon species, with some catches of pelagics from trolling activities. MIMRA continues to provide the transport vessels to collect the fish from the rural fish base, sometimes every 3–4 months, with the fish either landed in Majuro or Ebeye for marketing (Chapman 2004a).

The mid-1990s also saw the establishment of the Marshall Islands Ocean Development (MIOD) company in Majuro. MIOD set up shore freezers and ice machines in support of the live reef fish operation the company established. The freezers were mainly used for storing imported feed for the caged fish in the lagoon, as well as for storing fish that were not suitable for the live reef fish trade. The operation failed in the late 1990s and the facility was handed over to MIMRA in default of outstanding payments (Chapman 2004b).

Reef and reef fisheries (finfish and invertebrates)

The Marshall Islands coral reef is home to well over 1000 species of fishes, 1600 species of molluscs, and more than 250 species each of algae and stony corals (RMI 2000). Surveys conducted at various locations in 2001, 2002, and 2003 showed the reef to be in a very healthy condition, with a large number of fish, healthy corals, and algae (Pinca *et al.* 2002). The reefs have suffered minimal damage from bleaching, destructive fishing techniques, and sedimentation. However, signs of unsustainable resource exploitation are reducing stocks of giant clams, reef shark, grouper, and Napoleon wrasse populations. In addition, localised outbreaks of crown-of-thorns starfish and coral disease, principally on the capital atoll of Majuro, are ongoing (Pinca *et al.* 2002). The main threat to stony corals appears to be around the urban centres of each state, caused by dredging, filling, siltation through runoff and various development projects, and waste (solid and liquid) disposal (Smith 1992).

Reef fisheries

Reef fish are an important part of the local diet, especially on the outer islands. MIMRA (2003) noted that most outer island residents engage in fisheries; in Ailinglaplap, for example, 82% of households fish and, in Jaluit, this rises to 87%. Annual fish demand on Majuro is estimated at about 400 mt but, at the present time, the volume of fish from Arno reaching Majuro through organised distribution channels is only 50 mt/year.

The most common local fishing methods used are gillnetting, cast netting, bottom fishing, ocean and lagoon-reef pole-and-lining, spearfishing (day and night) and trolling. There is limited harvesting of octopus and lobster, mostly for personal consumption. Of the seven outer-atoll fish base facilities, six supply limited quantities of fresh reef fish to Majuro and Kwajalein Atolls (including Ebeye) and to Kili Island. The base at Arno sells significant product to Majuro because of its proximity. Due to local concerns about over-fishing at Arno, Japan has funded a stock assessment programme there (Hart 2005).

An aquarium fishery has operated in Majuro for more than 10 years. Three companies currently ship ornamental fish from RMI. They all fish around Majuro but wish to extend their operations to outer islands. Two of these companies have a land-based facility. The target species are high-value species, such as flame angels (*Centropyge loriculus*), but also deep-water species and rare species. Most of the fish go to USA but some of them are also shipped to Japan (SPC 2008). It is estimated that around 3000 fish of up to 50 species are exported each week and, in 1999, exports were valued at USD 473,000 (Gillett 2002). The marine ornamental trade (or aquarium trade) has been steadily rising, with exports increasing. Organisms exported out of RMI by local companies are live fish, giant clams, live rock, corals and various marine invertebrates (MIMRA 2006).

Bêche de mer

Information on bêche-de-mer stocks is sketchy. According to Smith (1992), no information was available on the distribution of sea cucumbers within the Marshall Islands. His report cites Richmond (1996), who found that black teatfish (*Holothuria* (*Microthele*) *nobilis*) and surf redfish (*Actinopyga mauritiana*) were present in Majuro lagoon, and Ebert (1978), who found lollyfish (*Holothuria* (*Halodeima*) *atra*) at Enewetak Atoll. A recent stock assessment survey undertaken in Jaluit showed that 11 species of sea cucumber were found on the reefs of the Atoll (*Holothuria atra*, *H. nobilis*, *H. horrens*, *H. edulis*, *H. fuscopunctata*, *Actinopyga mauritiana*, *Bohadschia argus*, *B. marmorata*, *Stichopus hermanni*, *Thelenota ananas* and *T. anax*). Population abundances were high for all species except for the commercial species currently harvested. As a result of commercial harvesting, the stocks of these commercial sea cucumbers (*H. nobilis*, *H. fuscopunctata*, *B. marmorata*, *S. hermanni* and *T. ananas*) were found to be low to very low within the lagoon (Bungitak and Lindsay 2004).

Attempts to develop a commercially viable fishery date back to 1984 on Jaluit and Majuro, followed in 1994–1995 by Ujae. From 1998 to 2001, the resource was sold to a Taiwanese company from Jaluit, Mili and other atolls. These operations are either no longer in effect or are unknown (McCoy and Hart 2002). Acknowledging the possibility of an income source for outer island communities, MIMRA has sought assistance in conducting feasibility studies. Researchers believe that, without sufficient resource data, the fishery is not economically viable. Secondly, they believe that, without a precautionary management approach, any fishery could lead to overharvesting (Hart 1995, McCoy and Hart 2002). There are currently no regulations on the harvesting of sea cucumbers within Jaluit Atoll or the Marshall Islands. There is a need for some community management to preserve remaining stocks within the lagoon in order to allow recruitment and possible future sustainable commercial harvesting to continue (Bungitak and Lindsay 2004).

Sea turtles

There are three species of sea turtle in Marshall Islands, the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricate*), and the leatherback turtle (*Dermochelys coriacea*). The green and hawksbill turtles are distributed throughout Marshall Islands, with green turtles being the most abundant and hawksbills relatively scarce. Green turtles have been recorded nesting throughout Marshall Islands. However, the level of exploitation of turtles is unknown, and there are no reports available on the status of turtle stocks in Marshall Islands (Smith 1992). Without data, it is impossible to effectively conserve and manage stocks. In 2003 a study of sea turtles in Marshall Islands was carried out to provide information for a turtle conservation programme (McCoy 2004).

Lobsters

The two species of rock lobster with commercial value in Marshall Islands are *Panulirus penicillatus* and *P. versicolor*. A less abundant species of low commercial value, *P. longipes femoristriga*, is also present. The slipper lobsters, *Parribacus antarcticus* and *Palinurellus wieneckii*, have been recorded from Enewetak (Smith 1992 cites Devaney *et al.* 1987), and *Scylarides* spp. may also be present. All species are believed to be distributed throughout Marshall Islands. In 1992, there was no documentary evidence to suggest that lobster stocks were being over-harvested, although MIMRA staff indicated that the stocks in Majuro Atoll may be over-harvested (Smith 1992). The RMI government is currently investigating the feasibility of farming spiny lobsters in Jaluit Atoll (SPC 2008).

Aquaculture and mariculture

Most aquaculture efforts in the past have focused on marine invertebrates, such as blacklip pearl oysters, giant clams, trochus and corals. With the exception of trochus, these resources are currently being grown commercially in Marshall Islands. Fish culture has been limited. A shortage of finfish, the usual incentive for fish culture in other countries, has not been the case here, as wild fish stocks have historically provided for the fish food needs of the Marshallese. This is now changing. With the ever-increasing urban drift into the population centres of Majuro and Ebeye, fish stocks in these areas are becoming depleted and fresh-fish prices are rising. More emphasis on finfish culture is therefore expected in the future (MIMRA 2004).

Black pearl oysters

The blacklip pearl oyster (*Pinctada margaritifera*) is found in Marshall Islands, but not in large quantities. It has been reported from Namodrik, Majuro and Arno atolls, and may also be present at Mili Atoll. Stock surveys were carried out in 1984 but, with the exception of oysters at Namodrik, little or no blacklip pearl oyster was encountered. Further surveys showed that stocks existed in both Majuro and Arno atolls, but no density surveys were conducted (Dashwood 1991, Alfred 1992, Smith 1992). Since the early 1990s there has been a low level of commercial black pearl production, with several thousand pearls produced. Two companies are presently involved in pearl farming at several atolls, including Majuro, Arno and Jaluit. Government, private-sector and academic institutions are involved in projects to develop pearl farming. A current priority is the establishment of commercial techniques for producing pearl oyster spat or techniques for collecting the juvenile oysters from the wild using artificial spat collectors. Training in pearl 'seeding' techniques has been conducted and pearl oyster spat has been produced by a pearl hatchery established on Majuro Atoll (Sarver 1994, Anon. 1996, Sims and Sarver 1998, Ponia 2002, MIMRA 2004).

Giant clams

The giant clam species *Tridacna gigas*, *T. squamosa*, *T. maxima* and *Hippopus hippopus* occur naturally in the wild, while hatchery-reared *T. derasa* has been introduced for mariculture purposes. *T. crocea* is listed in the fossil record for Enewetak Atoll (Kay and Johnson 1987). The first giant clam farm operations were established on Wau Island in 1985, to produce clams for food. Today, clams are produced primarily for the ornamental aquarium market. MIMRA operates a giant clam hatchery on Loto Island at Likiep Atoll, which provides young clams (of several species: *T. maxima*, *T. squamosa* and *T. gigas*) for restocking reef areas, supplying local farmers for grow-out and reselling, and for direct marketing to the Marshall Islands Mariculture Farm. MIMRA also trains interested farmers in propagation and management. A new hatchery to raise giant clams (and other targeted species) was constructed on Arno Atoll in early 2003. This hatchery has already had a successful run of spawned giant clams. The facility will serve as a research station and has the objective of enhancing giant clam populations in Marshall Islands. Hatchery-reared juveniles and transplanted wild adults will be used to establish giant clam sanctuaries (Anon. 1986, Anon. 1996, Ponia 2002, RMI Government 2002).

Trochus

The commercial trochus species *Trochus niloticus* was introduced into RMI during the period of 1915–1945 and is now established on at least six atolls (Jaluit, Majuro, Ailinglaplap, Arno, Mili and Enewetak). This resource has been overexploited via unregulated wild-stock harvesting since the 1980s and is now viewed as severely overfished. Trochus was commercially harvested in significant quantities until the stocks were depleted around the atolls of Kwajalein, Enewetak, Arno, Majuro, Jaluit, Mili, and Ailinglaplap. In 1983, the national government issued an ordinance and a moratorium on harvesting until the stocks could regenerate. There was a plan to restock the overexploited reefs with hatchery-produced seed from the MIMRA hatchery in Likiep. Several conservation measures have since been put forward, including introducing trochus to unpopulated atolls and re-seeding depleted atolls with mature broodstock (Clarke and Ianelli 1995, MIMRA 2004).

Corals

The species of corals sought for ornamental or curio purposes, such as branching corals (*Acropora*, *Seriatopora*, *Pocillopora*), stinging corals (*Millepora*, *Stylaster*), organ pipe corals (*Tubipora*), brain corals (*Goniastrea*, *Euphyllia*) and mushroom corals (*Fungia*), are found throughout Marshall Islands (Smith 1992). Techniques for coral culture are being refined by a private company involved in the export of marine ornamental products (SPC 2008). The main threat to stony corals appears to be around the urban centres of each state, caused by dredging, filling, siltation through runoff and various development projects, and waste (solid and liquid) disposal. The recently commenced export of coral is also a potential threat if not closely monitored (Smith 1992).

Seaweed

The potentially economic seaweed *Eucheuma cottonii* was introduced from Pohnpei to Majuro in 1990. From Majuro it was introduced to Mili and Likiep (Smith 1992). In 2002, a *Eucheuma cottonii* cultivation project was initiated by MIMRA with the help of FAO. Jaluit Atoll Local Government and MIMRA started a similar small-scale seaweed cultivation project in Jaluit around the same time (MIMRA 2003, 2004). There is no local use for raw or processed *Eucheuma* in Marshall Islands, so any production is restricted to the export market (Smith 1992).

1.3.3 Fisheries research activities

External researchers and institutions, in collaboration with the government and the private sector, have carried out marine research in Marshall Islands. The studies tend to fall into the following categories: determining the economic viability of a resource, studying man-made environmental impacts on marine life and their possible implications for human beings, and developing effective management programmes.

Research activities carried out in aquaculture include those on blacklip pearl oysters, giant clams, trochus, seaweeds and sponges. Pearl oyster spat has been collected in Majuro to compare growth and survival rates, using different suspension and holding techniques. Resource surveys have been carried out on trochus, seaweeds and sponges (Adams *et al.* 1995).

Local agencies, with the assistance of SPC, provide technical assistance to help communities manage their coastal resources. Marine resource surveys carried out by the Marine Science Programme, College of the Marshall Islands (MSP, CMI) provide vital information on the status of the marine environment. There is still a long way to go before marine reserves or other management measures are firmly established, but several atolls (Jaluit, Likiep, Mili and Rongelap) are spearheading this effort. MIMRA is conducting community workshops;

training local personnel in management and monitoring is essential to the success of any community-based solution to conservation and sustainability (Pinca 2003).

In 2004, a baseline study on sea turtles was carried out to gather information to assist local and national government to devise realistic conservation and management measures. The literature and site-visit study noted the need for additional work on reducing adverse interactions between sea turtles and the domestic-based foreign longline fishery in Majuro. An upcoming second phase of work in Marshall Islands funded by NOAA Fisheries will expand the outreach efforts to assist commercial tuna fishers to mitigate any interaction with sea turtles. This will be accomplished by improving the capabilities of MIMRA local staff and observers in recognising, handling, and reporting interactions between sea turtles and commercial tuna fisheries in RMI (McCoy 2004).

A sea turtle monitoring programme is being proposed to research the environmental impacts of nuclear activity in Marshall Islands. The first step is to collect local indigenous knowledge. By focusing on a culturally, traditionally and nutritionally important species and by investigating potential hazards to these species as well as to the human populations that rely on them, this project will allow local participants to help identify and mitigate these hazards (Woodrom *et al.* 2007).

The realisation that all resource users need to be acknowledged and supported in any effective management programme has led to research into the role of women in fisheries. In 1997, at the request of the Marshall Islands Government, SPC carried out an in-country baseline study on the social and economic roles played by women in the fisheries sector, including activities undertaken in the harvesting, processing and marketing of marine resources. The study identified the governmental and non-governmental support services available and the constraints that inhibit effective participation, and provided guidelines to enable effective participation. As a follow-up to this study, workshops on processing and marketing seafood were held in Ebeye and Jaluit. This study became a template for other national studies in the region (Tuara 1998). In 2003, an SPC/FFA gender study of the tuna industry in Marshall Islands was carried out. This study looked at the social costs and benefits of the industry and their implications for men, women, and children (Vunisea 2005).

1.3.4 Fisheries management

The development and management of marine resources is guided by national policy and legislation, local government bylaws, traditional laws, and institutional arrangements that allow government bodies to coordinate decision-making and to proactively integrate non-governmental interests.

The Marshall Islands Marine Resources Authority (MIMRA), established in 1988 under the *Marshall Islands Marine Resources Authority Act 1988,* plays a leading role in managing and developing marine resources. The Act was revised in 1997 (MIMRA Act 1997, also called the Marine Resources Act 1997), to give MIMRA more autonomy and flexibility in carrying out such responsibilities, and to ensure that MIMRA's overall function, as provided for in the Act, could be carried out more effectively. In terms of the resource base, the objectives of the MIMRA Act 1997 and the MIMRA 1997 Fisheries Policy are to promote sustainable economic development of fisheries, support commercial-scale fisheries, and preserve coastal reef and lagoon resources primarily for nutrition, food security and small-scale, sustainable, income-earning opportunities for the community (Chapman 2004a). Technical advice from the Asian Development Bank (ADB), SPC and Forum Fisheries Agency (FFA) has helped in the development of the fishery policy (Barclay and Cartwright 2006). The 2004 Tuna Management Plan has led to changes in purse-seine vessel access fees, collaboration with the Western and Central Pacific Fisheries Commission (WCPFC) in the observer programme, and assistance from SPC, FFA and Japan to develop a national fishery data centre to integrate all fishery data in a database network (MIMRA 2007). Other management plans have been compiled following stock assessment surveys. These plans have recommended restrictions on certain harvesting and collection techniques, combined with the establishment of sanctuaries and monitoring programmes.

Under the MIMRA Act 1997, MIMRA has the power to delegate its authority so that each local government council can manage the marine resources within its five-mile-zone jurisdiction. Several outer island communities are now working actively to develop community-based fisheries management (CBFM) plans and establish marine protected areas (MPAs) to protect their marine resources, fish stocks and fish habitats (MIMRA 2003, 2004).

1.4 Selection of sites in Marshall Islands

Four CoFish sites were selected in Marshall Islands following consultations with the Marshall Islands Marine Resources Authority (MIMRA), the atolls of Likiep, Ailuk and Arno and Laura on Majuro (Figure 1.5). These sites were selected as they shared most of the characteristics required for our study: they had active reef fisheries, were representative of the country, were relatively closed systems,[5] were appropriate in size, possessed diverse habitats, presented no major logistical limitations that would make fieldwork unfeasible, had been investigated by previous studies, and presented particular interest for MIMRA and the Island Councils.

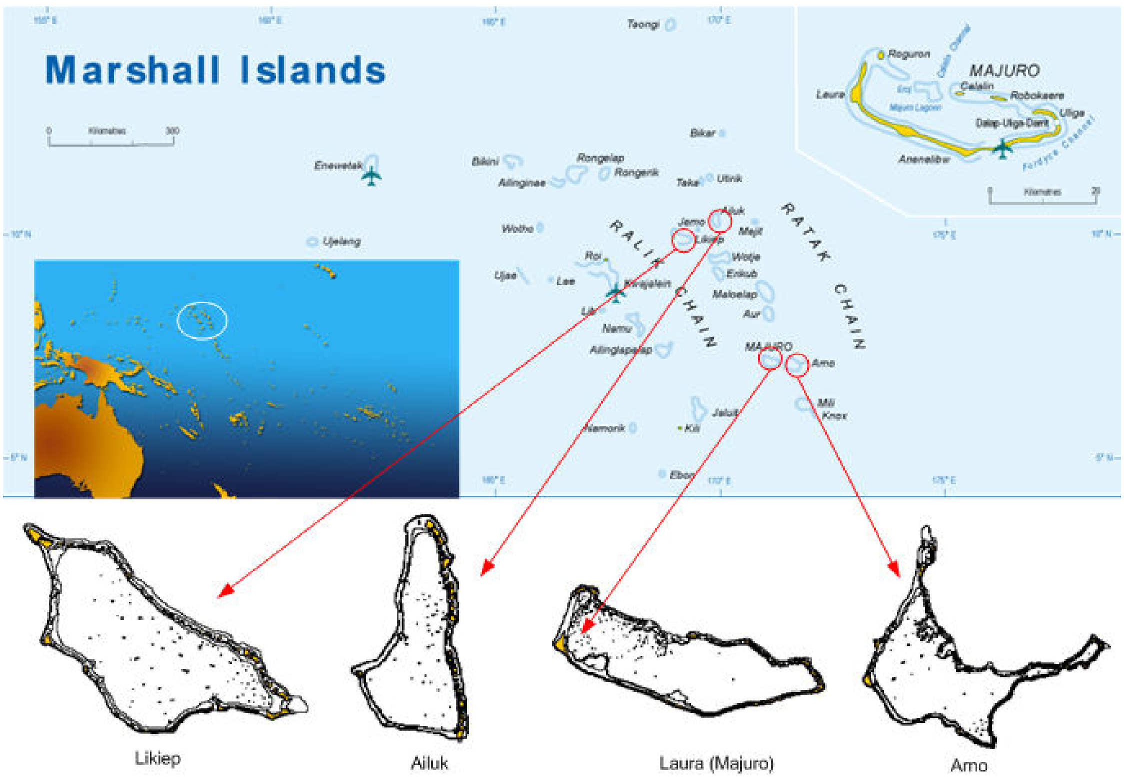

Figure 1.5: Map of the four CoFish sites selected in Marshall Islands.

[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 LIKIEP

2.1 Site characteristics

Likiep is a large atoll, much longer (45 km) than it is wide (15 km). It is located at the position 9º54' N and 169º08' E, oriented along a NW–SE axis (Figure 2.1). There is a relatively shallow lagoon encircled by islets or *motu* and exposed reef flats. Within the lagoon are patches of reef and pinnacles, which protrude from a predominantly sandy bottom. The continuous flow of oceanic water over the reefs in the north (and through passages in the south) generated a very oceanic and nutrient-poor lagoon system. Sedimentation was not an issue as there was little in the way of elevated land and run-off. The two main communities live in the southern islands. A fishing base, which was established through Japanese grants in 1993, runs on solar power and provides the only means of commercial fishing activity for the village. The MIMRA collection vessel travels to Likiep 3–4 times per year, purchases fish and transports it back to Majuro and Ebeye for sale.

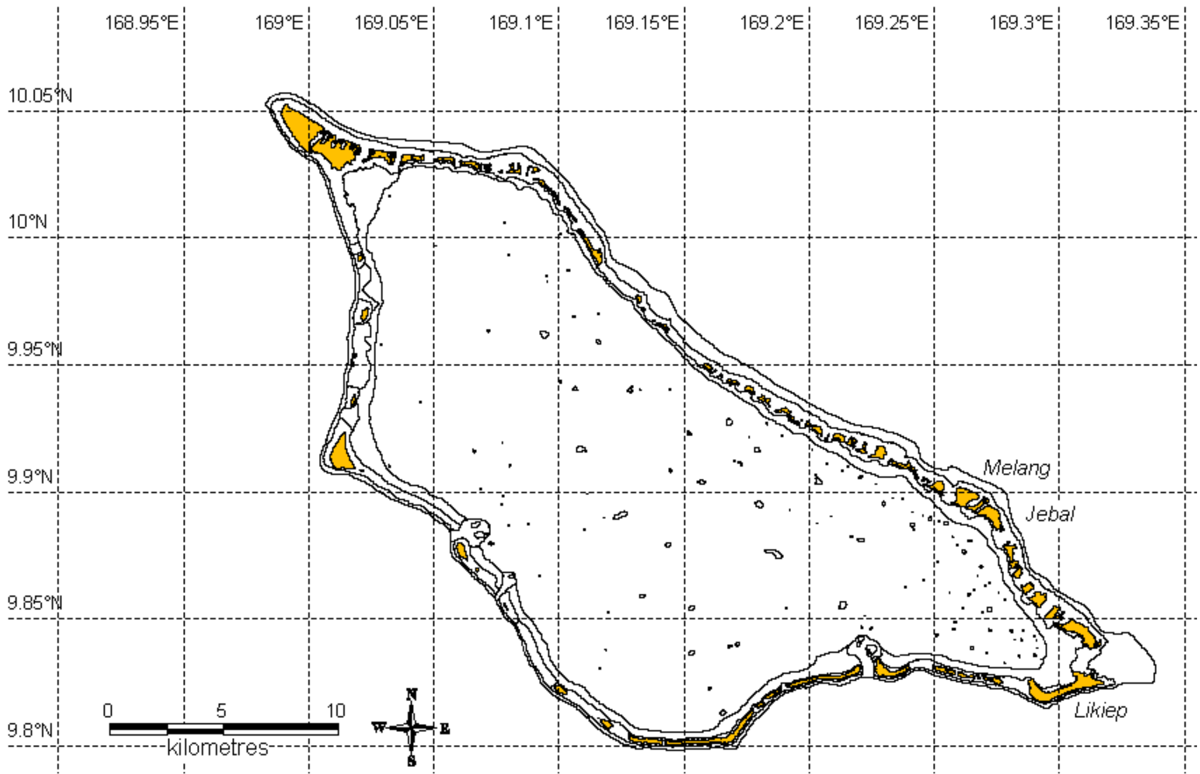

Figure 2.1: Map of Likiep.

2.2 Socioeconomic surveys: Likiep

Socioeconomic fieldwork was carried out in Likiep, RMI from 8 to 16 August 2008. Likiep is an isolated island where fishers have limited opportunities to generate income from fishing other than selling fish within the community on a very small scale or selling fish to the local fish base for export to Laura and Ebeye.

The Likiep community has a resident population of 463 and ~63 households. A total of 20 households (32% of the total households in the Likiep community) were surveyed; all of these households were engaged in some form of fishing activities. In addition, a total of 32 finfish fishers (23 males and 9 females) and 31 invertebrate fishers (18 males and

13 females) were interviewed. The average household size is moderate to large, with seven people, representing the isolated, traditional and rural lifestyle of the local people.

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 tinned fish and other food items was also conducted.

People from Likiep have access to various habitats for fishing, including sand flats, a deep lagoon area associated with coastal, mostly submerged, reefs, outer reefs, channels and passages.

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

Our results (Figure 2.2) suggest that sources other than fisheries play the major role for income generation in Likiep. These mainly include handicrafts and mat weaving (the first income source for 70% of all households), using leaves of pandanus, coconut stalks, and shells. Fisheries and agriculture both provide 35% of all households with first and second income, with fisheries being slightly more important for providing first income than agriculture. Salaries are the least important income source, and only provide 15% of all households with secondary income. The long distance and unreliable and difficult inter-island transport to Laura or any other market centre explain why fisheries and agricultural produce with little shelf life play a minor role, and handicrafts, such as mats, which can be easily stored, are more important. The size of the community further highlights the few administrative and governmental functions that may be needed, hence the limited opportunities for earning income from salaries. Pigs and chickens are popular; 70% of all households have a couple of pigs and 75% of households keep chickens for home consumption. Distributing fish and seafood among the community on a non-monetary basis is a very important and traditional practice in Likiep.

Commercially-oriented fishing is limited to the occasional export opportunities by plane transport to Ebeye and Laura or to the fishing centre in Likiep. However, the local fish centre depends on the infrequent visits by the MIMRA vessel and, often, only a certain quota of catch is taken. Fishing intensity increases on the day the MIMRA vessel visits to buy; however, this happened only twice during the 12 months prior to the survey. Fishing, therefore, does not provide local male fishers with a reliable and steady income-earning opportunity. Access to market is the major obstacle to fisheries development on Likiep, but this lack of access also acts to prevent over-exploitation of resources.

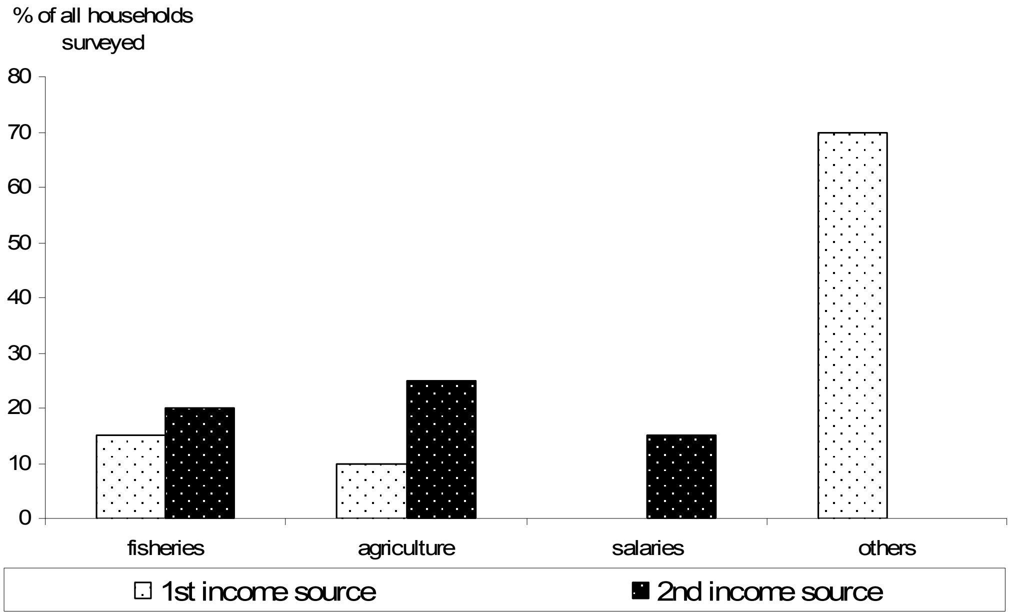

Figure 2.2: Ranked sources of income (%) in Likiep.
Total number of households = 20 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

Our results (Table 2.1) show that annual household expenditures are low, at an average of USD 1248. People are self-sufficient regarding agricultural and marine produce, and they have limited purchasing power due to the limited opportunities available for generating cash on the island.

It is, therefore, not surprising that 70% of all households on the island receive remittances, and that the amounts received are relatively high, i.e. on average USD 593 /HH/year, which covers about 48% of the average basic household expenditure.

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

Survey coverage	Site (n = 20 HH)	Average across sites (n = 78 HH)
Demography		
HH involved in reef fisheries (%)	100.0	98.7
Number of fishers per HH	2.40 (±0.24)	2.56 (±0.17)
Male finfish fishers per HH (%)	4.2	21.5
Female finfish fishers per HH (%)	0.0	0.0
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	0.0	15.5
Male finfish and invertebrate fishers per HH (%)	60.4	47.0
Female finfish and invertebrate fishers per HH (%)	35.4	16.0
Income		
HH with fisheries as 1st income (%)	15.0	32.1
HH with fisheries as 2nd income (%)	20.0	19.2
HH with agriculture as 1st income (%)	10.0	10.3
HH with agriculture as 2nd income (%)	25.0	38.5
HH with salary as 1st income (%)	0.0	20.5
HH with salary as 2nd income (%)	15.0	9.0
HH with other sources as 1st income (%)	70.0	37.2
HH with other sources as 2nd income (%)	0.0	12.8
Expenditure (USD/year/HH)	1248.36 (±368.12)	2210.55 (±226.09)
Remittance (USD/year/HH) (1)	592.86 (±103.26)	764.14 (±107.90)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	128.23 (±13.53)	105.45 (±7.52)
Frequency fresh fish consumed (times/week)	4.28 (±0.18)	3.56 (±0.13)
Quantity fresh invertebrate consumed (kg/capita/year)	9.28 (±3.47)	6.47 (±7.52)
Frequency fresh invertebrate consumed (times/week)	0.72 (±0.14)	0.94 (±0.08)
Quantity canned fish consumed (kg/capita/year)	3.38 (±0.56)	5.12 (±0.65)
Frequency canned fish consumed (times/week)	0.91 (±0.18)	1.12 (±0.11)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	100.0	94.9
HH eat canned fish (%)	90.0	94.9
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	25.0	15.8
HH eat fresh fish they are given (%)	50.0	84.2
HH eat fresh invertebrates they catch (%)	95.0	100.0
HH eat fresh invertebrates they buy (%)	0.0	0.0
HH eat fresh invertebrates they are given (%)	65.0	84.2

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 Likiep is 151, including 98 males and 53 females. Among these are six exclusive finfish fishers (males only), no exclusive invertebrate fishers, and 145 fishers who fish for both finfish and invertebrates (92 males, 53 females). About 40% of all households own a boat; most boats (~75%) are motorised; only ~25% are non-motorised canoes.

Consumption of fresh fish is high at over 128 kg/person/year, which exceeds the average across all the four study sites in RMI and is about four times the regional average of ~35 kg/person/year (Figure 2.3). By comparison, consumption of invertebrates (edible meat weight only) (Figure 2.4) is much lower at ~9 kg/person/year. Canned fish (Table 2.1) is not commonly eaten and adds only ~3 kg/person/year to the annual protein supply from seafood. The consumption pattern of seafood found in Likiep reflects the fact that people have limited access to agricultural and commercially available food items.

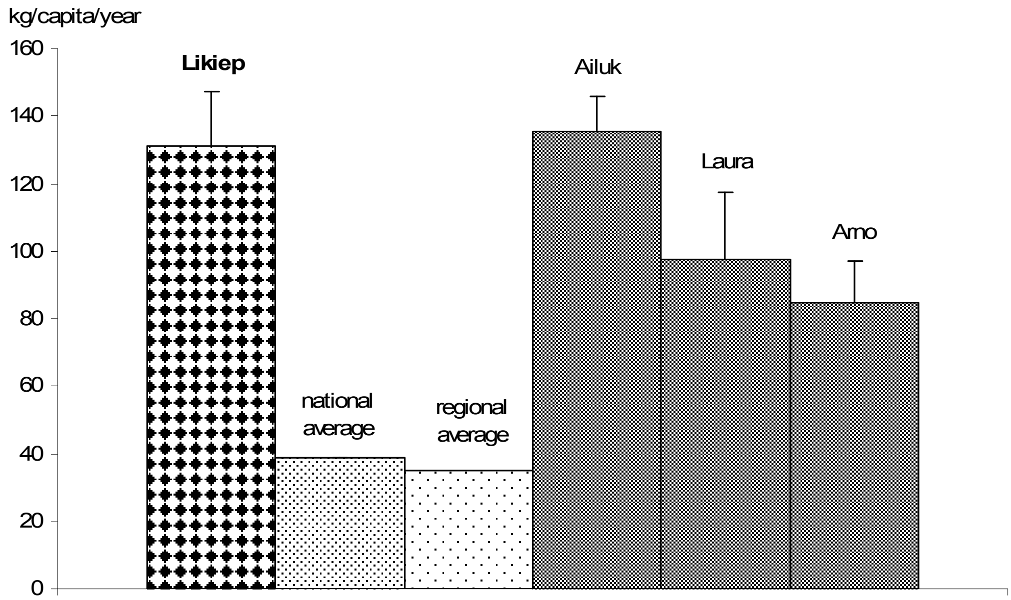

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Likiep (n = 20) compared to the national and regional averages (FAO 2008) and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

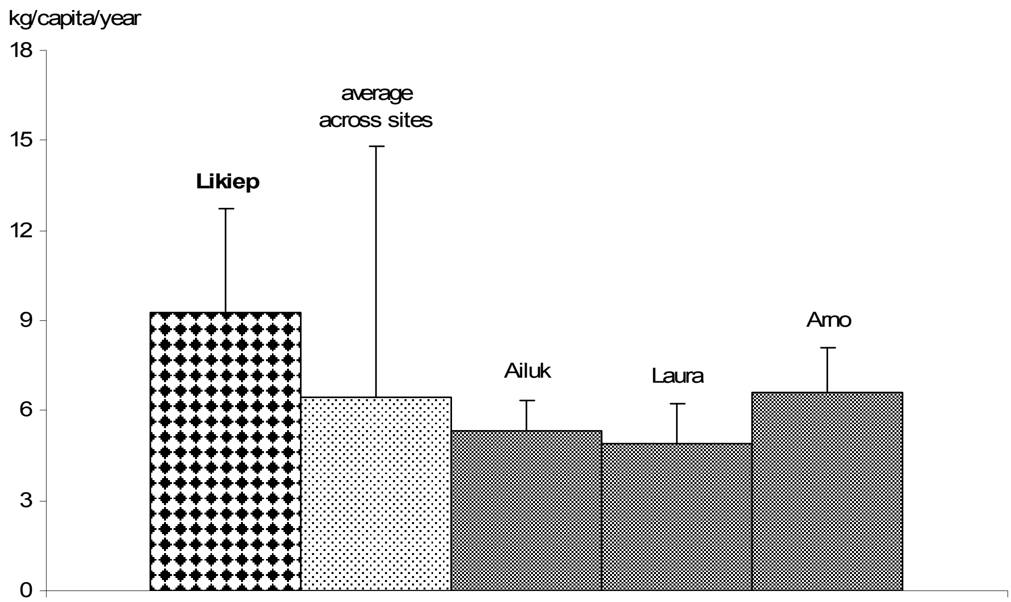

Figure 2.4: Per capita consumption (kg/year) of invertebrates (meat only) in Likiep (n = 20) compared to the average across sites and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results obtained for Likiep to the average figures across all four study sites surveyed in RMI, people of the Likiep community eat fresh fish more often than average, invertebrates less often and canned fish as found on average. The consumption of fresh fish and invertebrates is well above the average, while canned fish is consumed much less than observed elsewhere. Likiep people eat the same amount of fish and invertebrates that they catch as average, but they buy finfish more often, and exchange finfish and invertebrates on a non-commercial basis less often than is found on average across all sites in RMI. Handicrafts play a much greater role, and fisheries and salaries a much smaller role in providing income than the average found across all CoFish sites in RMI. The household expenditure level in Likiep is substantially lower than elsewhere (almost half). However, a much higher percentage of households receive remittances than found elsewhere, although the average amount of remittances received per year is less than average. By comparison, the rate of boat ownership is relatively similar to that found in the other sites in RMI.

2.2.2 Fishing strategies and gear: Likiep

Degree of specialisation in fishing

Fishing is done by both male and female fishers with little specialisation; both fish for finfish and invertebrates (Figure 2.5). As shown in Figure 2.5, only very few male fishers exclusively catch finfish. No fishers exclusively target invertebrates.

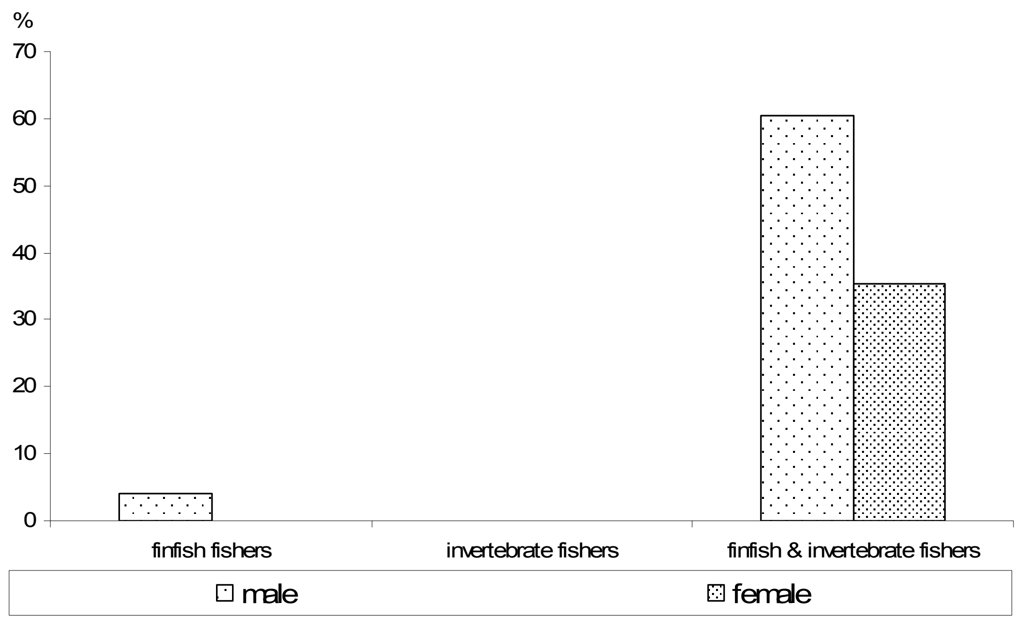

Figure 2.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Likiep.
All fishers = 100%.

Targeted stocks/habitat

Considering the limited number of boats, it is not surprising that Likiep finfish fishers mainly target the easily accessible habitats, namely the sheltered coastal reef and the lagoon. Both habitats are usually combined in one fishing trip. The outer reef and passages are fished only by male fishers, but not by as many fishers and not as frequently as the more accessible habitats (Table 2.2). Reeftop and intertidal (sand) gleaning are the most frequent invertebrate fisheries, with diving for lobster and 'others', such as clams and octopus, mostly performed by male fishers.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	95.7	100.0
	Outer reef	17.4	0.0
	Outer reef & passage	52.2	0.0
Invertebrates	Reeftop	38.9	92.3
	Intertidal	5.6	92.3
	Intertidal & reeftop	0.0	7.7
	Lobster	50.0	0.0
	Other	94.4	23.1

'Other' refers to the giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 23; females: n = 9. Invertebrate fisher interviews, males: n = 18; females, n = 13.

Fishing patterns and strategies

The number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Likiep on their fishing grounds (Tables 2.2 and 2.3).

Our survey sample suggests that fishers from Likiep have a good choice among sheltered coastal reef, lagoon and outer-reef fishing, including access to passages. Also, fishers seem to target the major habitats supporting invertebrate fisheries, with 32% of fishers gleaning the reeftop, 21% gleaning the intertidal areas, 31% diving for clams and octopus and 16% diving for lobsters (Figure 2.6). Data on gender show that females dominate the gleaning fisheries (reeftop, intertidal), while males mainly engage in diving for 'others' (clams, octopus and other gastropods), and are less involved in reeftop gleaning than female fishers. Females do not dive for lobsters (Figure 2.7).

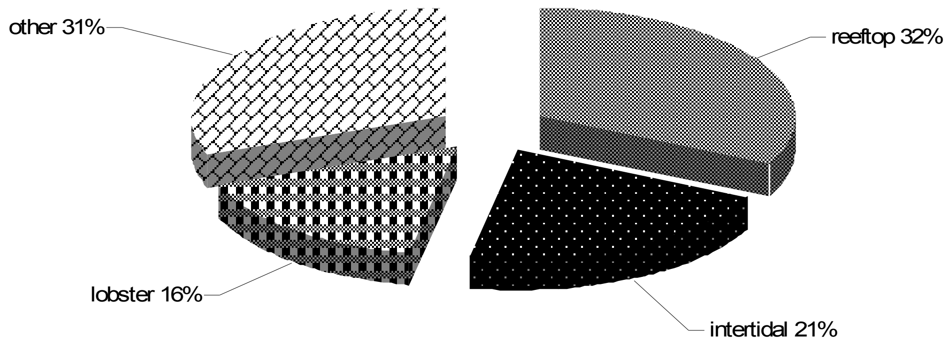

Figure 2.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Likiep.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the giant clam and octopus fisheries.

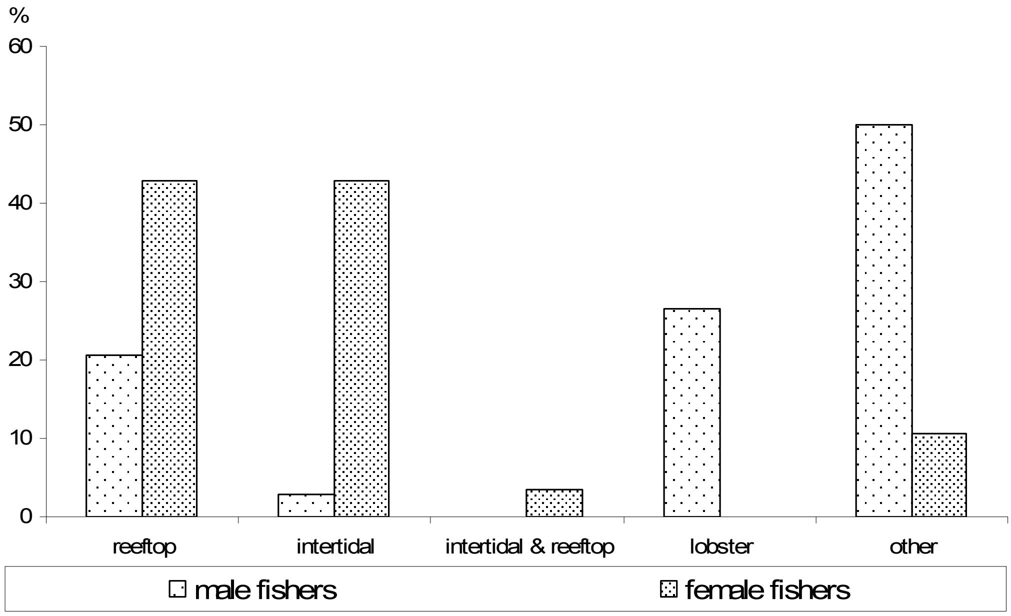

Figure 2.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Likiep.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 18 for males, n = 13 for females; 'other' refers to the giant clam and octopus fisheries.

Gear

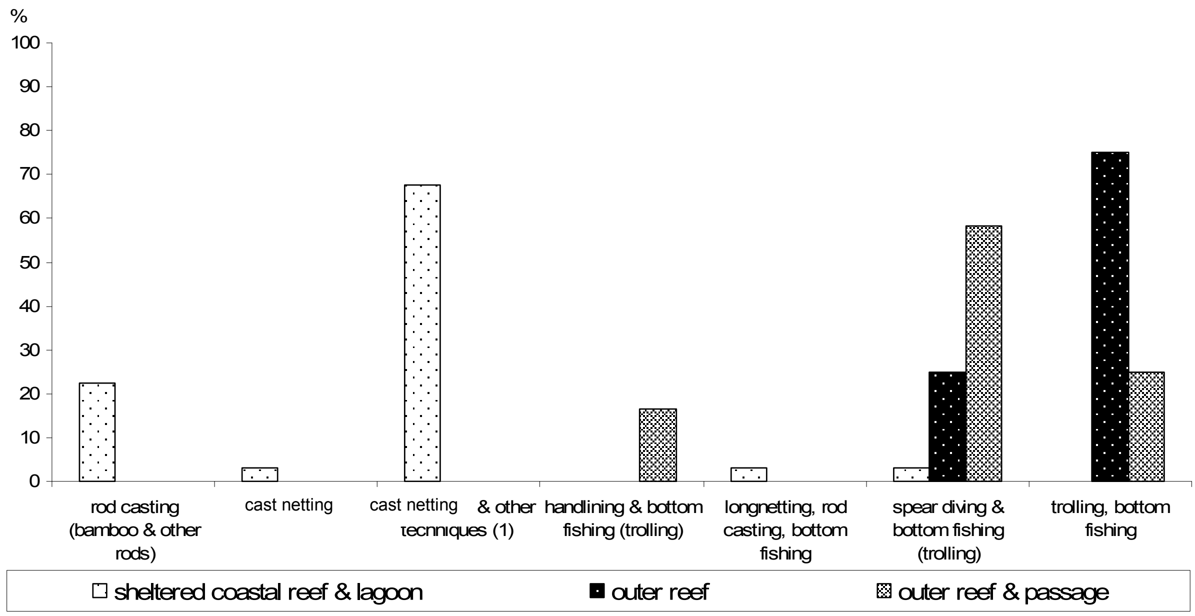

Figure 2.8: Fishing methods commonly used in different habitat types in Likiep.
(1) Bottom fishing, use of bush knives, gillnetting, bow and arrow, rod casting, handlining, spear diving. Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Figure 2.8 shows that Likiep fishers use fishing rods (bamboo and other rods), cast nets and a combination of cast nets and other tools and fishing gear if targeting the sheltered coastal reef and lagoon habitats. However, male fishers targeting the outer reef and passages usually select different techniques than those used closer to shore and often combine a few techniques in one fishing trip. Spear diving and bottom fishing, sometimes also mixed with trolling, are commonly used for outer-reef fishing and outer-reef and passage fishing combined. Here, another very common strategy is the combined use of trolling and bottom fishing.

Frequency and duration of fishing trips

Finfish fishers target the sheltered coastal reef and lagoon habitats about 2 to 2.5 times per week, while male fishers visit the outer reef and passages about once per week. Female fishers fish less frequently, about 1–2 times per week. Invertebrate trips are less frequently made by male and female fishers, usually once per fortnight. The average finfish fishing trip takes 2–3 hours for males and 1–2 hours for females. A typical invertebrate collection trip takes two hours for both male and female fishers. Only dive trips for invertebrates (lobsters, clams and octopus) take longer, averaging ~3 hours per trip.

Most finfish fishing is done according to tidal conditions, i.e. during the day or at night, and is performed throughout the year. Ice is hardly ever used on finfish fishing trips. Respondents only reported using ice in 25% of trips to the outer reef. None of the finfish fishing necessarily uses motorised or non-motorised boat transport; however, as distance from shore increases, boat transport becomes more important and is mandatory for fishing the passages and the outer reef. Gleaning for invertebrates is done by walking; if diving for clams, octopus or lobsters, boat transport is used. Invertebrates can be collected either at day or night, with lobster diving being the only night fishery. *Strombus* and *Nerites* spp. are usually collected at night during full moon.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.50 (±0.23)	1.56 (±0.24)	2.39 (±0.17)	1.61 (±0.16)
	Outer reef	1.50 (±0.29)	0	2.75 (±0.48)	0
	Outer reef & passage	1.21 (±0.15)	0	3.00 (±0.17)	0
Invertebrates	Reeftop	0.56 (±0.05)	0.67 (±0.05)	2.14 (±0.14)	2.33 (±0.14)
	Intertidal	0.46 (n/a)	0.67 (±0.07)	2.00 (n/a)	2.33 (±0.14)
	Intertidal & reeftop	0	0.23 (n/a)	0	2.00 (n/a)
	Lobster	0.54 (±0.04)	0	3.22 (±0.28)	0
	Other	0.69 (±0.07)	0.46 (±0.13)	2.76 (±0.11)	2.00 (±0.58)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 23; females: n = 18. Invertebrate fisher interviews, males: n = 9; females: n = 13.

2.2.3 Catch composition and volume – finfish: Likiep

The catches reported from the sheltered coastal reef and lagoon in Likiep contain a great variety of fish species. Serranidae, Lutjanidae, Kyphosidae and Lethrinidae represent the major species group by reported catch weight. At the outer reef, male fishers reported mainly catching Serranidae and Lethrinidae but also Acanthuridae and Holocentridae. The catch composition by dominant families does not vary much when comparing reported catches from the combined fishing of the outer reef and passages; however, Carangidae and Scombridae were also important. The catch composition greatly reflects the differences in fishing techniques used in the closer-to-shore habitats as compared to the outer reef and passages.

Detailed information on catch composition by species, species groups and habitats is reported in Appendix 2.1.1.

Figure 2.9 confirms the findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing serves mainly subsistence purposes and offers little opportunity to generate income. The total annual catch is estimated to amount to ~50.89 t, of which ~94% is used for subsistence needs, while only ~6% is sold externally. The dominance of male fishers by impact and production shows in the high proportion of catch that they take, i.e. 85% of the total annual catch. Thus, it can be concluded that male fishers are mainly responsible for providing food for the family and generating the little income possible from finfish fisheries. Although females do contribute to the household consumption, they contribute less (15% of total annual catch). Almost two-thirds of the total impact is imposed on the sheltered coastal reef and lagoon resources, and ~26% is accounted for by catches from the outer reef and passages.

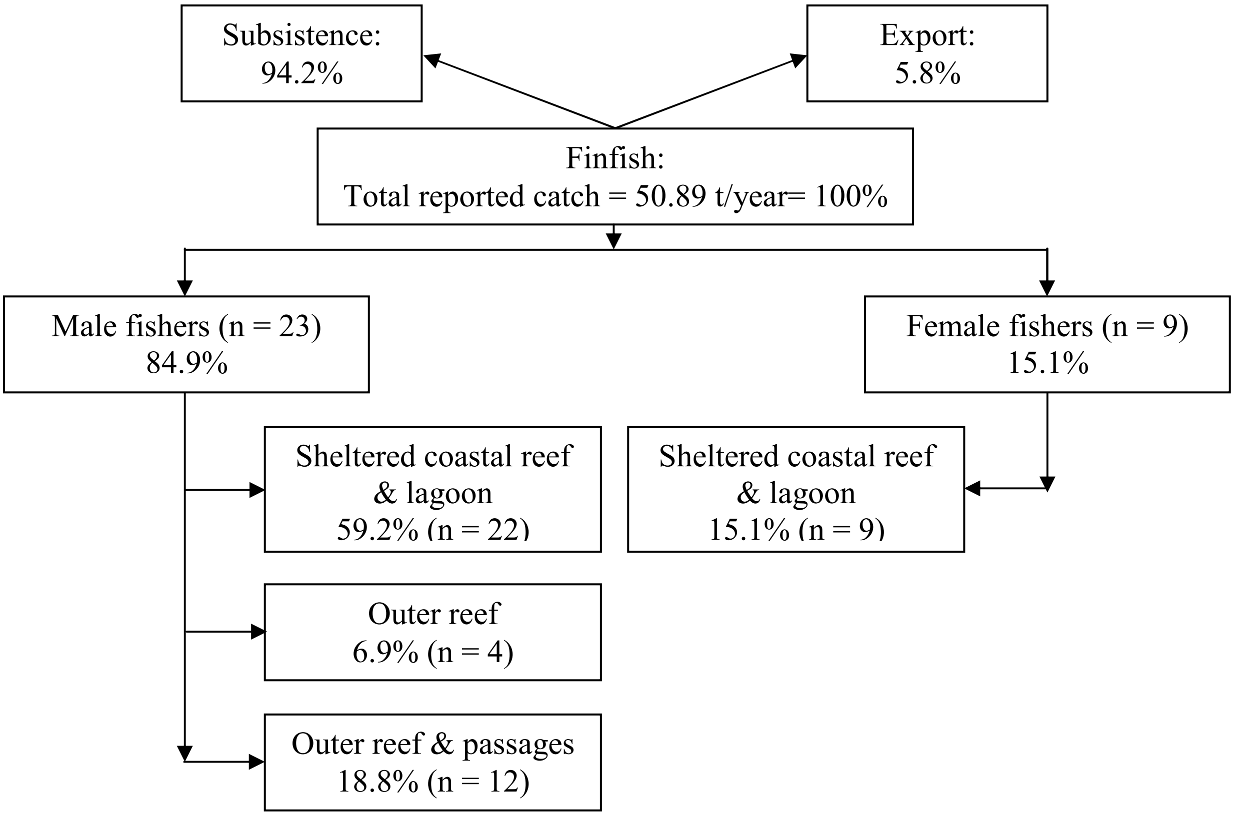

Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Likiep.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The distribution of annual catch weight between the more accessible sheltered coastal reef and lagoon and the more distant outer reef and passages, is a consequence of the number of fishers and, to some extent, also the annual catch rates. As shown in Figure 2.10, the average annual catch per male fisher is higher for sheltered coastal reef and lagoon fishing

(500 kg/fisher/year) than for outer-reef and passage fishing (~300 kg/fisher/year). Female fishers catch on average ~300 kg/fisher/year for the combined fishing of the sheltered coastal reef and lagoon. As mentioned earlier, female fishers do not target the outer reef and passages.

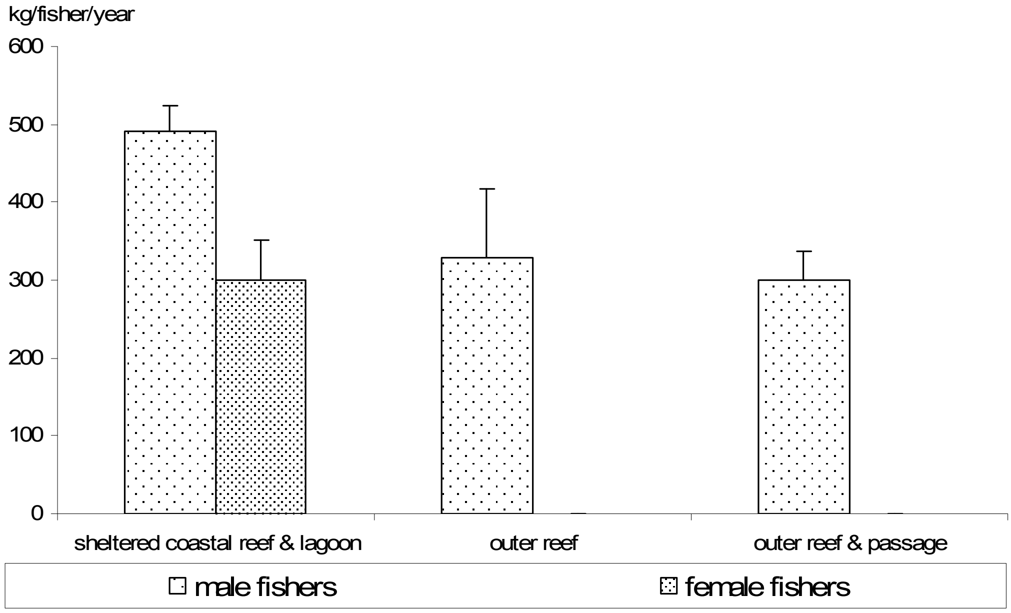

Figure 2.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Likiep.
Bars represent standard error (+SE).

Comparing productivity rates between genders and among habitats (Figure 2.11), there are no obvious differences among habitats fished. On average and across all habitats targeted, male fishers have an average CPUE of 2–2.5 kg/hour fishing trip; female fishers seem to be slightly more efficient with almost 3 kg catch per hour spent fishing.

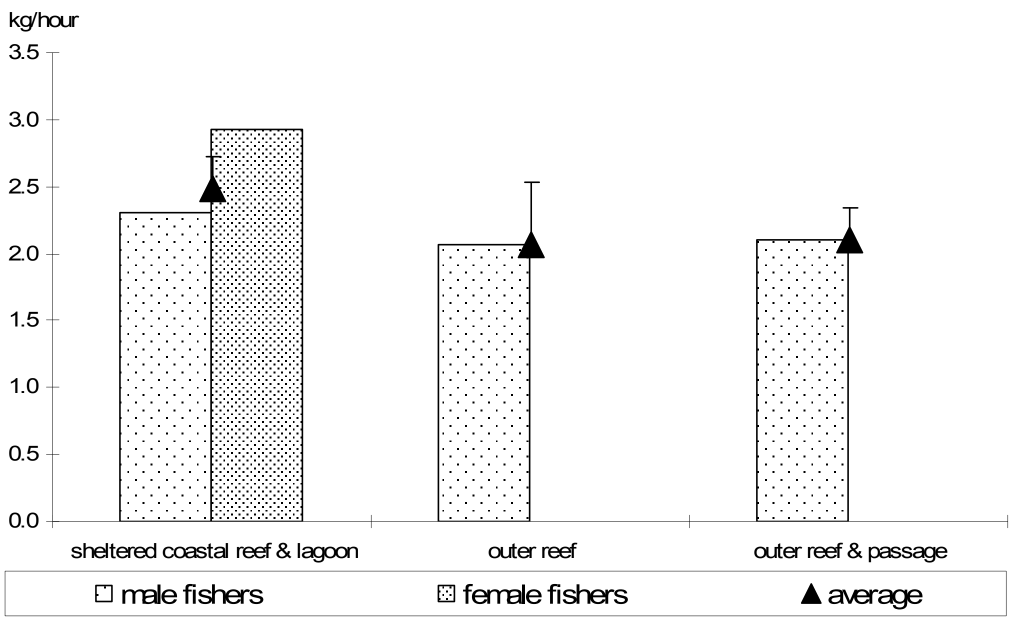

Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Likiep.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The importance of subsistence fishing for the Likiep community clearly shows in Figure 2.12. As observed earlier, male and female fishers target any of the habitats mainly for home consumption and little effort is undertaken to catch fish for sale.

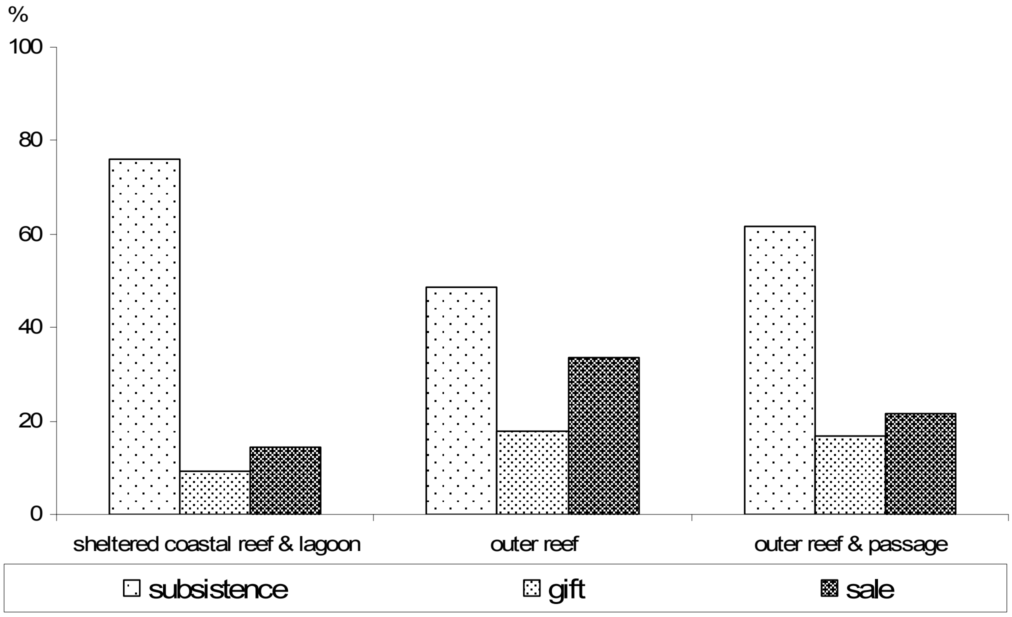

Figure 2.12: The use of finish catches for subsistence, gift and sale, by habitat in Likiep. Proportions are expressed in % of the total number of trips per habitat.

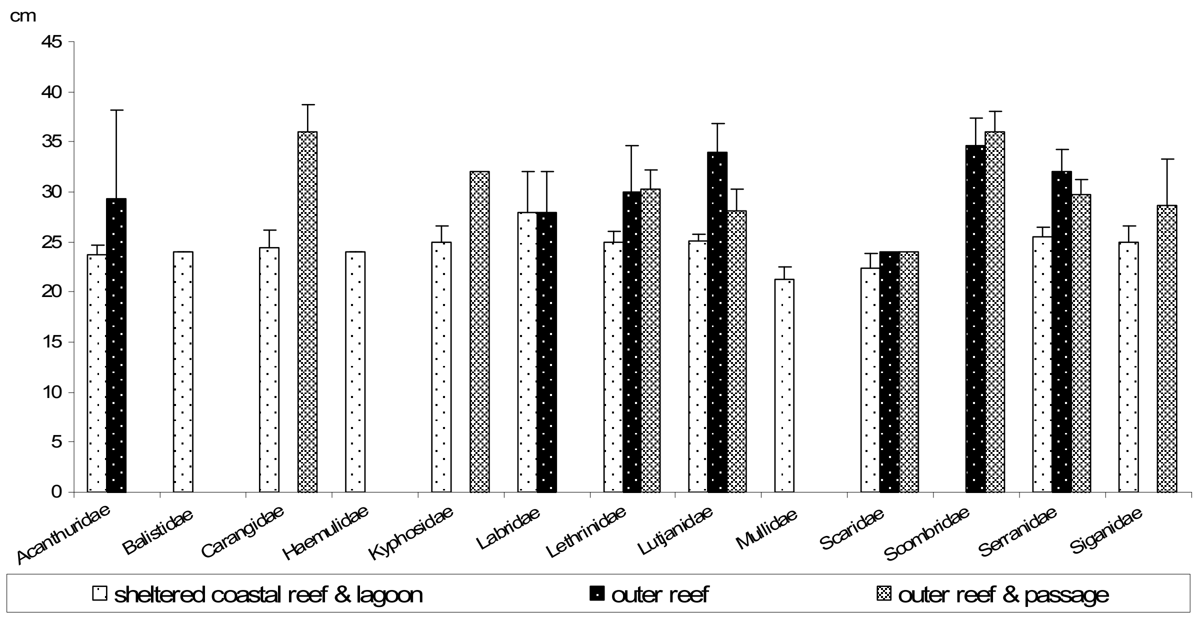

Figure 2.13: Average sizes (cm fork length) of fish caught by family and habitat in Likiep. Bars represent standard error (+SE).

The overall finfish fishing productivity was similar among the three habitats (Figure 2.11). This observation does not apply when comparing the reported average fish sizes (fork length) for the major families caught (Figure 2.13). As one would expect, there is an increase in the length of fish caught for the same species or species groups with increasing distance from the shore. This applies to Acanthuridae, Carangidae, Labridae, Lethrinidae, Lutjanidae, Scombridae and Serranidae. For other families, such as Scaridae, the sample size is not large enough to allow a valid comparison. However, there is no indication that this general trend does not apply for any major fish family.

The parameters selected to assess the current fishing pressure on Likiep reef and lagoon resources are shown in Table 2.4. Due to the large available reef surface and total fishing ground, population density, fisher density and catch rates per unit areas of reef and fishing ground are all very low. This picture remains consistent if we take into account the fact that ~94% of the total annual catches are used for subsistence. Any impact added by the small proportion of the annual catch that is sold (~6% only) will not make any difference to this conclusion.

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

Parameters	Habitat				
	Sheltered coastal reef & lagoon [4]	Outer reef	Outer reef & passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	443.93	29.79	37.7	117.42	481.62
Density of fishers (number of fishers/km^2 fishing ground) [1]	0.2	0.3	1	1	0.3
Population density (people/km^2) [2]				4	1
Average annual finfish catch (kg/fisher/year) [3]	435.73 (±31.61)	328.17 (±88.30)	300.21 (±36.79)		
Total fishing pressure of subsistence catches (t/km^2)				0.5	0.1

Figures in brackets denote standard error; [1] total number of fishers (= 151) is extrapolated from household surveys; [2] total population = 463; total subsistence demand = 56.44 t/year; [3] catch figures are based on recorded data from survey respondents only; [4] lagoon surface considered only.

2.2.4 Catch composition and volume – invertebrates: Likiep

Analysis of catches reported by invertebrate fishers by wet weight shows that six species account for an annual impact of >1 t each (wet weight). As shown in Figure 2.14, gastropods *Cerithium* spp., crustaceans including *Etisus splendidus*, lobsters *Panulirus* spp. and the coconut crab *Birgus latro*, as well as clams, notably *Hippopus hippopus* and *Tridacna squamosa*, but also *Tridacna* spp. and *T. maxima*, represent the major target species by wet weight. There are numerous others that are collected, including octopus, *Cypraea tigris*, *Strombus* spp. and *Turbo crassus*.

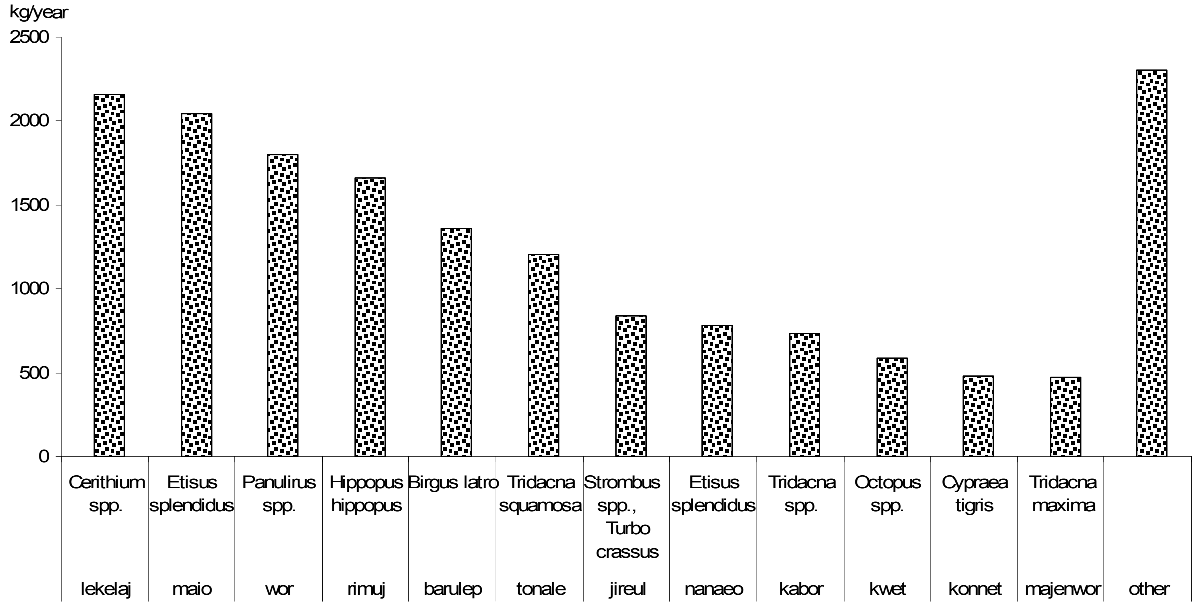

Figure 2.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Likiep.
'Other' includes *Etisus* spp. (*jebarbar*), *Donax cuneatus* (*juke*), *Turbo crassus* (*jirrol*), *Thais* spp. (*jubub in baren bob*), *Asaphis violascens* (*koi kor*), *Serpulorbis* spp. (*albij*), *Lambis lambis* (*aurak*), *Nerita polita* (*karrol*), *Thais* spp. (*jukjukinbrenbob*), *Nerita* spp. (*karred*) and *Strombus* spp. (*kadmok*).

The fact that quite a few species are locally collected shows in Figure 2.15, with 13 vernacular names being reported for reeftop catches, 9 for intertidal and 11 for diving for other species, including giant clams, octopus and others.

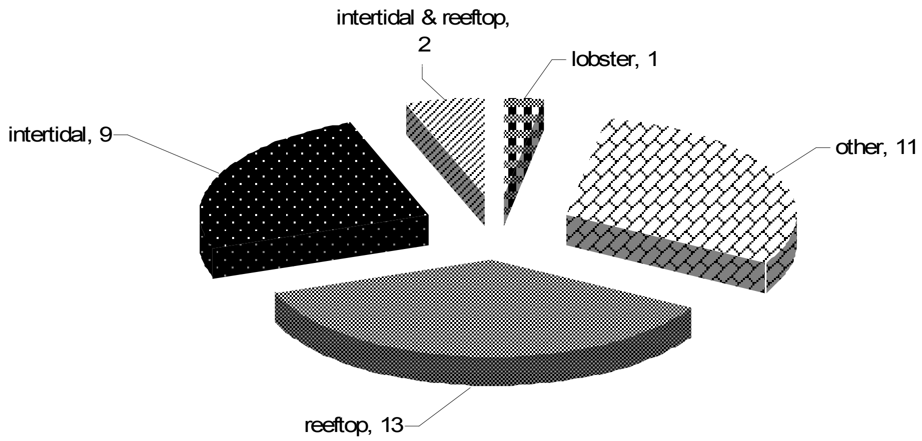

Figure 2.15: Number of vernacular names recorded for each invertebrate fishery in Likiep.
'Other' refers to the giant clam and octopus fisheries.

Analysis of the average annual catch per fisher by gender and fishery (Figure 2.16) reveals substantial differences among fisheries but not between genders. Reeftop collection and diving for mainly reef-associated species, including clams, octopus and others, provides the highest average annual catch per fisher, i.e. 300–350 kg/fisher/year, with little difference in reeftop gleaning catches obtained by male or female fishers. However, females do not dive and therefore cannot be compared with males in the category of diving for reef-associated invertebrates ('other'). Females, who have reported catches under this category, do not dive but may extend their collection to deeper waters. Lobster diving provides an average annual catch rate of 200 kg/male fishers, while catches from all other invertebrate fisheries are insignificant.

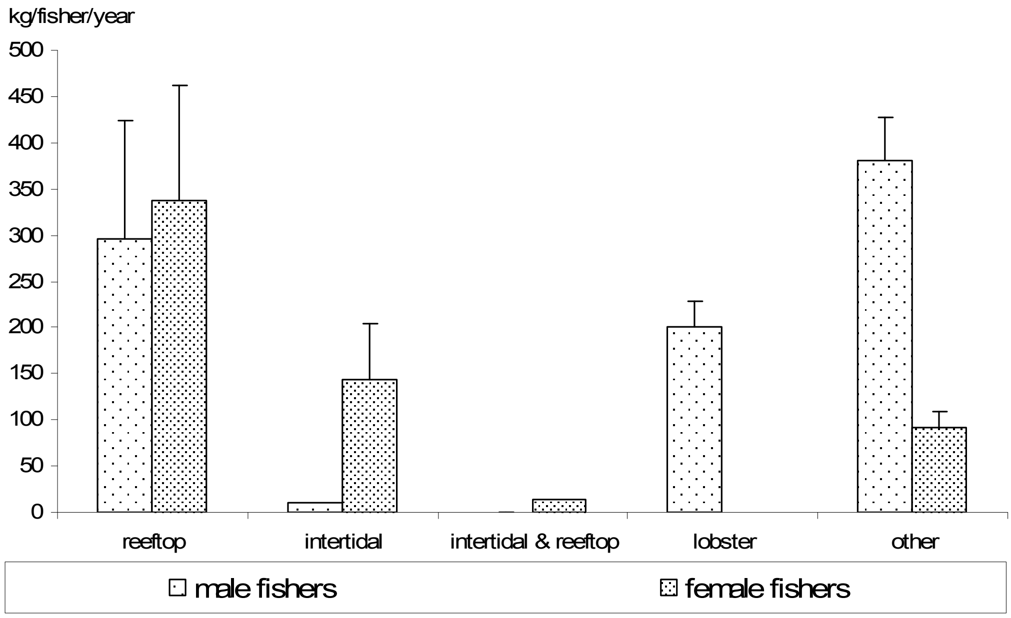

Figure 2.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Likiep.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 18 for males, n = 13 for females). Bars represent standard error (+SE).

The fact that the Likiep community is highly dependent on marine resources for subsistence is shown in Figure 2.17, which simply shows that all invertebrates are caught for home consumption, and none are sold.

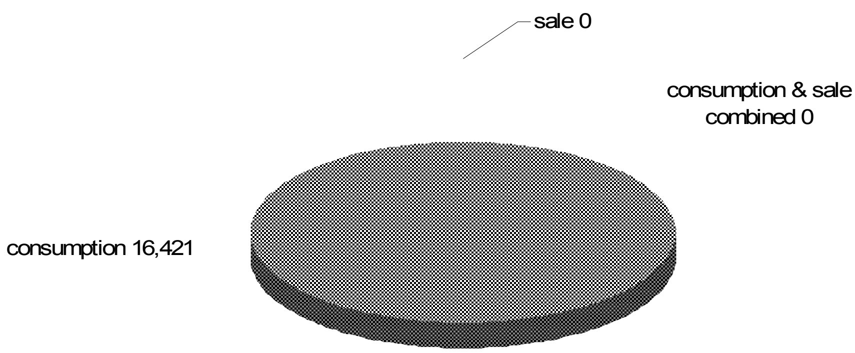

Figure 2.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Likiep.

As mentioned earlier, male fishers from Likiep are also very involved in invertebrate fisheries, accounting for ~63% of the total catch (wet weight) (Figure 2.18). Most male invertebrate fishers in Likiep target reef-associated species (‘others’), including clams, octopus and other species by diving. Coconut crabs, lobsters and clams are sent, if the opportunity arises, by plane to Laura or Ebeye in exchange for imported food items. Less impact is accounted for by male fishers on reeftop and lobster resources. Female fishers contribute 37% of the total annual catch by wet weight, and concentrate most effort on the reeftop and intertidal habitats.

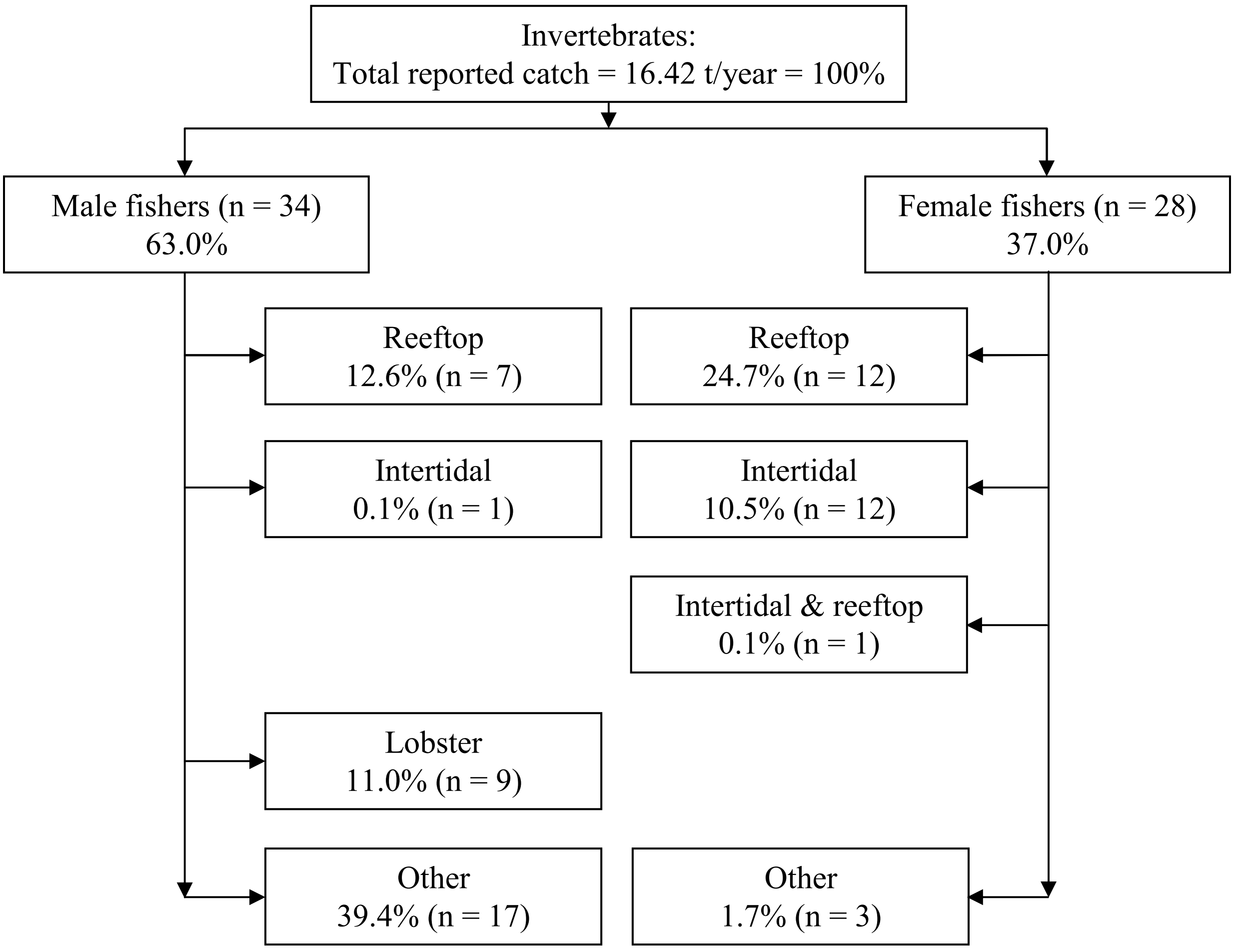

Figure 2.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Likiep.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

Taking into account available figures on the inner- and outer-reef surface areas, fisher density is low for any of the fisheries considered to be supported by reef areas. Also, average annual catch rates given for fishers participating in any of the fisheries (Table 2.5) are low. Although area surfaces are not known for the intertidal habitats, nor the outer-reef length for the lobster fishery, none of the parameters shown in Table 2.5 give any reason to assume that the current fishing pressure causes any detrimental effects on resources.

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

Parameters	Fishery / Habitat				
	Reeftop	Intertidal	Intertidal & reeftop	Lobster	Other
Fishing ground area (km^2)	26	n/a	n/a	n/a	26.06
Number of fishers (per fishery) (1)	85	55	4	46	99
Density of fishers (number of fishers/km^2 fishing ground)	3	n/a	n/a	n/a	4
Average annual invertebrate catch (kg/fisher/year) (2)	322.28 (±89.72)	133.81 (±55.47)	13.74 (n/a)	199.89 (±28.46)	337.26 (±46.38)

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; 'other' refers to the giant clam and octopus fisheries; (1) number of fishers extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only.

2.2.5 Management issues: Likiep

Marine tenure in RMI is mostly open-access. However, the area immediately beyond and adjacent to a community is usually regarded by the local population as being under their user jurisdiction. In the case of Likiep, which is an isolated island, there is hardly any impact by fishers from outside the community.

MIMRA has endorsed the establishment of the Coastal Management Advisory Council (CMAC), a committee that assists with the community-based fisheries management initiatives in communities. MIMRA, therefore, has a mechanism for introducing and providing support to coastal fisheries management work in the different islands of the country.

Management attempts by MIMRA, with the assistance of SPC, are still in their initial stage with little implementation on the ground. Given the fact that the Likiep community is small, that their appropriated reef and lagoon areas are large, and that fishing is done almost exclusively for subsistence purposes, current fishing pressure is low and no urgent interventions are required. Some management strategies have been introduced in Likiep by MIMRA, and a committee has been set up to oversee identified management areas. Areas have been identified to serve as potential reef reserves; however, there is no legislation to implement any rule or restriction. The committee confirmed that it is pursuing initiatives and needs to have management regulations decreed before implementing any management initiatives. Apparently, traditional mechanisms and user rules exist, and are still known to some extent; these could be included in any future fisheries management. Such traditional mechanisms include, for example, fishing patterns that are linked to seasons, moon phases, and tides. Implementation of any rules so far shows little effect, but this may also be explained by the fact that up until now there has been little if any need to regulate, reduce or control any of the fishing activities. If commercial opportunities become more important, i.e. there is an increase in volume of fish sold and an improvement in the reliability of transport and marketing facilities, fisheries management planning will be necessary. This is particularly true concerning certain high-cost, target species, such as lobster and clams, but may also be necessary for finfish.

Other traditional forms of management include the non-commercialisation of certain species, including *mollo* (rabbitfish), *joe* (goatfish) and *pegirik* (rudderfish). These are 'grade A' fish, which are only allowed to be caught for consumption. Dolphins are caught and consumed, but dolphin hunting is not allowed in the lagoon area. Turtles are only allowed to be hunted for traditional and social functions. The turtle-breeding area on the island is included in a breeding programme, which also involves school children. Eggs are collected and, when hatchlings surface, they are bred until they are big enough and released after tagging. According to local interviews, no tagged turtle has ever been fished by the community.

2.2.6 Discussion and conclusions: socioeconomics in Likiep

The Likiep community is small in size and isolated on an island surrounded by large reef and lagoon fishing grounds. Fishing is done for subsistence purposes, and little is caught for sale due to the limited opportunities for selling produce outside the island. The MIMRA boat is unreliable and infrequent, and air transport very limited. People pursue a very traditional lifestyle, supported by using agricultural and marine produce and by remittances sent from overseas. Most income is generated from handicrafts, and comparatively little is due to primary-sector activities or salaries. It is not surprising that the amount of finfish and invertebrates consumed is very high, that the household expenditure level is low, and that fishing mainly targets the more accessible sheltered coastal reef and lagoon, rather than the outer reef and passages. Due to the structure described, fishing pressure is low and does not require any urgent fisheries management intervention.

In summary:

- The Likiep population is highly dependent on marine resources for home consumption. It seems that fisheries, complementary to the already important handicraft sector, provide the only future option for generating income;

- The amount of fresh fish consumed is high; however, invertebrates are consumed to a much lesser extent. The canned fish consumption level is very low, which may be explained by the limited purchasing power of the community and the unlimited fresh seafood supply on the island.

- Traditional gender roles still exist, although both male and female fishers engage in finfish fishing and invertebrate collection. Female fishers do not target the outer reef and passages, nor do they participate in diving activities. Male fishers account for most impact (wet weight) regarding both finfish and invertebrates.

- Finfish is mainly sourced from the sheltered coastal reef and lagoon, but male fishers also access the outer-reef areas and passages. Boat transport is limited and shared among community members.

- CPUEs are comparative among habitats fished, and annual average catches per fisher are highest for the combined fishing of the sheltered coastal reef and lagoon.

- Fishing techniques vary according to the habitat targeted and mainly include cast nets and fishing rods in the closer-to-shore areas, and spear guns, trolling and deep-bottom lines at the outer reef and passages. Average fish sizes are large (≥25 cm), and increase with distance from shore.

- Results from surveys of invertebrate fishers show that the combined catches of gastropods, clams and crustaceans account for most of the annual harvest (wet weight).

Although people collect a wide variety of species, none of the reported impacts gives reason to assume there is any detrimental effect on the resources from fishing.

- Invertebrates are collected exclusively for home consumption.

- Parameters calculated for finfish fishing and invertebrate fisheries suggest that fishing pressure is low on all resources and habitats due to the large available reef and overall fishing ground area, and the low fisher densities, average annual catch rates, and annual catch per unit areas.

While the current demographic, resource and marketing situation does not require any fisheries management interventions further to the traditional and already established rules, sound fisheries management planning and strategies should be in place before any further development of commercial reef and lagoon fisheries occurs. As reported, when the arrival of the MIMRA boat is imminent, fishing activities increase drastically. With a reliable boat that visits more frequently and an increase in cooling, freezing and transport capacity, Likiep fishers are likely to use the opportunity to earn cash income.

2.3 Finfish resource surveys: Likiep

Finfish resources and associated habitats were assessed between 9 and 15 August 2007, from a total of 20 transects (6 intermediate-reef, 8 back-reef, and 6 outer-reef transects; see Figure 2.19 and Appendix 3.1.1 for transect locations and coordinates respectively).

Intermediate reefs were essentially represented by large pinnacles but their surface area was limited. Back-reefs were mainly found in the northern part of the atoll and were very rare anywhere else. Reefs that were partially composed of many living corals were quite rich in fish of large size. The outer reefs were, in general, well built by corals; however, the eastern side of the atoll could not be sampled due to the lack of passages and to rough weather.

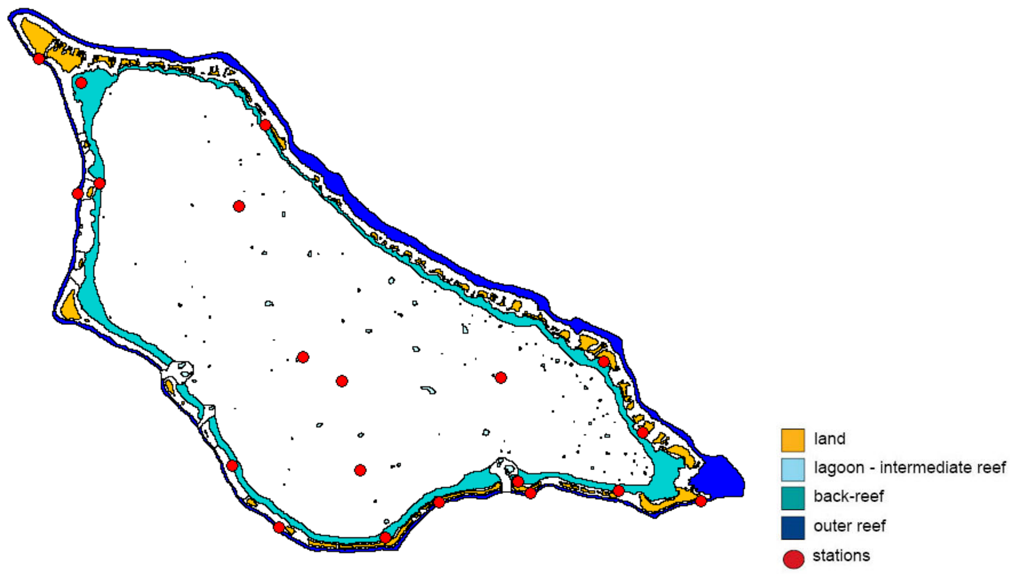

Figure 2.19: Habitat types and transect locations for finfish assessment in Likiep.

2.3.1 Finfish assessment results: Likiep

A total of 23 families, 62 genera, 170 species and 8478 fish was recorded in the 20 transects (See Appendix 3.1.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 47 genera, 146 species and 6575 individuals.

Finfish resources varied greatly among the three reef environments found in Likiep (Table 2.6). The outer reef contained a greater number of fish (0.4 fish/m^2), higher biomass (85 g/m^2), the highest biodiversity (62 species/transect) and the second-highest size ratio (53%) at the site. The intermediate reefs displayed very low density (0.2 fish/m^2), the lowest biomass (44 g/m^2), size ratio (49%) and biodiversity (38 species/transect), but the largest average size (19 cm FL). The back-reefs showed intermediate values between these two habitats.

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

Parameters	Habitat			
	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	8	6	20
Total habitat area (km^2)	2.0	37.0	29.8	68.8
Depth (m)	7 (3–10) (3)	3 (0–7) (3)	8 (6–15) (3)	5 (0–15) (3)
Soft bottom (% cover)	28 ±7	13 ±4	7 ±4	11
Rubble & boulders (% cover)	6 ±2	11 ±1	9 ±3	10
Hard bottom (% cover)	28 ±4	25 ±5	18 ±3	22
Live coral (% cover)	27 ±3	49 ±8	63 ±4	54
Soft coral (% cover)	8 ±5	1 ±0	2 ±1	2
Biodiversity (species/transect)	38 ±3	40 ±5	62 ±1	46 ±3
Density (fish/m^2)	0.2 ±0.0	0.4 ±0.1	0.4 ±0.1	0.4
Size (cm FL) (4)	19 ±1	17 ±1	17 ±1	17
Size ratio (%)	49 ±3	54 ±2	53 ±2	53
Biomass (g/m^2)	44.4 ±7.6	59.6 ±18.7	84.8 ±13.7	70.1

(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: Likiep

The intermediate-reef environment of Likiep was dominated by two major families in terms of density: Acanthuridae and Scaridae and, in addition and only in terms of biomass, by Serranidae and Balistidae (Figure 2.20, Table 2.7). These four families were represented by 39 species; particularly high biomass and abundance were recorded for *Acanthurus mata*, *Ctenochaetus striatus*, *Plectropomus laevis*, *Balistoides viridescens*, *Hipposcarus longiceps*, *Chlorurus microrhinos*, *Naso brevirostris*, *Epinephelus polyphekadion*, *Cetoscarus bicolor* and *Acanthurus nigricauda* (Table 2.7). This reef environment was equally composed of soft bottom, hard bottom and live coral (Table 2.6, Figure 2.20).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus mata*	Elongate surgeonfish	0.020 ±0.012	7.1 ±4.1
	Ctenochaetus striatus	Striated surgeonfish	0.050 ±0.013	5.2 ±1.6
	Naso brevirostris	Spotted unicornfish	0.014 ±0.014	2.1 ±2.1
	Acanthurus nigricauda	Epaulette surgeonfish	0.005 ±0.002	1.2 ±0.6
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.007 ±0.002	2.8 ±1.2
	Chlorurus microrhinos	Steephead parrotfish	0.003 ±0.002	2.4 ±1.6
	Cetoscarus bicolor	Bicolor parrotfish	0.001 ±0.001	1.4 ±1.0
Serranidae	*Plectropomus laevis*	Blacksaddle coralgrouper	0.002 ±0.001	5.2 ±3.1
	Epinephelus polyphekadion	Camouflage grouper	0.003 ±0.001	1.8 ±0.8
Balistidae	*Balistoides viridescens*	Titan triggerfish	0.001 ±0.001	3.5 ±2.3

The density, size ratio, biomass and diversity of finfish in the intermediate reefs of Likiep were the lowest at the site. Density was particularly low (0.2 fish/m^2). When compared to the other three sites in the country, Likiep intermediate reefs still displayed the lowest values of density and biodiversity and the second-lowest values of biomass, higher only than at Ailuk.

The trophic structure was dominated by herbivorous fish, mainly represented by Acanthuridae and Scaridae. However, piscivores (mainly Serranidae), plankton feeders and carnivores (Lutjanidae) were also similarly important in the biomass composition. Serranidae was the most abundant carnivorous family. Size ratio was slightly below the 50% value for Lethrinidae and Scaridae. This could be a result of fishing. However, the most frequently caught groups appeared to be Serranidae, Lutjanidae and, to a lesser extent, Siganidae. This reef presented a complex substrate composition with soft bottom, hard bottom and live corals in equal parts, and a limited cover of soft coral (8%). The rather high complexity of the substrate composition, including also a part of soft bottom, may explain the relatively high diversity of the main fish species groups representing the community, including herbivores, carnivores and planktivores.

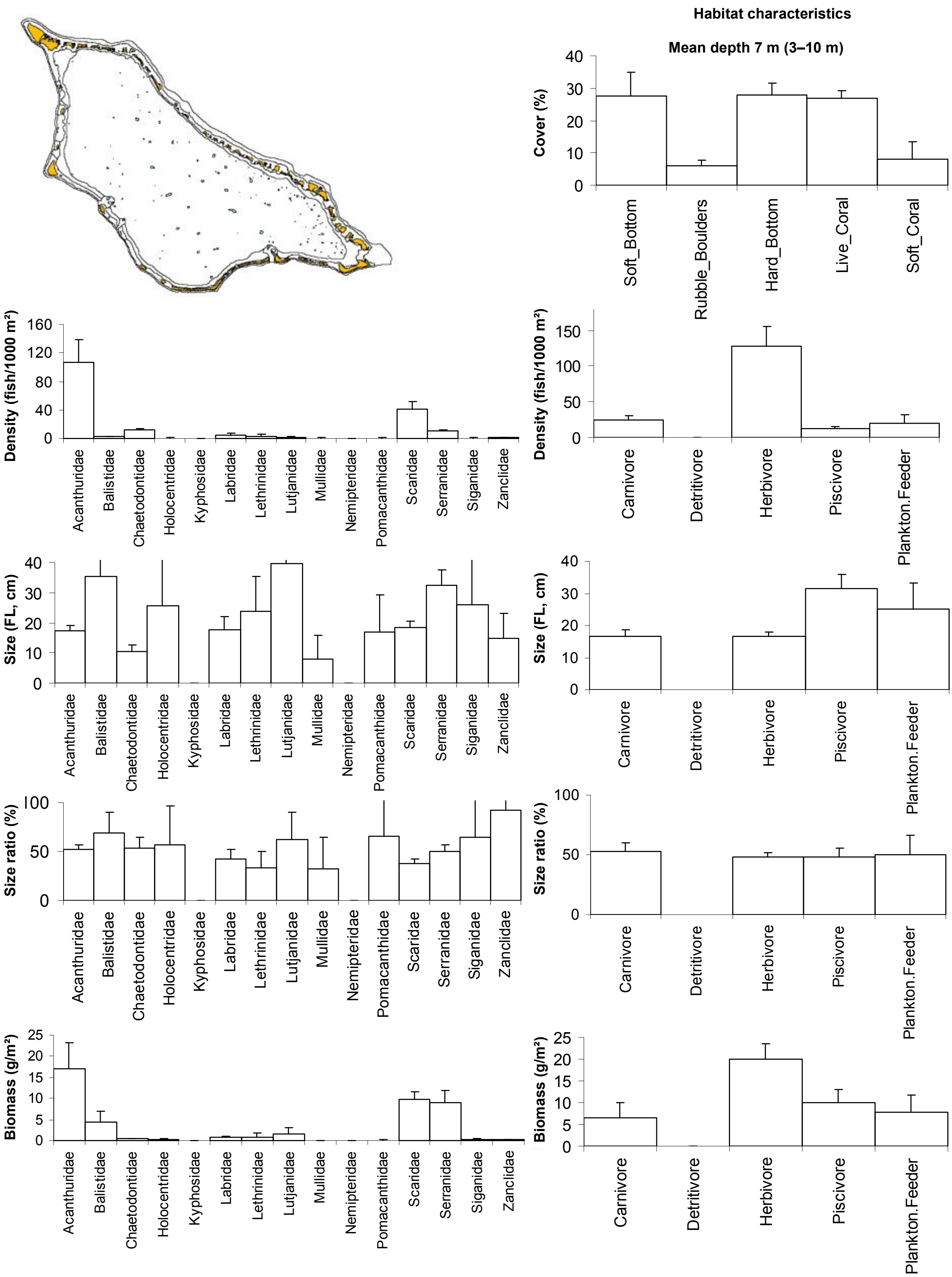

Figure 2.20: Profile of finfish resources in the intermediate-reef environment of Likiep.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Likiep

The back-reef of Likiep was dominated, in terms of density and biomass, by the herbivores Acanthuridae and Scaridae (Figure 2.21). These two families were represented by a total of 26 species, dominated by *Ctenochaetus striatus*, *Naso caesius*, *Chlorurus microrhinos*, *Acanthurus nigricans* and *Chlorurus sordidus* (Table 2.8). Live coral dominated the habitat with a very high cover (49%), while hard bottom occupied 25% of the substrate, and soft bottom and rubble were less prominent (Table 2.6 and Figure 2.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.135 ±0.065	14.7 ±6.7
	Naso caesius	Grey unicornfish	0.006 ±0.006	6.1 ±6.1
	Acanthurus nigricans	Whitecheek surgeonfish	0.028 ±0.018	3.1 ±2.1
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.008 ±0.004	3.9 ±2.6
	Chlorurus sordidus	Daisy parrotfish	0.026 ±0.006	2.3 ±1.1

The density of finfish at this reef was comparable to the outer-reef value (0.4 fish/m^2). Biomass and biodiversity values were midway between those of the intermediate and outer reefs. Size and size ratio were the highest recorded at this site. When compared to the other back-reefs in the country, Likiep displayed the highest values of biodiversity, density and size ratio, while biomass was the second-lowest, higher only than at Ailuk. Labridae, Lethrinidae, Mullidae, Scaridae and, especially, Serranidae displayed a size ratio below 50%, suggesting an impact from fishing. The trophic structure was strongly dominated by herbivores in terms of both abundance and biomass. The composition of the habitat, dominated by live coral and hard bottom was the type normally favouring herbivores such as Acanthuridae, here clearly dominating.

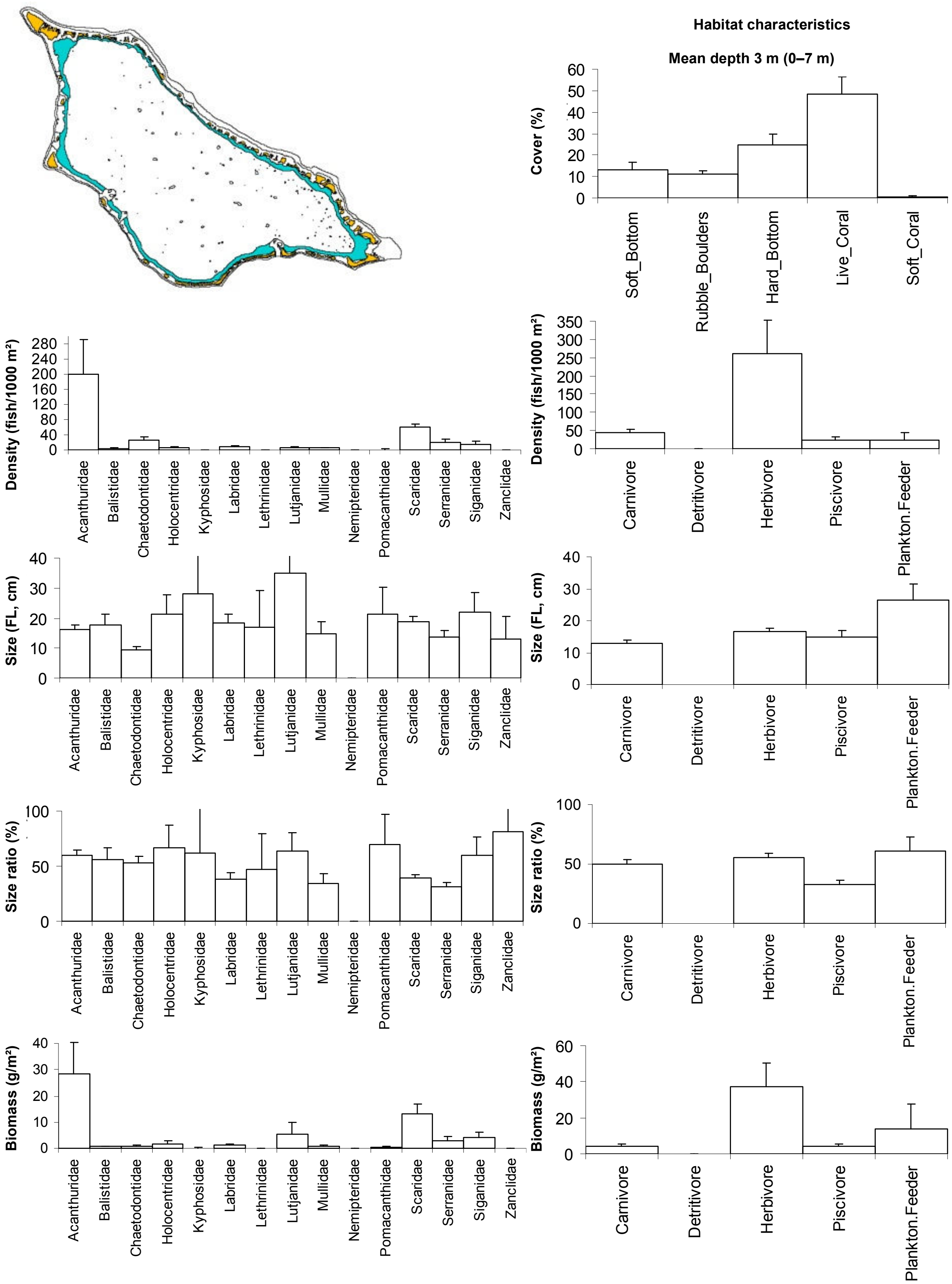

Figure 2.21: Profile of finfish resources in the back-reef environment of Likiep.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Likiep

The outer reef of Likiep was dominated, in terms of density and biomass, by the herbivores Acanthuridae and Scaridae and, in addition, particularly for biomass, by the carnivores Lutjanidae, Serranidae and Holocentridae (Figure 2.22). These five families were represented by a total of 50 species, dominated by *Ctenochaetus striatus*, *Acanthurus nigricans*, *Myripristis adusta*, *Macolor macularis*, *M. niger*, *Chlorurus microrhinos*, *Scarus altipinnis*, *C. sordidus* and *Plectropomus laevis* (Table 2.9). Live-coral cover (63%) highly dominated the habitat, which was also composed of hard bottom (18%), and rubble and sand (26%, Table 2.6 and Figure 2.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.089 ±0.031	8.6 ±2.8
	Acanthurus nigricans	Whitecheek surgeonfish	0.080 ±0.028	5.2 ±2.0
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.007 ±0.003	5.8 ±4.0
	Scarus altipinnis	Filamentfinned parrotfish	0.003 ±0.002	3.7 ±2.8
	Chlorurus sordidus	Daisy parrotfish	0.030 ±0.008	2.8 ±1.1
Serranidae	*Plectropomus laevis*	Blacksaddle coralgrouper	0.002 ±0.001	9.4 ±5.8
Lutjanidae	*Macolor macularis*	Black snapper	0.005 ±0.002	5.0 ±3.9
	Macolor niger	Black and white snapper	0.003 ±0.002	2.6 ±1.9
Holocentridae	*Myripristis adusta*	Shadowfin soldierfish	0.007 ±0.006	2.7 ±2.3

The biomass and, especially, the biodiversity of finfish in the outer reef were the highest at the site. Density, size and size ratio were equivalent to the values recorded in the back-reefs. When compared with the other outer reefs, biodiversity was still the highest compared to the other three sites; size and biomass were second to values in Ailuk, and density was lower than the densities in both Laura and Arno. Lethrinidae, Scaridae, Mullidae and Siganidae displayed low average size ratios, much below 50% of the maximum ever recorded for the respective species, suggesting an impact from fishing. The trophic structure was dominated by herbivores in terms of density, mainly represented by average-sized species of Acanthuridae and large-sized species of Scaridae. Piscivores (Serranidae), planktivores (Holocentridae) and other carnivores (Lutjanidae, with the large-sized *Macolor* spp. displaying very high biomass, and Labridae) also contributed to the biomass composition. The habitat type, mostly made up of live coral and hard bottom (91%), was the kind that normally favours herbivores, such as Acanthuridae and Scaridae, here clearly dominant, but also certain families of carnivores (particularly Serranidae, Lutjanidae and Holocentridae). Fishing in the outer-reef habitat was rarer than lagoon fishing and mainly done by bottom fishing and trolling but also spear diving.

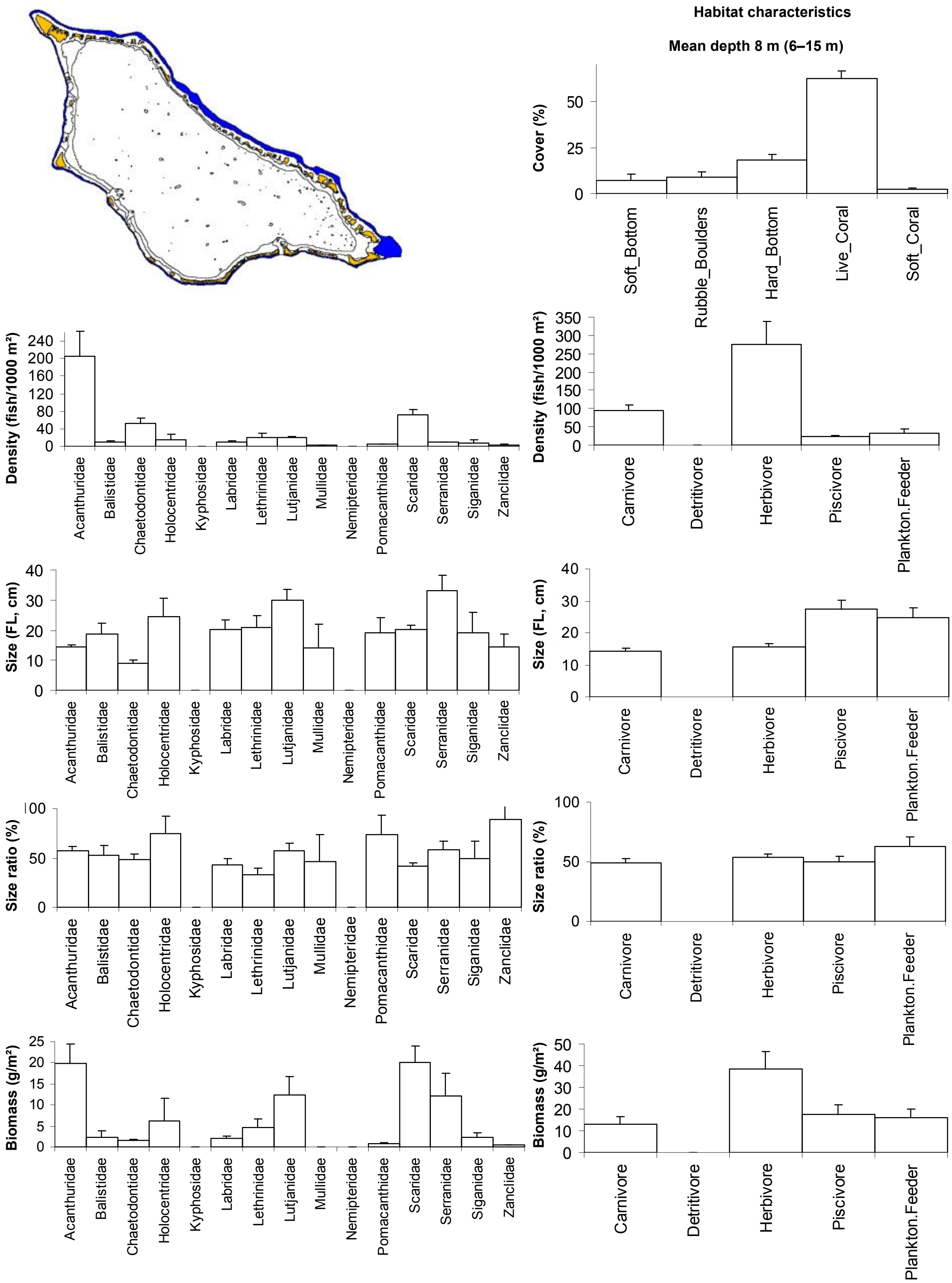

Figure 2.22: Profile of finfish resources in the outer-reef environment of Likiep.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Likiep

Overall, the reefs of Likiep were heavily dominated by two main herbivorous families, Acanthuridae and Scaridae (Figure 2.23) in terms of density and biomass, and by two carnivorous families, Lutjanidae and Serranidae in terms of biomass only. These four families were represented by a total of 56 species, dominated by *Ctenochaetus striatus*, *Acanthurus nigricans*, *Naso caesius*, *Macolor macularis*, *M. niger*, *Chlorurus microrhinos*, *C. sordidus*, *Scarus altipinnis* and *Plectropomus laevis* (Table 2.10). Live coral dominated the overall habitat cover, with a high average value (54%), while hard bottom covered 22% of the total substrate, and rubble and soft bottom together occupied 21% (Table 2.6 and Figure 2.23). The overall substrate and fish assemblage in Likiep shared characteristics of primarily back- and outer reefs (54% and 43% of total habitat respectively) and, to a minimal extent, of intermediate reefs (3%).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.112	11.8
	Acanthurus nigricans	Whitecheek surgeonfish	0.050	3.9
	Naso caesius	Grey unicornfish	0.004	3.8
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.007	4.7
	Chlorurus sordidus	Daisy parrotfish	0.027	2.5
	Scarus altipinnis	Filamentfinned parrotfish	0.004	2.3
Serranidae	*Plectropomus laevis*	Blacksaddle coralgrouper	0.001	4.2
Lutjanidae	*Macolor macularis*	Black snapper	0.003	3.1
	Macolor niger	Black and white snapper	0.002	2.3

Overall, Likiep appeared to support a relatively good finfish resource, with highest biodiversity, and values of density, size and size ratios comparable to the Laura values and higher than the values at the two other sites. The biomass values were similar among the four sites, ranging between 69 and 73 g/m². The average biomass value was second to those at Laura and Arno. These results suggest that the overall finfish resource in Likiep was in average condition compared to the other sites. However, on a regional scale, density and biomass were at the lower end of the scale, although biomass was in the first 15 ranked sites, suggesting good natural conditions. Detailed assessment at family level revealed a dominance of Acanthuridae and Scaridae in the fish community. The trophic composition was dominated by herbivores in terms of density and biomass; however, carnivores were fairly well represented, especially by Serranidae and Lutjanidae. The dominance of herbivores can be explained by the composition of the habitat, which was mainly composed of live coral and hard rock, with very little percentage of soft substrate, which normally favours most invertebrate-feeding carnivores, such as Mullidae and Lethrinidae. The study of size and size ratio trends disclosed the presence of smaller-than-average fish, indicating a first impact on some selected families of both herbivores and carnivores; Scaridae, Mullidae, Serranidae and especially Lethrinidae displayed overall small size ratios. Catches of such carnivores could be another factor contributing to the type of composition of the fish community, heavily skewed towards a few herbivores. Serranidae, Lutjanidae and Lethrinidae appeared to be the most targeted families in both the lagoon and outer-reef habitats.

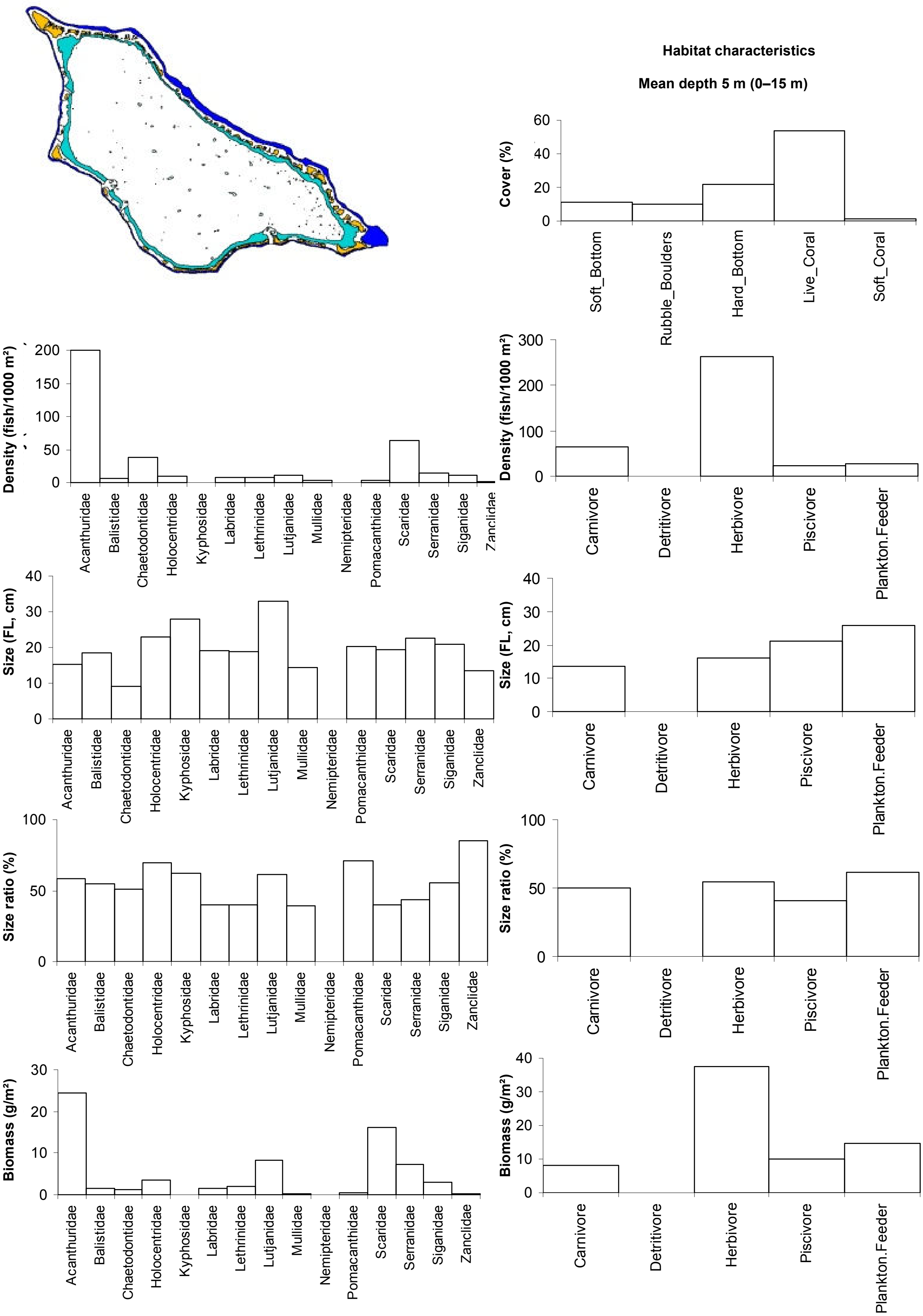

Figure 2.23: Profile of finfish resources in the combined reef habitats of Likiep (weighted average).
FL = fork length.

2.3.2 Discussion and conclusions: finfish resources in Likiep

The assessment indicated that the status of finfish resources at this site at the time of surveys was average to good when compared to the other three country sites. However, when comparing Likiep values to the average status for the region, conditions were relatively poor, especially in terms of density and biomass of finfish.

- The habitat was found to be generally healthy, with a good variety of substrate types and a high cover of live coral, the highest among the four sites and the highest in the region.

- Fish density and biomass were average to low on a regional scale but in the average range of the four country sites. Biodiversity was the highest in the country, and average on a regional scale. Size and size ratios were at the higher end of the country range (similar to those in Laura). Large-sized species of parrotfish (*Chlorurus microrhinos*, *Hipposcarus longiceps* and *Scarus altipinnis*) were rather common. Apex predators were quite frequent (A total of 41 sharks were observed along transects.).

However:

- A total absence of large groupers and napoleon wrasses, as well as other large carnivores was noted.

- No exceptional sizes or densities were recorded.

Moreover, differences were detected among the three reef habitats.

- At the intermediate reefs, the general status of corals was fairly good, with the best coral coverage in front of the northern islands, with many tabular and branching corals. The back-reefs (49% live-coral cover) and outer reefs (63%) were really rich in live coral and showed the highest values of percentage cover among the four sites. On the outer reef, coral coverage was rather high in the shallow (flat reef), with many soft corals (*Lemnalia*), branching corals (*Pocillopora*) and tabulate corals (*Acropora*). However, at this habitat, the amount of coral cover varied widely, with areas of barren bedrock and rock boulders covered with turfs and encrusting algae mixed with areas of higher coral cover, comprising massive and submassive Porites corals and tabulate, encrusting and digitate corals especially abundant below 20 m depth.

- Similar to the habitat conditions, the finfish resources also varied among the three reef types.

- The intermediate reefs, although representing only 3% of the total reef area in Likiep, were poor in fish fauna, displaying low density, biomass, and biodiversity, although the fish community was dominated by a mix of herbivores and carnivores, mainly Acanthuridae, Scaridae and Serranidae. Fish were quite fearful of divers and more abundant in the northwestern area, far from the main village. Reef fishing was done mainly for subsistence (80% of all catches) in this habitat, yet the highest annual catches came from these reefs. Average size ratios were particularly low for Scaridae, Lethrinidae and Mullidae, suggesting an impact from fishing.

- The back-reefs displayed intermediate values of density and biomass, average size and diversity among the three habitat types. The average sizes of several families (Lethrinidae, Scaridae, Mullidae and Serranidae) were much lower than 50% of their maximum recorded values, indicating an impact from fishing on these targeted species.

- The outer reefs displayed the best conditions of the site, with biomass double that of the intermediate reefs. The biodiversity was high even when compared to the regional values, Likiep outer reefs displaying the fifth-highest value in terms of number of species. However, no *Bolbometopon muricatum* and only very few *Cheilinus undulatus* of small size were recorded. Moreover, sizes of fish were low for Lethrinidae, Mullidae, Scaridae and Siganidae.

2.4 Invertebrate resource surveys: Likiep

The diversity and abundance of invertebrate species at Likiep were independently determined using a range of survey techniques (Table 2.11), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 2.24) and finer-scale assessment of specific reef and benthic habitats (Figures 2.25 and 2.26).

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

Table 2.11: Number of stations and replicates completed at Likiep

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	13	78 transects
Reef-benthos transects (RBt)	18	108 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	6	36 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	7	42 search periods
Reef-front search by walking (RFs_w)	2	12 search periods
Sea cucumber day searches (Ds)	5	30 search periods
Sea cucumber night searches (Ns)	2	12 search periods

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

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

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

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

2.4.1 Giant clams: Likiep

Shallow-reef habitat that is suitable for giant clams within the atoll lagoon of Likiep was extensive (59.2 km^2); however, for a lagoon area of 415 km^2, the amount of inshore shallow reef available (approximately 26.1 km^2) shows that hard-reef benthos was quite sparsely distributed. This was because much of the shallow benthos in the lagoon was sandy, and shorelines were often sandy rubble with low relief and complexity. Outside the lagoon, solid limestone structures and live corals on the barrier reef front and slope were more substantial and interconnected (33.1 km^2).

Nutrient inputs from land were limited and, in general, the system looked to be nutrient-poor. However, shallows in the west of the lagoon were subject to dynamic water circulation through the numerous passages that bisected the barrier. In parts of the east (in front of Likiep Island), and along the northeast side of the lagoon (from Loto and *motu* to the north, e.g. Kidaden), conditions were more depositional, and epiphytic growth and silt deposition contrasted greatly with the cleaner reefs in the west.

Broad-scale sampling provided an overview of giant clam distribution at Likiep. Reefs at this site held four species of giant clam: the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, the true giant clam *T. gigas*, and the horse-hoof or bear's paw clam *Hippopus hippopus*. The smooth clam *T. derasa* was present as a result of translocation from Palau in 1990. Initially, Likiep received 5000 1–2 cm clams but, today, only 150 clams, which are around 35–40 cm in size, are left. Although there were anecdotal reports of natural reproduction resulting in a F1 generation being recorded as far as >20 km to the northwest of the hatchery, no records were made in our surveys. Records from broad-scale sampling revealed that *T. maxima* had the widest distribution (found in all 13 stations and 64 of 78 transects), followed by *H. hippopus* (in 12 stations and 36 transects), then *T. squamosa* (9 stations and 18 transects) and *T. gigas* (4 stations and 6 transects). The average station density of *T. maxima* in broad-scale assessments was 457.9 /ha ±83.6 (See Figure 2.27.).

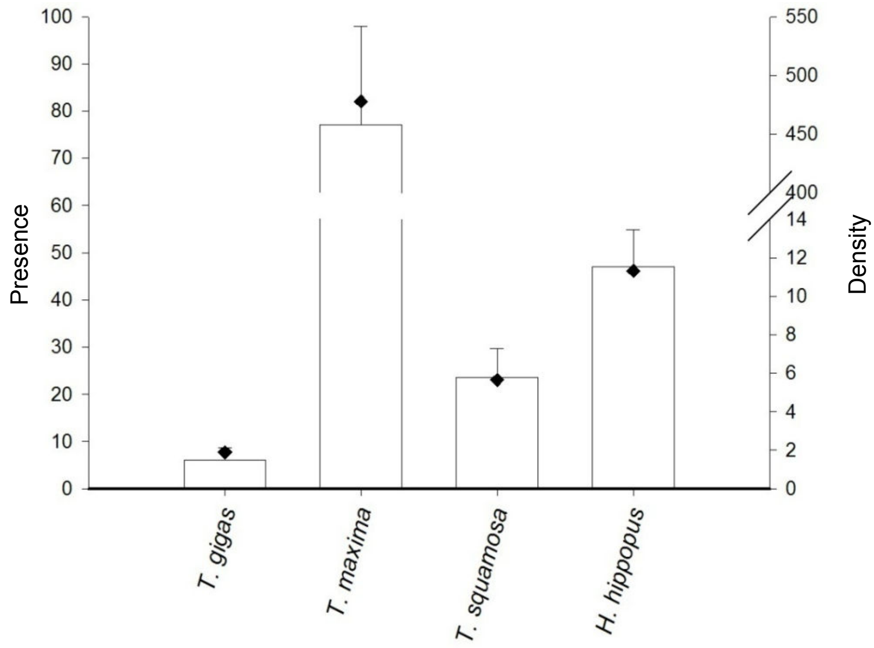

Figure 2.27: Presence and mean density of giant clam species at Likiep based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 2.28). In these reef-benthos assessments (RBt), *T. maxima* was present in 94% of stations at a mean density of 740.7 /ha ±203.1.

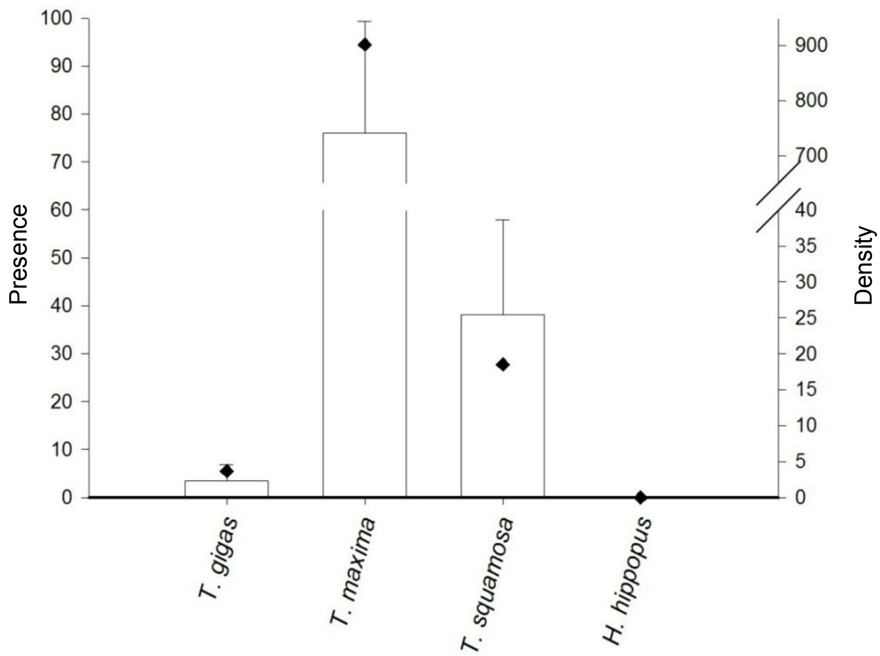

Figure 2.28: Presence and mean density of giant clam species at Likiep based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

One RBt station near the main settlement island of Likiep did not return any records for *T. maxima*. Six RBt stations on the western side of the atoll, where water movement was greatest, held clams at high density (mean of 1541.4 /ha ±446.6). At their highest density, clams in one transect were recorded at approximately 1 clam per 2 metres. These densities were noticeably higher than those recorded from reefs on the eastern edge of the lagoon (mean of 312.5 /ha ±90.8).

Of the 741 records taken during all assessment techniques, the average length of clams was 11.3 cm ±0.2 (n = 625) for *T. maxima*, 27.1 cm ±0.9 for *T. squamosa* (n = 40), 71.1 cm ±6.3 for *T. gigas* (n = 9) and 22.1 cm ±0.8 for *H. hippopus* (n = 67). A full range of lengths for *T. maxima* and the other species was recorded in survey, although the proportion of larger *T. maxima* clams (≥16 cm) was small considering the rest of the measured stock (See Figure 2.29.).

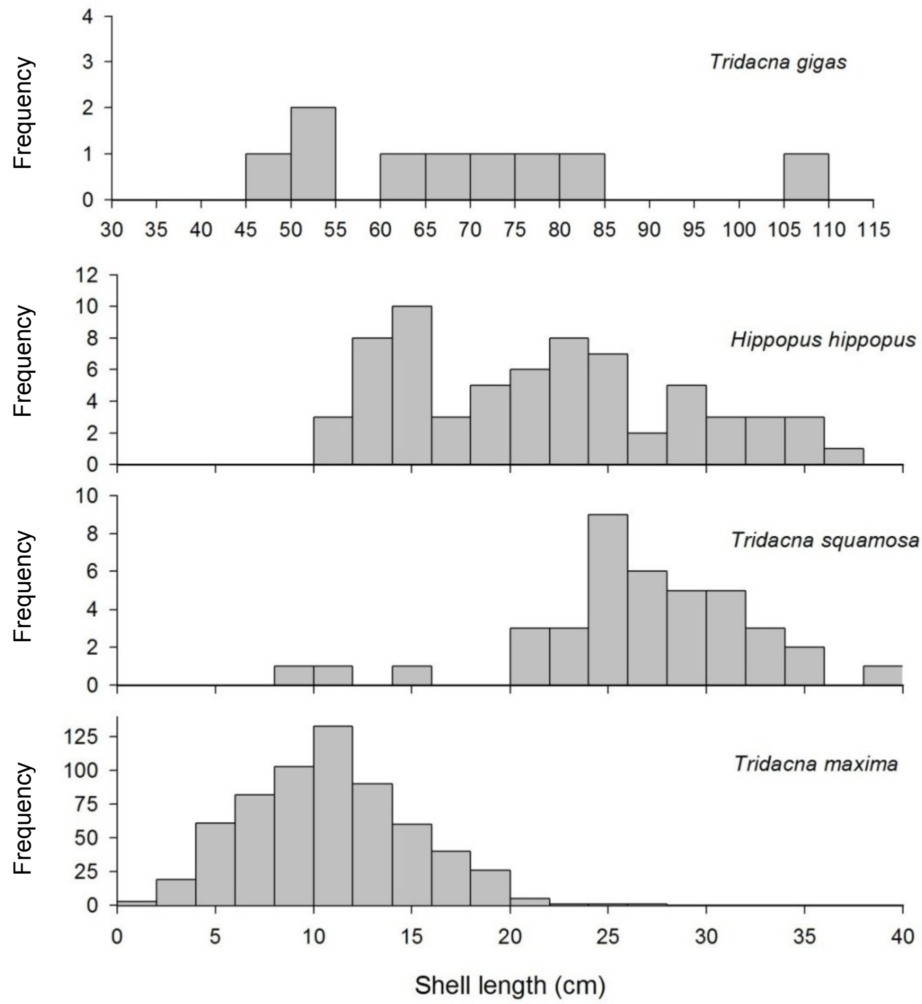

Figure 2.29: Size frequency histograms of giant clam shell length (cm) for Likiep.

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

Marshall Islands lies between 4–14° N and 160–173° E. Likiep, as part of the Ratak chain, lies at approximately 168° E, which is within the east–west range of the commercial topshell, *Trochus niloticus* (found naturally on islands as far east as Wallis), but too far north (9° N) to have local populations of this species.

Trochus were introduced to RMI by the Japanese during the 1930s, with introductions to Jaluit, Laura, Ailinglaplap and, apparently, also Arno, Kwajalein and Enewetak (Asano and Inenami 1939, McGowan 1958 cited in Wright *et al.* 1989). Gillett (1991) lists the following details of transplants in the RMI: 1939 - Truk to Jaluit, a 6143 t cargo ship carried shells in four water tanks; 1939 - Palau to Jaluit, shells transferred to other atolls of Marshall Islands including Laura and Ailinglaplap, with a transfer to Ebon not successful; 1954 - unknown location to Kili, attempt was unsuccessful; 1984 - somewhere in Marshall Islands to Ebon, Aur and Maloelap, done in conjunction with a trolling resource survey. Trochus were also brought to Likiep by a local resident (anecdotally from Ailinglaplap) and placed out on reefs in the channel between the hatchery island (Loto Island) and Likiep Island. None have been sighted in previous surveys and the introduction was thought to be unsuccessful.

The outer reef at Likiep (107.6 km lineal distance of exposed reef perimeter) constitutes a very extensive benthos for *T. niloticus*. The reef was not all well suited to commercial trochus; the northeastern-facing section was subject to very large swells, which had flattened the relief and complexity of the benthos, and most of the more suitable westerly reef had a steep reef slope. In addition, most surfaces were clean in the ocean-influenced system, with little algae evident for trochus grazing. On the other hand, the back-reefs and intermediate reefs near the passages on the south and west coasts provided suitable habitat, and these areas could potentially support a significant number of this commercial species.

CoFish survey work did not locate any live or dead *T. niloticus* at Likiep.

Table 2.12: Presence and mean density of *Tectus pyramis* and *Pinctada margaritifera* in Likiep
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Tectus pyramis				
B-S	0.6	0.4	3/13 = 23	3/78 = 4
RBt	6.9	4.0	3/18 = 17	3/108 = 3
RFs	1.1	0.8	1/7 = 14	2/42 = 5
MOPs	3.8	2.1	2/6 = 33	3/36 = 6
Pinctada margaritifera				
B-S	0.4	0.3	2/13 = 15	2/78 = 3
RBt	0		0/18 = 0	0/108 = 0
RFs	0		0/7 = 0	0/42 = 0
MOPs	0		0/6 = 0	0/36 = 0

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

The potential suitability of reefs for grazing gastropods was 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 not common and at relatively low density at Likiep (n = 11 recorded in survey, Table 2.12). The mean size (basal width) of *T. pyramis* was 6.1 cm ±0.2, and no large recruitment pulse was identified.

Blacklip pearl oysters (*Pinctada margaritifera*) are normally cryptic and sparsely distributed in open-lagoon systems. This atoll lagoon was relatively enclosed despite the numerous westerly passages; however, blacklip pearl oysters were rarely noted in survey (n = 2, Table 2.12). This was despite the fact that a longline of oysters was strung up in the embayment near Likiep Island. This longline was established in November 2005, with 1000–2000 juvenile oysters, which are now adult. Little monitoring of this aquaculture development programme has been possible, and no seeding of shell has taken place to date. All oysters were bred at the College of the Marshall Islands Arrak facility in Laura.

2.4.3 Infaunal species and groups: Likiep

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

2.4.4 Other gastropods and bivalves: Likiep

Seba's spider conch (*Lambis truncata*) (the larger of the two common spider conchs) was recorded at low-to-moderate density (n = 11 individuals), generally outside the lagoon. Sixteen *L. lambis* and only a single strawberry or red lipped conch (*Strombus luhuanus*) was recorded (Appendices 4.1.1 to 4.1.7), which is another indication of the lack of grazing material available on the benthos of this lagoon system.

Out of the range of small turban shells (e.g. *Turbo argyrostomus*, *T. chrysostomus* and *T. setosus*), only a small number of *T. argyrostomus* were recorded (n = 5). It was possible to closely inspect the surf zone at Likiep, yet no turban species were evident. Other resource species targeted by fishers (e.g. *Cassis*, *Conus*, *Cypraea* and *Thais*) were also recorded during independent survey (Appendices 4.1.1 to 4.1.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus*, are also in Appendices 4.1.1 to 4.1.7. No creel survey was conducted at Likiep.

2.4.5 Lobsters: Likiep

Likiep had 107.6 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef, represents a large amount of habitat for lobsters. Lobsters are an unusual invertebrate species, which can recruit from near and distant reefs as their larvae drift in the ocean for 6–12 months (up to 22 months) before settling as transparent miniature versions of the adult (*pueruli*, 20–30 mm in length).

There was no dedicated night reef-front assessment of lobsters (See Methods.), and no lobsters (*Panulirus* spp. or *Parribacus* spp.) were recorded in these surveys. Even night-time assessments for nocturnal sea cucumber species (Ns) failed to record any lobsters. This type of assessment is completed on inshore reefs, whereas night reeftop surveys in the north of the atoll would have provided the best opportunity to assess the presence of lobsters.

2.4.6 Sea cucumbers[6]: Likiep

Likiep has an extensive shallow lagoon system (414.7 km²), which is surrounded by low-lying *motu* or sand islands (10.3 km² total land area). 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, rubble and limestone pavement. There was little land

[6] 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.

influence, except close to shore in the southeast and, generally, surfaces were without heavy algal and epiphytic growth. In general, the system can be considered to be largely oceanic-influenced. Outside the barrier reef, the reef slope was impacted by large swells in the northeast and shelved off relatively steeply into deeper water in the more protected south and west.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 2.13, Appendices 4.1.1 to 4.1.6; also see Methods). At Likiep, six commercial species of sea cucumber were recorded during in-water assessments (Table 2.13), similar to the number found in the other atoll CoFish sites in Marshall Islands. The range of sea cucumber species recorded in Likiep reflected the isolated position of these dispersed atolls in Marshall Islands, and the largely exposed, oceanic-influenced nature of the habitats present. However, the lagoon, passages and outer reef of Likiep suited some deposit feeders, and the results are listed below (Sea cucumber species eat organic matter in the upper few mm of bottom substrates.).

Sea cucumber species associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were very rare (found in 6% of broad-scale and no reef-benthos transects). When recorded, the density was low although the deep-water areas held >6 /ha of a dark-brown coloured variety, which had eye spots that were hardly visible.

Stocks of black teatfish (*Holothuria nobilis*), a high-value sea cucumber that can usually be found in shallow water and is therefore susceptible to fishing pressure, were not recorded in survey. This was despite there being significant suitable areas within the back-reef for this species. There is evidence from around the Pacific that this species, once heavily depleted, can take years to recover to densities of >10 /ha, so it is possible that previous heavy fishing, even decades before occurring could still be impacting the viability of this species at Likiep if it exists at all. The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was also not found at any stations, and may be absent from Marshall Islands.

Surf redfish (*Actinopyga mauritiana*) were not recorded across the site, despite the completion of seven RFs stations and two RFs_w stations on the reeftop. This species can be recorded at commercial densities of 500–600 /ha in other oceanic-influenced atoll islands in French Polynesia and Tonga.

In more protected areas of reef and soft benthos at embayments in the lagoon, no blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), elephant trunkfish (*Holothuria fuscopunctata*) or curryfish (*Stichopus hermanni*) were recorded. Some lower-value species, e.g. lollyfish (*H. atra*), pinkfish (*H. edulis*) and brown sandfish (*Bohadschia vitiensis*), were noted. Lollyfish and pinkfish were moderately common.

Deep-water assessments (30 searches of five minutes, average depth 23.7 m, maximum depth 43 m) were completed to obtain a preliminary abundance estimate for white teatfish (*H. fuscogilva*), prickly redfish (*T. ananas*), amberfish (*T. anax*) and, partially, for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the passages had suitably dynamic water movement for these species, but the high-value *H. fuscogilva* was not recorded. Deep-water assessments did detect amberfish, and prickly redfish was noted in a few broad-scale and shallow-reef stations at low average density.

2.4.7 Other echinoderms: Likiep

The edible collector urchin (*Tripneustes gratilla*) was not present and slate urchins (*Heterocentrotus mammillatus*) were rarely noted (n = 2 individuals). Other urchins that can be used as a food source or potential indicators of habitat condition (*Echinometra mathaei*, *Diadema* spp. and *Echinothrix* spp.) were recorded at low level, and only outside the lagoon. The large, black *Echinothrix* spp. (*E. diadema* and *E. calamaris*) were rare (mean station density <8 /ha for RFs and MOPs survey stations), and none were noted in RBt stations (Appendices 4.1.1 to 4.1.7).

Starfish were sparsely distributed at Likiep; the common blue starfish (*Linckia laevigata*) was not recorded at all, but pincushion stars (*Culcita novaeguineae*) were noted at 62% of broad-scale stations, although not at high density (only 4.7 /ha). Only four records of another coralivore (coral eating) starfish, the crown-of-thorns star (*Acanthaster planci*, COTS) was noted. Although rare, its presence was concentrated to the passage between Aikne and Eootle islands, in front of Eneen-uwa island (See presence and density estimates in Appendices 4.1.1 to 4.1.7.).

Table 2.13: Sea cucumber species records for Likiep

Species	Common name	Commercial value [5]	B-S transects n = 78			Reef-benthos stations n = 18			Other stations RFs = 7; MOPs = 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												
Bohadschia argus	Leopardfish	M	1.7	26.7	6							6.2	10.3	60 Ds
Bohadschia vitiensis	Brown sandfish	L	0.4	33.3	1									
Holothuria atra	Lollyfish	L	374.6	1623.1	23	1266.2	3256.0	39	0.6	3.9	14 RFs			
Holothuria edulis	Pinkfish	L	376.7	1469.2	26	324.1	883.3	39				1.0	2.4	40 Ds
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria hilla	-	L												
Holothuria impatiens	-	L												
Holothuria nobilis [4]	Black teatfish	H												
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H	2.6	22.2	12	2.3	41.7	6	10.1	60.6	17 MOPs			
Thelenota anax	Amberfish	M	1.7	26.7	6							7.6	9.5	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; MOPs = mother-of-pearl search; Ds = day search; Ns = night search.

2.4.8 Discussion and conclusions: invertebrate resources in Likiep

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

In summary, data on giant clam distribution, density and shell size suggest that:

- The reefs at Likiep, both inside and outside the atoll lagoon, provided very suitable habitat for a range of giant clams. The most suitable areas were on the western side of the atoll, where water movement was more dynamic, and on patch reefs within the lagoon. Fringing reef within the lagoon on the eastern side provided less suitable habitat as most reef areas comprised sandy rubble, and water flow in some areas was limited. Land influence on Likiep was only noticeable in the southeast; in general, the system was mostly oceanic-influenced.

- The lagoon and barrier reefs provided suitable habitat for the full range of giant clams found in Marshall Islands, and five species of giant clam were recorded at Likiep (the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, the true giant clam *T. gigas*, and the horse-hoof or bear's paw clam *Hippopus hippopus*. The smooth clam *T. derasa* was also present as a result of translocation from Palau in 1990).

- Giant clam distribution and density indicated that the clam fishery was moderately impacted. Coverage across the study area was high, apart from a noticeable decline around the main settlement island of Likiep and, where habitat was suitable, densities were moderately high.

- The anecdotal reports of first-generation *T. derasa* being recorded in the northwest, as far as >20 km from the hatchery (where the broodstock aggregations are held), offers a good opportunity to monitor colonisation by *T. derasa*. This information is useful in furthering understanding of the stock dynamics of clams (which is usually confounded by a multitude of potential parent stocks being present), but also useful in understanding how lagoon water flows might influence the success of marine protected areas if they are to be sited in the southeast or northwest of the lagoon. At present, it seems that recruitment of juveniles is spreading from the hatchery site, up the northeastern shoreline, towards the north.

- Giant clams are broadcast spawners that only mature as females at larger size classes (protandric hermaphrodites). This means that, for successful stock management, clams need to be maintained at higher density and include larger-sized individuals to ensure there is sufficient spawning taking place to produce new generations.

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

Data on MOP distribution, density and shell size suggest that:

- The reefs at Likiep can support the commercial topshell, *Trochus niloticus*, and have received an introduction in the past. Unfortunately, the introduction was made in a small, shallow pass in the southeast; the most likely place for a successful introduction is on lagoon reef near the passages in the south and west.

- Trochus was not recorded at Likiep, either as live or dead shell. This was despite a wide survey, including the area where the trochus had been introduced.

- The false trochus or green topshell (*Tectus pyramis*) gave an indication that, in general, algal-grazing Trochidae might not be very successful at colonising the oceanic-influenced reefs at Likiep. Although complex reefs were present, in general surfaces were clean, and an insufficient algal diet may restrict the build-up of commercial grazing gastropods.

- The blacklip pearl oyster, *Pinctada margaritifera*, was uncommon at Likiep.

In summary, the distribution, density and length recordings of sea cucumbers at Likiep reveal that:

- A restricted range of sea cucumber species was present at Likiep. This is possibly due to biogeographical influences: the isolated position of Likiep in the Pacific, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system.

- The high-value black teatfish (*Holothuria nobilis*), which is easily targeted by fishers, was absent from Likiep, as were several other potentially commercial species.

- The medium-value prickly redfish (*Thelenota ananas*) was recorded, as was the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish (*Holothuria atra*); however, distribution was sparse and densities were too low to warrant any commercial interest.

- Assessments targeting deeper-water white teatfish (*Holothuria fuscogilva*) stocks were not successful in locating this high-value species.

- It is unknown whether sea cucumber stocks at Likiep were over-fished during previous periods (more than a decade ago) and have failed to recover, or whether Likiep is just naturally deficient in both the range and density of these commercial species. However, what can be deduced is that there is no potential for developing a commercial sea cucumber fishery based on the stocks around Likiep at this time.

2.5 Overall recommendations for Likiep

- Traditional and already established rules be continued under current fishing pressure and practices.

- Sound fisheries management planning and strategies be developed and put in place prior to any further development of commercial reef and lagoon fisheries.

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

- Controls be put in place to limit the use of spearfishing, especially at night.

- The communities be supported in their efforts to establish marine reserves, as this has been discussed and suggested for many years without action.

- Juvenile *Tridacna derasa* giant clam stocks be monitored around the lagoon to plot where recruitment is happening in regard to the hatchery where the broodstock aggregations are held.

- There is no potential for developing of a commercial sea cucumber fishery based on stocks around Likiep at this time.

3. PROFILE AND RESULTS FOR AILUK

3.1 Site characteristics

Ailuk atoll is a typical atoll located at the average position of 10º20' N and 169º56' E (Figure 3.1), with an extensive lagoon that is about 30 km long and 13 km wide (maximum depth of 40 m) encircled by approximately 55 islets (*motu*), which lie predominantly along the eastern reef. Its elongated shape is oriented north–south. The atoll has four main channels, all on the west barrier, which also facilitate water exchange, but access to the ocean can be made at many locations on high tide when swell conditions allow. Water circulation inside the lagoon is high, with the main water exchange occurring over the reef from the east and escaping the lagoon through the main passages and submerged areas of the barrier. There is little in the way of elevated land, and run-off and sedimentation is not common. As in Likiep, the lagoon is predominantly oceanic-influenced and has small pinnacles and patches of live and dead corals.

Figure 3.1: Map of Ailuk.

3.2 Socioeconomic surveys: Ailuk

Socioeconomic fieldwork was carried out in Ailuk, RMI on 17–27 August 2008. Ailuk is an isolated island, where fishers have limited opportunities to generate income from fishing other than selling within the community on a very small scale, due to the 15-hour boat trip required to reach the nearest urban centre and the rather unreliable and expensive air transport opportunities to bring marine produce to Laura and Ebeye.

The Ailuk community has a resident population of 439 and ~60 households. A total of 19 households, which is 32% of the total households in the Ailuk community, were surveyed, with all of these households being engaged in some form of fishing activities. In addition, a total of 15 finfish fishers (13 males and 2 females) and 29 invertebrate fishers (17 males and 12 females) were interviewed. The average household size is moderate to large, with seven people, reflecting the isolated, traditional and rural lifestyle of the Ailuk community.

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

People from Ailuk have access to various habitats, including sand flats, a deep-lagoon area associated with coastal, mostly submerged, reefs, outer reefs, channels, and passages.

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

Our results (Figure 3.2) suggest that sources other than fisheries play the major role for income generation in Ailuk. These mainly include handicrafts and mat weaving (the first and second income source for 63% and 21% of all households respectively), using leaves of pandanus, coconut stalks, and shells. Handicrafts from Ailuk are very much sought after in Laura and marketing is done by a local buyer. Agriculture is not important as a main income but rather as a complementary cash source. About half of all households in Ailuk get their second income from agriculture. This is mainly due to the production and selling of copra, a commodity that has a long shelf life and can be sold in bulk when the inter-island vessel arrives. Fisheries are much less important, i.e. only 10.5% of all households earn their first and second income from fisheries. The percentage of households with income from salaries is also low. Pigs and chickens are popular; 85% of all households have a couple of pigs and 79% of households keep at least 16 chickens for home consumption. Distributing fish and seafood produce on a non-monetary basis is a very important and traditional practice in Ailuk.

Commercially-oriented fishing is limited to the occasional export opportunities provided by inter-island vessel or plane transport to Ebeye and Laura.

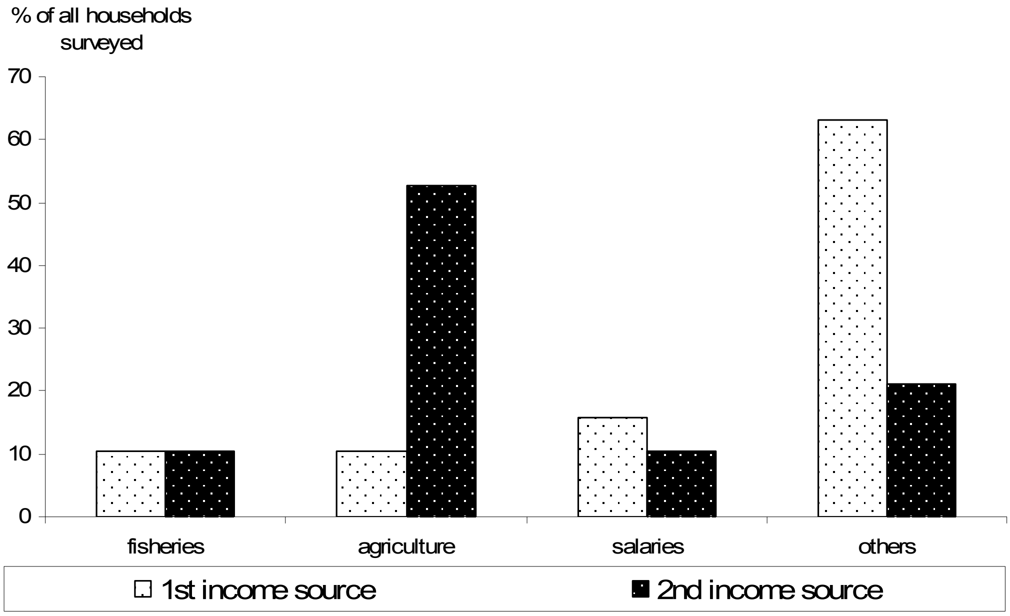

Figure 3.2: Ranked sources of income (%) in Ailuk.
Total number of households = 19 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small business.

Our results (Table 3.1) show that annual household expenditures are low, at an average of USD 1093. People are self-sufficient regarding agricultural and marine produce, and they have limited purchasing power due to the limited opportunities for generating cash on the island.

However, only 24% of all households benefit from remittances. The average remittances received are small, on average USD ~420 /household/year, or ~38% of the average annual household expenditure.

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

Survey coverage	Site (n = 19 HH)	Average across sites (n = 78 HH)
Demography		
HH involved in reef fisheries (%)	100.0	98.7
Number of fishers per HH	3.11 (±0.38)	2.56 (±0.17)
Male finfish fishers per HH (%)	8.5	21.5
Female finfish fishers per HH (%)	0.0	0.0
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	22.0	15.5
Male finfish and invertebrate fishers per HH (%)	50.8	47.0
Female finfish and invertebrate fishers per HH (%)	18.6	16.0
Income		
HH with fisheries as 1st income (%)	10.5	32.1
HH with fisheries as 2nd income (%)	10.5	19.2
HH with agriculture as 1st income (%)	10.5	10.3
HH with agriculture as 2nd income (%)	52.6	38.5
HH with salary as 1st income (%)	15.8	20.5
HH with salary as 2nd income (%)	10.5	9.0
HH with other sources as 1st income (%)	63.2	37.2
HH with other sources as 2nd income (%)	21.1	12.8
Expenditure (USD/year/HH)	1093.33 (±139.06)	2210.55 (±226.09)
Remittance (USD/year/HH) (1)	420.00 (±195.45)	764.14 (±107.90)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	119.67 (±9.84)	105.45 (±7.52)
Frequency fresh fish consumed (times/week)	4.50 (±0.17)	3.56 (±0.13)
Quantity fresh invertebrate consumed (kg/capita/year)	5.35 (±0.97)	6.47 (±7.52)
Frequency fresh invertebrate consumed (times/week)	1.07 (±0.11)	0.94 (±0.08)
Quantity canned fish consumed (kg/capita/year)	4.12 (±1.03)	5.12 (±0.65)
Frequency canned fish consumed (times/week)	0.77 (±0.15)	1.12 (±0.11)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	100.0	94.9
HH eat canned fish (%)	100.0	94.9
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	15.8	15.8
HH eat fresh fish they are given (%)	84.2	84.2
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 (%)	84.2	84.2

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

Survey results indicate an average of three fishers per household and, when extrapolated, the total number of fishers in Ailuk amounts to 186 (110 males and 76 females). Among these are 16 exclusive finfish fishers (males only), 40 exclusive invertebrate fishers (females only), and 130 fishers who fish for both finfish and invertebrates (95 males, 35 females). About 58% of households own a boat; most (~63%) are sailboats, 27% are non-motorised canoes, and only ~10% of boats are fitted with an outboard engine.

Per capita consumption of fresh fish is high at almost 120 kg/person/year, which exceeds the average across all the four study sites in RMI, and is about four times the regional average of ~35 kg/person/year (Figure 3.3). By comparison, the consumption rate of invertebrates (edible meat weight only) (Figure 3.4) is much lower at ~5 kg/person/year. Canned fish (Table 3.1) is not commonly eaten and adds only ~4 kg/person to the annual protein supply from seafood. The consumption pattern of seafood found in Ailuk highlights the fact that the people have limited access to agricultural and commercially available food items.

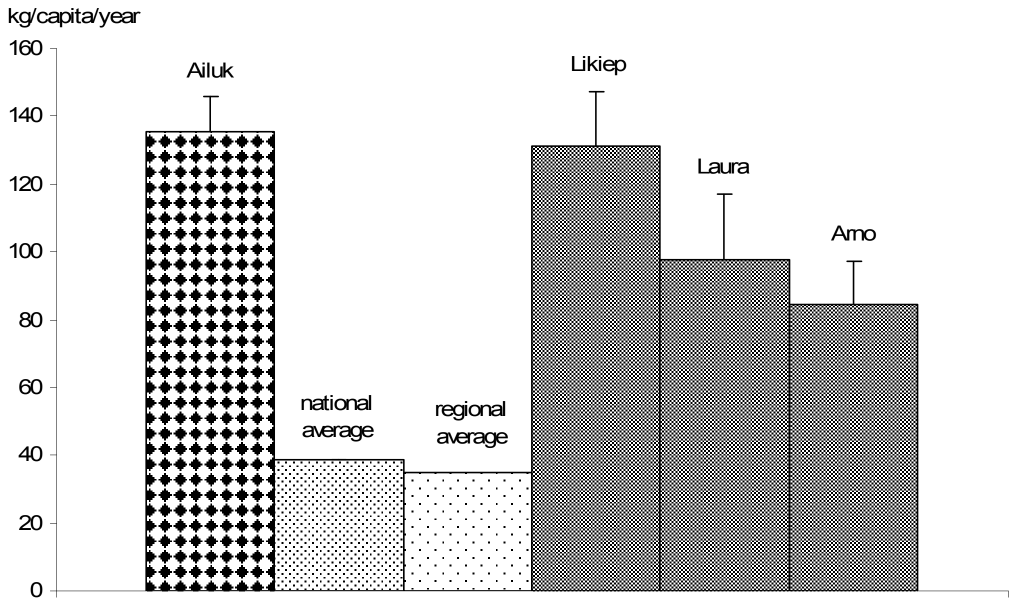

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Ailuk (n = 19) compared to the national and regional averages (FAO 2008) and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

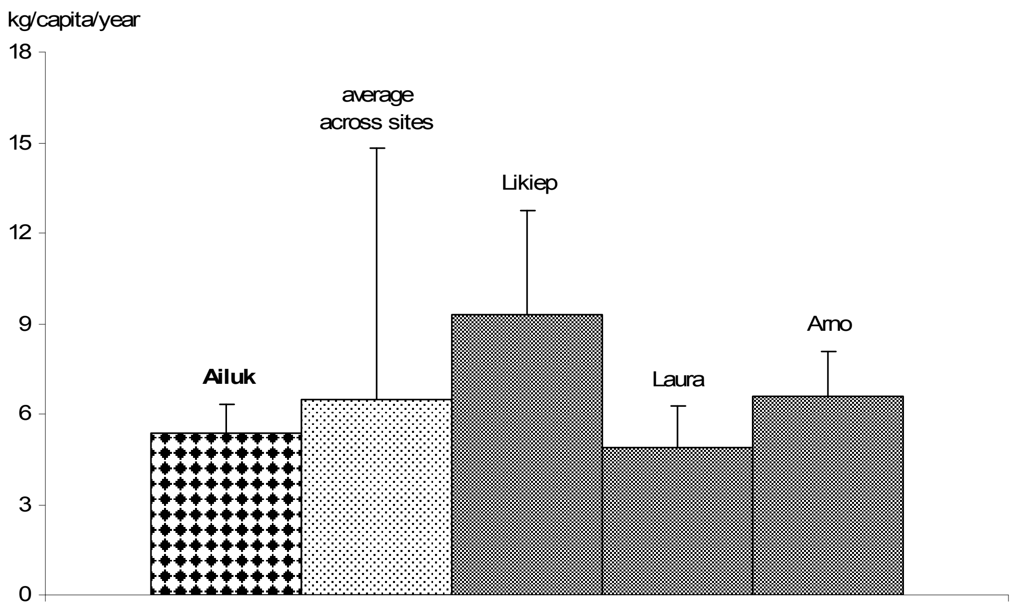

Figure 3.4: Per capita consumption (kg/year) of invertebrates (meat only) in Ailuk (n = 19) compared to the average across sites and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results obtained for Ailuk to the average figures across all the four study sites surveyed in RMI, the people of the Ailuk community eat fresh fish more often, canned fish less often, and invertebrates about as often as found on average. The per capita consumption of fresh fish is well above the average, while much less invertebrates and canned fish are consumed than is observed elsewhere. Compared to the country site average, the Ailuk people eat a similar amount of fish and invertebrates that they have caught, bought and been given as a gift. It is worth noting that invertebrates are never bought. Handicrafts play an exceptionally important role in providing income, complemented by copra selling. Salaries and fisheries are much less important for generating income than at the other three CoFish sites in RMI. Household expenditure level in Ailuk is substantially lower (less than half) than elsewhere. The percentage of households receiving remittances is similar to elsewhere, but the annual average amount of remittances received is below average. By comparison, the percentage of households that own a boat is higher than elsewhere; however, the proportion of motorised boats is low.

3.2.2 Fishing strategies and gear: Ailuk

Degree of specialisation in fishing

Fishing is done by both males and females; however, traditional roles are evident (Figure 3.5). Males are much more engaged in finfish fisheries, while females are more focused on invertebrates. However, it is worth mentioning that most males, and about half of all females considered here fish for both finfish and invertebrates.

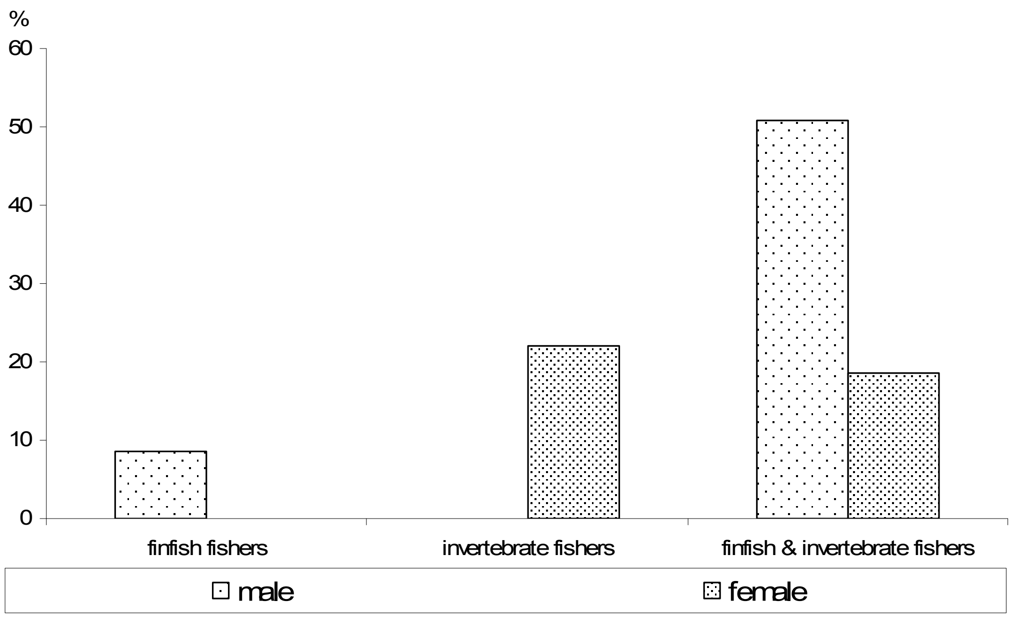

Figure 3.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Ailuk.
All fishers = 100%.

Targeted stocks/habitat

Considering the low cash flow, the isolation and the limited commercial opportunities in Ailuk, it is not surprising that Ailuk finfish fishers mainly target the easily accessible habitats, namely the sheltered coastal reef and the lagoon. Both habitats are usually combined in one fishing trip. The outer reef and passages are fished by male fishers only, but not by as many and not as often as the more easily accessible habitats (Table 3.2). Reeftop and intertidal (sand) gleaning are the most frequently performed invertebrate fisheries, with diving for lobster and 'others', such as clams and octopus, also being an important activity for male fishers.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	100.0	100.0
	Outer reef & passage	76.9	0.0
Invertebrates	Reeftop	64.7	100.0
	Intertidal	11.8	66.7
	Lobster	52.9	0.0
	Other	94.1	8.3

'Other' refers to giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 132; females: n = 2. Invertebrate fisher interviews, males: n = 17; females, n = 12.

Fishing patterns and strategies

The number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Ailuk on their fishing grounds (Tables 3.2 and 3.3).

Our survey sample suggests that fishers from Ailuk have a good choice among sheltered coastal reef, lagoon and outer-reef fishing, including access to passages. Also, fishers seem to equally target the major habitats supporting invertebrate fisheries, with 38% of fishers gleaning the reeftop, 20% gleaning the intertidal areas, 28% diving for clams and octopus, and 15% diving for lobsters (Figure 3.6). Data on gender participation show that females dominate the gleaning fisheries (reeftop and intertidal), while males mainly engage in diving for 'others' (clams, octopus and other gastropods) and lobsters, but also in reeftop gleaning. Females do not dive for lobsters (Figure 3.7).

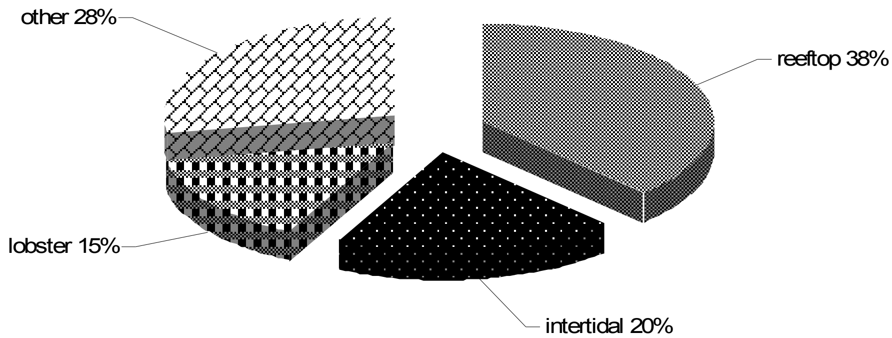

Figure 3.6: Proportion (%) of fishers targeting the four primary invertebrate habitats found in Ailuk.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to giant clam and octopus fisheries.

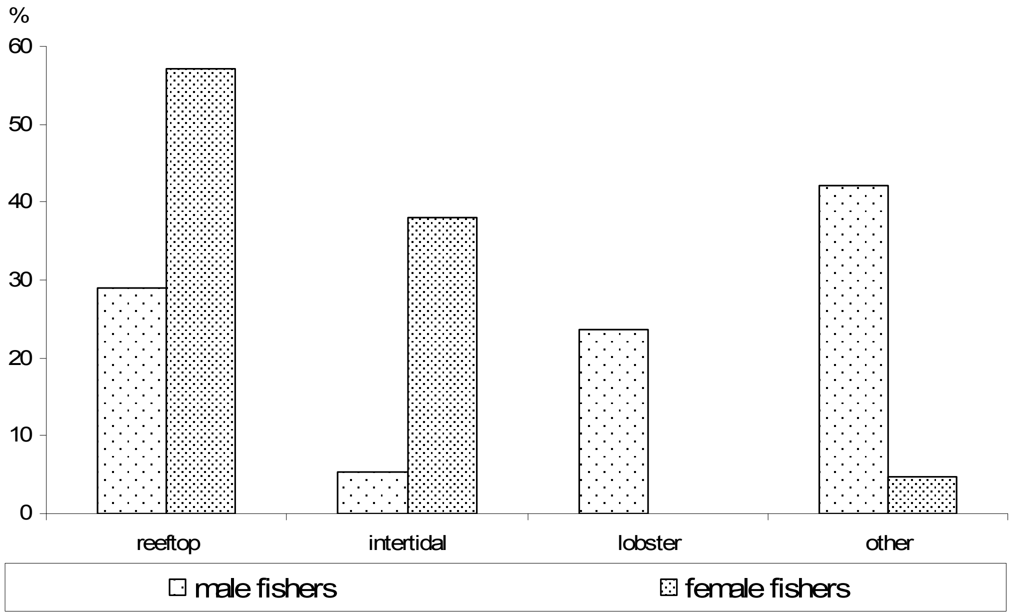

Figure 3.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Ailuk.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 13 for males, n = 2 for females; 'other' refers to giant clam and octopus fisheries.

Gear

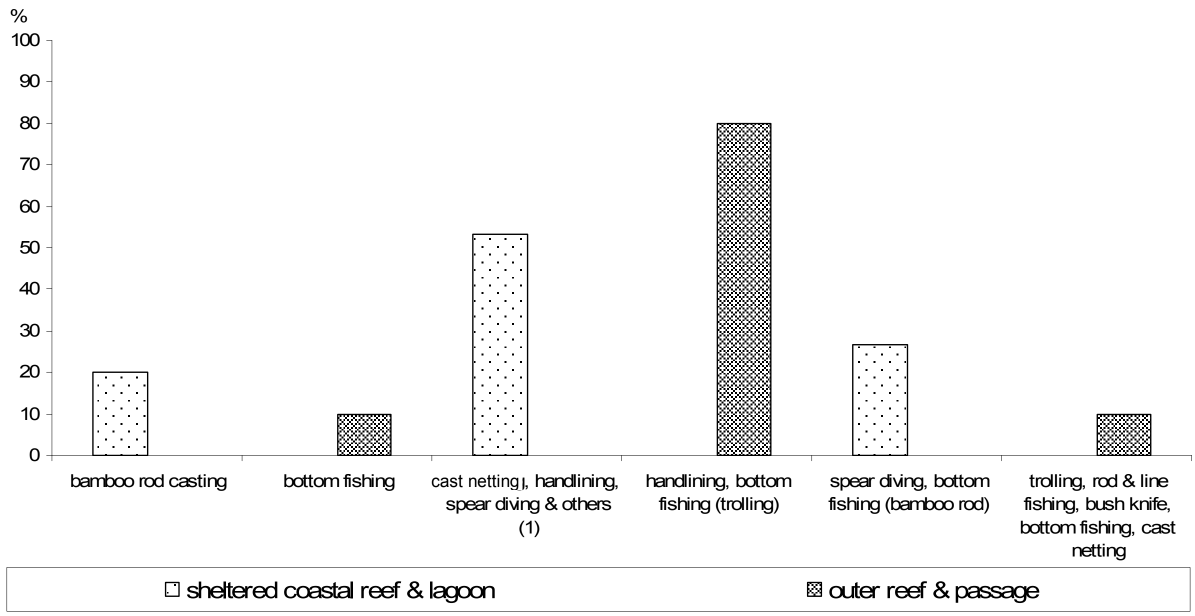

Figure 3.8: Fishing methods commonly used in different habitat types in Ailuk.
(1) Spear handheld walking or from canoe, bow and arrows, cast net, petfish net and bottom fishing. Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Figure 3.8 shows that Ailuk fishers use a number of mainly low-cost fishing techniques during one fishing trip. Most frequently, a combination of cast netting, handlining, spear diving, and other methods are used. When the outer reef and passages are the target, handlining and deep-bottom fishing are the main methods used. Trolling and other techniques, however, are also used.

Frequency and duration of fishing trips

Finfish fishers target the sheltered coastal reef and lagoon habitats about 2 to 3 times per week, while male fishers visit the outer reef and passages about once per week. Female fishers fish less frequently, about twice per week. Invertebrate trips are less frequently made by male and female fishers, usually once per fortnight and, in some cases, once per week. The average finfish fishing trip takes about 3 hours for males, and 2.5 hours for females. A typical invertebrate collection trip takes two hours for both male and female fishers. Only dive trips for invertebrates (lobsters, clams and octopus) take longer, averaging ~3 hours per trip.

Most finfish fishing is done according to tidal conditions, i.e. during the day or at night, and is performed throughout the year. Ice is never used on finfish fishing trips. None of the finfish fishing necessarily uses boat transport; however, as distance from shore increases, boat transport becomes more important and is mandatory for reaching the passages and the outer reef. Gleaning for invertebrates is mostly done by walking, but some habitats may be reached using canoes. If diving for clams, octopus or lobsters, boat transport is mainly used. Invertebrates can be collected either at day or night, with lobster diving being the only night fishery. *Strombus* and *Nerites* spp. are usually collected at night during full moon.

One of the unique features of Ailuk is the number of traditional canoes that are used. People are traditional canoe builders and they are encouraged to build and use canoes as a means of transport and for fishing. The skills to build canoes are acquired from an early age.

Fishing is done individually or in groups. Particular species may be targeted only if the possibility arises to send the catch by plane or inter-island vessel to family members elsewhere, or for village functions. Fishing methods are, therefore, mainly traditional, with little improved gear. Females, especially, glean using sticks and hands, and use cast nets and rods for finfish fishing only.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.88 (±0.32)	2.00 (±0.00)	2.81 (±0.11)	2.50 (±0.50)
	Outer reef & passage	1.20 (±0.13)	0	3.90 (±0.31)	0
Invertebrates	Reeftop	0.70 (±0.07)	0.94 (±0.20)	2.09 (±0.09)	2.42 (±0.19)
	Intertidal	0.69 (±0.23)	0.75 (±0.08)	2.00 (±0.00)	2.00 (±0.19)
	Lobster	0.71 (±0.17)	0	3.00 (±0.00)	0
	Other	0.97 (±0.09)	0.46 (n/a)	2.56 (±0.13)	2.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 13; females: n = 2. Invertebrate fisher interviews, males: n = 17; females: n = 12.

3.2.3 Catch composition and volume – finfish: Ailuk

The catches reported from the sheltered coastal reef and lagoon in Likiep contain a great variety of species, with Serranidae, Lutjanidae, Lethrinidae and Siganidae representing the major species group by reported catch weight. At the outer reef, male fishers reported mainly catching Lutjanidae, Serranidae and Lethrinidae but also Carangidae and Acanthuridae. The catch composition closely reflects the differences in fishing techniques used in the closer-to-shore habitats as compared to the outer reef and passages.

Detailed information on catch composition by species, species groups and habitats is reported in Appendix 2.2.1.

Figure 3.9 confirms the findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing serves almost exclusively subsistence purposes and offers little opportunity to generate income. The total annual catch is estimated at ~42.66 t, and the reported and extrapolated reef fisheries catch is not enough to satisfy local demand. Local demand is further satisfied by artisanal pelagic fish catches, which are not considered here. Also, the subsistence demand presented here does not specify the source of the fish, i.e. it could be caught by a family member or it may be bought from a local fisher. Local sales of finfish include fish that has been salted and dried.

The dominance of male fishers by impact and production shows in the proportion of the total annual catch that they take (93%). Thus, it can be concluded that male fishers are mainly responsible for providing food for the family and generating the little income possible from finfish fisheries. Females do contribute to household consumption, but little by comparison (7% of total annual catch). Almost 80% of the total impact by male fishers is imposed on the sheltered coastal reef and lagoon resources, and only ~20% on the resources in the outer reef and passages.

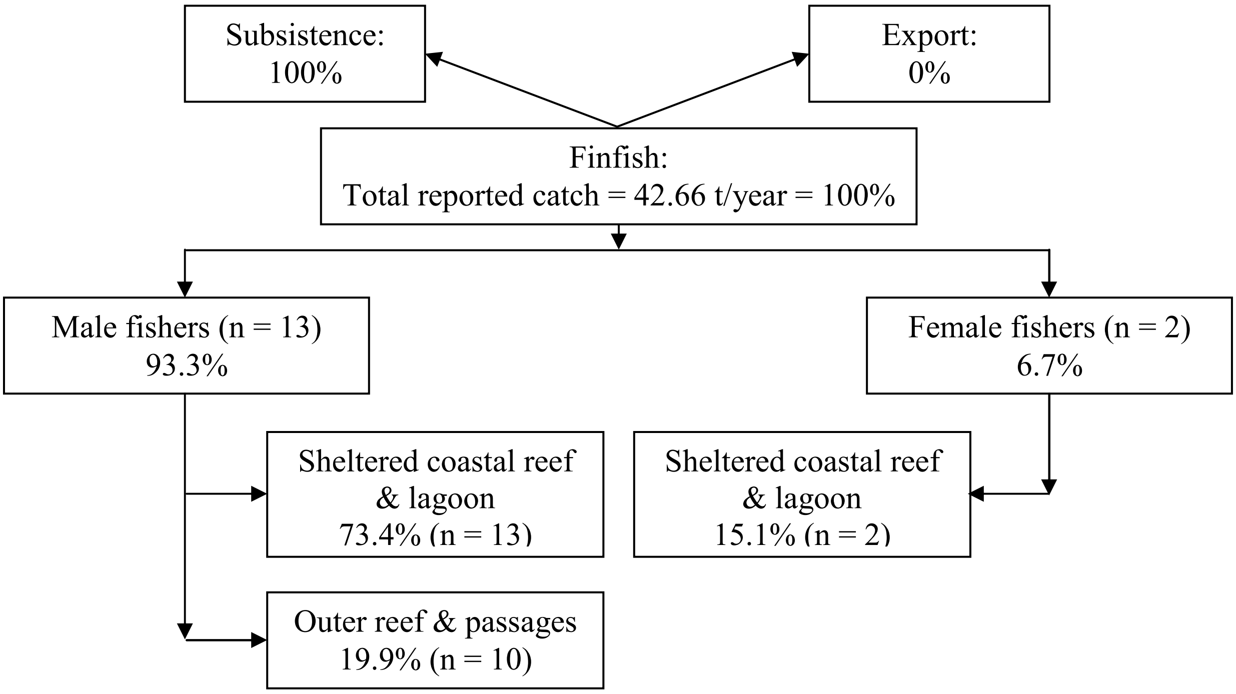

Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ailuk.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The distribution of annual catch weight between the more accessible sheltered coastal reef and lagoon and the more distant outer reef and passages is a consequence of the number of fishers and, to some extent, the annual catch rates. As shown in Figure 3.10, the average annual catch per male fisher for sheltered coastal reef and lagoon fishing (500 kg/fisher/year) is more than double that of outer-reef and passage fishing (~200 kg/fisher/year). Female fishers have a productivity of ~300 kg/fisher/year for the combined fishing of the sheltered coastal reef and lagoon. As mentioned earlier, female fishers do not target the outer reef and passages.

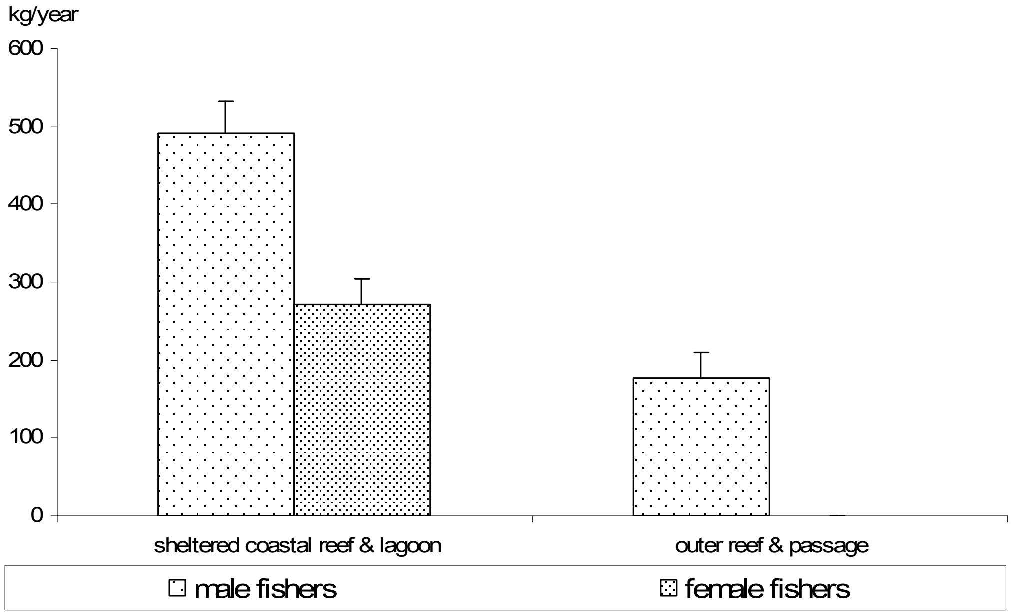

Figure 3.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Ailuk. Bars represent standard error (+SE).

Comparing productivity rates between genders and habitats (Figure 3.11), there are also significant differences between habitats fished. Overall, CPUEs are low; however, while on average fishers (males and females) reach a CPUE of 1.3 kg/hour fished in the habitats closer to shore, the CPUE is only 0.8 kg/hour fished if the outer reef and passages are targeted. The overall low CPUE rates and the reduced efficiency at the outer reef and passages can only be explained, given the local socioeconomic and geographic conditions, by the time-consuming methods of transport used and the lack of incentives. The prevalent use of paddling canoes and sailboats, and the lack of a local or outside market may support this argument.

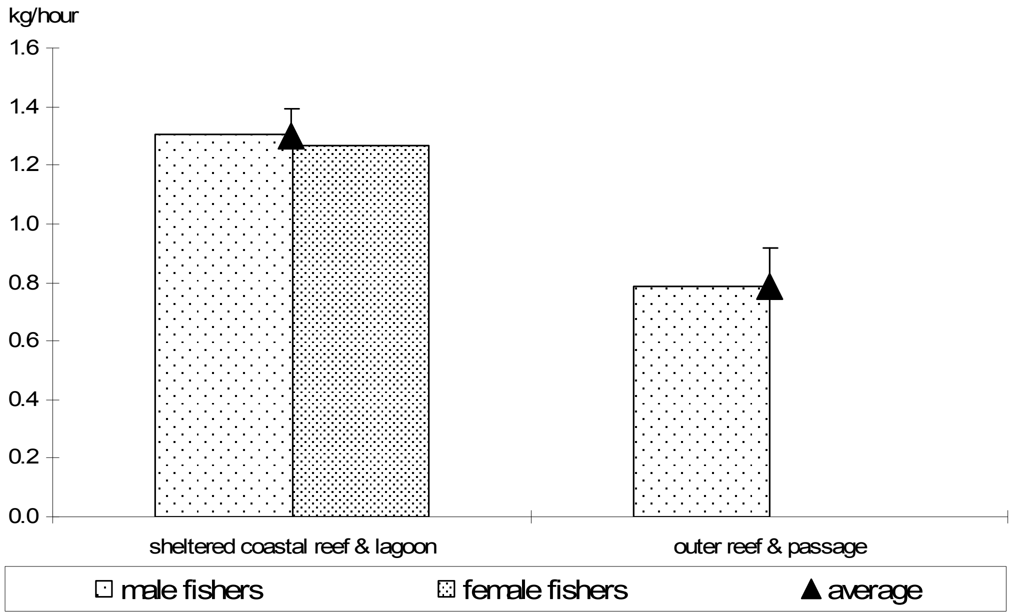

Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Ailuk.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The importance of subsistence fishing for Ailuk clearly shows in Figure 3.12. As observed earlier, male and female fishers target any of the habitats mainly for home consumption; little effort is made to catch fish for sale.

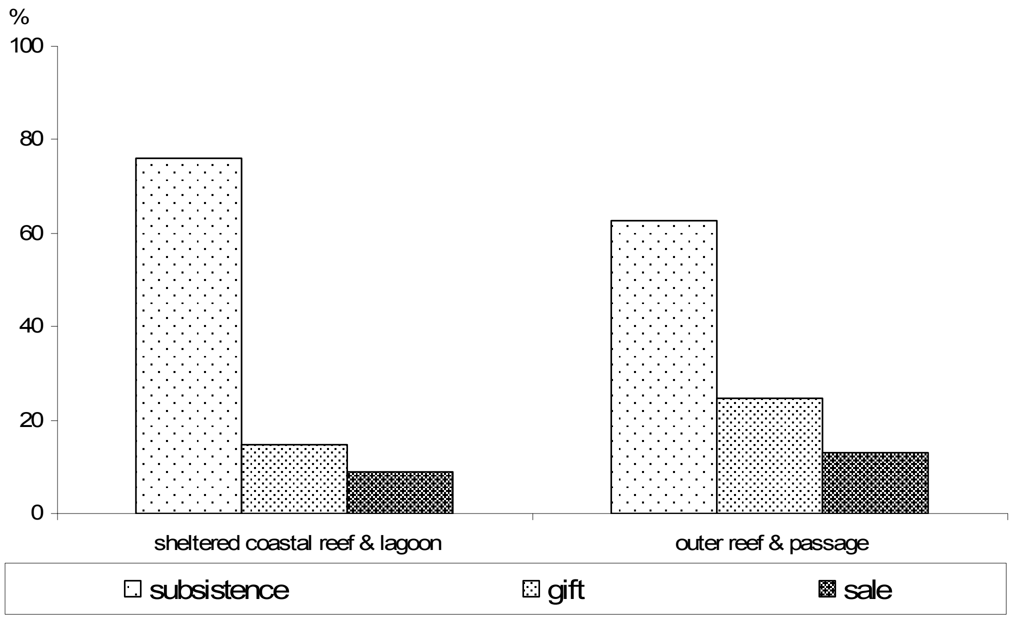

Figure 3.12: The use of finish catches for subsistence, gift and sale, by habitat in Ailuk.
Proportions are expressed in % of the total number of trips per habitat.

The overall finfish fishing productivity varied between habitats (Figure 3.11); productivity was much lower for fishing the outer reef and passages. This observation does not apply if comparing the reported average fish sizes (fork length) for the major families caught

(Figure 3.13). Firstly, average fish sizes are large and range between 25 and 35 cm. Secondly, and as expected, there is an increase in the size of fish caught for the same species or species groups with increasing distance from the shore. This applies to Acanthuridae, Kyphosidae, Lethrinidae, Lutjanidae, Serranidae and Siganidae. For other families, such as Scaridae, sample size does not allow a valid comparison. However, there is no indication that this general trend does not apply for any major fish family.

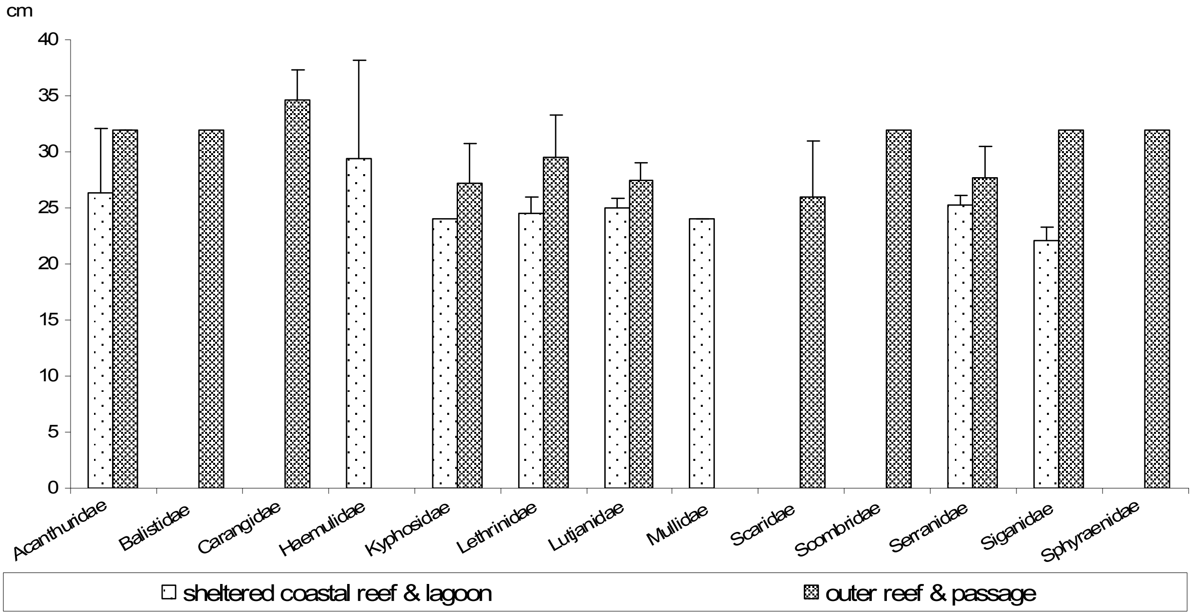

Figure 3.13: Average sizes (cm fork length) of fish caught by family and habitat in Ailuk.
Bars represent standard error (+SE).

The parameters selected to assess the current fishing pressure on Ailuk reef and lagoon resources are shown in Table 3.4. Due to the large available reef surface and total fishing ground, population density, fisher density and catch rates per unit areas of reef and fishing ground are all very low.

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

Parameters	Habitat			
	Sheltered coastal reef & lagoon (4)	Outer reef & passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	228.87	9.45	61.83	238.32
Density of fishers (number of fishers/km^2 fishing ground) (1)	0	5	2	1
Population density (people/km^2) (2)			7	2
Average annual finfish catch (kg/fisher/year) (3)	461.04 (±40.98)	177.58 (±31.02)		
Total fishing pressure of subsistence catches (t/km^2)			1	0
Number of fishers	97	48	145	145

Figures in brackets denote standard error; (1) total number of fishers (= 145) is extrapolated from household surveys; (2) total population = 439; total subsistence demand = 42.66 t/year; (3) catch figures are based on recorded data from survey respondents only; (4) lagoon surface considered only.

3.2.4 Catch composition and volume – invertebrates: Ailuk

Analysis of catches reported from invertebrate fishers by wet weight shows that seven species groups *Charonia tritonis*, clams (in particular *Tridacna maxima* and *T. squamosa*), other gastropods (*Cypraea tigris*, *Strombus* spp. and *Turbo* spp.), crustaceans (coconut crab and lobsters *Panulirus* spp.), and octopus account for one or more mt per year each (wet weight). As shown in Figure 3.14, there are also many other invertebrates that are targeted for consumption and other use (handicrafts): e.g., *Conus* spp., *Etisus splendidus*, and *Nerites* spp.

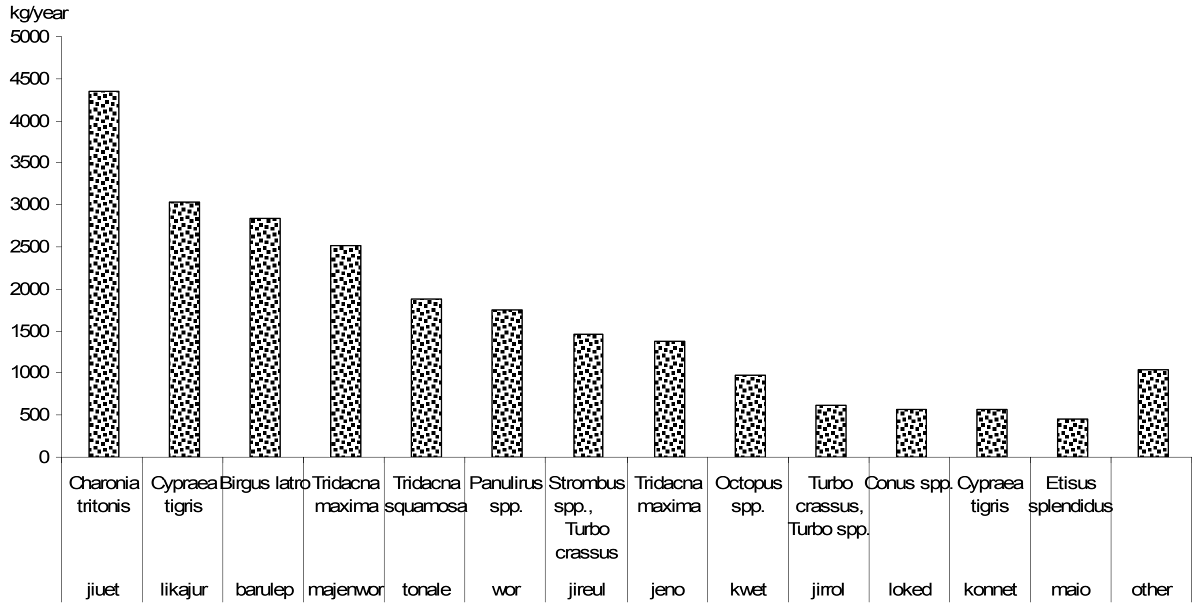

Figure 3.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Ailuk.
'Other' includes *Nerita polita* (*karrol*), *Nerita* spp. (*karred*), *Asaphis violascens* (*koi kor*, *tak kor*), *Donax cuneatus* (*juke*), *Lambis lambis* (*aurak*), *Serpulorbis* spp. (*albij*), *Thais* spp. (*jubub in baren bob*), *Saccostrea* spp. (*en*), n/a (*won*).

The fact that quite a few species are locally collected shows in Figure 3.15, with 17 vernacular names reported for reeftop catches alone, four for intertidal, and eight for diving for 'other' species, including giant clams and octopus.

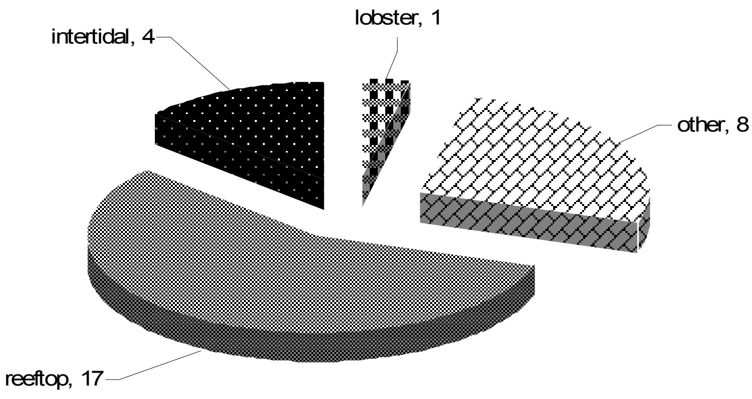

Figure 3.15: Number of vernacular names recorded for each invertebrate fishery in Ailuk.
'Other' refers to giant clam and octopus fisheries.

The average annual catch per fisher by gender and fishery (Figure 3.16) reveals substantial differences among fisheries but not between genders. Reeftop collection and diving for mainly reef-associated species, including giant clams and octopus, produce the highest average annual catch per fisher (~500 kg/fisher/year), with little difference in average reeftop gleaning catches between male and female fishers (However, females' average catch rates have a high standard error, suggesting a wide variation among female fishers' performances.). However, and as already mentioned, females do not dive and, therefore, cannot be compared with males in the category of diving for reef-associated invertebrates ('other'). The females who did report catches under this category do not dive but may extend their collection to deeper waters. Lobster diving provides an average catch rate of 200 kg/male fisher/year; while all other invertebrate collection activities provide rather insignificant catches.

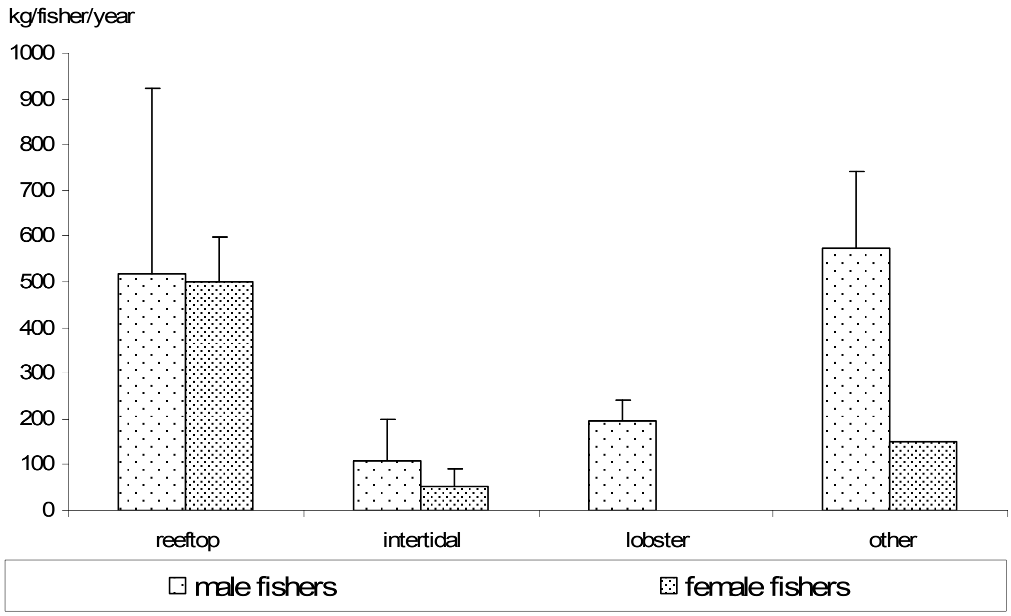

Figure 3.16: Average annual invertebrate catch (kg wet weight/year) by fisher and gender in Ailuk.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 17 for males, n = 12 for females). 'Other' refers to giant clam and octopus fisheries.

The fact that the Ailuk community is highly dependent on marine resources for subsistence shows in Figure 3.17; all invertebrates are caught for home consumption and none are sold.

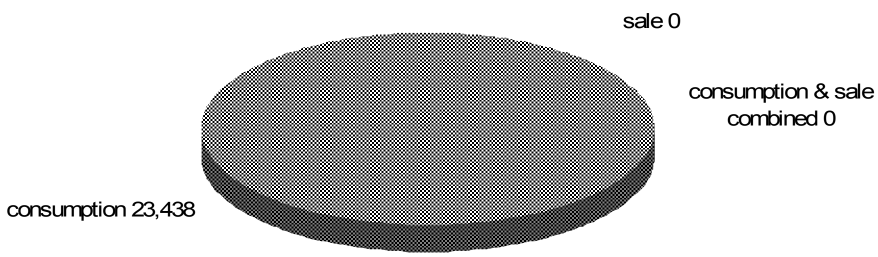

Figure 3.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Ailuk.

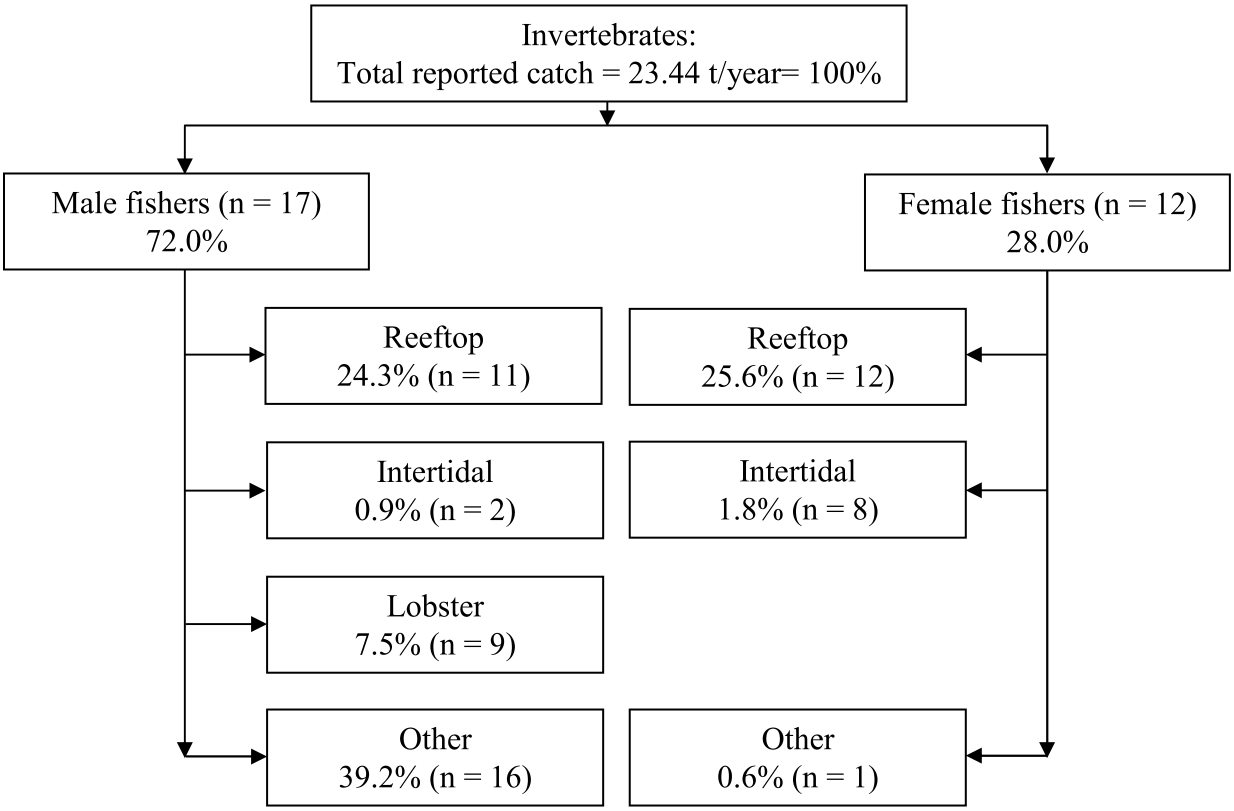

Figure 3.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Ailuk.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

As mentioned earlier, male fishers from Ailuk play a big role in invertebrate fisheries, accounting for ~72% of the total catch (Figure 3.18). Most Ailuk male invertebrate fishers target reef-associated species by diving ('others'), including clams and octopus. Coconut crabs, lobsters and clams are sent, if the opportunity arises, by plane to Laura or Ebeye in exchange for imported food items. Less impact is accounted for by male and female fishers on intertidal resources or, in the case of male fishers, on lobsters. Female fishers contribute 28% of the total annual catch by wet weight, and most of their effort is concentrated on the reeftops.

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

Parameters	Fishery / Habitat			
	Reeftop	Intertidal	Lobster	Other
Fishing ground area (km^2)	17	n/a	76 [3]	17
Number of fishers (per fishery) [1]	137	62	50	95
Density of fishers (number of fishers/km^2 fishing ground)	8	n/a	1	6
Average annual invertebrate catch (kg/fisher/year) [2]	508.59 (±195.14)	64.81 (±32.63)	195.61 (±44.94)	548.91 (±159.62)

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] lobster fishing area denoted by length of reef (km); 'other' refers to the giant clam and octopus fisheries.

Taking into account available figures on the reef surface areas, as well as on the outer-reef length that is used in the case of the lobster fishery, fisher density is low for any of the fisheries considered to be supported by reef areas. Also, the average annual catch rates given for fishers participating in any of the fisheries (Table 3.5) are low. Although area surfaces are unknown for the intertidal fisheries, none of the parameters shown in Table 3.5 give any reason to assume that the current fishing pressure causes any detrimental effects upon the resources.

3.2.5 Management issues: Ailuk

Fisheries management work in Ailuk was found to be more progressive and well implemented as compared to the other sites studied in RMI. In 2006, a reef fisheries survey team conducted rapid resource assessments on resource availability in Ailuk and made recommendations for management strategies.

The reef fisheries survey team that worked with MIMRA also assisted in securing funds, which resulted in some of the recommendations being implemented with the full support of the community. The survey team, which consisted of MIMRA, College of Marshall Islands (CMI) and Natural Resources Assessments Surveys (NRAS) staff members, was mainly funded by NRAS. Possible sites, channels, and spawning areas needing protection or management were identified from this survey. The community now has a Fisheries Committee, which oversees and meets on decisions to be taken with regards to the management initiative in place. The site has a wider approach to management, with the building of a community training centre and construction of the airport terminal as part of the project. These projects are part of AusAID assistance and enable management initiatives to be properly set up in the community, providing avenues for alternative income and livelihood sources. The community participation and co-management by external partners has proved successful and, consequently, this approach could be modified and used in other atolls and locations in Marshall Islands. The Ailuk management project, which has already started, has accomplished several initiatives identified under the management plan. These include the identification of some sites for protection, the work on building an education and awareness centre, which has been completed, the work on improving the airport terminal to assist in transportation, and support for people in maintaining the use of canoes.

3.2.6 Discussion and conclusions: socioeconomics in Ailuk

The Ailuk community is small in size and isolated on an island surrounded by large reef and lagoon fishing grounds. Fishing is done for subsistence purposes, and little is caught for sale due to the limited opportunities for selling outside the island. The MIMRA boat is unreliable and infrequent, and air transport very limited. People pursue a very traditional lifestyle, relying on agricultural and marine produce and supported by cash revenues from handicrafts and remittances sent from overseas. Comparatively little income is due to primary-sector activities or salaries. It is not surprising that the amount of finfish eaten is very high, that the household expenditure level is low, and that fishing mainly targets the more accessible sheltered coastal reef and lagoon rather than the outer reef and passages. Due to the structure described, fishing pressure is low and provides time for the further development of the ongoing community-based fisheries management projects and activities.

In summary:

- The Ailuk population is highly dependent on marine resources for home consumption. It seems that fisheries, complementary to the already important handicraft sector and copra production, provide the only future potential for generating income.

- The amount of fresh fish consumed is high; however, invertebrates are consumed to a much lesser extent. The canned fish consumption level is low, which may be explained by the limited purchasing power of the community and the plentiful supply of fresh seafood on the island.

- Traditional gender roles still exist, although both male and female fishers engage in finfish fishing and invertebrate collection. Female fishers do not target the outer reef and passages, nor do they participate in diving activities. Male fishers account for most impact regarding both finfish and invertebrates.

- Finfish is mainly sourced from the sheltered coastal reef and lagoon, but male fishers also access the outer-reef areas and passages. Boat transport is mainly locally built canoes, a special skill of the Ailuk people. Motorised boat transport is very limited.

- CPUEs are low, but higher for fishing closer to shore as compared to the outer reef and passages. However, given the circumstances, these low CPUE figures do not suggest resource depletion but rather reflect the very limited marketing opportunities available to fishers in the community.

- Techniques vary according to the habitat targeted and mainly include cast nets, spear diving and fishing rods in the areas closer to shore, and handlines and deep-bottom lines at the outer reef and passages. Average fish sizes are large (25–35 cm), and the average fish sizes reported increase with distance from shore.

- Results from the surveys of invertebrate fishers show that the combined catches of gastropods, clams, crustaceans and octopus account for most of the annual harvest. Although people collect a wide variety of species, none of the reported impacts gives reason to assume there is any detrimental effect on resources from fishing.

- Invertebrates are collected exclusively for home consumption.

- The parameters calculated for finfish fishing and invertebrate fisheries suggest that fishing pressure on all resources and habitats is low due to the large available reef and overall fishing ground area and the low fisher densities, average annual catch rates, and catch per unit areas.

Although the current demographic, resource and marketing situation does not demand any fisheries management interventions, Ailuk has benefited from a very comprehensive and successful community-based management fisheries programme and co-management assistance from MIMRA and others. Ongoing and future fisheries management activities will definitely be important to ensure that the marine resources in Ailuk are used sustainably once access to more reliable and improved marketing facilities is established. With reliable inter-island boat transport and more reliable and frequent air transport services, a significant increase in fishing activities is to be expected, and Ailuk fishers are likely to use the opportunity given to earn more cash income.

3.3 Finfish resource surveys: Ailuk

Finfish resources and associated habitats were assessed in Ailuk (Figure 3.19) between 17 and 23 August 2007, from a total of 19 transects (6 intermediate-reef, 7 back-reef and 6 outer-reef transects; see Figure 3.19 and Appendix 3.2.1 for transect locations and coordinates respectively).

The back-reefs were rather detritical or sandy but surprisingly rich where more corals were present. The intermediate reefs were generally represented by small patches or pinnacles and were not very abundant. The outer reefs of the eastern coast could not be sampled due to difficulties of both accessibility and weather.

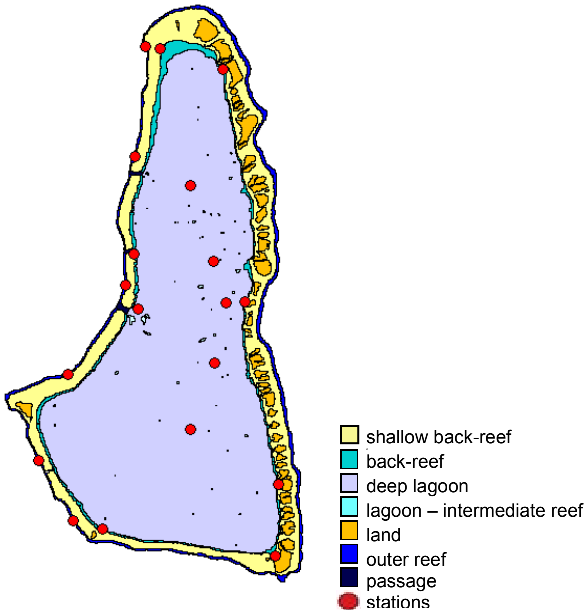

Figure 3.19: Habitat types and transect locations for finfish assessment in Ailuk.

3.3.1 Finfish assessment results: Ailuk

A total of 19 families, 57 genera, 160 species and 6075 fish were recorded in the 19 transects (See Appendix 3.2.1 for list of species.). Only data on the 15 most dominant families (See Methods for species selection.) are presented below, representing 47 genera, 146 species and 5488 individuals.

Finfish resources varied slightly among the three reef environments found in Ailuk (Table 3.6). The outer reef contained the highest density (0.4 fish/m²), largest size (18 cm FL) and size ratio (58%), highest biomass (99 g/m²) and highest biodiversity (57 species/transect) among the three habitats, while the intermediate reefs displayed the lowest density and biomass, and the back-reefs the lowest size, size ratio and biodiversity of the site.

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

Parameters	Habitat			
	Intermediate reef [(1)]	Back-reef [(1)]	Outer reef [(1)]	All reefs [(2)]
Number of transects	6	7	6	19
Total habitat area (km^2)	0.7	8.4	9.1	18.2
Depth (m)	5 (1–12) [(3)]	4 (1–15) [(3)]	7 (4–11) [(3)]	6 (1–15) [(3)]
Soft bottom (% cover)	24 ±6	28 ±5	3 ±2	15
Rubble & boulders (% cover)	13 ±2	14 ±5	3 ±1	9
Hard bottom (% cover)	33 ±4	25 ±3	60 ±9	43
Live coral (% cover)	26 ±7	28 ±8	33 ±10	30
Soft coral (% cover)	1 ±1	4 ±3	1 ±1	3
Biodiversity (species/transect)	40 ±2	35 ±4	57 ±0	43±3
Density (fish/m^2)	0.2 ±0.0	0.2 ±0.0	0.4 ±0.1	0.3
Size (cm FL) [(4)]	17 ±1	16 ±1	18 ±1	17
Size ratio (%)	53 ±3	45 ±2	58 ±2	52
Biomass (g/m^2)	36.7 ±9.0	40.4 ±13.8	99.4 ±25.1	69.6

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

Intermediate-reef environment: Ailuk

The intermediate-reef environment of Ailuk was dominated by two herbivorous families, Acanthuridae and Scaridae and, only in terms of density, by one carnivorous family, Chaetodontidae (present with 10 species, Figure 3.20). These two major families were represented by 27 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus blochii*, *Naso brevirostris*, *A. mata*, *A. nigricans*, *Chlorurus sordidus*, *Hipposcarus longiceps*, *Scarus altipinnis* and *Chl. microrhinos* (Table 3.7). This reef environment presented a diverse habitat with similar percentages of hard and soft bottom (33% and 24%), a good cover of live corals (26%) and small amount of rubble (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 intermediate-reef environment of Ailuk

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.050 ±0.015	5.6 ±1.5
	Acanthurus blochii	Ringtail surgeonfish	0.005 ±0.004	5.0 ±4.7
	Naso brevirostris	Spotted unicornfish	0.009 ±0.009	3.2 ±3.2
	Acanthurus mata	Elongate surgeonfish	0.009 ±0.008	2.9 ±2.6
	Acanthurus nigricans	Whitecheek surgeonfish	0.021 ±0.015	2.1 ±1.6
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.015 ±0.006	1.9 ±0.9
	Hipposcarus longiceps	Pacific longnose parrotfish	0.004 ±0.002	1.3 ±0.8
	Scarus altipinnis	Filamentfinned parrotfish	0.003 ±0.001	1.2 ±0.5
	Chlorurus microrhinos	Steephead parrotfish	0.005 ±0.003	1.2 ±0.6

The biomass of finfish in the intermediate reefs of Ailuk was the lowest at the site. However, the density was the same as in the back-reefs (0.2 fish/m^2). Size, size ratio and biodiversity were higher than in the back-reefs but lower than the outer-reef values.

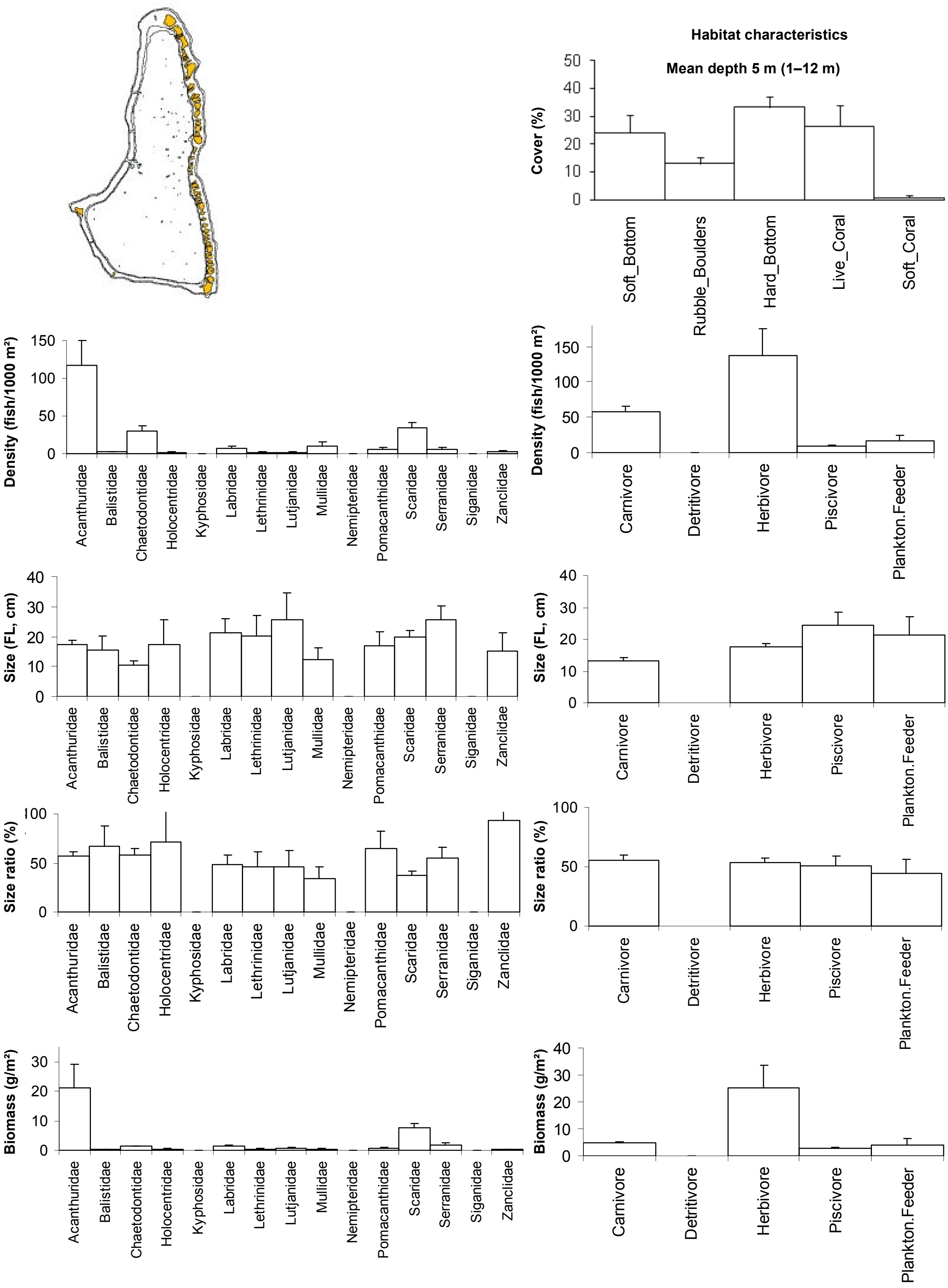

Figure 3.20: Profile of finfish resources in the intermediate-reef environment of Ailuk.
Bars represent standard error (+SE); FL = fork length.

When compared to the same type of habitat at the other sites, Ailuk presented the highest biodiversity and second-highest average size ratio, a comparable size to values at Laura and Arno (17 cm FL) but smaller than in Likiep, a comparable density to that in Likiep (lower than in both Laura and Arno), but the lowest biomass among the four sites (37 g/m²). Trophic composition was dominated by herbivores in terms of both density and especially biomass. Many of the most important species were, in fact, large-sized herbivores of both Acanthuridae and Scaridae families. Mullidae, Scaridae, Lethrinidae and Lutjanidae showed average size ratios much lower than 50% of the maximum sizes, for the respective species, probably suggesting an impact from fishing. Fishing in this habitat was the most intense, showing the highest frequency and catches per year compared to the outer reefs. The intermediate-reef habitat of Ailuk displayed a fairly diverse composition of hard and soft bottom, with an average-to-high cover of live corals (26%), hosting a good abundance of Chaetodontidae. Although the substrate composition included a good percentage of soft bottom, there was a scarcity of sand-associated species (e.g. Mullidae and Lethrinidae), which probably suggests an impact from fishing.

Back-reef environment: Ailuk

The back-reef environment of Ailuk was dominated by four major families: the herbivores Acanthuridae and Scaridae, and the carnivores Lethrinidae and, to a lesser extent and only for density, Chaetodontidae (Figure 3.21). These four families were represented by 42 species; particularly high biomass and abundance were recorded for *Monotaxis grandoculis*, *Chlorurus microrhinos*, *Lethrinus microdon*, *Ctenochaetus striatus* and *Chl. sordidus* (Table 3.8). This reef environment presented a similar composition of live coral (28%), hard bottom (25%) and soft bottom (28%, Table 3.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.034 ±0.014	2.9 ±1.1
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.023 ±0.023	11.8 ±11.2
	Lethrinus microdon	Longface emperor	0.002 ±0.002	5.6 ±5.6
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.006 ±0.004	6.5 ±4.2
	Chlorurus sordidus	Daisy parrotfish	0.020 ±0.014	2.9 ±1.1

The density, size, size ratio and biodiversity of finfish in the back-reefs of Ailuk were the lowest among the three habitats. Biomass was intermediate between the lagoon and outer-reef values but still less than half the value recorded at the outer reefs. By comparing these parameters to values recorded in the back-reefs of the other three sites, Ailuk appeared to have the lowest density, size and biomass of all sites. However, biodiversity was higher than that in both Arno and Laura and only lower than that in Likiep (Table 3.8). The trophic structure of this back-reef was almost equally composed of herbivores and carnivores in terms of density, and dominated by carnivores in terms of biomass. Lethrinidae, in fact, were present in high numbers of large-sized species. Scaridae were also mainly represented by large species. Mullidae, Scaridae and Lethrinidae displayed low average size ratios, probably suggesting an impact from fishing. The back-reefs of Ailuk displayed a substrate with a fairly high cover of live coral (the second-highest after Likiep for back-reefs), and a similar percentage of hard and soft bottom. This composite habitat offers niches to different species and families and may explain the mixed composition of the most important species in this community. The abundance of Lethrinidae may be explained by the availability of soft bottom. The high abundance and diversity of Chaetodontidae (12 species) reflected a reef which was fairly rich in live corals.

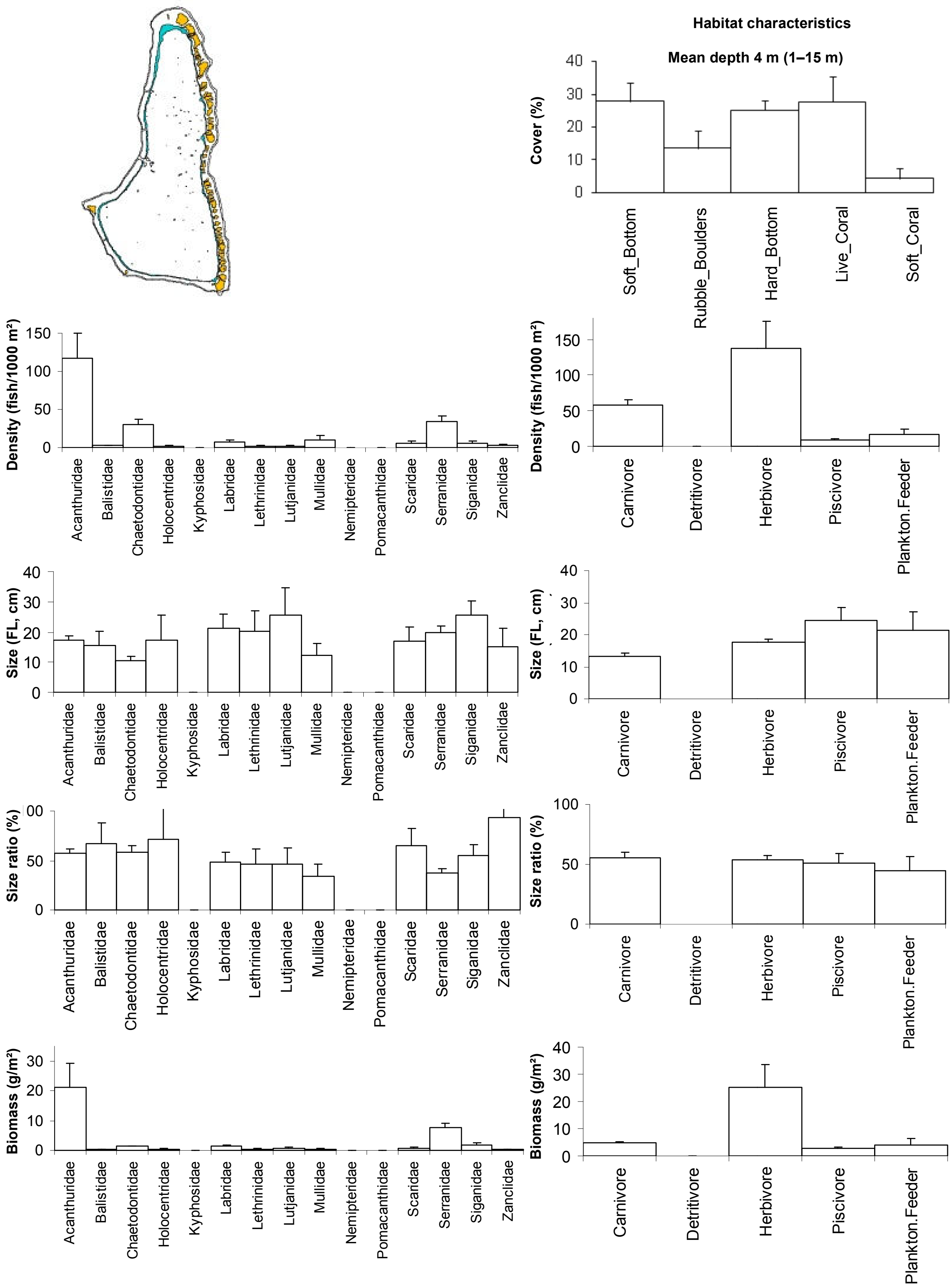

Figure 3.21: Profile of finfish resources in the back-reef environment of Ailuk.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Ailuk

The outer-reef environment of Ailuk was strongly dominated by one herbivorous family, Acanthuridae (Figure 3.22), in terms of density. Scaridae, Lutjanidae and Serranidae were also prominent in terms of biomass. These four families were represented by 40 species; particularly high biomass and density were recorded for *Chlorurus microrhinos*, *Lutjanus gibbus*, *Ctenochaetus striatus*, *Acanthurus nigricans*, *Scarus altipinnis*, *Plectropomus laevis*, *Cetoscarus bicolor, S. forsteni*, *Lutjanus monostigma* and *Naso lituratus* (Table 3.9). This reef environment presented a dominance of hard bottom (60%), high coral cover (33%), and very little rubble (3%) and soft bottom (3%, Table 3.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.090 ±0.022	9.5 ±2.2
	Acanthurus nigricans	Whitecheek surgeonfish	0.094 ±0.027	8.3 ±2.4
	Naso lituratus	Orangespine unicornfish	0.006 ±0.002	1.8 ±0.8
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.012 ±0.004	12.7 ±4.4
	Scarus altipinnis	Filamentfinned parrotfish	0.004 ±0.003	7.4 ±6.1
	Cetoscarus bicolor	Bicolor parrotfish	0.003 ±0.002	5.2 ±2.7
	Scarus forsteni	Fortson’s parrotfish	0.008 ±0.004	3.1 ±1.5
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.030 ±0.029	12.3 ±11.8
	Lutjanus monostigma	Onespot snapper	0.005 ±0.003	2.4 ±1.8
Serranidae	*Plectropomus laevis*	Blacksaddle coralgrouper	0.001 ±0.001	6.3 ±6.3

The density, size, size ratio, biomass and biodiversity of finfish in the outer reefs of Ailuk were higher than at the other habitats. When compared to the outer reefs of the other sites, size, size ratio and biomass were higher than everywhere else, while density and biodiversity were the second-highest values (Table 3.9). The trophic structure of this outer reef was clearly dominated by herbivores, mainly represented by a high density of Acanthuridae, mostly comprising the small, ubiquitous *C. striatus* and *A. nigricans*, and a high biomass of Scaridae. Lutjanidae, Serranidae, Lethrinidae and Mullidae were the most prominent carnivores. Average size ratio was low for Lethrinidae (43% of maximum size), suggesting a possible impact from fishing. The outer reefs of Ailuk displayed a rich substrate with a high cover of live coral (33%), and almost no soft bottom, partially explaining the high presence of Acanthuridae.

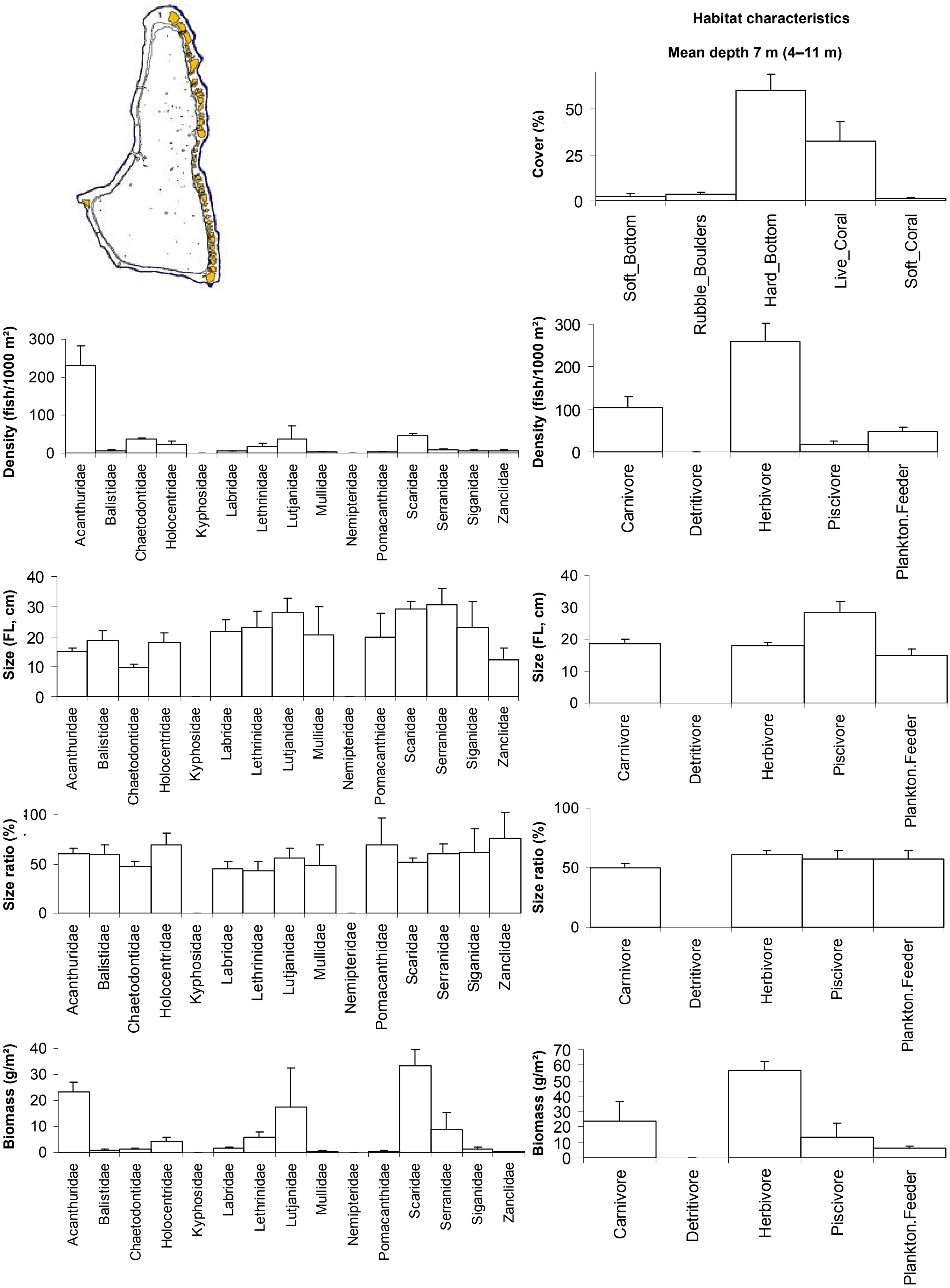

Figure 3.22: Profile of finfish resources in the outer-reef environment of Ailuk.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Ailuk

Overall, the fish assemblage of Ailuk was dominated by the herbivore family Acanthuridae, followed by Scaridae, and the carnivores Chaetodontidae, in terms of density only, and by Lethrinidae, Lutjanidae and Serranidae in terms of biomass (Figure 3.23). These six families were represented by a total of 82 species, dominated (in terms of biomass and density) by *Chlorurus microrhinos*, *Monotaxis grandoculis*, *Ctenochaetus striatus*, *Lutjanus gibbus*, *Acanthurus nigricans*, *Scarus altipinnis*, *Plectropomus laevis*, *Cetoscarus bicolor*, *Lethrinus microdon* and *Lutjanus monostigma* (Table 3.10). The average substrate was dominated by hard bottom (43%) and live coral (30%), with an average amount of soft bottom (15%) and little rubble (9%). The overall substrate composition and fish assemblage in Ailuk shared characteristics of primarily outer reef (50% of total reef habitat of this site), then back-reef (46%) and, to a smaller extent, intermediate reef (4%).

Table 3.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Ailuk (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.063	6.3
	Acanthurus nigricans	Whitecheek surgeonfish	0.048	4.2
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.009	9.4
	Scarus altipinnis	Filamentfinned parrotfish	0.003	4.1
	Cetoscarus bicolor	Bicolor parrotfish	0.002	2.7
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.018	7.9
	Lethrinus microdon	Longface Emperor	0.001	2.6
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.015	6.1
	Lutjanus monostigma	Onespot snapper	0.002	1.3
Serranidae	*Plectropomus laevis*	Blacksaddle coralgrouper	0.001	3.4

Overall, Ailuk appeared to support a rather poor finfish resource, with the lowest values of density (0.3 fish/m^2) and biomass (70 g/m^2) at the site, the second-highest value of size ratio (52%), average size similar to those in Likiep and Laura (17 cm FL), but second-highest biodiversity. Overall, size ratios were low for Lethrinidae (42%), Mullidae (40%) and Scaridae (43%), suggesting an impact from fishing on these families. The more detailed assessment at the trophic and family level revealed a dominance of herbivores over carnivores, especially in terms of density. This trend could partially be explained by the type of habitat, which was dominated by hard bottom and corals. This type of condition favours herbivores and a few families of carnivores, mainly Lutjanidae, which are normally associated with hard bottom. However, selective fishing (targeting mainly Serranidae, Lethrinidae, Lutjanidae and Mullidae along with the herbivore Siganidae) might explain this composition. In conclusion, Ailuk appeared to be naturally rich, as shown by a good substrate composition and high fish biodiversity, but already showed dwindling resources (low abundance of carnivores and small average sizes), probably due to fishing.

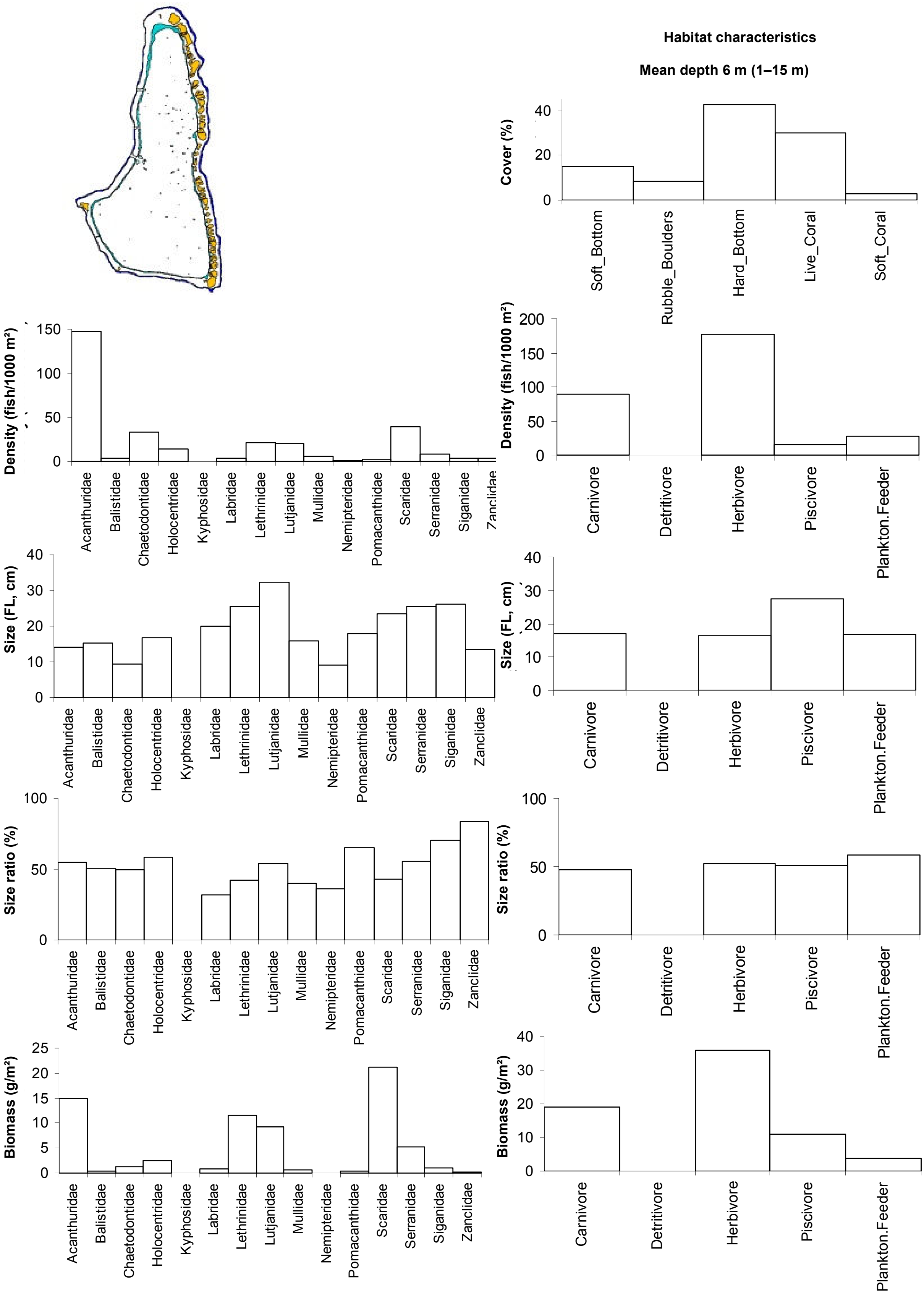

Figure 3.23: Profile of finfish resources in the combined reef habitats of Ailuk (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Ailuk

The assessment indicated that the status of finfish resources at this site was rather poor: Ailuk appeared to be naturally fairly rich, as shown by the healthy substrate composition and fish biodiversity; however, it already showed dwindling resources (scarcity of carnivores and small average sizes), probably due to fishing.

- The good general conditions were assured by the general health of the reefs, with relatively high live-coral cover, even if slightly lower than as recorded in Likiep (where the regional highest live-coral cover was recorded).

- The biodiversity of fish averaged over the three habitats was the second-highest recorded at the four country sites (43 species/transect versus 46 recorded in Likiep), however:

  - Density and biomass were the lowest of the four sites.
  - Sizes were smaller in the intermediate reef and back-reef compared to at the other sites.
  - In general, fish were wary of the presence of divers.
  - We noted a few large-sized species of Scaridae (*Scarus altipinnis*, *Chlorurus microrhinos*, *Hipposcarus longiceps*, *Cetoscarus bicolor* and *S. frenatus*) but at lower-than-expected size (size ratio <45% of maximum size). No *Bolbometopon muricatum* was recorded.
  - Large-sized carnivores (Serranidae and Lutjanidae) were rare or absent.
  - Apex predators were present but not in exceptional numbers.

We found remarkable differences among the three reef types.

- At the back-reefs, corals were alive and healthy even very close to the surface. Less coral cover was found at the intermediate reefs, where much of the substrate was detritical or sandy, and rock and corals were covered in algae (especially Microdyction). Among the three habitats present, the outer reefs were by far the richest and better built. In general, the reefs in the southern and western part of the atoll were vertical walls, reducing the live-coral surface, which, however, appeared to be very rich and diverse.

Similar to the substrate composition, the finfish resources also varied greatly:

- At the intermediate reefs, density and biomass were the smallest; however, biodiversity was high (the highest among the intermediate reefs of all the atolls). There were abundant planktivorous fish of good size but, in general, fish were scared of divers.

- At the back-reefs, fish were very wary and displayed average-to-small sizes and low densities. The biomass recorded here was the lowest of the records from the four atolls.

- At the outer reefs, the fish were rather scared of divers, in some areas more than others. Sizes were quite large and densities rather high, higher than at the other two habitats. Biomass was high, the highest of the three habitats as well as of the four sites. No *Bolbometopon muricatum* and only very few *Cheilinus undulatus* of small size were recorded. Quite a few sharks of average-to-small size were encountered.

3.4 Invertebrate resource surveys: Ailuk

The diversity and abundance of invertebrate species at Ailuk were independently determined using a range of survey techniques (Table 3.11), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 3.24) and finer-scale assessment of specific reef and benthic habitats (Figures 3.25 and 3.26).

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

Table 3.11: Number of stations and replicates completed at Ailuk

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	73 transects
Reef-benthos transects (RBt)	19	114 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	7	42 transects
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches (RFs)	8	48 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

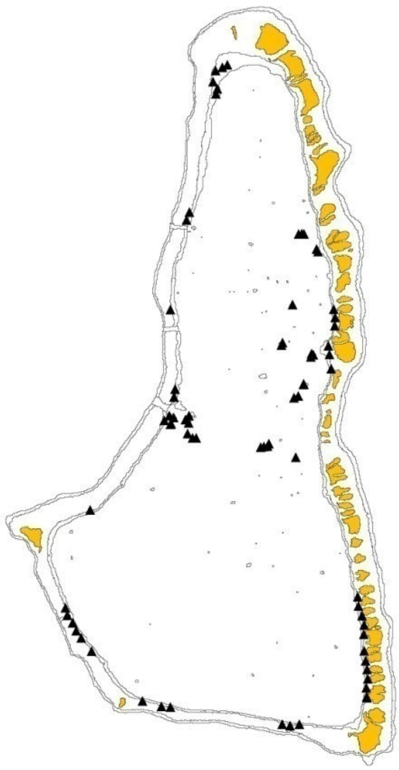

Figure 3.24: Broad-scale survey stations for invertebrates in Ailuk.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

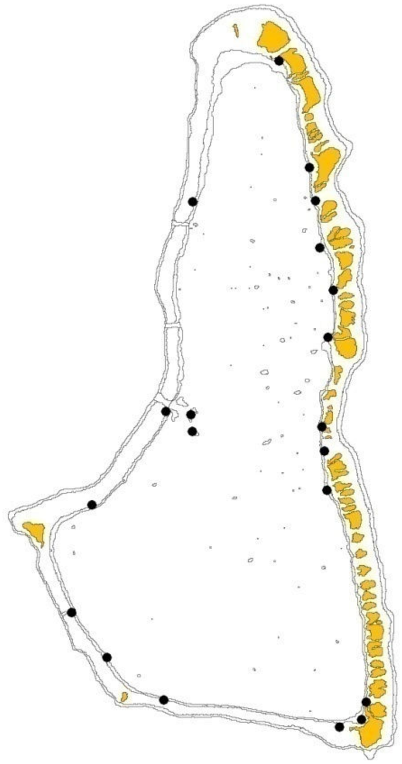

Figure 3.25: Fine-scale reef-benthos transect survey stations in Ailuk.
Black circles: reef-benthos transect stations (RBt).

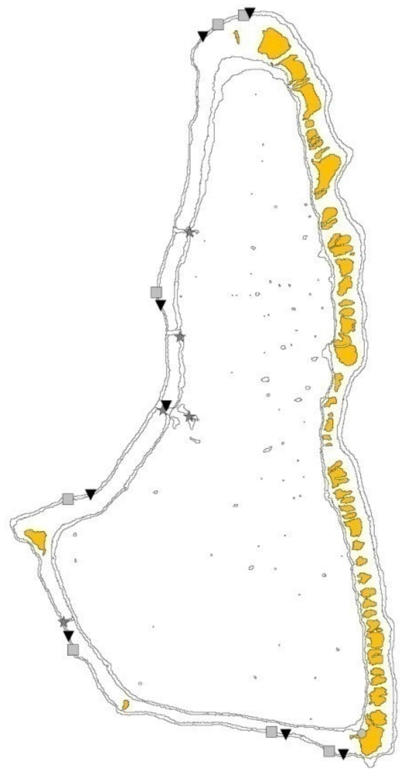

Figure 3.26: Fine-scale survey stations for invertebrates in Ailuk.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Forty-two species or species groupings (groups of species within a genus) were recorded in the Ailuk invertebrate surveys. These included 6 bivalves, 15 gastropods, 9 sea cucumbers, 3 urchins, 4 sea stars and 1 cnidarian (Appendix 4.2.1). Information on key families and species is detailed below.

3.4.1 Giant clams: Ailuk

Shallow-reef habitat that is suitable for giant clams at the atoll of Ailuk was extensive (31.3 km^2); however, for the relatively large lagoon (over 25 km long with an area of 205.7 km^2), shallow reef was not always common along shorelines and as intermediate reef (only approximately 17 km^2). Hard-reef benthos was sparsely distributed, especially along the eastern lagoon shoreline (The shallows were sandy.) and the other shorelines supported reef which generally was of low relief and complexity. This was not the case near the passages that connected the lagoon to the open ocean. Outside the lagoon, more exposed reef of the barrier reef front and reef slope (14.4 km^2) supported more live corals. However, no surveys could be completed on the wave-impacted eastern side of Ailuk due to the lack of safe boat support (Most surveys were conducted from a boat with <15 HP engine.).

Nutrient inputs from the land were limited and, in general, the system looked to be nutrient-poor. As in the neighbouring atoll of Likiep, the shallows in the west of the lagoon were subject to dynamic water circulation where passages bisected the barrier. Otherwise, in parts of the east and along the northeast side of the lagoon, conditions were more depositional, with sedimentation and epiphytic growth contrasting greatly with the cleaner reefs in the west.

Broad-scale sampling provided an overview of giant clam distribution at Ailuk. Reefs at this site held three species of giant clam: the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa* and the horse-hoof or bear's paw clam *Hippopus hippopus*. The true giant clam, *T. gigas*, was commonly noted as dead shells, especially on the tops of intermediate patch reefs, but no live specimens were recorded. In addition, no smooth clam, *T. derasa*, which had been introduced to neighbouring Likiep, was present. Records from broad-scale sampling revealed that *T. maxima* had the widest distribution (found in all 12 stations and 67 of 73 transects), followed by *H. hippopus* (in 11 stations and 18 transects) and then *T. squamosa* (5 stations and 9 transects). The average station density of *T. maxima* in broad-scale assessments was 381.0 /ha ±76.4 (See Figure 3.27.).

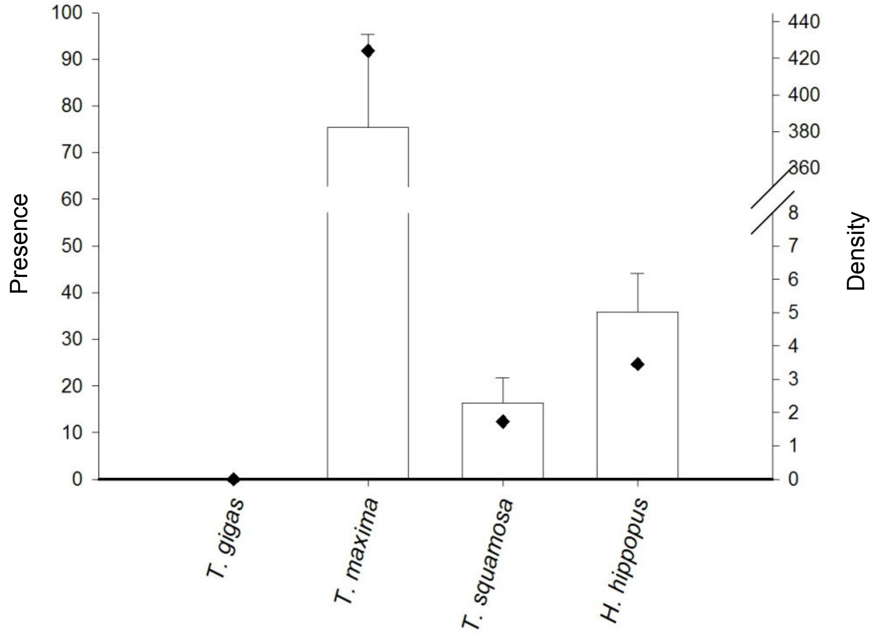

Figure 3.27: Presence and mean density of giant clam species at Ailuk based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 3.28). In these reef-benthos assessments (RBt), *T. maxima* was present in 95% of stations at a mean density of 2649.1 /ha ±444.0.

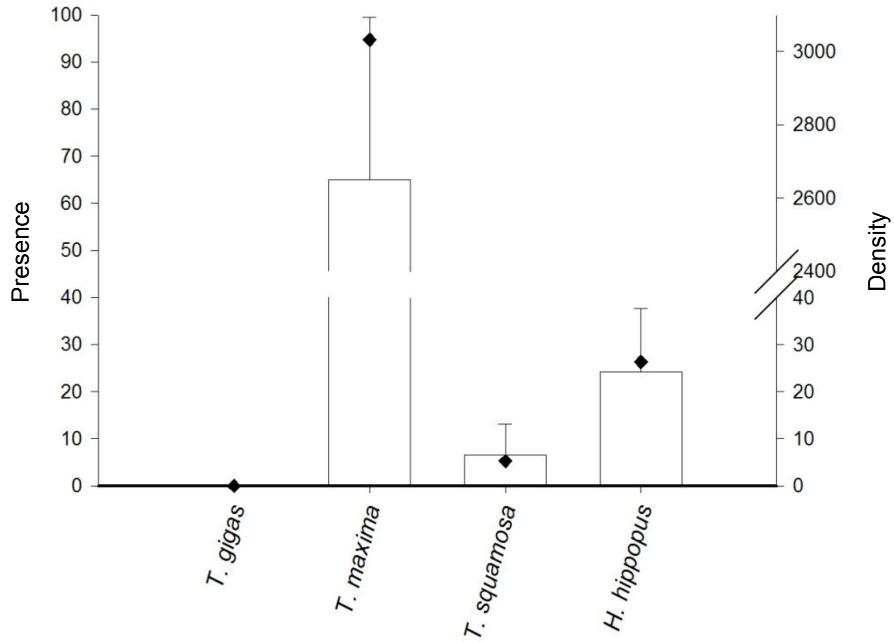

Figure 3.28: Presence and mean density of giant clam species at Ailuk based on reef-benthos transect survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Only at one RBt station were no clams recorded, and this was situated near the main settlement at Ailuk Island. RBt stations placed on suitable benthos all around the lagoon had similar densities of *T. maxima*, apart from near the village in the south and on the northerly loop, where densities were significantly reduced. At their highest density, clams in one transect were recorded at approximately 1.5 clams/m².

Of the 9529 clams recorded during all assessment techniques, the average length of clams was 10.6 cm ±0.1 (n = 1325) for *T. maxima*, 28.1 cm ±1.5 for *T. squamosa* (n = 21), and 24.3 cm ±1.2 for *H. hippopus* (n = 34). A range of lengths was recorded for the three clam species; however, the largest *T. maxima* were in general small, and the larger size classes were not well represented. *T. maxima* clams that were larger than 16 cm comprised just 3.9% of the measured stock. Although *T. squamosa* are normally relatively cryptic (although not as cryptic as *H. hippopus*), the low number of juveniles seen would suggest there has not been significant recruitment of this species in the last 2–3 years (See Figure 3.29.).

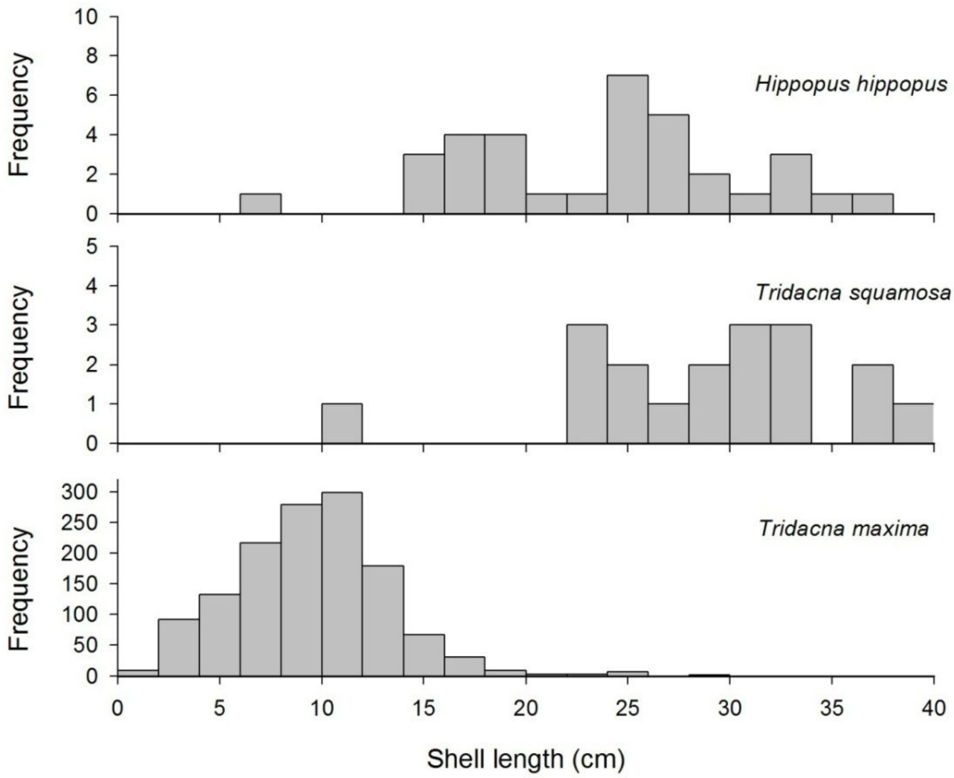

Figure 3.29: Size frequency histograms of giant clam shell length (cm) for Ailuk.

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

Marshall Islands lies between 4–14° N and 160–173° E. Ailuk, as part of the Ratak chain, lies at approximately 169° E, which is within the east–west range of the commercial topshell, *Trochus niloticus* (found naturally on islands as far east as Wallis), but too far north (9° N) to have local populations of this species.

Trochus were introduced to RMI by the Japanese during the 1930s, with introductions to Jaluit, Laura, Ailinglaplap and, apparently, also Arno, Kwajalein and Enewetak (Asano and Inenami 1939, McGowan 1958, cited in Wright *et al.* 1989). As far as we know, no trochus has yet been brought to Ailuk, but the outer reef at Ailuk (75.8 km lineal distance of exposed reef perimeter) constitutes a very extensive benthos suitable for *T. niloticus*. Reefs that were visited on the westerly side of the island were not all well suited to commercial trochus, as the slope was relatively steep and the impact area did not have a very developed architecture (complexity). However, this shoreline had a developed reeftop that would constitute a suitable juvenile habitat; first impressions were that Ailuk was a better prospect for trochus introduction than Likiep. No survey was possible on the easterly reefs due to lack of boat support.

CoFish survey work did not locate any live or dead *T. niloticus* at Ailuk.

Table 3.12: Presence and mean density of *Tectus pyramis* and *Pinctada margaritifera* in Ailuk
Based on various assessment techniques; mean density measured in numbers/ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Tectus pyramis				
B-S	0.2	0.2	1/12 = 8	1/73 = 1
RBt	4.4	3.1	2/19 = 11	2/113 = 2
RFs	0.5	0.5	1/8 =13	1/48 = 2
MOPs	1.1	1.1	1/7 = 14	1/42 = 2
Ds	0		0/5 = 0	0/30 = 0
Pinctada margaritifera				
B-S	5.3	1.3	10/12 = 83	17/73 = 23
RBt	4.4	3.1	2/19 = 11	2/113 = 2
RFs	0		0/8 =0	0/48 = 0
MOPs	0		0/7 = 0	0/42 = 0
Ds	2.9	1.1	1/5 = 20	1/30 = 3

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

The potential suitability of reefs for grazing gastropods was somewhat highlighted by results for the false trochus or green topshell *Tectus pyramis* (Table 3.12). This related, but less valuable species of topshell (an algal-grazing gastropod with a similar life history to trochus) was not common and occurred at relatively low density at Ailuk (n = 5 recorded in survey). The mean size (basal width) of *T. pyramis* was 5.0 cm ±0.6, and no large recruitment pulse was identified.

Blacklip pearl oysters, *Pinctada margaritifera*, are normally cryptic and sparsely distributed in open-lagoon systems. This atoll lagoon was relatively enclosed despite the four westerly passages, and blacklip pearl oysters were quite commonly noted in survey (n = 31, mean shell height 16.2 cm ±0.4). Most blacklip oysters were noted within the lagoon and coverage was relatively comprehensive (found in 10/12 broad-scale stations).

3.4.3 Infaunal species and groups: Ailuk

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

3.4.4 Other gastropods and bivalves: Ailuk

Seba's spider conch *Lambis truncata* (the larger of the two common spider conchs) was recorded at low density (n = 2 individuals) inside the lagoon. Nine *L. chiragra* but no *L. lambis* or strawberry or red lipped conch *Strombus luhuanus* were noted (Appendices 4.2.1 to 4.2.7). This is another indication that there is a lack of algal development on the sediments and lagoon floor.

Of the range of small turban shells, only a small number of *Turbo argyrostomus*, *T. petholatus* and *Astralium* spp. were recorded (n = 10). It was possible to closely inspect the surf zone only on the western side of Ailuk, and more turban shells may have been present on the swell-impacted eastern side. Other resource species targeted by fishers (e.g. *Charonia*, *Chicoreus*, *Conus*, *Cypraea*, *Mitra* and *Pleuroploca*) were also recorded during independent survey (Appendices 4.2.1 to 4.2.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama* and *Spondylus* spp., are also in Appendices 4.2.1 to 4.2.7. No creel survey was conducted at Ailuk.

3.4.5 Lobsters: Ailuk

Ailuk had 75.8 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef, represents a large amount of habitat for lobsters.

There was no dedicated night reef-front assessment of lobsters (See Methods.), and only one lobster (*Panulirus* sp.) was recorded in broad-scale transects. No slipper or sand lobsters were recorded during the surveys. Even night-time assessments for nocturnal sea cucumber species (Ns) did not result in the recording of lobsters, although the stations were close to the village of Ailuk. This type of assessment is completed on inshore reefs, whereas night time searches along the reeftop around the atoll would have provided the best opportunity to assess lobster presence.

3.4.6 Sea cucumbers[7]: Ailuk

Ailuk has an extensive shallow lagoon system (205.7 km²), which is surrounded by low-lying *motu* (5.4 km² total land area). 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, rubble and limestone pavement, without noticeable inputs of nutrients that could support large populations of sea cucumbers.

There was little influence from the land, except close to the *motu* that supported bird colonies or had settlements. In these places, surfaces had some algal and epiphytic growth but, in general, the system was very oceanic. Outside the barrier reef the reef slope was impacted by large swells in the east, and even in the west and south the reef slope was not extensive as it shelved off relatively steeply into deeper water.

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

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 3.13, Appendices 4.2.2 to 4.2.6; also see Methods). At Ailuk, eight commercial species of sea cucumber were recorded during in-water assessments, plus one indicator species (Table 3.13), a similar amount to the number found in the other atoll CoFish sites in Marshall Islands. The range of sea cucumber species recorded in Ailuk reflected the isolated position of these dispersed atolls and the largely exposed, oceanic-influenced nature of the habitats present.

Sea cucumber species associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were rare (found in 18% of broad-scale and no reef-benthos transects). When recorded, the density was low although the deep-water areas held >7 /ha of a dark brown variety, which had eye spots that were hardly visible.

Stocks of black teatfish (*Holothuria nobilis*), a high-value sea cucumber usually found in shallow water and, therefore, highly susceptible to fishing pressure, were also not common. This species was not noted in the lagoon but was recorded on SCUBA searches (MOPs) outside the lagoon (n = 3 individuals). This was surprising as there was significant back-reef habitat at Ailuk on the western side that was suitable for this species. Whether the reason for the low density is previous over-fishing or environmental stress, there is evidence that this species, once heavily depleted, can take many years to recover to reasonable densities (>10 /ha). The fast growing and medium/high-value greenfish (*Stichopus chloronotus*) was also not found at any stations, and may be absent from Marshall Islands.

Surf redfish (*Actinopyga mauritiana*) were also not recorded across the site, despite the completion of eight RFs stations to search the reef-front slope near the crest. We also had the opportunity to cross the barrier reef at high tide on some occasions (in the northwest), and still no surf redfish were observed. This species can be recorded at commercial densities of 500–600 /ha in other oceanic-influenced atoll islands in French Polynesia and Tonga.

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

Deep-water assessments (30 searches of five minutes, average depth 17.2 m, max depth 33 m) were completed to obtain a preliminary abundance estimate for white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the passages had suitably dynamic water movement for these species, but the high-value *H. fuscogilva* was only recorded at one passage. The size and density of this species at this location indicated that the area had not been commercially targeted in recent years. Deep-water assessments did detect amberfish (in 100% of stations) and prickly redfish (in 4 of 5 stations) and both these species were also noted in broad-scale surveys. However, the average density of these species was not high.

3.4.7 Other echinoderms: Ailuk

The edible collector urchin (*Tripneustes gratilla*) was not present and slate urchins (*Heterocentrotus mammillatus*) were rarely noted (n = 2 individuals). Other urchins that can be used as a food source or potential indicators of habitat condition (*Diadema* spp., *Echinothrix* spp. and *Echinometra mathaei*) were recorded at very low levels. The large, black *Echinothrix* sp. (*E. diadema*) had a mean station density of <9 /ha for RBt survey stations and was not noted in RFs and MOPs surveys (See Appendices 4.2.1 to 4.2.7.).

Starfish were sparsely distributed at Ailuk; the common starfish *Linckia* spp. (*L. laevigata* and *L. guildingi*) were recorded in very small numbers, but pincushion stars (*Culcita novaeguineae*) were more common and noted in 83% of broad-scale stations (n = 95 individuals). These coralivore (coral eating) starfish were hardly ever at high density (mean only 8.6 /ha ±1.7). Only five records of another coral-eating star, the crown-of-thorns (*Acanthaster planci*, COTS) were noted. The presence of COTS was not concentrated to any one place in the lagoon and is not of any critical concern at this density (See presence and density estimates in Appendices 4.2.1 to 4.2.7.).

Table 3.14: Sea cucumber species records for Ailuk

Species	Common name	Commercial value [5]	B-S transects n = 73			Reef-benthos stations n = 19			Other stations RFs = 8; MOPs = 7			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												
Bohadschia argus	Leopardfish	M	4.1	23.1	18							7.1	7.1	100 Ds
Bohadschia vitiensis	Brown sandfish	L	0.2	16.7	1							8.9	17.8	50 Ns
Holothuria atra	Lollyfish	L	643.3	2935	22	386	1222.2	68				151.1	151.1	100 Ns
Holothuria edulis	Pinkfish	L	3.2	25.9	12	28.5	541.7	5	1.1	7.6	14 MOPs	1.0	2.4	40 Ds
Holothuria fuscogilva [4]	White teatfish	H										4.3	21.4	20 Ds
Holothuria hilla	-	L												
Holothuria impatiens	-	L												
Holothuria nobilis [4]	Black teatfish	H							2.2	15.2	14 MOPs			
Synapta spp.	-	-	0.2	16.7	1									
Thelenota ananas	Prickly redfish	H	1.8	26.7	7							9.0	11.3	80 Ds
Thelenota anax	Amberfish	M	3.9	31.5	12	2.2	41.7	1				4.3	4.3	100 Ds

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

3.4.8 Discussion and conclusions: invertebrate resources in Ailuk

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

In summary, data on giant clam distribution, density and shell size suggest that:

- The reefs at Ailuk, both inside and outside the atoll lagoon, were suitable for a range of giant clams. The most suitable areas were on the western side of the atoll, where water movement was more dynamic and there was a mix of lagoon and open-water oceanic influences. Patch reefs within the lagoon, especially those close to the channels, were also suitable. Fringing reefs within the lagoon, especially areas in the east and north, were less suitable as most reefs were composed of shallow sandy rubble, and water flows in some areas were limited. Land influence on Ailuk was only noticeable in the southeast and, in general, the system was mostly oceanic-influenced, despite some depositional, sedimentary areas in the north.

- Lagoon and barrier reef habitat was suitable for the full range of giant clams found in Marshall Islands, and three species of giant clam were recorded at Ailuk (the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the horse-hoof or bear's paw clam *Hippopus hippopus*). The true giant clam, *Tridacna gigas*, was noted in significant numbers as dead shells, particularly on the platforms formed by the intermediate reefs in the lagoon. The smooth clam, *T. derasa*, that was present in nearby Likiep atoll after translocation, was not present at Ailuk.

- Giant clam distribution and density was indicative of a marginally impacted clam fishery, although clam stocks near to the main village were exhausted. Coverage and densities of *T. maxima* were moderately high. *H. hippopus* was less common and at lower density but still recorded in reasonable numbers; however, the larger *T. squamosa* was rare. This was despite one station near the main island of Ailuk recording a number of *T. squamosa* that were likely to have been relocated and stockpiled for later use.

- Giant clams are broadcast spawners that only mature as females at larger size classes (protandric hermaphrodites). This means that, for successful stock management, clams need to be maintained at higher density and to include larger-sized individuals to ensure sufficient spawning takes place to produce new generations. The newly devised no-fishing zones in Ailuk should ensure that some clam stocks remain protected from fishing.

- Although a 'full' range of size classes was noted for most species, which indicates successful spawning and recruitment, the abundance of small *T. squamosa* clams was low, clam stocks close to the main settlement were exhausted, and *T. maxima* clams of large size were relatively sparse, supporting the assumption that all clam stocks are impacted by fishing.

- If possible, the true giant clam *T. gigas* should be re-stocked on the intermediate reeftops, if a successful breeding programme of *T. gigas* can be achieved in nearby Likiep atoll. If local Ailuk broodstock can be found this will negate any potentially negative genetic implications from the translocated clams, although a local hatchery will need to be set up for a short period. Movement of large clams between islands is not recommended.

Data on MOP distribution, density and shell size suggest that:

- The reefs at Ailuk can potentially support the commercial topshell, *Trochus niloticus*, but this species may never have been introduced here in the past, and no trochus were recorded in this survey.

- The occurrence of the false trochus or green topshell (*Tectus pyramis*) gave an indication that, in general, algal-grazing Trochidae may not be very successful at colonising the oceanic-influenced reefs at Ailuk. Although complex reefs were present, in general, surfaces were clean of algae and this lack of food supply may restrict the build-up of commercial grazing gastropod stocks.

- The blacklip pearl oyster, *Pinctada margaritifera*, was relatively common at Ailuk.

In summary, the distribution, density and length recordings of sea cucumbers at Ailuk reveal that:

- A restricted range of commercial sea cucumber species was present at Ailuk, although a neighbouring atoll, Likiep, had even fewer species recorded. This is possibly due to biogeographical influences: the isolated position of Ailuk in the Pacific, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system.

- The high-value black teatfish (*Holothuria nobilis*) which is easily targeted by fishers, was present at Ailuk, although the abundance recorded was very low and, as was the case for all species noted, below the threshold density recommended before commercialisation can be considered.

- The medium-value prickly redfish (*Thelenota ananas*) was recorded, as was the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish (*H. atra*); however, their distribution was sparse and densities were too low to warrant any commercial interest.

- Surveys targeting deeper-water white teatfish (*Holothuria fuscogilva*) stocks only found one small aggregation of this species from the four passages and one lagoon site sampled. Again, there was no potential for commercialisation unless greater coverage by this species is found. This is unlikely, as the better areas within the system have already been sampled.

- It is unknown whether sea cucumber stocks at Ailuk were over-fished during previous periods (more than a decade ago) and stocks have failed to recover, or whether Ailuk is just naturally deficient in both the range and density of these commercial species due to environmental factors and stressors. However, what can be deduced is that there is no potential for any development of a commercial sea cucumber fishery based on stocks at Ailuk at this time.

3.5 Overall recommendations for Ailuk

- The ongoing community-based fisheries management projects and activities be further developed and strengthened.

- The community committees be supported in their efforts to establish four marine reserves and observe the relative restrictions as well as the species catch restrictions in the whole atoll, as proposed in the fishery management plan.

- A monitoring system be set in place to follow any further changes in finfish resources, especially in marine reserves.

- Controls be put in place to limit the use of spearfishing, especially in the lagoon and at night.

- Some larger clams be placed in the newly devised ‘no-fishing zones’ in Ailuk to ensure that clam stocks remain protected from fishing.

- Restocking of the true giant clam, *Tridacna gigas*, be considered for the intermediate reeftops, if a successful breeding programme of *T. gigas* can be achieved at nearby Likiep atoll. A local hatchery would need to be set up to enable juvenile-only clams to be moved from Likiep to Ailuk for breeding purposes. Translocating adult clams is not recommended.

- There is no potential for developing a commercial sea cucumber fishery based on stocks at Ailuk at this time.

4. PROFILE AND RESULTS FOR ARNO

4.1 Site characteristics

Arno atoll is located about 20 km east of Majuro atoll, at 07°05' N and 171°42' E. It includes 133 islands around its rim, covering an area of only 13 km² and enclosing three different lagoons: a large central one, and two smaller ones in the north and east. Its main lagoon encloses an area of 339 km². The most populous islands are Ajeltokrok, Kobjeltak, Rearlaplap, Langor and Tutu (Figure 4.1). A fish base was established on Arno in 1989, financed by Japanese aid. The fish base purchased fish from local fishers and then transported the product to Majuro for marketing. Although this has now been operating for 20 years, many operators now land their fish direct to markets in Majuro and not to the Arno fish base.

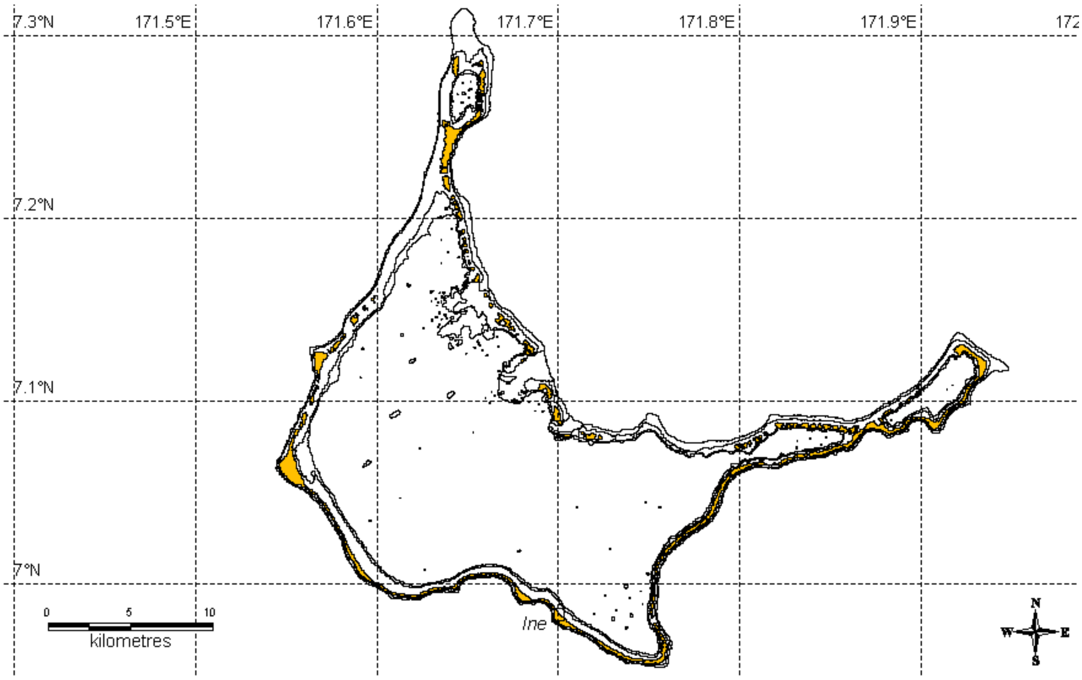

Figure 4.1: Map of Arno.

4.2 Socioeconomic surveys: Arno

Socioeconomic fieldwork was carried out in Arno, RMI from 12 to 21 September 2008. Arno is an island with easy access to Laura and hence easy access to markets to sell fisheries and other produce. The establishment of a huge fish-buying centre on the island, which at the time of survey was the major supplier of finfish to the MIMRA fish market on Laura, further supports commercial fisheries. RMI has an open-access fisheries system, which allows fishers from Arno to extend their fishing wherever they wish, and allows fishers from other communities to fish around Arno.

The Arno community has a resident population of 656 and ~80 households. In total, 15 households, i.e. 19% of the total households in the Arno community, were surveyed, with all 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 14 invertebrate fishers (8 males and 6 females) were interviewed. The household size is moderate to large, with 8 people on average, reflecting the traditional and rural lifestyle of the local people.

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

People from Arno have access to various fishing habitats; these include the sand flats, a deep-lagoon area associated with coastal, mostly submerged reefs, outer reefs, channels and passages.

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

Our results (Figure 4.2) show that fisheries play the most important role for generating income in Arno. This situation has been triggered by the establishment of the MIMRA fish market, which buys catch locally and sends the catch to Laura at least twice per week. About 94% of all households earn their first income from fisheries, and the remaining 7% quoted fisheries as their complementary, second income source. All other sectors are much less important by comparison, with agriculture (i.e. copra production and some vegetable and livestock sales) providing 60% of all households with secondary income. Salaries provide first income for 7% of all households, and handicrafts provide secondary income to 27% of all households in the community. Handicrafts, as in other islands, are made by females, who use leaves of pandanus, coconut stalks, and shells, and sell their products at Laura. Pigs and chickens are popular; 47% of households have a couple of pigs and 94% keep at least 14 chickens for home consumption. Distribution of fish and seafood produce on a non-monetary basis is still important and is practised to a certain extent in Arno.

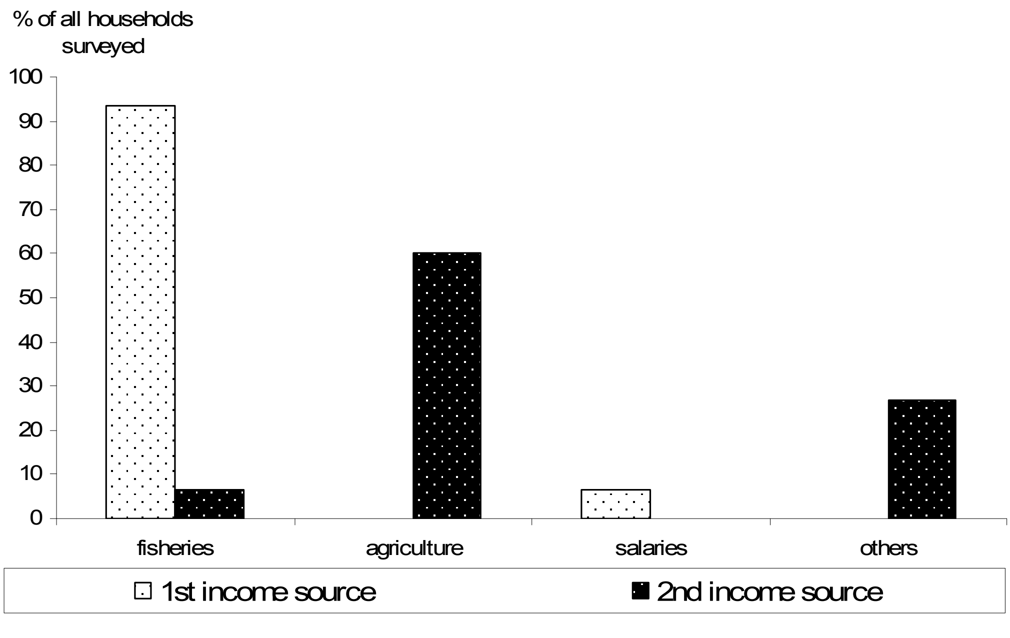

Figure 4.2: Ranked sources of income (%) in Arno.
Total number of households = 15 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

Our results (Table 4.1) show that annual household expenditures are moderate, at an average of USD 1637. People are self-sufficient regarding agricultural and marine produce, and they have some purchasing power due to cash income from fisheries, copra and handicrafts. However, only 13% of all households benefit from remittances, and the average remittances received are moderate at USD 780 /household/year, or ~47% of the average annual household expenditure.

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

Survey coverage	Site (n = 15 HH)	Average across sites (n = 78 HH)
Demography		
HH involved in reef fisheries (%)	100.0	98.7
Number of fishers per HH	3.07 (±0.47)	2.56 (±0.17)
Male finfish fishers per HH (%)	15.2	21.5
Female finfish fishers per HH (%)	0.0	0.0
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	32.6	15.5
Male finfish and invertebrate fishers per HH (%)	43.5	47.0
Female finfish and invertebrate fishers per HH (%)	8.7	16.0
Income		
HH with fisheries as 1st income (%)	93.3	32.1
HH with fisheries as 2nd income (%)	6.7	19.2
HH with agriculture as 1st income (%)	0.0	10.3
HH with agriculture as 2nd income (%)	60.0	38.5
HH with salary as 1st income (%)	6.7	20.5
HH with salary as 2nd income (%)	0.0	9.0
HH with other sources as 1st income (%)	0.0	37.2
HH with other sources as 2nd income (%)	26.7	12.8
Expenditure (USD/year/HH)	1637.38 (±207.42)	2210.55 (±226.09)
Remittance (USD/year/HH) (1)	780.00 (±420.00)	764.14 (±107.90)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	82.55 (±12.13)	105.45 (±7.52)
Frequency fresh fish consumed (times/week)	3.23 (±0.20)	3.56 (±0.13)
Quantity fresh invertebrate consumed (kg/capita/year)	6.61 (±1.48)	6.47 (±7.52)
Frequency fresh invertebrate consumed (times/week)	1.41 (±0.18)	0.94 (±0.08)
Quantity canned fish consumed (kg/capita/year)	6.05 (±1.21)	5.12 (±0.65)
Frequency canned fish consumed (times/week)	1.21 (±0.19)	1.12 (±0.11)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	100.0	94.9
HH eat canned fish (%)	100.0	94.9
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	0.0	15.8
HH eat fresh fish they are given (%)	20.0	84.2
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 (%)	20.0	84.2

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

Survey results indicate an average of three fishers per household and, when extrapolated, the total number of fishers in Arno amounts to 245 (144 males and 101 females). Among these are 37 exclusive finfish fishers (males only), 80 exclusive invertebrate fishers (females only) and 128 fishers who fish for both finfish and invertebrates (107 males, 21 females). About 27% of households own a boat and these are all fitted with an outboard engine.

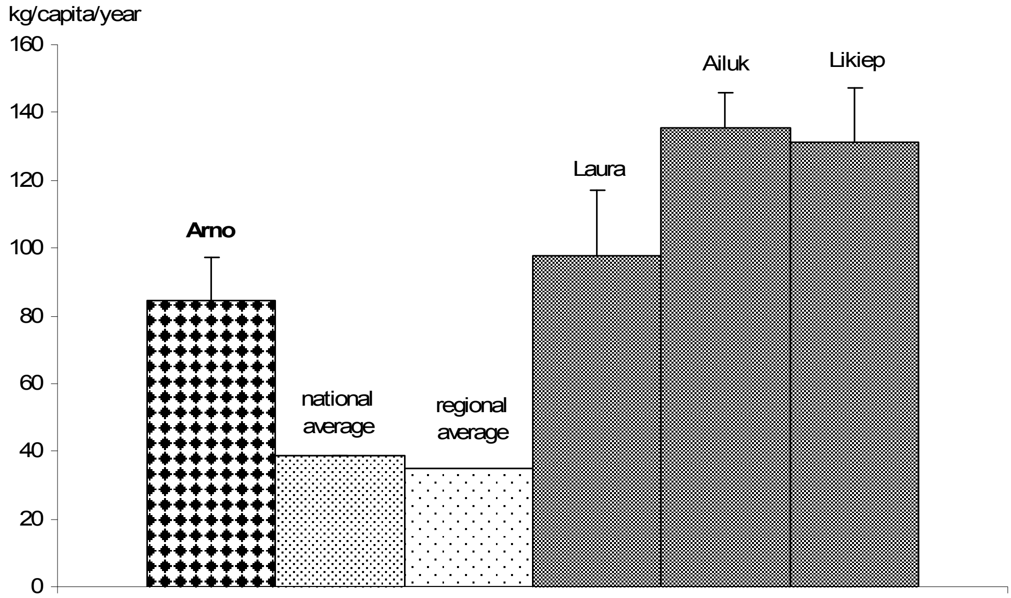

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Arno (n = 15) compared to the regional average (FAO 2008) and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

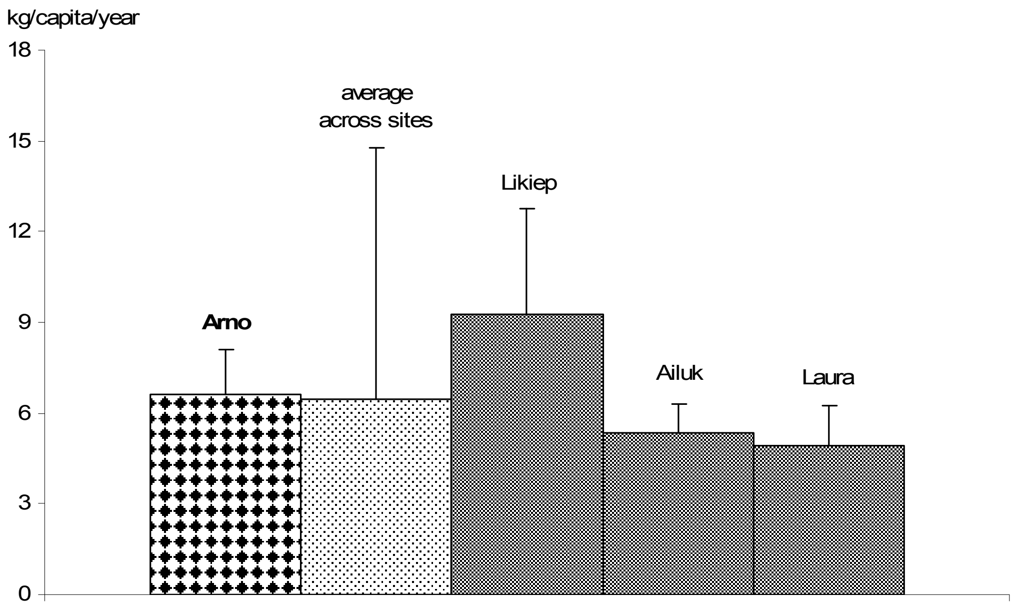

Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Arno (n = 15) compared to the average across sites and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Per capita consumption of fresh fish is high at 83 kg/person/year, but much less than the average across all four study sites in RMI. However, this amount is still more than double the regional average of ~35 kg/person/year (Figure 4.3). By comparison, per capita consumption of invertebrates (edible meat weight only) (Figure 4.4) is much lower at ~7 kg/person/year. Canned fish (Table 4.1) is not commonly eaten and adds only ~6 kg/person to the annual protein supply from seafood. The consumption pattern of seafood found in Arno highlights the fact that people have limited access to agricultural produce and heavily depend on easily and freely available seafood.

Comparing the results obtained for Arno to the average figures across all four study sites surveyed in RMI, the people of the Arno community eat fresh fish, invertebrates and canned fish about as often as average. However, consumption of fresh fish is below average, invertebrate consumption is about average and canned fish consumption is higher than average. Compared to the country site average, the Arno people eat a similar amount of fish and invertebrates that they have caught, but buy seafood far less often than average, and exchange far less catch among community members on a non-commercial basis. Fisheries are the most important income source, which is very different from the case in the other sites studied, and handicrafts and agriculture, mainly copra production, provide complementary, secondary income. The household expenditure level in Arno is still lower than average, and the proportion of households receiving remittances is smaller. The remittances received are about average. By comparison, boat ownership is less than elsewhere; however, the community has only motorised boats.

The difference between Arno and the other sites surveyed is strongly determined by its participation in the outer islands fishing project that is supervised by the Coastal Fisheries Division. The project includes the establishment and monitoring of two markets, seven fish bases, and two pilot fishing projects, with the aim of increasing the standard of living in the outer islands by creating better income opportunities. Fish sold at the Outer Island Fish Market Center (OIFMC) are from atolls including Arno, Aur, Jaluit, and Maloelap. Qualified site managers are stationed on each participating atoll to buy from local fishers, check the quality of catch and establish designated fishing ground areas to prevent any risk of ciguatera from the catch.

4.2.2 Fishing strategies and gear: Arno

Degree of specialisation in fishing

Fishing is done by both males and females; however, traditional roles are still evident (Figure 4.5). Males are much more engaged in finfish fisheries, while females are more focused on invertebrates. However, it is worth mentioning that most males, and about one-quarter of all females considered here fish for both finfish and invertebrates.

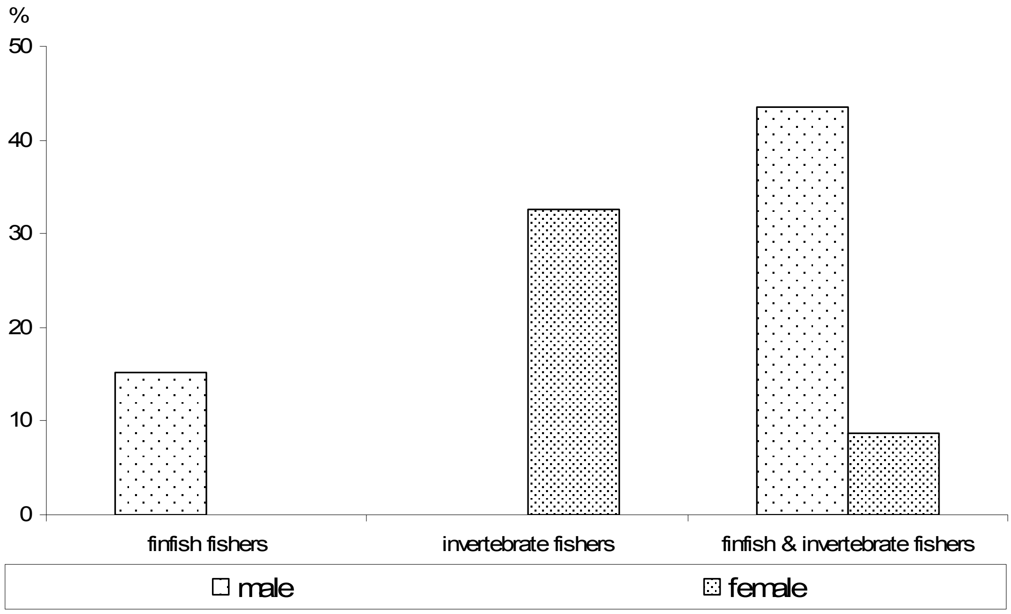

Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Arno.
All fishers = 100%.

Targeted stocks/habitat

Considering the low-cash flow, the isolation, and the limited commercial opportunities in Arno, it is not surprising that Arno finfish fishers mainly target the easily accessible habitats, namely the sheltered coastal reef and the lagoon. Both habitats are usually combined in one fishing trip. The outer reefs are targeted in combination with the lagoon and attract ~53% participation from male fishers only (Table 4.2). Reeftop gleaning and diving for reef-associated invertebrates (clams, lobsters, octopus, etc.) are the most important fisheries. However, at times, reeftop harvesting is combined with soft-benthos (seagrass) fishing.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	46.7	100.0
	Lagoon & outer reef	53.3	0.0
Invertebrates	Reeftop & other	75.0	50.0
	Soft benthos & reeftop	0.0	16.7
	Soft benthos & reeftop & other	25.0	33.3

'Other' refers to free diving for lobsters and giant clams.
Finfish fisher interviews, males: n = 15; females: n = 2. Invertebrate fisher interviews, males: n = 6; females, n = 8.

Fishing patterns and strategies

The number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Arno on their fishing grounds (Tables 4.2 and 4.3).

Our survey sample suggests that fishers from Arno can choose among sheltered coastal reef, lagoon and outer-reef fishing. Invertebrate fisheries are more restricted to the reeftops (44%)

and reef-associated invertebrates (41% 'other') and much less to the soft-benthos habitats, i.e. seagrass (16%) (Figure 4.6). Data on gender participation show that males dominate all invertebrate fisheries except for the combined soft-benthos and reeftop gleaning, which is exclusively performed by female fishers. As elsewhere, females do not engage in diving for lobsters, clams or 'others', which may explain why their participation in the combined reeftop and 'other' fisheries ('other' representing mainly dive fisheries) is less than that of male fishers (Figure 4.7).

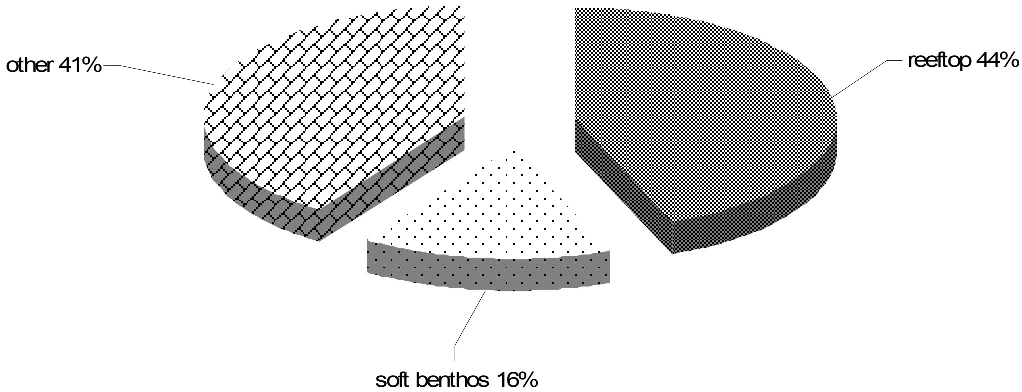

Figure 4.6: Proportion (%) of fishers targeting the three primary invertebrate habitats found in Arno.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to free diving for lobsters and giant clams.

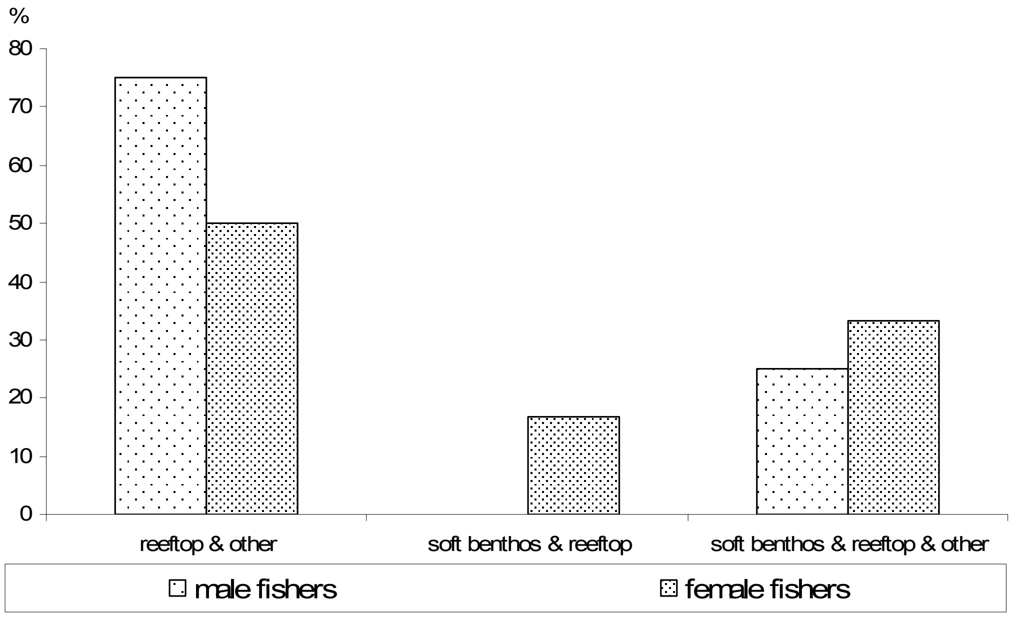

Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Arno.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 8 for males, n = 6 for females.

Gear

Figure 4.8 shows that Arno fishers use a number of fishing techniques during one fishing trip. Most frequently, a combination of gillnets, 'others' (handlines, spear diving) and handlines dominate fishing in the combined sheltered coastal reef and lagoon habitats. If lagoon fishing is combined with outer-reef fishing, handlines and 'others' (longlines, spear diving) are predominantly used, but also deep-bottom lines, cast rods and gillnets.

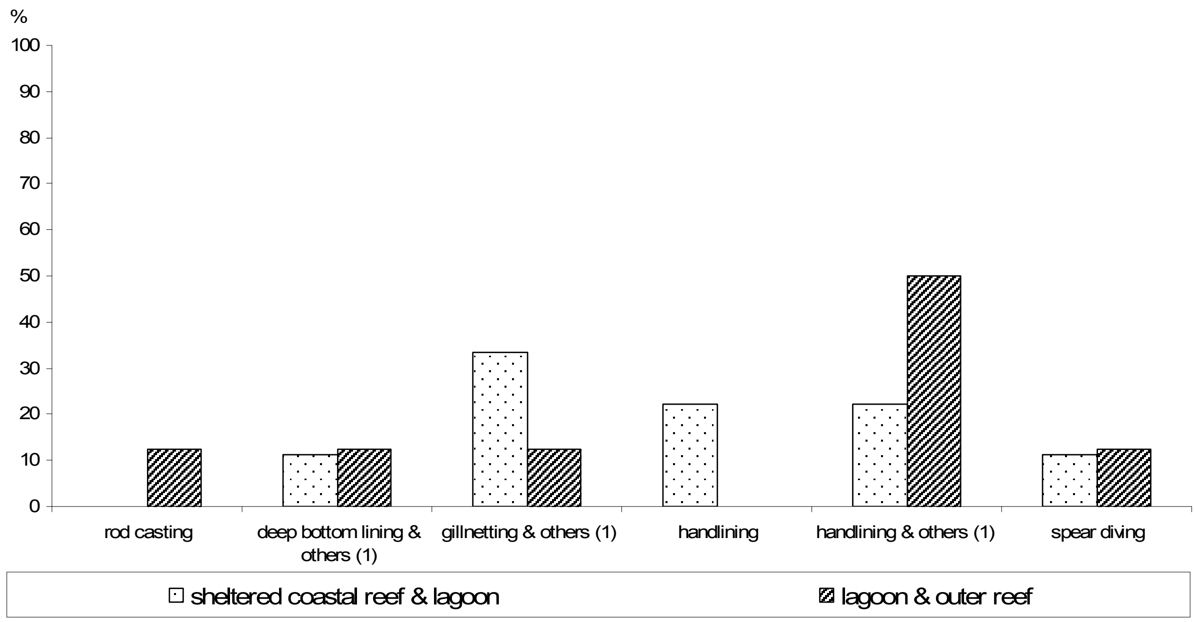

Figure 4.8: Fishing methods commonly used in different habitat types in Arno.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. (1) Handlining, longlining, spear diving.

Frequency and duration of fishing trips

Male finfish fishers visit the sheltered coastal reef and lagoon, and the lagoon and outer-reef habitats about 2 to 3 times per week, while female fishers may venture out once a week to the sheltered coastal reef and lagoon only. Invertebrate trips are less frequently made by both male and female fishers, once or twice per week. The average duration of a finfish fishing trip is about 3–4 hours for males, and 2.5 hours for females. A typical invertebrate collection trip takes 2–3 hours for both male and female fishers. Finfish fishing and invertebrate collection are continued throughout the year.

Most finfish fishing is done according to tidal conditions, i.e. during the day or night. Ice is not essential but was quoted to be used 'always' during 11–25% of fishing trips, and 'sometimes' during 56–63% of fishing trips. Finfish fishing is mostly done using boat transport, while invertebrate fishing is primarily performed while walking.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.00 (±0.29)	1.00 (±0.00)	4.43 (±0.61)	2.50 (±0.50)
	Lagoon & outer reef	3.13 (±0.23)	0	3.75 (±0.41)	0
Invertebrates	Reeftop & other	1.42 (±0.27)	0.56 (±0.23)	2.67 (±0.33)	3.00 (±0.00)
	Soft benthos & reeftop	0	2.00 (n/a)	0	2.00 (n/a)
	Soft benthos & reeftop & other	1.50 (±0.50)	1.12 (±0.88)	3.00 (±0.00)	3.00 (±0.00)

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to free diving for lobsters and giant clams.
Finfish fisher interviews, males: n = 15; females: n = 2. Invertebrate fisher interviews, males: n = 8; females: n = 6.

4.2.3 Catch composition and volume – finfish: Arno

The catches reported from the sheltered coastal reef and lagoon in Arno contain a great variety of species. Siganidae, Serranidae, Holocentridae, and Kyphosidae are the most important by weight caught, but Lethrinidae, Acanthuridae and other species are also significant. Reported catches from the combined lagoon and outer reef have a different composition, with Lutjanidae, Siganidae, Acanthuridae and Scaridae alone determining ~58% of the reported catch weight.

Detailed information on catch composition by species, species group and habitat are reported in Appendix 2.3.1.

Figure 4.9 confirms the findings from the socioeconomic survey reported earlier, i.e. that finfish fishing is important for generating income, with 58% of the total catch being sold outside the community and 42% used for satisfying local food demand. The total annual catch is estimated to amount to ~105.53 t.

The dominance of male fishers by impact and production shows in the proportion of the total annual catch that they account for, i.e. 97%. Thus, it can be concluded that male fishers are mainly responsible for generating income but also for providing food for the family. Females do contribute to household consumption, but only a little by comparison (3% of total annual catch). Interestingly, in contrast to the fisher participation reported earlier, most of the impact is due to fishing the lagoon and outer reef (57%) rather than sheltered coastal reef and lagoon habitats (43%).

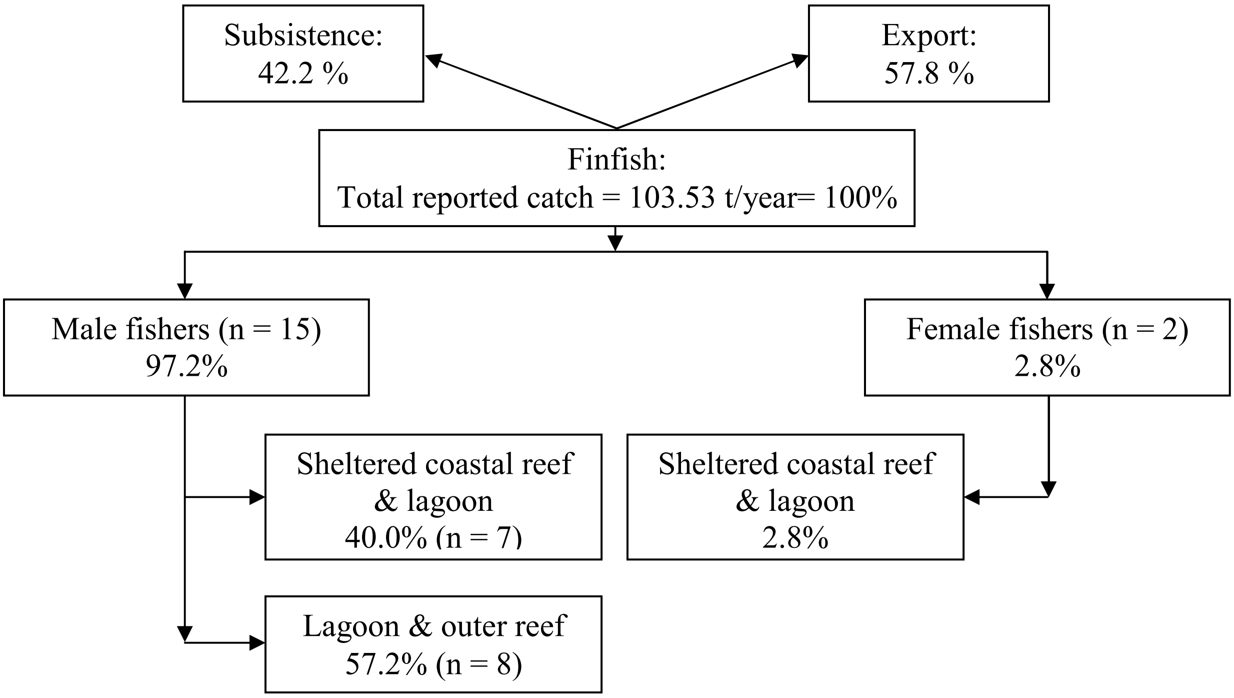

Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Arno.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The distribution of annual catch weight between the more accessible sheltered coastal reef and lagoon and the more distant lagoon and outer reef is a consequence of annual productivity rather than the number of fishers. As shown in Figure 4.10, the average annual catch per male fisher is about 150–200 kg more if targeting the combined lagoon and outer reef as compared to the sheltered coastal reef and lagoon. Female fishers have a productivity of ~150 kg/fisher/year for the combined fishing of the sheltered coastal reef and lagoon. As mentioned earlier, female fishers do not target the lagoon and outer reef, and their productivity confirms the earlier suggestion that they contribute relatively little and fish only for home consumption.

Comparing productivity rates between genders and habitats (Figure 4.11), there are no significant differences between habitats fished. Overall, CPUEs are low; on average all fishers (males and females) reach a CPUE of 1.6–1.8 kg/hour fished regardless of which habitat they target.

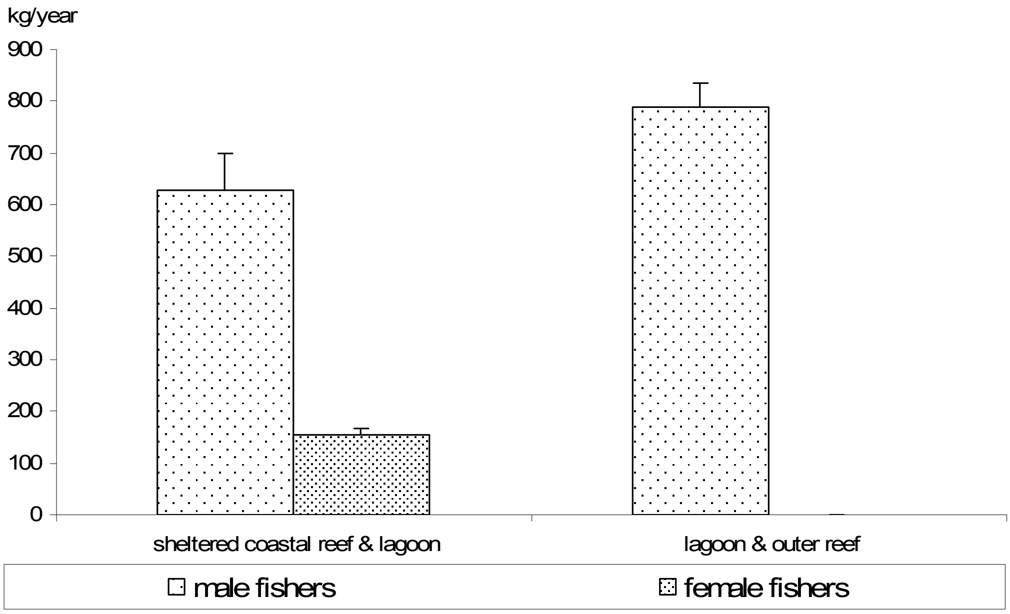

Figure 4.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Arno.
Bars represent standard error (+SE).

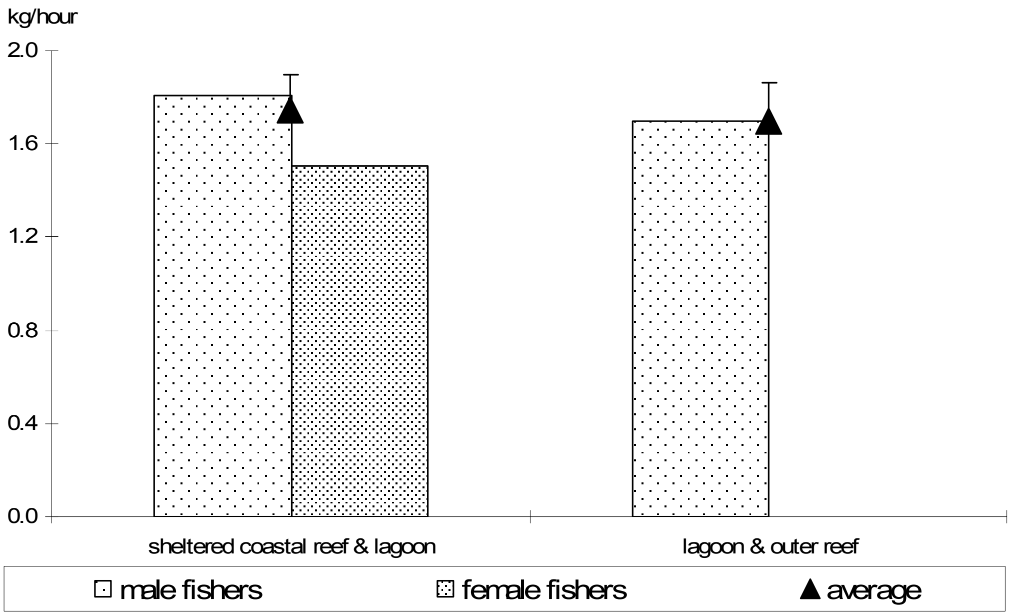

Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Arno.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The importance of both commercial and subsistence fishing for the Arno community clearly shows in Figure 4.12. As observed earlier, fishers target all habitats mainly for commercial purposes, but also very importantly for home consumption. The fact that the practice of sharing fisheries produce among community members on a non-commercial basis is not as common in Arno as elsewhere shows in the little effort spent in fishing for gifts.

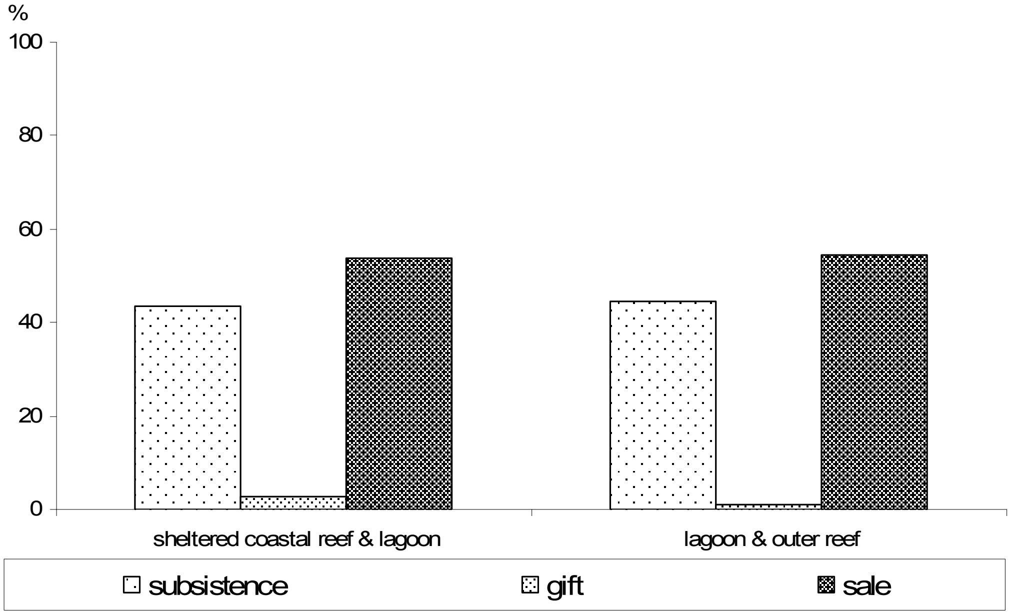

Figure 4.12: The use of finish catches for subsistence, gift and sale, by habitat in Arno. Proportions are expressed in % of the total number of trips per habitat.

The overall finfish fishing productivity is comparative between both habitats (Figure 4.11) and does not suggest any difference in resource status. One would, however, expect the average reported fish size to increase with distance from shore, and clearly show larger sizes in catches from the lagoon and outer reef as compared to catches from the sheltered coastal reef and lagoon. This assumption is, however, not supported by all the data collected. While the reported average fish size does indeed increase for Kyphosidae, Lutjanidae and Siganidae with distance from shore, the opposite is true for Lethrinidae and Serranidae. Average reported fish length is comparative for Acanthuridae, Labridae and possibly Mullidae (Figure 4.13). Average fish sizes are large and range between 25 and 35 cm.

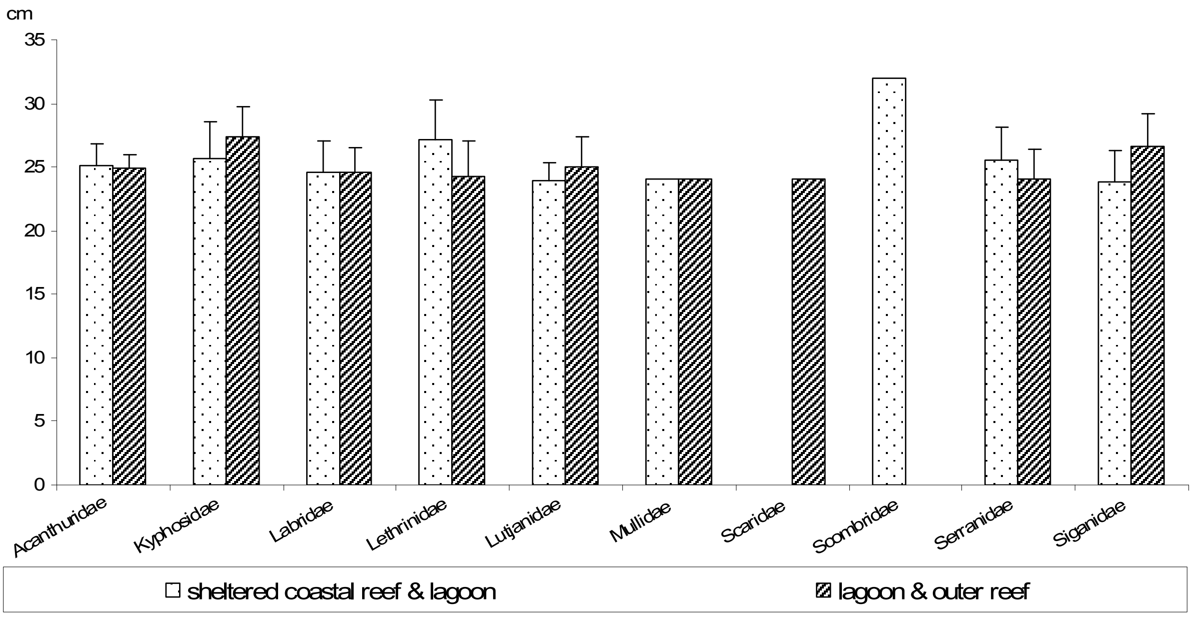

Figure 4.13: Average sizes (cm fork length) of fish caught by family and habitat in Arno. Bars represent standard error (+SE).

The parameters selected to assess the current fishing pressure on Arno's reef and lagoon resources are shown in Table 4.4. The fact that fishers always combine two habitats in one fishing trip makes it difficult to calculate the total impact. However, overall, if considering the available total reef surface and total fishing ground, population density, fisher density and catch rates per unit areas of reef and fishing ground are all very low. Catch rates (total annual catch 1.6 mt/km² of reef and 0.5 mt/km² of fishing ground respectively) remain low even if we take into account the additional 57% of annual catch externally sold.

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

Parameters	Habitat			
	Sheltered coastal reef (SCR) & lagoon	Lagoon & outer reef (OR)	Total reef area	Total fishing ground
Fishing ground area (km^2)	SCR = 0.422	Lagoon = 190.19 OR = 16.89	66.62	207.5
Density of fishers (number of fishers/km^2 fishing ground) (1)	n/a	n/a	2	1
Population density (people/km^2) (2)			10	3
Average annual finfish catch (kg/fisher/year) (3)	523.51 (±87.74)	787.59 (±46.97)		
Total fishing pressure of subsistence catches (t/km^2)			0.7	0.2
Number of fishers	89	77	166	166

Figures in brackets denote standard error; n/a = no information available; (1) total number of fishers (= 166) is extrapolated from household surveys; (2) total population = 656; total subsistence demand = 43.74 t/year; (3) catch figures are based on recorded data from survey respondents only.

4.2.4 Catch composition and volume – invertebrates: Arno

Analysis of catches reported from invertebrate fishers by wet weight shows that three species, *Tridacna maxima*, *Hippopus hippopus* and octopus account for the major share of the total annual catch (wet weight). As shown in Figure 4.14, there are also other invertebrates, such as *Strombus* spp., *Turbo* spp., *Lambis lambis* and *Sipunculus* spp.; however, their contribution to the catch is relatively insignificant.

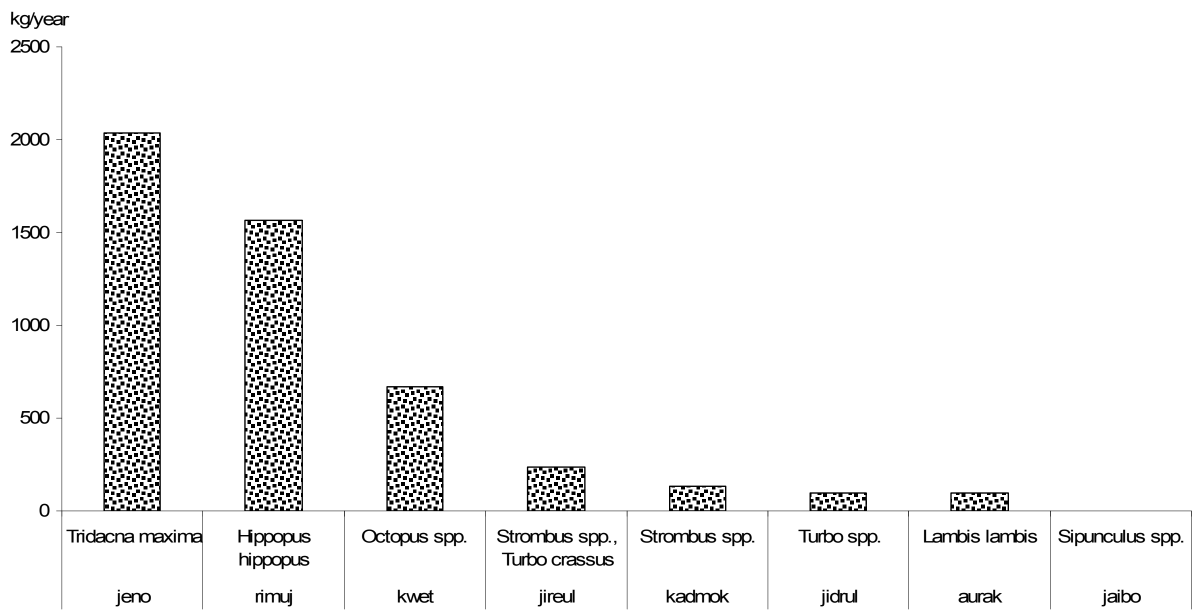

Figure 4.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Arno.

The fact that fewer species are locally collected than perhaps observed elsewhere in RMI shows in Figure 4.15. Seven vernacular names are reported for reeftop catches and combined reeftop and soft-benthos catches, and only two vernacular names are allocated to the soft-benthos (seagrass) fishery.

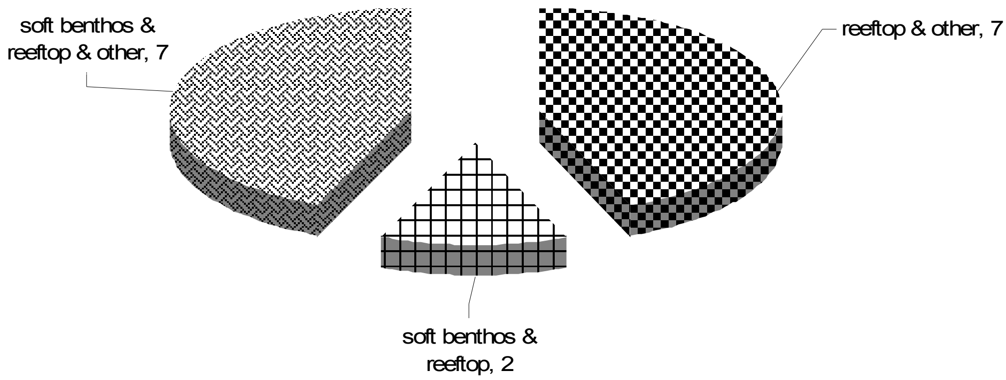

Figure 4.15: Number of vernacular names recorded for each invertebrate fishery in Arno.

The average annual catch per fisher by gender and fishery (Figure 4.16) reveals substantial differences between genders. The collection of reef-associated invertebrates through gleaning or diving basically represents all invertebrate fishing on Arno; very little is derived from soft benthos (seagrass). Average annual catches vary considerably between individual fishers (Note the SE in Figure 4.16.); however, on average male fishers catch 500–600 kg each. Female fishers have a much lower annual productivity (100 kg/fisher/year), regardless of whether or not the soft-benthos habitat is included in the reeftop-gleaning activity.

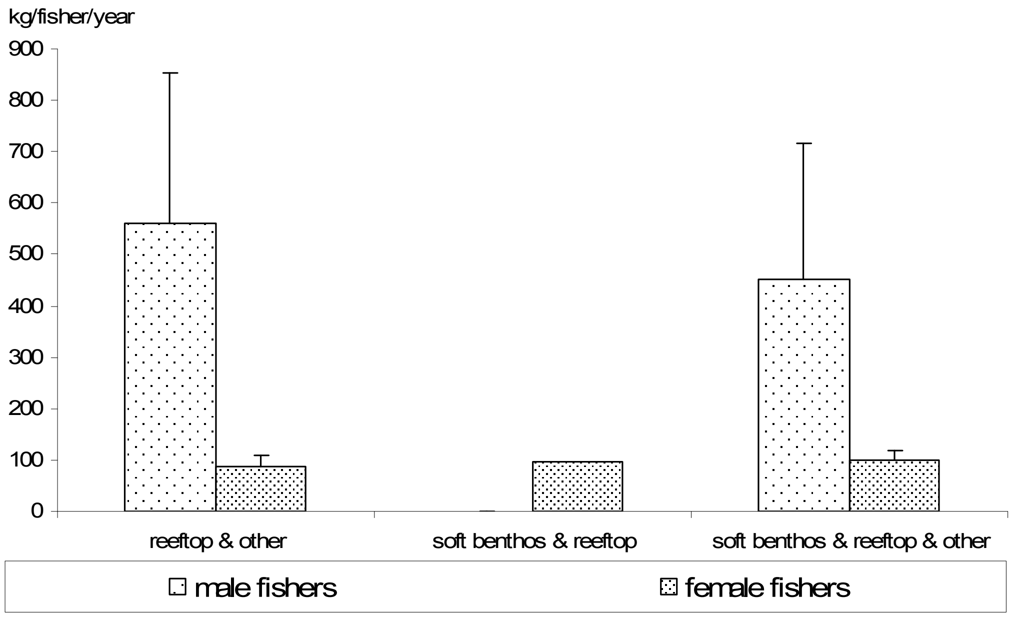

Figure 4.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Arno.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 8 for males, n = 6 for females). Bars represent standard error (+SE).

The fact that the Arno community is highly dependent on marine resources for income only applies to finfish fisheries. As shown in Figure 4.17, almost all invertebrates are caught for home consumption, and only a very small percentage (1.5–3%) may be sold.

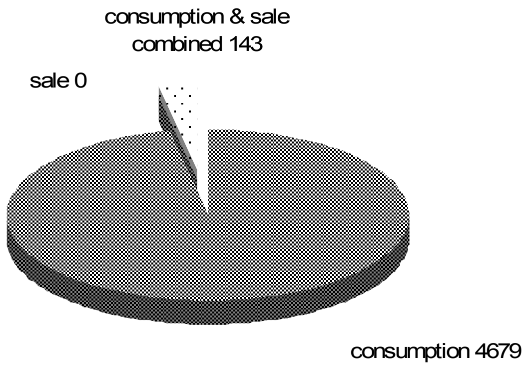

Figure 4.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Arno.

As mentioned earlier, male fishers from Arno play a big role in invertebrate fisheries, accounting for ~88.5% of the total catch (wet weight) (Figure 4.18). Most Arno invertebrate fishers target reef-associated species by diving (‘others’ including clams and octopus) and by gleaning (~75%). Less impact is accounted for by male and female fishers on soft-benthos resources (~20% including reeftop gleaning as well). Female fishers contribute only 11.5% of the total annual catch by wet weight, and most of their effort is concentrated on the reeftops.

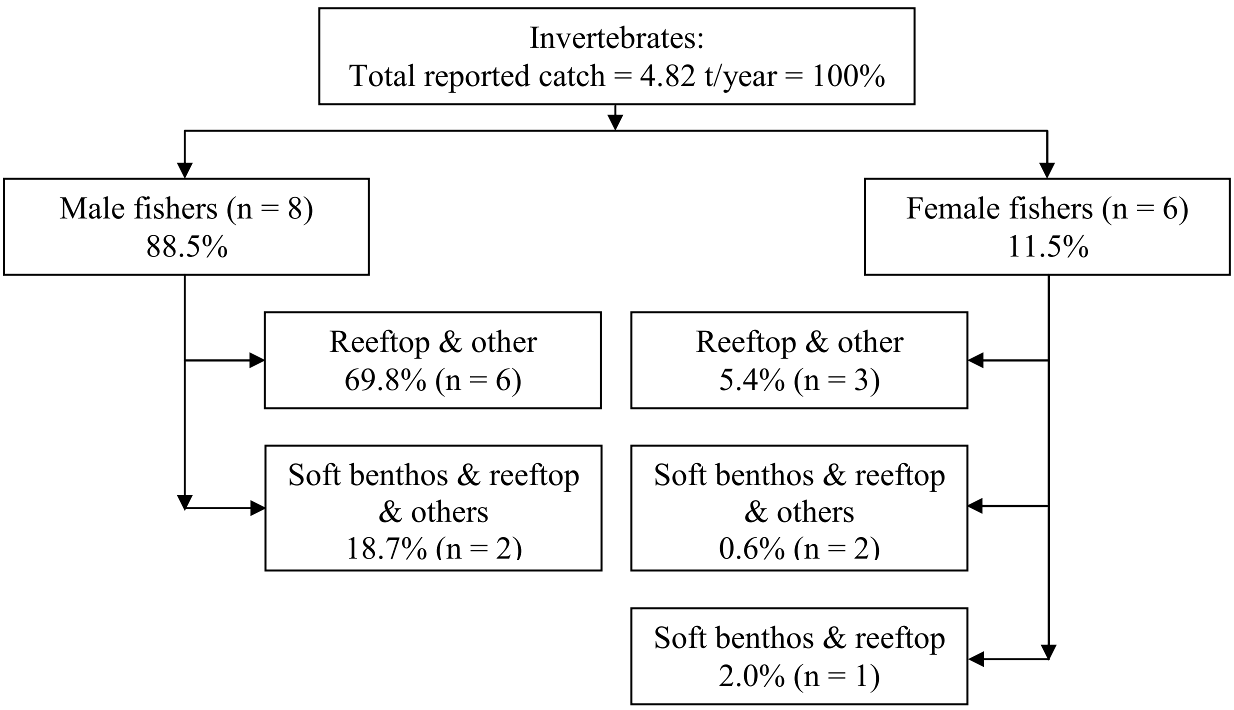

Figure 4.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Arno.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

Taking into account available figures on the reef surface areas, fisher density is low for any of the fisheries considered to be supported by reef areas. Also, the average annual catch rates given for fishers participating in any of the fisheries (Table 4.5) are low. Although area surfaces are unknown for soft-benthos fisheries, none of the parameters shown in Table 4.5 give any reason to assume that the current fishing pressure causes any detrimental effects on resources.

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

Parameters	Fishery / Habitat		
	Reeftop & other [(3)]	Soft benthos & reeftop	Soft benthos & reeftop & other
Fishing ground area (km^2)	26	n/a	n/a
Number of fishers (per fishery) [(1)]	131	17	60
Density of fishers (number of fishers/km^2 fishing ground)	5	n/a	n/a
Average annual invertebrate catch (kg/fisher/year) [(2)]	402.59 (±204.40)	95.54 (n/a)	275.76 (±148.53)

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; [(1)] number of fishers extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only; [(3)] reeftop only considered.

4.2.5 Management issues: Arno

There has been some work on fisheries management in Arno, and this has included building a clam hatchery. In November 2004, the locations approved by the Arno communities for setting up MPAs were surveyed and the exact positions of the locations were pinpointed using GPS. With the approval of the Arno Atoll Local Government, buoys were deployed as markers to identify the 23 community MPAs that had been inserted into the pending Arno Atoll Fisheries Management Ordinance, which was still with the Attorney General's Office for approval. Thus, together with fisheries development, there have also been concerted efforts at fisheries management in Arno.

Also, a part of the project was the setup of the Arno Giant Clam Hatchery. The construction work of the hatchery (consisting of wet and dry laboratories, work space, accommodation, concrete tanks, and engine room) was completed in April 2003. Two local staff were trained to carry out regular maintenance of the facility, and seed production of *Tridacna squamosa*, *T. maxima* and *Hippopus hippopus* was achieved. Clams were spawned and distributed to trained farmers to raise the juvenile clams to a marketable size. These were then bought back by the hatchery. The harvested clams were sold to a private aquarium mariculture farm in Laura. The clam hatchery had, however, been taken over by a private company two years prior to the CoFish survey.

Community management currently targets localised areas; however, it needs to be conducted on a broader scale, e.g. several proposed MPAs could be merged to form a larger protected area. Further work on management should also involve other stakeholders who fish in the area, the private company that operates on Arno, and the communities. This is especially important given that the Arno fishing areas are open-access and vulnerable to the nearby urban centre. The fisheries centre that has been set up may also result in fishing activities being intensified.

4.2.6 Discussion and conclusions: socioeconomics in Arno

The Arno community is relatively small in size but in close proximity to Laura. The community benefits from the establishment of the fish base, which has drastically changed the community, as well as from participation in the MIMRA outer island development project activities. Fishing is now the primary income source and serves both commercial and subsistence interests. In addition, copra production and handicrafts supply complementary income. The lifestyle of the community is still traditional and limited by a relatively low cash income. Dependency on marine resources for food is high, and external financial input (remittances) is relatively small. Although fishing is highly commercial and governed by an open-access system, the catch rates and other parameters measured do not suggest any detrimental effects on resources caused by the current fishing intensity. However, local people have expressed concern regarding reduced finfish sizes and lower abundance of invertebrates. Some of the reported finfish catch sizes may support these concerns, as sizes decreased in catches reported further from shore. However, MIMRA has already begun working towards a fisheries management plan, and the current situation gives a good reason to immediately implement and further develop it.

In summary:

- The Arno population is highly dependent on marine resources for income and home consumption. Fisheries are the most important income source, complemented by handicraft and copra production. The fish base established in the island and the proximity to Laura markets strongly suggests that future fishing intensity will increase rather than decrease.

- Per capita consumption of fresh fish is high; however, invertebrates are consumed to a much lesser extent. The canned fish consumption level is also low, which may be explained by the limited purchasing power and plentiful supply of fresh seafood on the island.

- Traditional gender roles still exist although both male and female fishers engage in finfish fishing and invertebrate collection. Female fishers do not target the outer reef, nor do they participate in diving activities. Male fishers account for most impact regarding both finfish and invertebrates (wet weight).

- Finfish is mainly sourced (by weight) from the lagoon and outer reef, although more male fishers target the sheltered coastal reef and lagoon areas. Boat transport is all motorised, but boat ownership is not that common throughout the community.

- CPUEs are low but comparative across all the habitats fished.

- Fishing techniques and gear vary according to the habitat targeted; they mainly include gillnets, handlines and spear diving in the sheltered coastal reef and lagoon, and may also include deep-bottom lines if the lagoon is fished in combination with the outer reef. Average fish sizes are smaller than found elsewhere (20–25 cm) and the average fish sizes reported do not necessarily increase with distance from shore, indicating an impact from fishing.

- Results from the invertebrate fisher surveys show that the combined catches of clams and octopus account for most of the annual harvest (wet weight). People collect a small variety of species; however, present catch rates give no reason to assume any detrimental effect on resources from fishing.

- Invertebrates are almost exclusively collected for home consumption.

- The parameters calculated for finfish fishing and invertebrate fisheries suggest that fishing pressure on all resources and habitats is low due to the large available reef and overall fishing ground area, and the low fisher densities, average annual catch rates, and catches per unit areas.

Although the fishing pressure parameters do not indicate any detrimental effects on resources, the average reported fish sizes and the variety of invertebrates targeted by the Arno population are lower than found in the other sites studied in RMI. The fish base, which has recently been established and has, as intended, drastically increased finfish fisheries, has changed and improved community income. The community now primarily relies on fisheries, and this fact, combined with the good market access to Laura, gives reason to believe that finfish fishing will further increase. Therefore, it is recommended that fisheries management be urgently addressed in Arno and its fishing grounds, and that as many as possible of the 23 identified areas for MPAs be implemented, and a much larger zone in addition be protected. The success of the fisheries management intervention will depend on the level of compliance. Therefore, we request that a community-based management approach be adopted, in order to combine resource conservation and economic development in concert. Regulation of fishing gear, target species, quotas, etc. should be assessed and planned in consultation with the community.

4.3 Finfish resource surveys: Arno

Finfish resources and associated habitats were assessed in Arno between 12 and 17 September 2007, from a total of 18 transects (6 intermediate-, 6 back- and 6 outer-reef transects; see Figure 4.19 and Appendix 3.3.1 for transect locations and coordinates respectively).

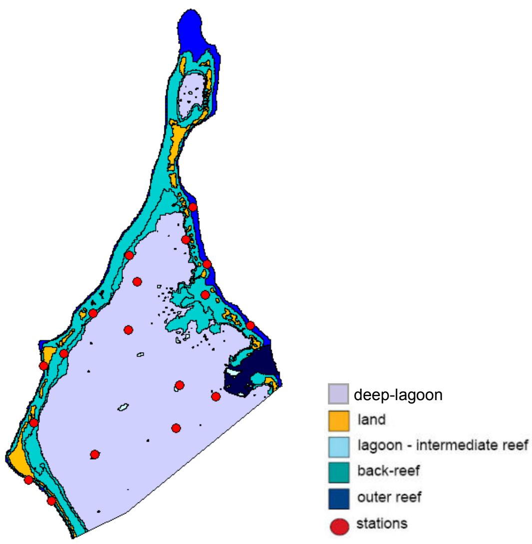

Figure 4.19: Habitat types and transect locations for finfish assessment in Arno.

4.3.1 Finfish assessment results: Laura

A total of 22 families, 58 genera, 148 species and 8180 fish were recorded in the 18 transects (See Appendix 3.3.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 44 genera, 130 species and 7464 individuals.

Finfish resources varied considerably among the three reef environments found in Arno (Table 4.6). The intermediate reef contained the highest biomass of the site (95 g/m²), a density similar to that in the outer reefs (0.5 fish/m²), and a biodiversity (39 species/transect) of middle value between the back-reef and the outer reef. The outer reef, on the contrary, displayed the largest density (very similar to the Laura outer-reef value), size ratio (55%) and biodiversity (45 species/transect) of this site, but the lowest size (15 cm FL). The back-reef displayed the lowest density (0.3 fish/m²), size ratio (43%) and biodiversity (26 species/transect) at the site.

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

Parameters	Habitat			
	Intermediate reef [(1)]	Back-reef [(1)]	Outer reef [(1)]	All reefs [(2)]
Number of transects	6	6	6	18
Total habitat area (km^2)	1.0	49.3	11.9	62.2
Depth (m)	9 (2–18) [(3)]	5 (1–15) [(3)]	9 (5–14) [(3)]	8 (1–18) [(3)]
Soft bottom (% cover)	24 ±6	39 ±9	2 ±0	32
Rubble & boulders (% cover)	6 ±1	10 ±4	2 ±1	8
Hard bottom (% cover)	48 ±4	39 ±8	43 ±6	40
Live coral (% cover)	18 ±7	9 ±2	49 ±5	17
Soft coral (% cover)	0 ±0	0 ±0	2 ±1	1
Biodiversity (species/transect)	39 ±3	26 ±3	45 ± 1	37±2
Density (fish/m^2)	0.5 ±0.0	0.3 ±0.1	0.5 ±0.1	0.4
Size (cm FL) [(4)]	17 ±1	17 ±1	15 ±1	16
Size ratio (%)	46 ±2	43 ±2	55 ±2	49
Biomass (g/m^2)	95.1 ±35.8	79.1 ±52.5	65.6 ±8.2	73.0

[(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.

Intermediate-reef environment: Arno

The intermediate-reef environment of Arno was dominated by one herbivorous family, Acanthuridae (Figure 4.20), whose density was the highest among the four atoll intermediate reefs (more than twice as high as Likiep and Ailuk values). This family was represented by 15 species; particularly high biomass and abundance were recorded for *Acanthurus mata*, *Ctenochaetus striatus*, *A. thompsoni* and *Naso lituratus* (Table 4.7). This reef environment presented a very diverse habitat dominated by hard bottom (48%), with a good cover of soft bottom (24%) but a low cover of live coral (18%, 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 Arno

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus mata*	Elongate surgeonfish	0.042 ±0.040	33.9 ±31.7
	Ctenochaetus striatus	Striated surgeonfish	0.138 ±0.040	8.0 ±2.5
	Acanthurus thompsoni	Thompson's surgeonfish	0.077 ±0.050	4.6 ±2.7
	Naso lituratus	Orangespine unicornfish	0.003 ±0.002	1.4 ±1.3

The density and biomass of finfish in the intermediate reefs of Arno were the lowest at the site. Average fish size was higher than in the outer reefs and the same as in the back-reefs. Biodiversity was intermediate between the values in the back-reefs and outer reefs. On a country comparison, the intermediate reefs of Arno displayed the highest density and biomass, smaller size than in Likiep, and a biodiversity smaller only than found in Ailuk. Size ratio was, on the contrary, the lowest among the four intermediate reefs. Trophic composition was dominated by herbivores in terms of density but plankton feeders and carnivores were also well represented. Biomass was equally composed of herbivores and planktivores (41%). The two most important species, with the highest density (*Acanthurus mata* and *A. thompsoni*) are, in fact, planktivores. The fish community composition was very uniform and low in species number, with only one family (Acanthuridae) contributing to the majority of the density and biomass. Size ratio was very low, lower than 50% of the maximum, for several families: Lethrinidae (34%), Scaridae (37%), Mullidae (38%), Siganidae, (43%), Acanthuridae (47%) and Serranidae (46%), most probably indicating a fishing impact on these targeted families. Siganidae, Serranidae, Kyphosidae and Lethrinidae were the families most frequently caught in this habitat, which was also more often targeted than the outer reefs. The intermediate reefs of Arno displayed a fairly diverse habitat composition, with a dominance of hard bottom, a good representation of soft bottom, but a rather poor cover of live coral. The important species of this reef are normally associated with hard bottom, here present in high percentage (48%); however, the extremely low density and biomass of Lethrinidae and Mullidae among other families associated with a soft-bottom habitat, are most probably attributed to fishing impact.

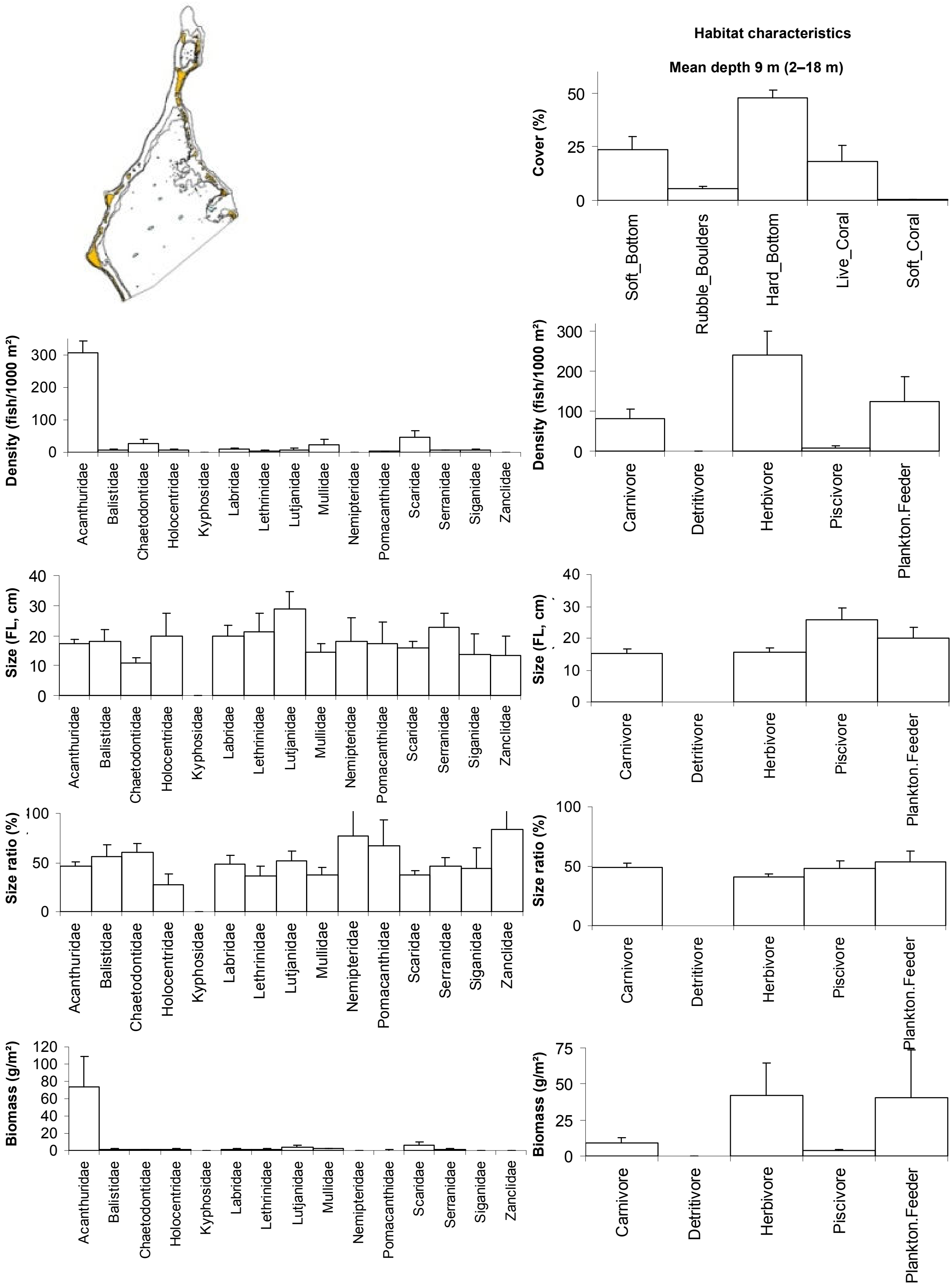

Figure 4.20: Profile of finfish resources in the intermediate-reef environment of Arno.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Arno

The back-reef environment of Arno was dominated by two herbivorous families: Acanthuridae and Scaridae (for both density and biomass) but also, and mainly in terms of biomass, by the carnivores Lutjanidae and, to a much smaller extent, Lethrinidae (Figure 4.21). These four families were represented by 26 species; particularly high biomass and abundance were recorded for *Lutjanus gibbus*, *Hipposcarus longiceps*, *Chlorurus microrhinos*, *Naso brevirostris*, *Ctenochaetus striatus*, *Monotaxis grandoculis*, *Lethrinus olivaceus*, *C. sordidus* and *Lutjanus bohar* (Table 4.8). This reef environment presented a habitat equally composed of hard and soft bottom (39% each), a small amount of rubble (10%) and very little cover of live coral (9%, 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 Arno

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Naso brevirostris*	Spotted unicornfish	0.016 ±0.016	10.2 ±10.2
	Ctenochaetus striatus	Striated surgeonfish	0.128 ±0.050	4.8 ±2.0
Scaridae	*Hipposcarus longiceps*	Pacific longnose parrotfish	0.014 ±0.012	10.8 ±10.4
	Chlorurus microrhinos	Steephead parrotfish	0.011 ±0.009	10.7 ±9.2
	Chlorurus sordidus	Daisy parrotfish	0.057 ±0.032	1.6 ±0.9
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.013 ±0.013	24.8 ±24.6
	Lutjanus bohar	Twinspot snapper	0.009 ±0.009	1.0 ±1.0
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.009 ±0.008	3.7 ±3.5
	Lethrinus olivaceus	Longface emperor	0.004 ±0.004	2.7 ±2.3

Density, size ratio and biodiversity of finfish in the back-reefs were the lowest among the three habitats in Arno. Similarly, these values were the lowest among the four atoll back-reefs, except for density, which was only higher than the Ailuk value. Size and biomass were higher than in the outer reef, and biomass was also the highest among the four back-reef values. The trophic structure showed that herbivores were more important in terms of density but that herbivores and carnivores were equally important in terms of biomass. Siganidae and, to a lesser extent, Scaridae, Mullidae, Lethrinidae and Acanthuridae showed size ratios below half of the maximum for the relative species, suggesting a first sign of impact from fishing. The fish community composition was rather complex and principally composed of several species of herbivores and carnivores, suggesting that the system is still in relatively good condition. The substrate was composed of both hard and soft bottom, offering niches for the sand-associated fish (some species of Lethrinidae, i.e. *Lethrinus olivaceus* and *L. harak*), as well as the rock-associated fish, such as Acanthuridae and Lutjanidae. Live-coral cover was very poor in this environment.

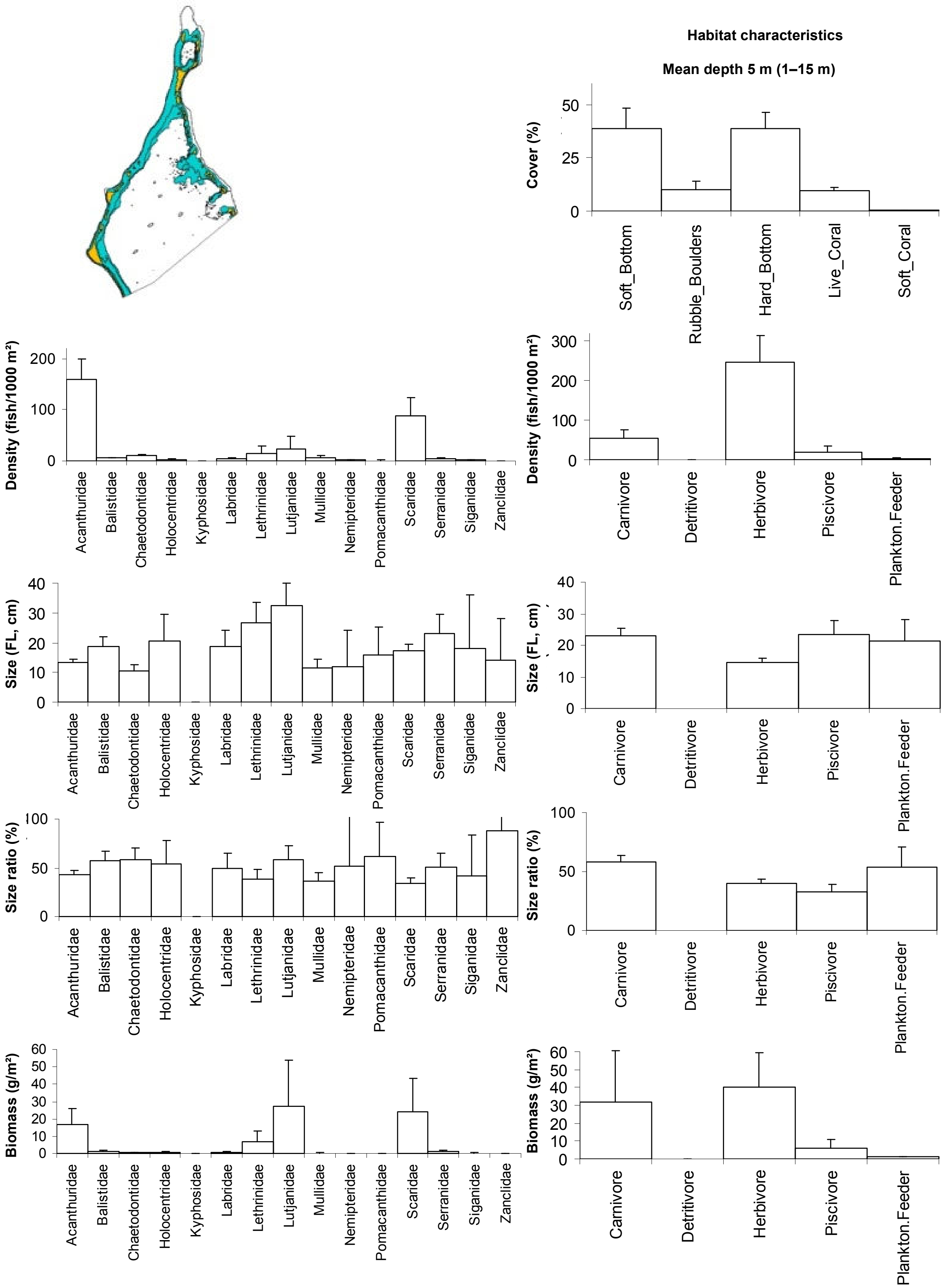

Figure 4.21: Profile of finfish resources in the back-reef environment of Arno.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Arno

The outer-reef environment of Arno was dominated by Acanthuridae in terms of numbers as well as biomass, followed by Scaridae (Figure 4.22). These two families were present with 19 species. Highest biomass and density were represented by *Ctenochaetus striatus*, *Acanthurus nigricans*, *C. microrhinos*, *A. lineatus*, *Chlorurus sordidus* and *Hipposcarus longiceps* (Table 4.9). This reef environment presented a very diverse habitat with very high cover of live coral (49%) and hard rock (43%), but almost no rubble (2%) or soft bottom (2%, Table 4.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.215 ±0.080	17.8 ±7.6
	Acanthurus nigricans	Whitecheek surgeonfish	0.132 ±0.036	8.9 ±2.6
	Acanthurus lineatus	Lined surgeonfish	0.021 ±0.021	5.5 ±5.5
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.007 ±0.004	6.2 ±3.0
	Chlorurus sordidus	Daisy parrotfish	0.029 ±0.010	3.2 ±1.2
	Hipposcarus longiceps	Pacific longnose parrotfish	0.002 ±0.001	2.0 ±0.7

The density of finfish in the outer reefs was the highest recorded at the site and among the four country sites. However, size and biomass were the lowest among the habitats and among all outer reefs. Biodiversity was higher than at the intermediate and back-reefs but the lowest of the outer-reef values of the four atolls. Size ratio was much higher than the low values recorded at the other two habitats and the second-highest outer-reef country value after Ailuk, but still low as an absolute value (55%). Trophic composition was dominated by herbivores due to the high abundance of Acanthuridae. Size ratio was low only for Scaridae (39% of maximum size for the corresponding species). Scaridae were represented by both small (*Chlorurus sordidus*) and large-sized species (i.e. *Hipposcarus longiceps, Chl. microrhinos*), which, however, displayed low size ratios. The outer reefs of Arno displayed a habitat dominated by hard bottom with almost half of the surface covered in live coral (49%), the second-highest percentage cover for outer reefs after Likiep.

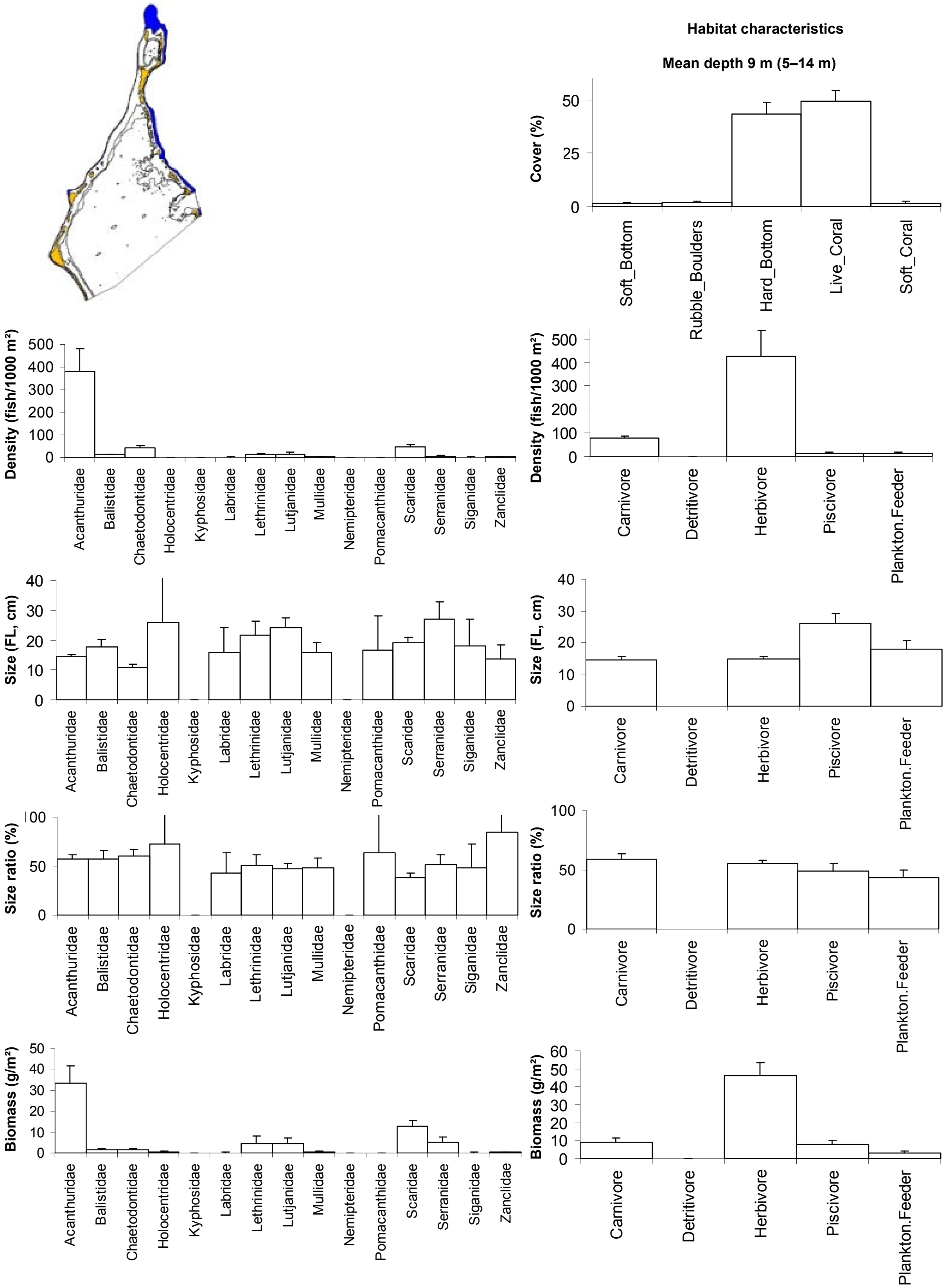

Figure 4.22: Profile of finfish resources in the outer-reef environment of Arno.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Arno

Overall, the fish assemblage of Arno was composed of Acanthuridae and Scaridae in terms of density and biomass and by Lutjanidae and Lethrinidae in terms of biomass only (Figure 4.23). These four most important families were represented by a total of 43 species, dominated (in terms of biomass and density) by *Lutjanus gibbus*, *Ctenochaetus striatus*, *Chlorurus microrhinos*, *Hipposcarus longiceps*, *Naso brevirostris*, *Acanthurus nigricans*, *Monotaxis grandoculis*, *A. lineatus* and *Chlorurus sordidus* (Table 4.10). The average substrate at this site was composed of both hard bottom (40%) and mobile bottom (40%), with a rather low cover of live coral (17%). The overall habitat and fish assemblage in Arno shared characteristics of mostly back-reefs (79% of total habitat surface), outer reefs (19% of habitat) and only to a very limited amount intermediate reefs (2%, Table 4.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.172	11.4
	Naso brevirostris	Spotted unicornfish	0.007	4.7
	Acanthurus nigricans	Whitecheek surgeonfish	0.067	4.5
	Acanthurus lineatus	Lined surgeonfish	0.010	2.7
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.007	11.9
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.009	8.1
	Hipposcarus longiceps	Pacific longnose parrotfish	0.008	6.0
	Chlorurus sordidus	Daisy parrotfish	0.042	2.5
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.005	2.9

Overall, Arno appeared to support a poor finfish resource, with fish density similar to values in Likiep and Laura (0.4 fish/m^2) and higher than in Ailuk (0.3 fish/m^2), biomass similar to all other sites (70 g/m^2), but the smallest size (16 cm FL), size ratio (49%) and biodiversity (37 species/transect, compared to 46 species/transect in Likiep). A detailed assessment at the family level revealed a high diversity of the fish community, composed principally by two carnivorous and two herbivorous families represented by average- to large-sized species. The trophic composition was dominated by herbivores, especially in terms of density. These observations confirm the conclusion that this site is in only average condition. Overall, size ratios were below the 50% values for Scaridae, Mullidae, Lethrinidae and Siganidae. The reduced size of some families could be a first sign of impact of such selective fishing. In the outer-reef habitats, fishing was mostly carried out by spear diving, a very size-selective tool. Habitat was composed of a generally rather poor cover of coral (17%), a high cover of hard bottom (40%) and soft bottom (32%) and little rubble (8%), offering a range of habitats to several families with various requirements. However, the scarcity of Mullidae, Serranidae and Siganidae suggests that this fish community has been partially impacted by fishing.

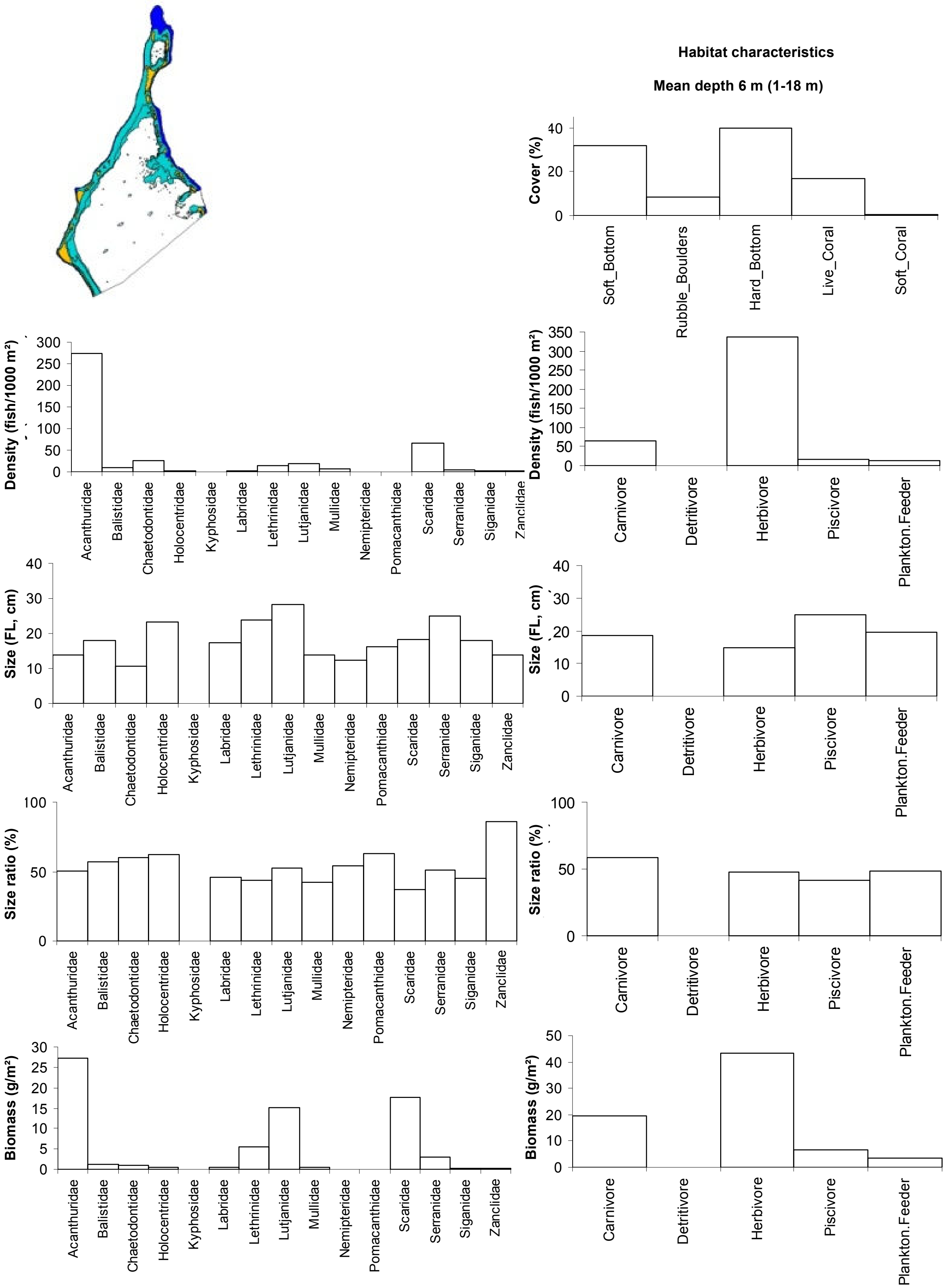

Figure 4.23: Profile of finfish resources in the combined reef habitats of Arno (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Arno

The assessment indicated that the status of finfish resources in this site was rather poor at the time of surveys. Fishing in Arno was mostly conducted for commercial purposes. The atoll is near the main centre of Laura and has an active fish base; therefore, there is a high demand for fresh fish, which gets shipped to the capital almost every two days (67% of catches were for export.). Fishing represented the source of first income for most people in Arno, although the level of consumption was the lowest among the four visited sites. Annual catches were the highest among the four sites and, as a consequence, fishing pressure was quite high on Arno reefs. The reefs are naturally rich but already suffering from this high pressure.

- The reefs appeared to be generally quite healthy in all three habitats but poorer in live coral than the other sites.

- Fish density and biomass were comparable to values at the other sites, but in the lower half of the range on a regional scale. Biodiversity was also quite low and the lowest among the four sites.

  Moreover:
  - Some signs of fishing impact were detectable as low average size ratios for certain families, especially Scaridae, Mullidae, Lethrinidae, Acanthuridae and Siganidae, which were recorded among the families mostly targeted by fishers.
  - Large carnivores as well as top predators were rather rare everywhere, possibly a first sign of deteriorating conditions.

Resources were very variable among the three habitats and among the survey stations.

- The intermediate and back-reefs displayed a very low live-coral cover, while hard rock and soft substrate were dominant. The back-reef habitats were mostly covered by rubble and sand, with patches of massive, submassive and digitate corals. The outer reefs were much richer in live corals that were also quite diverse, with submassive and massive corals dominating at all six stations.

- The finfish resources were also very variable among the three habitats:
  - The intermediate reefs of Arno were the richest among all habitats and among all four intermediate reefs in the country, with the highest density and biomass. However, biodiversity was very low. Trophic composition was dominated by herbivorous species and mid- to large-sized planktivorous species. The highlight of this habitat in terms of fish assemblage was the presence of *Acanthurus mata* observed in almost all stations. Juvenile *Cheilinus undulatus* (40–50 cm) were also sighted in almost all the stations surveyed.
  - The back-reefs displayed low values of density, while biomass was intermediate between the other two habitats but the highest of the four country sites and also high compared to the regional average. The trophic composition displayed a relatively good representation of carnivores, with the presence of large Lutjanidae. White-tip reef sharks were a common sight in almost all the back-reef stations on the northeast side of the atoll.
  - Fish biodiversity was highest at the outer reef, as is normally the case in this type of habitat, but sizes and biomass were small, ranking Arno outer reefs as the poorest in the country and among the poorest habitats in the region. Trophic composition was highly dominated by herbivores composed of small species of Acanthuridae and large species of Scaridae that, however, displayed small average sizes.

4.4 Invertebrate resource surveys: Arno

The diversity and abundance of invertebrate species at Arno were independently determined using a range of survey techniques (Table 4.11), broad-scale assessment (using the 'manta tow' technique; 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 is to describe the distribution pattern of invertebrates (rareness/commonness, patchiness) at large scale and, importantly, to identify target areas for further, fine-scale assessment. Then, fine-scale assessment is conducted in targeted areas to specifically describe the status of resource in areas of suitable habitat (naturally higher abundance).

Table 4.11: Number of stations and replicates completed at Arno

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	13	78 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches (RFs)	10	60 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)	0	0 search period

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

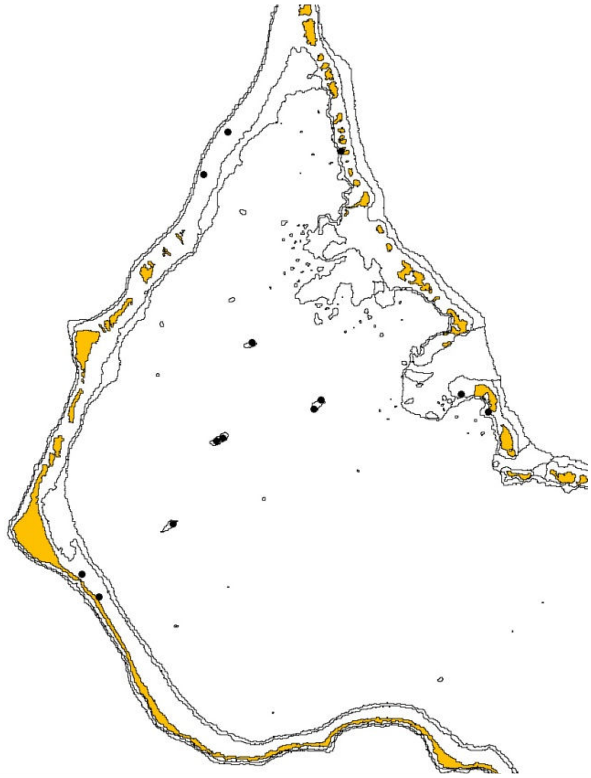

Figure 4.25: Fine-scale reef-benthos transect survey stations in Arno.
Black circles: reef-benthos transect stations (RBt).

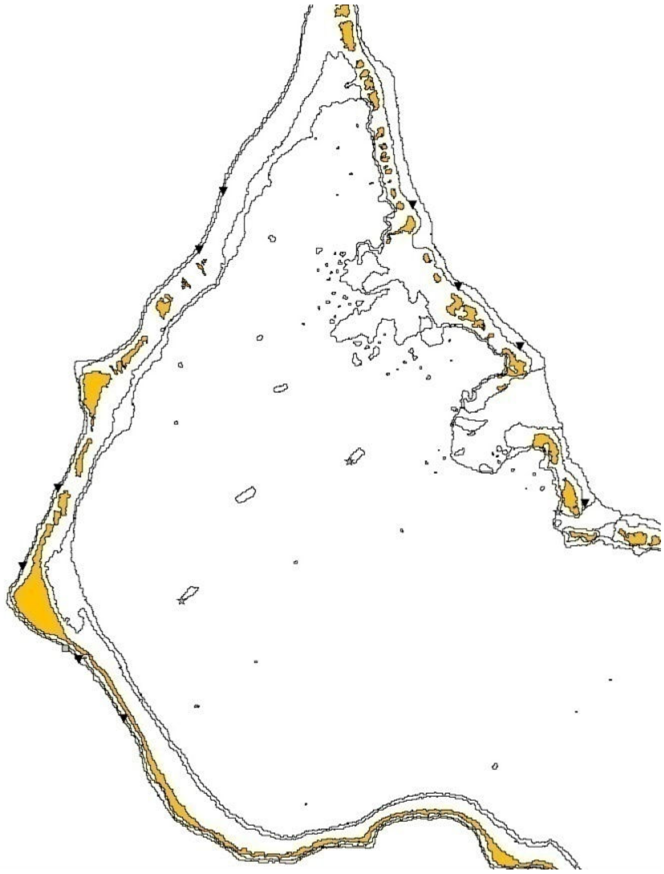

Figure 4.26: Fine-scale survey stations for invertebrates in Arno.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Forty-three species or species groupings (groups of species within a genus) were recorded in the Arno invertebrate surveys. These included 6 bivalves, 18 gastropods, 8 sea cucumbers, 4 urchins, 3 sea stars, 1 cnidarian and 2 lobsters (Appendix 4.3.1). Information on key families and species is detailed below.

4.4.1 Giant clams: Arno

The site surveyed was roughly the western half of Arno atoll, excluding the northwestern tip. Shallow-reef habitat that is suitable for giant clams within the atoll and on the outer slope was quite extensive (38.1 km² shallow reef); however, for the relatively large lagoon (373 km² total size of the atoll – 42 km long and 37 km wide) shallow reef (only ~26 km²) was not always common along the shorelines and within the lagoon. Shallow areas mainly comprised sandy bottoms, flat pavement that was almost devoid of resources, and reeftop that was largely exposed, making suitable reef benthos sparse across the system. In addition, the inner part of the lagoon was rather deep, with very few intermediate reefs and pinnacles. Outside the lagoon, more exposed reef at the barrier, reef crest and slope (11.9 km²) supported more live coral and a complex habitat that was suitable for clams.

As in most atolls, the system at Arno appeared to be nutrient-poor and predominantly ocean-influenced. Land area was limited and land influence in the way of nutrient inputs was negligible. As in the neighbouring site of Laura, on Majuro atoll, the main passages were situated in the central northeast, facing the prevailing winds, and this part of the lagoon had the most dynamic water flow. The more protected areas (due to the continuous land in the south and the partially exposed reeftop in the west), had the least water circulation, with more depositional conditions.

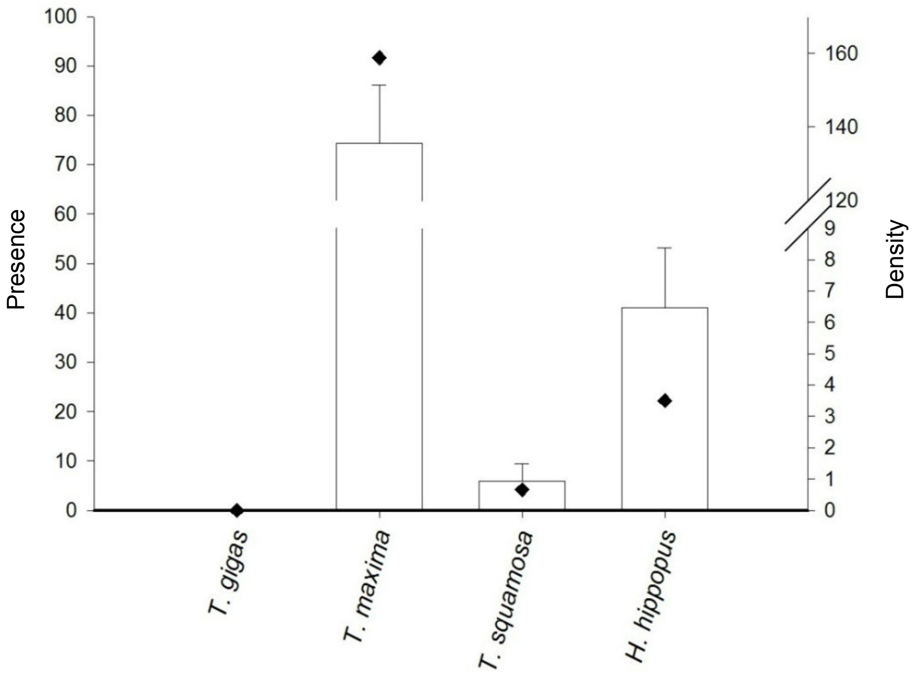

Figure 4.27: Presence and mean density of giant clam species at Arno based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Broad-scale sampling provided an overview of giant clam distribution at Arno. Reefs at this site held three species of giant clam: the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the horse-hoof or bear's paw clam *Hippopus hippopus*. Records revealed that *T. maxima* had the widest distribution (found in all 12 stations and 66 of 72 transects), followed by *H. hippopus* (in 9 stations and 16 transects) and *T. squamosa* (3 stations and 3 transects). The average station density of *T. maxima* in broad-scale assessments was 135.5 /ha ±16.0 (Figure 4.27).

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 85% of stations at a mean density of 583.3 /ha ±126.4.

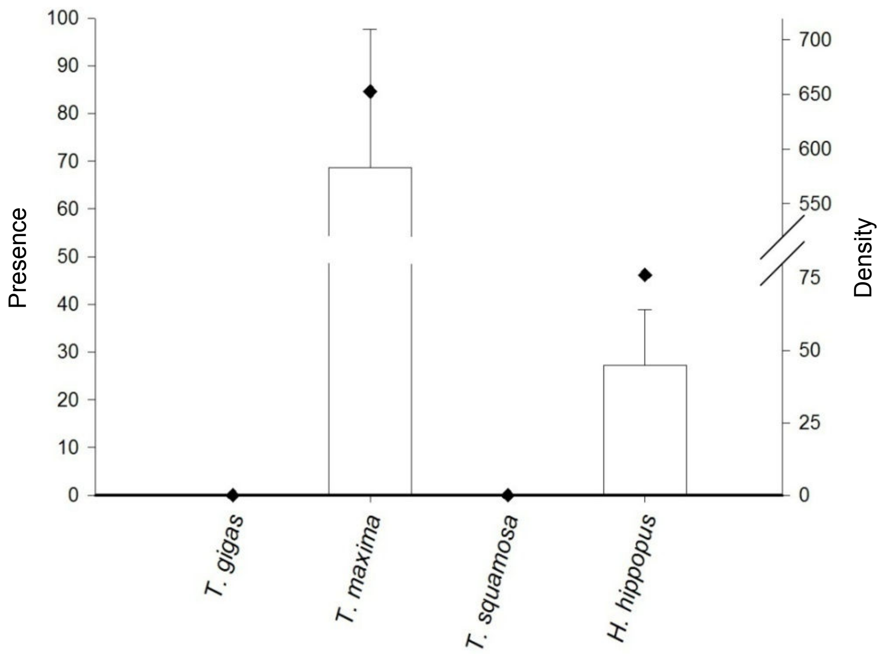

Figure 4.28: Presence and mean density of giant clam species at Arno based on reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

RBt stations with the highest densities were most often found at intermediate reefs in the middle of the lagoon, far from the villages (5 of the 6 stations with the highest clam density). The maximum density recorded for *T. maxima* reached 1333 /ha ±139.4. Along the shoreline in the vicinity of inhabited places the densities recorded were lower. On the oceanic side of the reef, one RFs station recorded 118 live *T. maxima* clams (~510 specimens/ha) and at least as many dead clams that had been freshly harvested, showing that some areas still have good concentrations of giant clams but that harvesting pressure is high.

Of the 989 *T. maxima* clams recorded during all assessment techniques, 500 were measured, with a mean length of 8.6 cm ±0.2. The mean length of *T. squamosa* and *H. hippopus* was 30.3 cm ±2.8 (n = 4) and 21.3 cm ±1.0 (n = 41) respectively. A range of lengths was recorded for the three clam species (Figure 4.29); however, the largest *T. maxima* clams were generally small, and the larger size classes for this species were depleted (*T. maxima* clams that were larger than 16 cm comprised just 3.4% of the measured stock.).

H. hippopus was sparsely distributed, with more specimens found in the northeastern part of the site. However, the population had a healthy size range present, with both juvenile and large adults noted. The population of *T. squamosa*, which can also be found in deeper water, proved to be small; only four specimens were recorded, but these were quite large (Figure 4.29).

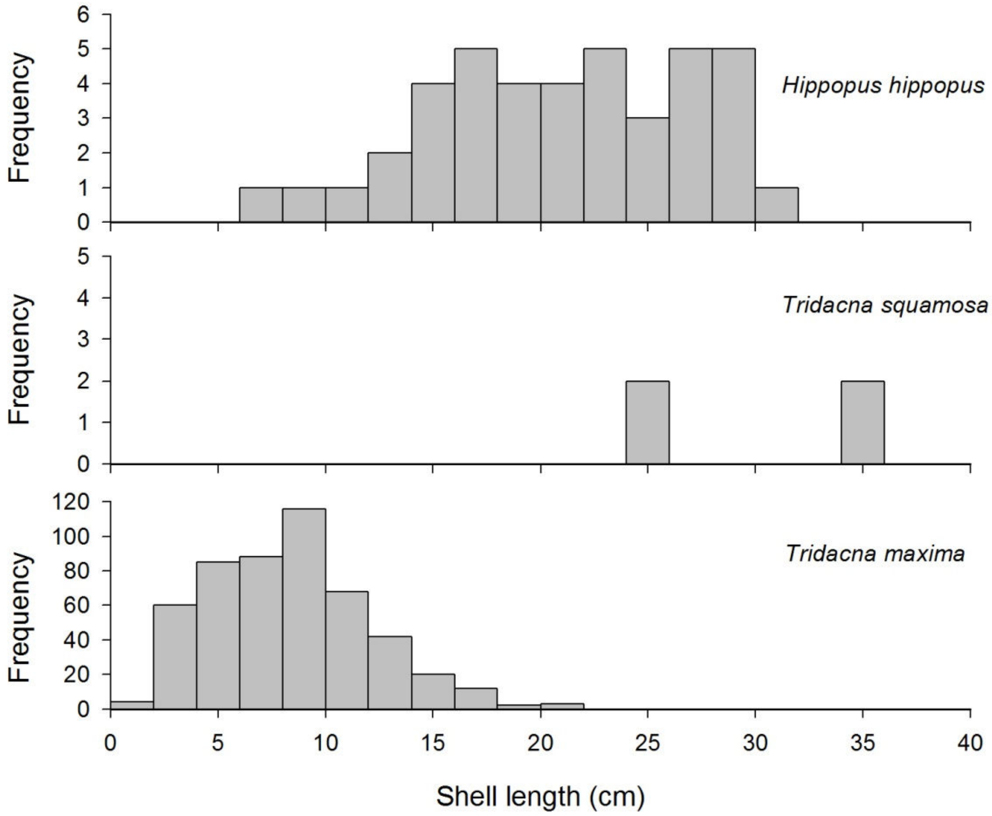

Figure 4.29: Size frequency histograms of giant clam shell length (cm) for Arno.

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

The commercial topshell, *Trochus niloticus*, was introduced to RMI by the Japanese during the 1930s, with introductions to Jaluit, Laura, Ailinglaplap and apparently also Ailuk, Kwajalein and Enewetak (Asano and Inenami 1939, McGowan 1958 cited in Wright *et al.* 1989).

In Arno, *Trochus niloticus* was introduced in 1990, with 200 specimens collected from the nearby atoll of Laura. The animals were transplanted to reefs in front of the Arno fish base jetty on the south coast.

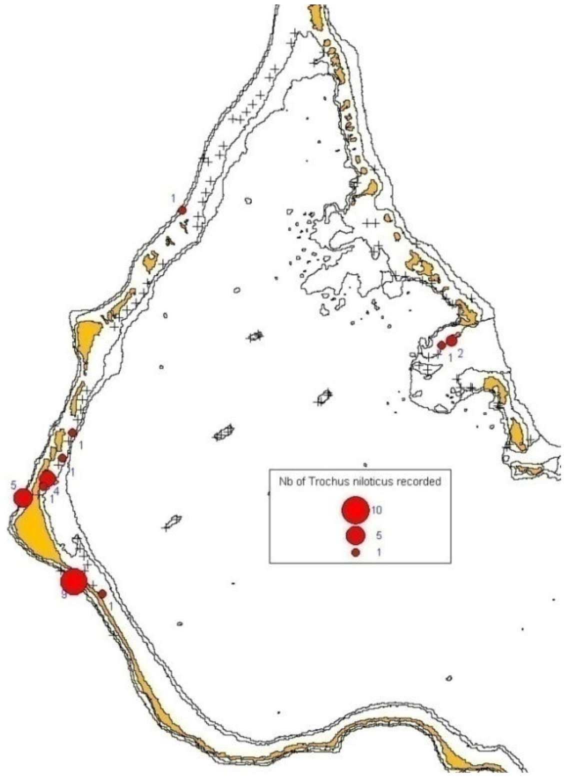

Figure 4.30: Numbers of trochus recorded at survey stations at Arno.

In surveys, the habitat was seen to be suitable for trochus, especially on the outer-reef slope in the northeast (Table 4.12). However, *T. niloticus* was mostly recorded around the place where it had been introduced 15 years previously. Apparently, the trochus introduction was not very successful and there had only been limited colonisation of nearby reefs and the fast-flowing passage areas (Figure 4.30). After 15 years of presence, one might expect a better colonisation of reefs across the atoll. There is no obvious reason why the colonisation was limited, and we have no information about the water flow regime at Arno to support any theories of why movement from the initial transplantation site has been so limited.

Table 4.12: Presence and mean density of *Trochus niloticus*, *Tectus pyramis* and *Pinctada margaritifera* in Arno
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	1.1	3/12 = 25	6/72 = 8
RBt	3.2	3.2	1/13 = 8	1/78 = 1
RFs	5.9	1.8	3/10 = 30	11/60 = 18
Tectus pyramis				
B-S	0			
RBt	0			
RFs	2.4	1.2	2/10 = 20	4/60 = 7
Pinctada margaritifera				
B-S	0.5	0.3	2/12 = 17	2/72 =3
RBt	3.2	3.2	1/13 = 8	1/78 = 1
RFs	0		0/10 = 0	0/60 = 0

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

The number of trochus recorded in survey was small, with no noticeable areas holding large aggregations of trochus at high density. The highest density was recorded in front of the Arno giant clam hatchery, where the trochus had been introduced (RFs station at 35.3 /ha ±8.0). Even this density is low and would be considered unsuitable for any consideration of commercial fishing.

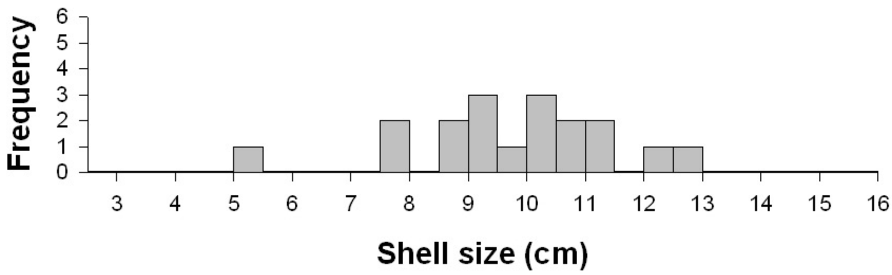

Figure 4.31: Size frequency histograms of trochus (*Trochus niloticus*) shell base diameter (cm) for Arno.

From the 26 trochus recorded, 18 were measured (mean basal width of 9.8 cm ±0.2). The size-class distribution record reveals a complete range of sizes from juvenile to large mature adults. This shows that the trochus population, even though scarce and mainly confined to the original translocated position, is still reproducing effectively (Figure 4.31).

Tectus pyramis, an algal-grazing gastropod with a similar life history to trochus, was rare and at low density at Arno (n = 6 individuals recorded in survey). The mean size (basal width) was 6.0 cm ±0.2. This shows that, despite the habitat being suitable for trochus, certain unrecorded environmental parameters may be hindering large-scale settlement of these grazing species.

Blacklip pearl oysters, *Pinctada margaritifera*, are normally cryptic and sparsely distributed in open-lagoon systems. This atoll lagoon was relatively enclosed, despite the two northern passages: however, blacklip pearl oysters were rarely noted in survey (n = 3, mean shell height 10.7 cm ±1.8).

4.4.3 Infaunal species and groups: Arno

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

4.4.4 Other gastropods and bivalves: Arno

Seba's spider conch, *Lambis truncata* (the larger of the two common spider conchs), was recorded but at very low density inside the lagoon (n = 3 individuals), as was the smaller spider shell, *L. lambis* (n = 1). However, the rugose spider conch, *L. chiragra*, was more common (n = 13), reaching a density of 22.4 /ha ±13.8 in RBt stations. The strawberry or red lipped conch, *Strombus luhuanus*, was also present (n = 17 individuals) at 17% of broad-scale stations at a mean density of 3.9 /ha ±3.5. Interestingly, two specimens of this common species were 'albino' (The red opening was totally white.) (Appendices 4.3.1 to 4.3.7).

One species of turban shell, the edible silver-mouthed turban (*Turbo argyrostomus*), was recorded during surveys. It was present in 39% of the RBt stations at an average density of 25.6 /ha ±11.1. It was also recorded in RFs at the low density of 0.8 /ha ±0.5.

Other resource species targeted by fishers (e.g. *Astralium*, *Cassis*, *Conus*, *Cypraea*, *Thais* and *Vasum*) were also recorded during independent surveys (Appendices 4.3.1 to 4.3.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Arca* and *Spondylus* spp., are also in Appendices 4.3.1 to 4.3.7. No creel survey was conducted at Arno.

4.4.5 Lobsters: Arno

The site surveyed at Arno had 46.3 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef, represents a large amount of habitat for lobsters.

There was no dedicated night reef-front assessment of lobsters (See Methods.), and no lobsters or slipper lobsters were recorded in survey. One sand lobster (*Lysiosquillina maculata*) was recorded in RBt. It was captured and measured (21 cm long from the extremity of the cephalothorax to the extremity of the telson). Several small Portunidae were also noted.

4.4.6 Sea cucumbers[8]: Arno

Arno has an extensive, shallow lagoon system (373.5 km²), which is surrounded by low-lying *motu* (around 15 km² total land area). 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, rubble and limestone pavement, without noticeable inputs of nutrients that would support large populations of sea cucumbers (Sea cucumber species eat organic matter and general detritus in the upper few mm of bottom substrates.).

There was little influence from land, except close to the *motu* that supported settlements. In these locations, the surfaces of limestone had some algal and epiphytic growth but, in general, the system was mostly very oceanic. Outside the barrier reef, the slope was impacted by large swells in the east, while in the west and south the reef slope was not extensive as it shelved off relatively steeply into deeper water.

Species presence and density were determined across Arno through broad-scale, fine-scale and dedicated survey methods (Table 4.13, Appendices 4.3.1 to 4.3.6, also see Methods). At Arno, seven commercial species of sea cucumber were recorded during in-water assessments, plus one indicator species (Table 4.13), a similar number to the amount recorded at the other atoll CoFish sites surveyed in Marshall Islands. The range of sea cucumber species recorded in Arno reflected the isolated position of these dispersed atolls and the largely exposed, oceanic-influenced nature of the habitats present.

[8] 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.

Sea cucumber species associated with shallow-reef areas, such as leopardfish (*Bohadschia argus*), were rare (found in 6% of broad-scale transects and not in reef-benthos stations) and at the low density of 0.9 /ha ±0.5 (n = 4 individuals).

Black teatfish (*Holothuria nobilis*), a common high-value sea cucumber, which can usually be found in shallow water at both land- and oceanic-influenced areas and is highly susceptible to fishing pressure, was not recorded.

Sea cucumber species especially associated with reef crests, such as the medium commercial value surf redfish (*Actinopyga mauritiana*), were rare (6% presence in broad-scale transects) and at the low density of 0.9 /ha ±0.4 (n = 4 individuals). Surprisingly, this species was not recorded from the reef-front slope, its main habitat, despite the 10 RFs stations surveyed. This species can be recorded at commercial densities of 500–600 /ha in other oceanic-influenced atoll islands in French Polynesia, Cook Islands and Tonga.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was also not found at any stations, despite a local male fisher saying that they used to be present and were the target of fishing. In fact, this species was absent from all the four CoFish sites in Marshall Islands, and the information given by the male fisher may be due to misidentification.

In more protected areas of reef and soft benthos at embayments in the lagoon no blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), elephant trunkfish (*Holothuria fuscopunctata*) or curryfish (*Stichopus hermanni*) were recorded.

Some lower-value species, e.g. lollyfish (*Holothuria atra*) and brown sandfish (*Bohadschia vitiensis*), however, were noted; neither species was well distributed across the site and both were present at low density. This is unusual, as generally *H. atra* can be found at high density in very shallow water, even in 'nutrient-poor' systems.

Deep-water assessments (18 searches of five minutes, average depth 23.0 m, max depth 32 m) were completed to obtain a preliminary abundance estimate for white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the passages had suitably dynamic water movement for these species. The high-value *H. fuscogilva* was recorded on the Ds station made close to the passage (two specimens only), but was absent from the two Ds stations made along the main patch reef of the lagoon, despite the good environmental conditions (good water flow and substratum). Amberfish (*T. anax*) was only recorded on these last two Ds stations within the lagoon, but was still one of the most recorded species on Arno, with 43 specimens. Its density is high for the species at 34.1 /ha ±19.9 (deep-water surveys). No prickly redfish were detected in Ds stations, but the species was noted at low density in broad-scale transects (1.9 /ha ±1.0). Elephant trunkfish was not recorded at Arno, and Marshall Islands could be outside the range of this species.

4.4.7 Other echinoderms: Arno

The edible collector urchin (*Tripneustes gratilla*) was not present and slate urchins (*Heterocentrotus mammillatus*) were not abundant (n = 14 individuals). Other urchins that can be used as a food source or potential indicators of habitat condition (*Echinothrix* spp. and *Echinometra mathaei*) were recorded at very low levels. The large, thick, black-spined *Echinothrix* species (*E. diadema*) had a mean station density of 6.4 /ha ±6.4 for RBt survey stations and 3.1 /ha ±1.5 in RFs. This species was not recorded on MOPs surveys (See Appendices 4.3.1 to 4.3.7.).

Starfish were sparsely distributed at Arno; the common starfish (*Linckia laevigata*) and the coralivore pincushion stars (*Culcita novaeguineae*) were recorded in small numbers (11 and 9 specimens, respectively). Only three records of another coral-eating star, the crown-of-thorns (*Acanthaster planci*, COTS), were noted. The presence of COTS was not concentrated to any one place in the lagoon and is not of any concern to coral health and live-coral cover at this density (See presence and density estimates in Appendices 4.3.1 to 4.3.7.).

Table 4.13: Sea cucumber species records for Arno

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef-benthos stations n = 13			Other stations RFs = 10; MOPs = 1			Other stations Ds = 3		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.9	16.5	6									
Bohadschia argus	Leopardfish	M	0.9	16.7	6									
Bohadschia vitiensis	Brown sandfish	L	0.2	16.7	1									
Holothuria atra	Lollyfish	L				22.4	145.8	15						
Holothuria edulis	Pinkfish	L												
Holothuria fuscogilva [4]	White teatfish	H										1.6	4.8	33
Holothuria hilla	-	L				25.6	111.1	23						
Holothuria impatiens	-	L				3.2	41.7	8						
Holothuria nobilis [4]	Black teatfish	H												
Synapta spp.	-	-				3.2	41.7	8						
Thelenota ananas	Prickly redfish	H	1.9	26.7	7									
Thelenota anax	Amberfish	M										34.1	51.2	67

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

4.4.8 Discussion and conclusions: invertebrate resources in Arno

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

In summary, data on giant clam distribution, density and shell size suggest that:

- Parts of the barrier reef and areas within the lagoon at Arno were suitable for the full range of giant clams found in Marshall Islands. In general, the system was mostly oceanic-influenced, although land influence was noticeable in the southwest, close to the shore, and was less marked where the almost continuous land strip constitutes a barrier between the lagoon and ocean water in the south. At the northern part of the site, water movement was more dynamic and the reef was open to the ocean through large passages. Despite the enclosed nature of much of the lagoon, water flow around the main patch reefs in the lagoon was still notable, with tidal currents.

- Three species of giant clam were noted; the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the horse-hoof or bear's paw clam *Hippopus hippopus*. No true giant clam, *T. gigas*, was recorded, even though this icon species occurs naturally in Marshall Islands.

- The most suitable areas for *T. maxima* were located on the patch reef in the lagoon and on the oceanic side of the barrier reef. *H. hippopus* was sparsely distributed, with the best location along the back-reef and reef slopes within the lagoon. The reeftops of the barrier reef were mostly composed of dead substrate that was largely exposed at most states of the tide and was not suitable for Tridacnidae.

- Giant clam distribution and density indicated that the clam fishery was moderately impacted. Clam stocks near the main settlement areas were the most depleted. Coverage and densities of *T. maxima* clams were moderately high, with *H. hippopus* being less common and at lower density, and the larger *T. squamosa* rare.

- Although a 'full' range of size classes was noted for *T. maxima* and *H. hippopus* clams, which suggests successful spawning and recruitment, the larger size classes of *T. maxima* were relatively sparse, and no recruitment of *T. squamosa* was noted.

- Giant clams are broadcast spawners that only mature as females at larger size classes (protandric hermaphrodites). This means that, for successful stock management, clams need to be maintained at higher density and include larger-sized individuals to ensure that sufficient spawning takes place to produce new generations. Clams at Arno were not critically impacted (with the exception of *T. squamosa* and the possible earlier loss of *T. gigas*) but protective measures to ensure aggregations of large adults at high density are protected from fishing will assist in ensuring the ongoing stability and growth of these resources.

Data on environment, MOP distribution, density and shell size suggest that:

- There was no apparent reason why the reefs at Arno would not support commercial populations of the topshell, *Trochus niloticus*, but the slow spread of colonisation away from the place of release over the last 15 years suggests that the system is in some way not ideal. Some unidentified parameter, such as periodic shortages of algae for grazing or active fishing of newly colonised stock, may be negatively affecting the establishment of this species.

- As the water flow around Arno may be negatively affecting the settlement of larvae from the original location, any future introduction should be considered to the north of the atoll, where the water flow is greater. The outer reef northeast of the site and locations east of the study site could be alternative release locations, as good environmental conditions were recorded there.

- Trochus density was very low across the site at Arno, even in the most dense aggregations that were recorded. Despite the low numbers, the trochus population held a range of sizes, including juveniles and large mature adults, showing that density was sufficient to maintain ongoing reproduction and recruitment. Although the population appears to be self-sustaining, no commercial fishing of this resource can be expected in the coming years.

- Data on the false trochus or green topshell (*Tectus pyramis*) indicated that, in general, algal grazers from the Trochidae family are not very successful at colonising the oceanic-influenced reefs at Arno. Although complex reefs were present, in general surfaces were relatively clean, and the algal diet may have been insufficient, restricting the build-up of commercial stocks.

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

In summary, data on the environment, distribution and density of sea cucumbers at Arno reveal that:

- The environment at Arno was characteristic of an oceanic atoll system with little land mass and limited land influence in an exposed system. Sea cucumbers are generally benthic feeders and, therefore, there is generally limited scope for these commercial invertebrates in such systems, especially in such a remote archipelago on the eastern side of the Pacific.

- The number of commercial sea cucumber species noted at Arno (seven species only), was limited due to biogeographical influences: the isolated position of Arno in the Pacific, the poverty of the primary production, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system.

- Fishing may also have played a role in the decline of some species groups, as important high-value stocks, such as the black teatfish (*Holothuria nobilis*), were absent from Arno. This shallow-water species is easily targeted by fishers and preliminary surveys across the Pacific suggest that this species does not respond well to heavy fishing pressure.

- The high-value white teatfish (*Holothuria fuscogilva*) and the medium-value prickly redfish (*Thelenota ananas*) were recorded, as were the lower-value leopard or tigerfish (*Bohadschia argus*) and lollyfish (*H. atra*); however, distribution was sparse and densities were too low to warrant any commercial interest.

- The low-to-medium value amberfish (*T. anax*) was recorded at reasonably high density on the sandy bottom of the lagoon.

- It is unknown whether the sea cucumber stocks at Arno were over-fished during previous periods (more than a decade ago) and stocks have failed to recover, or whether Arno is just naturally deficient in both the range and density of these commercial invertebrates due to environmental factors and stressors. However, what can be deduced from these surveys is that there is no potential for developing a commercial sea cucumber fishery based on existing stocks at Arno at this time.

4.5 Overall recommendations for Arno

- The legalisation of the 23 marine reserves that have been approved by the Arno community be strongly supported and assisted by MIMRA.

- The ongoing community-based fisheries management projects and activities be further developed and strengthened, especially in regard to the 23 marine reserves.

- Care be taken to ensure that only reserves that can be actively patrolled be implemented to avoid ineffective management as well as the setting up of negative examples.

- More awareness be provided at the village levels to heighten the understanding of the functions of MPAs and to alleviate concerns among landowners.

- Continued support of the Coastal Management Advisory Committee be required to ensure that any recommendations from scientists are fully considered in future management plans and measures for Arno.

- A monitoring system be designed and set in place to follow any further changes in finfish resources, especially in marine reserves.

- Controls be put in place to limit the use of spearfishing, especially at the frequently fished outer reef, and at night.

- Consideration be given to imposing a fee on tourist divers visiting Arno, in order to provide financial support to sustain the management of the marine reserves.

- Some larger clams be placed in the marine reserves at Arno to ensure that clam stocks remain protected from fishing.

- No commercial harvest of the trochus resource be undertaken or even considered in the coming years.

- Any future introduction of trochus to Arno take place in the area to the north of the atoll, where water flow is greater; an alternative release site could be the outer reef northeast of the site and locations east of the study site.

- There is no potential for developing of a commercial sea cucumber fishery based on existing stocks at Ailuk at this time.

5. PROFILE AND RESULTS FOR LAURA

5.1 Site characteristics

Laura is a village located at the western tip of Majuro atoll, positioned at 07°08' N, 171°01' E (Figure 5.1). The lagoon is relatively shallow (30–40 m) and houses several pinnacles and patch reefs, mostly found in the extreme western side and in the central area. As in the other three sites, there are no coastal reefs in Laura. Laura is a large peri-urban community, with more than 200 households.

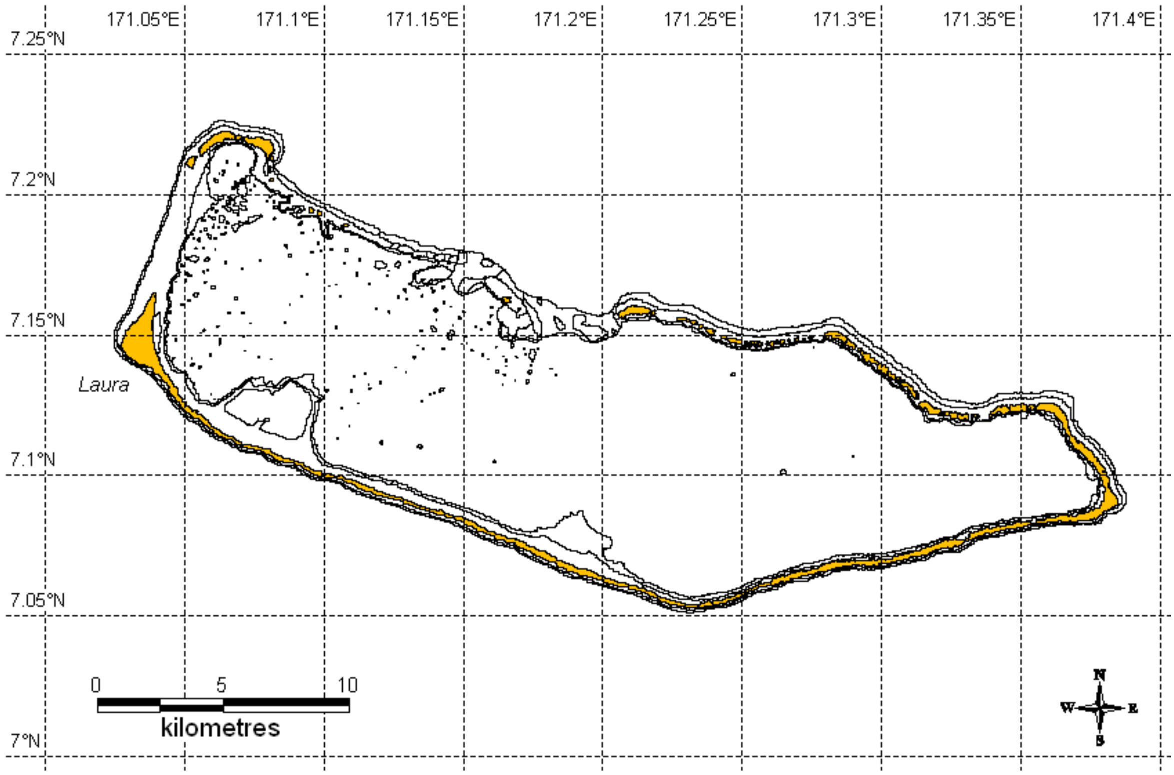

Figure 5.1: Map of Laura.

5.2 Socioeconomic surveys: Laura

Socioeconomic fieldwork was carried out in Laura, RMI from 6 to 15 September 2008. Laura is located about 15 km from the main urban centre. People from Laura depend on fisheries for subsistence and income due to the lack of alternative income opportunities. Fishing, either part time or full time, offers a way to generate some of the necessary cash income. The close proximity to Laura's urban centre, the road transport, the cars available in the community and the regular bus transport system, all serve to make the marketing of fisheries and other produce easy. Laura itself is well endowed with 17 small shops and canteens, some of which buy fish locally. Some fish and invertebrates are sold by local fishers at the roadside in Laura or brought to the Laura market. Male fishers are organised into fishing groups to share the high cost of fuel and transport and to jointly market their catch. A middleman operates in Laura by recruiting male fishers under a salary-based agreement and marketing their catch.

Because Laura is a huge community, only the proportion of the population that uses the same fishing grounds and operates under the same fishing rights was chosen for sampling. Thus, the Laura community is considered to have a total population of 1343 people and about 180 households. In total, 24 households, i.e. 13% of the total households in the Laura community, were surveyed, with most (96%) of these households being engaged in some form of fishing activities. In addition, a total of 18 finfish fishers (males only) and 9 invertebrate fishers (7 males and 2 females) were interviewed. The household size is moderate to large, with seven people on average, which reflects the traditional lifestyle of people in RMI, although Laura is a more semi-urban community than all the other sites studied.

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

People from Laura have access to various habitats for fishing, including the combined lagoon and coastal reef areas, the outer reef, channels and passages. While intertidal, soft-benthos and reeftop habitats are available, invertebrate collection was not common due to the decline of these resources. Usually, invertebrates were only collected when found during finfish fishing trips, and only particular target species, such as lobsters, were fished on purpose.

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

Our results (Figure 5.2) show that salaries play the most important role for income generation, followed by fisheries and agricultural production. While Laura people have access to salaries due to the proximity to Laura's urban centre, fisheries still supply a quarter of households with first and 33% of households with complementary, secondary income.

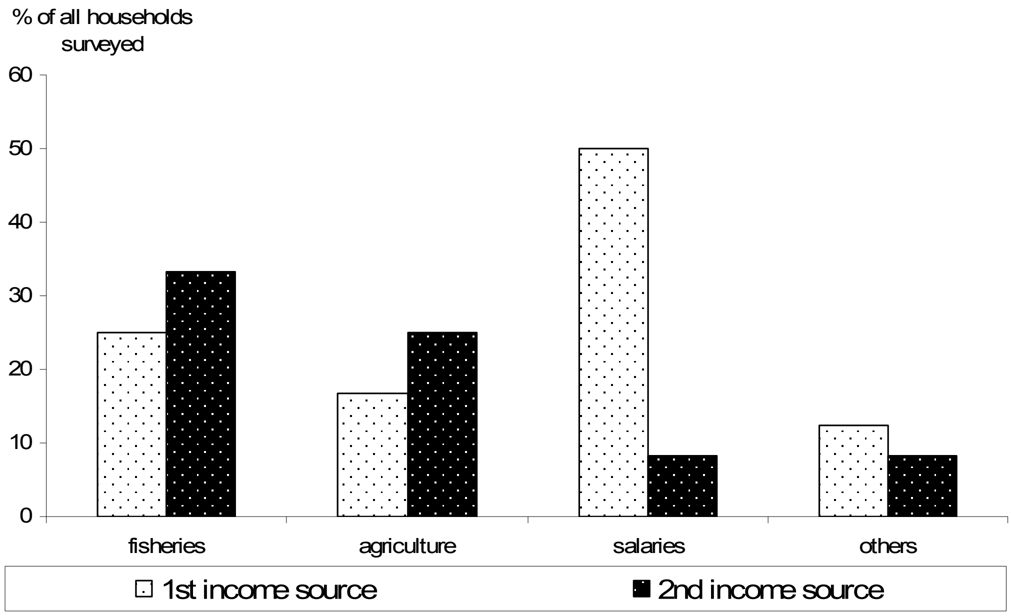

Figure 5.2: Ranked sources of income (%) in Laura.
Total number of households = 24 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

By comparison, agriculture is less important, and so are home-based shops, restaurants, other private businesses and handicrafts. Pigs and chickens are popularly reared; 63% of households have a couple of pigs and 58% of households keep at least 12 chickens for home consumption. Distribution of fish and seafood produce on a non-monetary basis is still important and regularly practised in Laura.

Our results (Table 5.1) show that the annual household expenditures reflect the semi-urban character of the community, with an average of USD 4209, almost double the average found across all four sites studied in Marshall Islands. People are dependent on imported goods and have to pay for the private cars and other infrastructure available on Laura.

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

Survey coverage	Site (n = 24 HH)	Average across sites (n = 78 HH)
Demography		
HH involved in reef fisheries (%)	95.8	98.7
Number of fishers per HH	1.96 (±0.24)	2.56 (±0.17)
Male finfish fishers per HH (%)	61.7	21.5
Female finfish fishers per HH (%)	0.0	0.0
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	6.4	15.5
Male finfish and invertebrate fishers per HH (%)	31.9	47.0
Female finfish and invertebrate fishers per HH (%)	0.0	16.0
Income		
HH with fisheries as 1st income (%)	25.0	32.1
HH with fisheries as 2nd income (%)	33.3	19.2
HH with agriculture as 1st income (%)	16.7	10.3
HH with agriculture as 2nd income (%)	25.0	38.5
HH with salary as 1st income (%)	50.0	20.5
HH with salary as 2nd income (%)	8.3	9.0
HH with other sources as 1st income (%)	12.5	37.2
HH with other sources as 2nd income (%)	8.3	12.8
Expenditure (USD/year/HH)	4208.51 (±413.81)	2210.55 (±226.09)
Remittance (USD/year/HH) (1)	1275.00 (±232.80)	764.14 (±107.90)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	89.52 (±17.94)	105.45 (±7.52)
Frequency fresh fish consumed (times/week)	2.44 (±0.13)	3.56 (±0.13)
Quantity fresh invertebrate consumed (kg/capita/year)	4.91 (±1.34)	6.47 (±7.52)
Frequency fresh invertebrate consumed (times/week)	0.73 (±0.17)	0.94 (±0.08)
Quantity canned fish consumed (kg/capita/year)	6.79 (±1.69)	5.12 (±0.65)
Frequency canned fish consumed (times/week)	1.53 (±0.26)	1.12 (±0.11)
HH eat fresh fish (%)	100.0	100.0
HH eat invertebrates (%)	83.3	94.9
HH eat canned fish (%)	91.7	94.9
HH eat fresh fish they catch (%)	95.8	100.0
HH eat fresh fish they buy (%)	41.7	15.8
HH eat fresh fish they are given (%)	50.0	84.2
HH eat fresh invertebrates they catch (%)	58.3	100.0
HH eat fresh invertebrates they buy (%)	25.0	0.0
HH eat fresh invertebrates they are given (%)	25.0	84.2

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

However, 33% of households still benefit from remittances, and the average remittances received per household are high, at USD 1275 /year, or about 30% of the average annual household expenditure.

Survey results indicate an average of two fishers per household and, when extrapolated, the total number of fishers in Laura amounts to 353 (330 males and 23 females). Among these are 218 exclusive finfish fishers (males only), 23 exclusive invertebrate fishers (females only), and 113 fishers who fish for both finfish and invertebrates (males only). About 42% of households own a boat, and these are all (100%) fitted with an outboard engine.

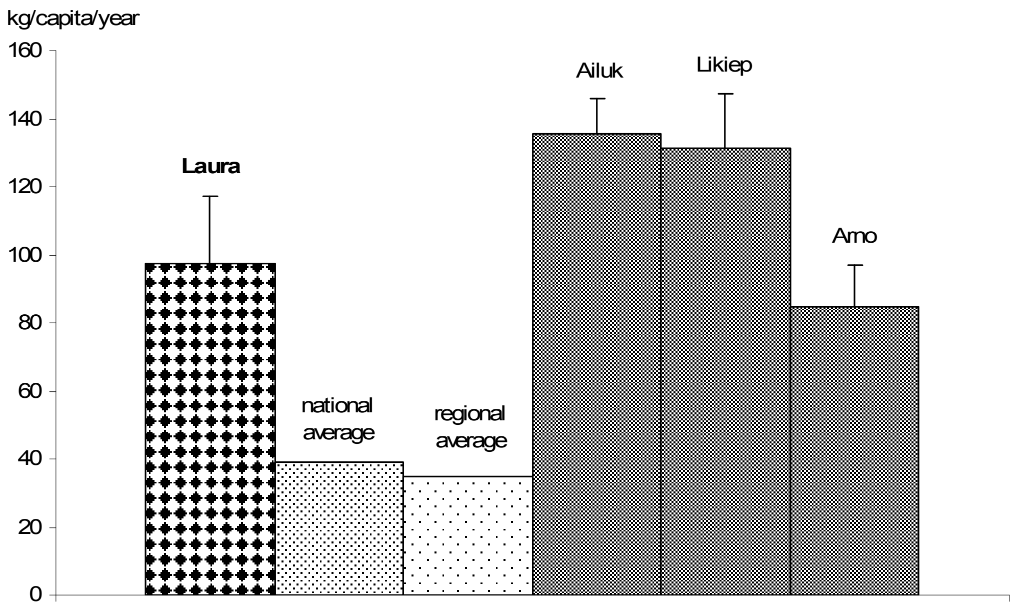

Figure 5.3: Per capita consumption (kg/year) of fresh fish in Laura (n = 24) compared to the regional average (FAO 2008) and the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Per capita consumption of fresh fish is high at almost 90 kg/person/year. Although this is much less than the average across all the four study sites in RMI, it is still more than double 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 at ~5 kg/person/year. Canned fish (Table 5.1) is not commonly eaten and adds only ~7 kg/person to the annual protein supply from seafood. The consumption pattern of seafood found in Laura highlights the fact that people have a high dependency on fresh fish and prefer it as a food item, that they have limited interest and/or access to invertebrate resources, and spend little on imported canned fish products.

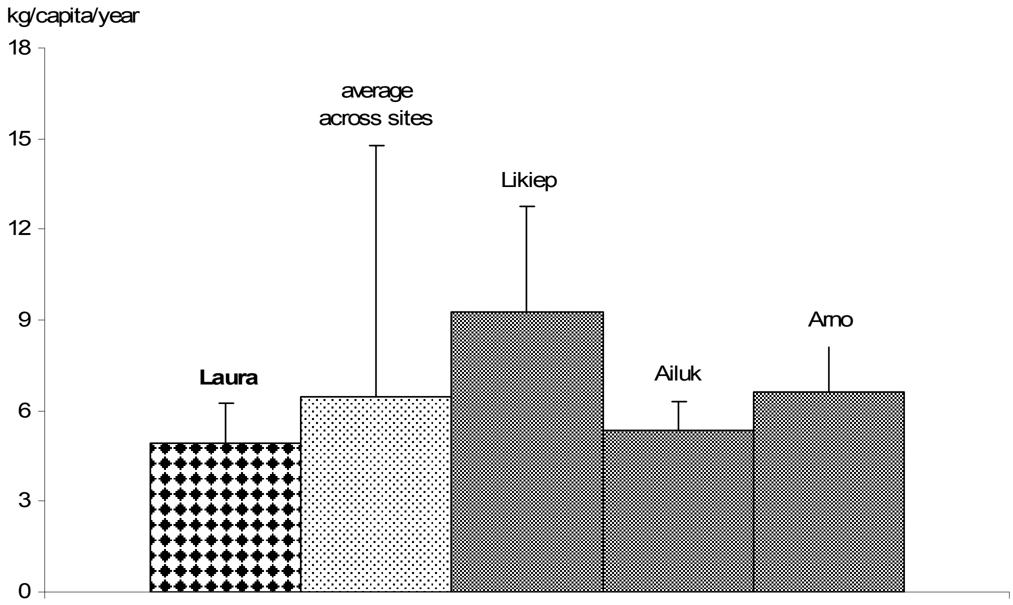

Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Laura (n = 24) compared to the other three CoFish sites in Marshall Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing the results obtained for Laura to the average figures across all the four study sites surveyed in RMI, people of the Laura community are the most urban in character as shown by the high basic household expenditure level and the high dependency on (and access to) salary-based income. However, although people from Laura may consume fresh fish and invertebrates less often than average, they do consume large quantities of fresh fish. People in the Laura community eat less seafood that they have caught than average, and eat seafood that they have purchased more often than average. Salaries are the most important income source, which is very different from the case in the other communities studied, and fisheries provide the most important complementary secondary income. The proportion of households receiving remittances is about average, but the remittances received are much larger than average. By comparison, boat ownership is about average; however, the community has only motorised boats.

5.2.2 Fishing strategies and gear: Laura

Degree of specialisation in fishing

Our survey showed that fishing is no longer done by both gender groups, but that gender roles are defined. Fishing is mainly a male domain, as males are either exclusive finfish fishers or combine both finfish fishing and invertebrate collection. The relatively small proportion of females participating in fisheries seems to focus only on invertebrate collection (Figure 5.5). Laura is a semi-urban community compared to the overall situation in the Marshall Islands, and females are also engaged in salary-based income activities. Females are no longer considered to be involved in fishing, and their contribution was hardly ever mentioned or acknowledged during the interviews.

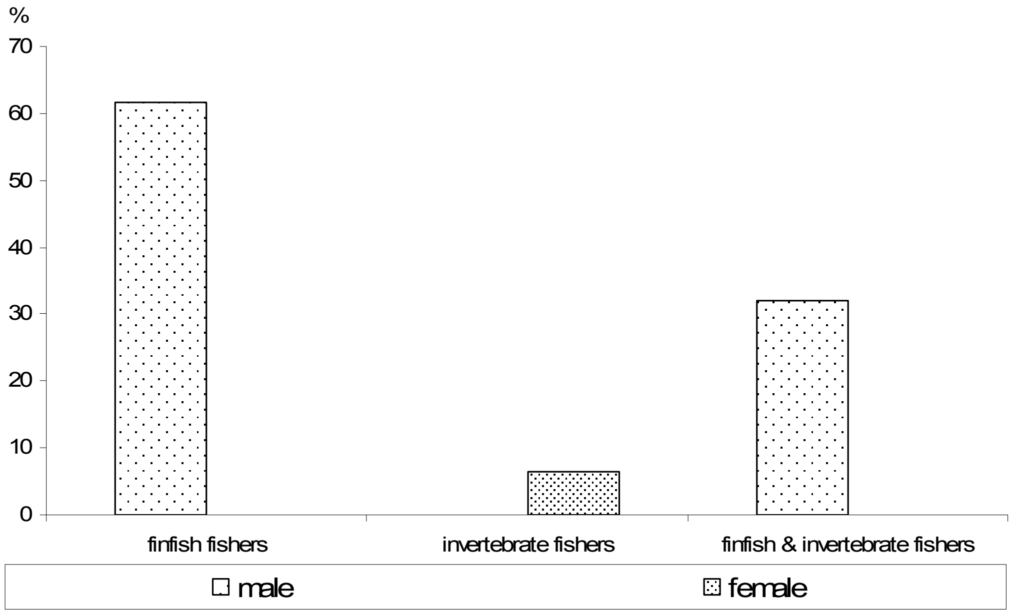

Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Laura.
All fishers = 100%.

Targeted stocks/habitat

Considering the fact that fishing in Laura serves the subsistence needs of a community that has a high per capita consumption, and is also performed to generate income, it is not surprising that Laura finfish fishers target different habitats depending on the purpose of the fishing trip. Most fishers target the more accessible sheltered coastal reef and lagoon areas, while fewer fish the lagoon, outer reef and passages. Usually, at least two habitats are combined in one fishing trip; either the sheltered coastal reef and lagoon, or the lagoon and outer reef (Table 5.2). According to the observation made earlier, i.e. the dwindling invertebrate resource status and hence the little effort spent in harvesting invertebrates, the invertebrate fisheries are not specific and species may be collected from any of the habitats. Lobster fishing and diving for giant clams and octopus are the exceptions and these species are specifically targeted.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	83.3	0.0
	Lagoon & outer reef	16.7	0.0
	Outer reef	16.7	0.0
	Outer reef & passage	22.2	0.0
Invertebrates	Reeftop	0.0	50.0
	Reeftop & other	28.6	0.0
	Soft benthos & reeftop & other	14.3	0.0
	Seagrass & other	14.3	0.0
	Seagrass & reeftop	0.0	50.0
	Seagrass & reeftop & other	14.3	0.0
	Lobster	42.9	0.0
	Other	28.6	0.0

'Other' refers to giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 18; females: n = 0. Invertebrate fisher interviews, males: n = 7; females, n = 2.

Fishing patterns and strategies

The number of fishers, the frequency of fishing trips and the average catch per fishing trip are the basic factors used to estimate the fishing pressure imposed by people from Laura on their fishing grounds (Tables 5.2 and 5.3).

Our survey sample suggests that fishers from Laura have a choice among sheltered coastal reef, lagoon and outer-reef fishing. Invertebrate fisheries are restricted, not because of habitat limits, but because of the poor resource status. Most females glean the reeftops (29%), while most males dive for giant clams and octopus ('others' 33%) or specialise in collecting lobsters (14%) (Figure 5.6). Data on gender participation show that males dominate all invertebrate fisheries except for reeftop gleaning and the combined seagrass and reeftop gleaning, which is exclusively performed by female fishers. As elsewhere, females do not dive for lobsters, clams or any other species (Figure 5.7).

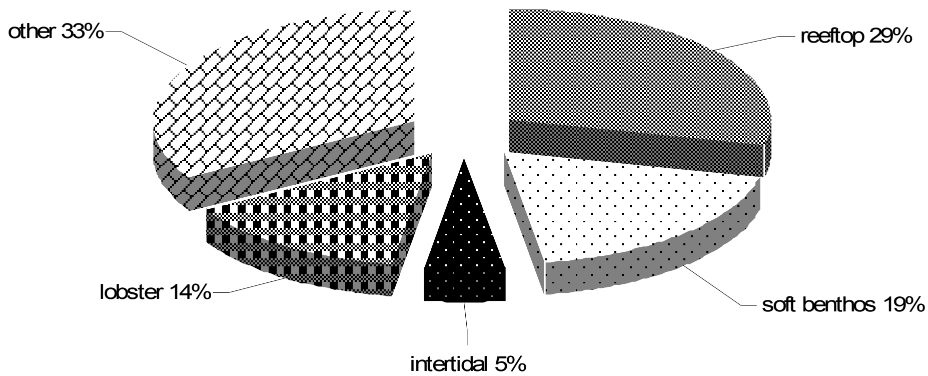

Figure 5.6: Proportion (%) of fishers targeting the five primary invertebrate habitats found in Laura.
Data based on individual fisher surveys; data for combined fisheries are disaggregated.

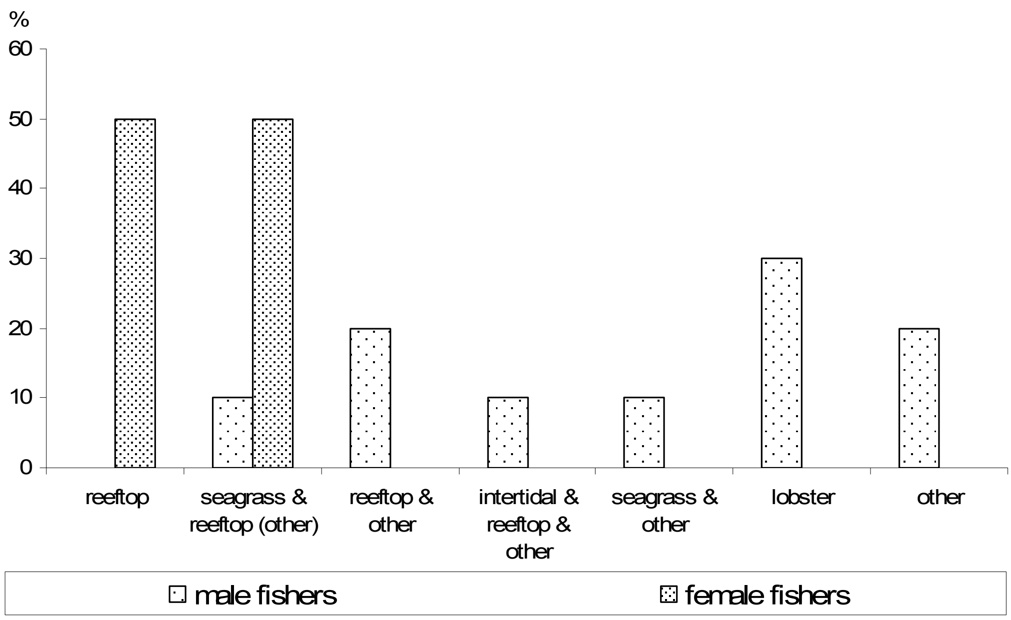

Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Laura.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 7 for males, n = 2 for females.

Gear

Figure 5.8 shows that Laura fishers use a number of fishing techniques during one fishing trip. Most frequently, a combination of gillnets, cast nets, handlines and 'others' (e.g. spear diving) dominate fishing in the combined sheltered coastal reef and lagoon habitats. If the lagoon is combined with the outer reef, handlines, bottom fishing, and spear diving are the main methods used. Bottom fishing and spear diving are mainly used at the outer reef and passages.

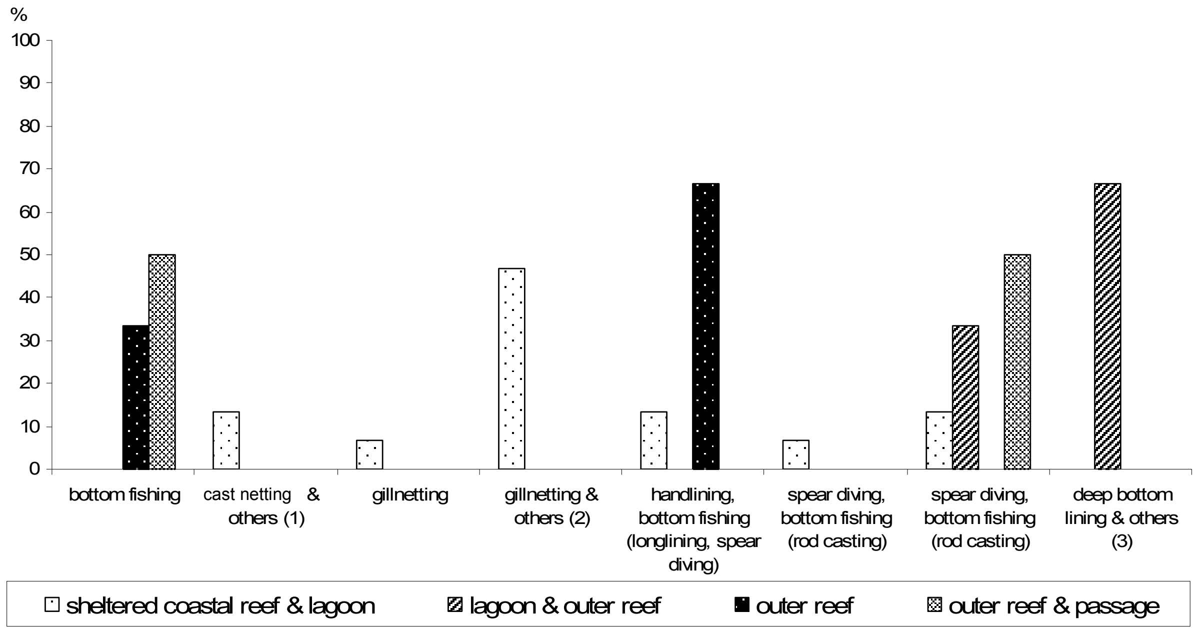

Figure 5.8: Fishing methods commonly used in different habitat types in Laura.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip. (1) Gillnetting, bottom fishing, handlining, spear diving; (2) handlining, spear diving, bottom fishing, rod casting, longlining, spear handheld walking or from canoe; (3) gillnetting, handlining, longlining, spear diving.

Frequency and duration of fishing trips

Finfish fishers go out fishing about twice a week regardless of which habitat or combination of habitats they target. Invertebrate trips are less frequently made by male fishers, once or twice per month, and about once per week by female fishers. The average duration of a finfish fishing trip is ~4–5 hours for males targeting the sheltered coastal reef and lagoon or the lagoon and outer reef, but much longer (7–8 hours) if targeting the outer reef and passages. A typical invertebrate collection trip takes 3–4 hours, or 5–6 hours for lobster fishing. Females make much shorter fishing trips for invertebrates (2–3 hours only) (Table 5.3).

Most finfish fishing is done according to tidal conditions, i.e. during the day or at night, and performed throughout the year. Ice is always used when fishers target the outer reef alone or in combination with the passages, and is often used when fishing elsewhere. Finfish fishing is mostly done using boat transport, invertebrate gleaning is primarily performed while walking, and diving for lobster and 'others' uses boat transport. Invertebrates are mostly caught during the day; however, lobsters are targeted during the day and at night. Invertebrate fisheries are performed continuously throughout the year, with no particular season.

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

Resource	Stock	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.23 (±0.18)		4.73 (±0.51)	
	Lagoon & outer reef	2.00 (±0.00)	0	4.33 (±0.33)	0
	Outer reef	1.33 (±0.33)	0	7.00 (±0.58)	0
	Outer reef & passage	1.75 (±0.25)	0	8.25 (±0.63)	0
Invertebrates	Reeftop	0	0.46 (n/a)	0	3.00 (n/a)
	Reeftop & other	0.62 (±0.38)	0	3.00 (±1.00)	0
	Intertidal & reeftop & other	1.00 (n/a)	0	4.00 (n/a)	0
	Soft benthos & other	1.00 (n/a)	0	3.00 (n/a)	0
	Soft benthos & reeftop	0	1.00 (n/a)	0	2.00 (n/a)
	Soft benthos & reeftop & other	1.15 (n/a)	0	4.00 (n/a)	0
	Lobster	0.38 (±0.08)	0	5.33 (±0.67)	0
	Other	0.40 (±0.29)	0	3.50 (±0.50)	0

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to octopus, clam and lobster fisheries.
Finfish fisher interviews, males: n = 18; females: n = 0. Invertebrate fisher interviews, males: n = 7; females: n = 2.

5.2.3 Catch composition and volume – finfish: Laura

The catches reported from the sheltered coastal reef and lagoon in Laura contain a great variety of species, with Serranidae, Siganidae, Lethrinidae and Lutjanidae being the most important by weight caught, but with Acanthuridae, Kyphosidae and other species also making a significant contribution. Reported catches from the combined lagoon and outer reef are different in composition as they are dominated by Lutjanidae and Serranidae, while Kyphosidae and Siganidae play a minor role. Outer-reef catches are mainly composed of Serranidae, Lutjanidae, Pomacentridae and Lethrinidae; these increase in importance if the outer reef is combined with passage fishing.

Detailed information on catch composition by species, species groups and habitats is reported in Appendix 2.4.1.

Figure 5.9 confirms findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing serves mostly subsistence purposes, representing 71% of the total catch, but also plays a role in generating income (29%). The total annual catch is estimated to amount to ~163.07 t.

Our survey did not reveal any participation by females in finfish fisheries among the Laura community members. Male fishers mainly target the sheltered coastal reef and lagoon habitats, presumably for home consumption purposes (64% of total annual impact). The impact imposed on resources in the lagoon and outer reef, as well as the outer reef and passages, nevertheless accounts for 26% of the total catch, with most (23%) sourced from the outer reef and passages.

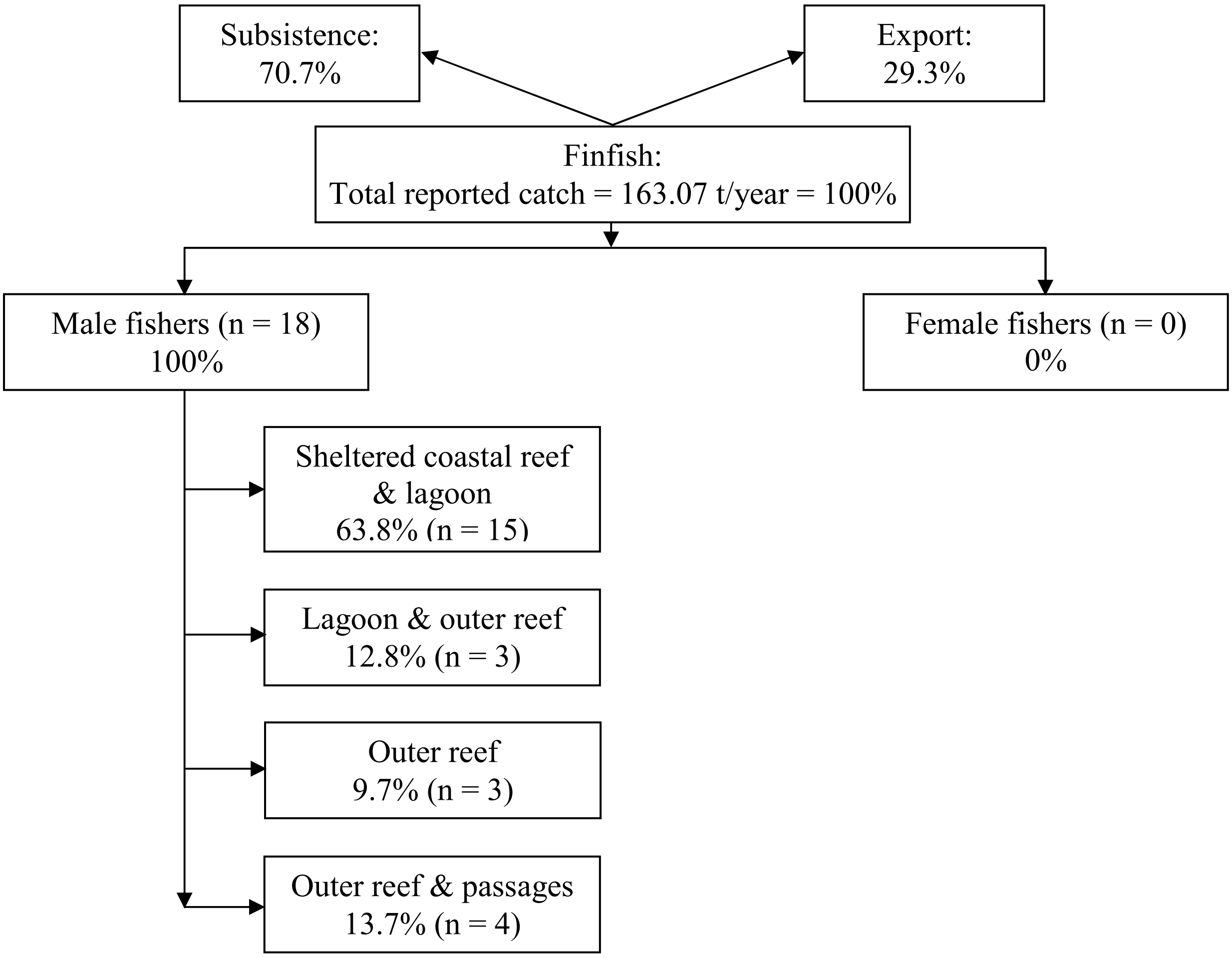

Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Laura.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The distribution of annual catch weight among the more accessible sheltered coastal reef, the lagoon and the more distant lagoon and outer reef is a consequence of the number of fishers rather than productivity or efficiency. As shown in Figure 5.10, the average annual catch per male fisher is about 400–450 kg more per fisher if targeting the combined sheltered coastal reef and lagoon and lagoon and outer reef, as compared to the outer reef and the combined outer reef and passages (300–350 kg/fisher/year).

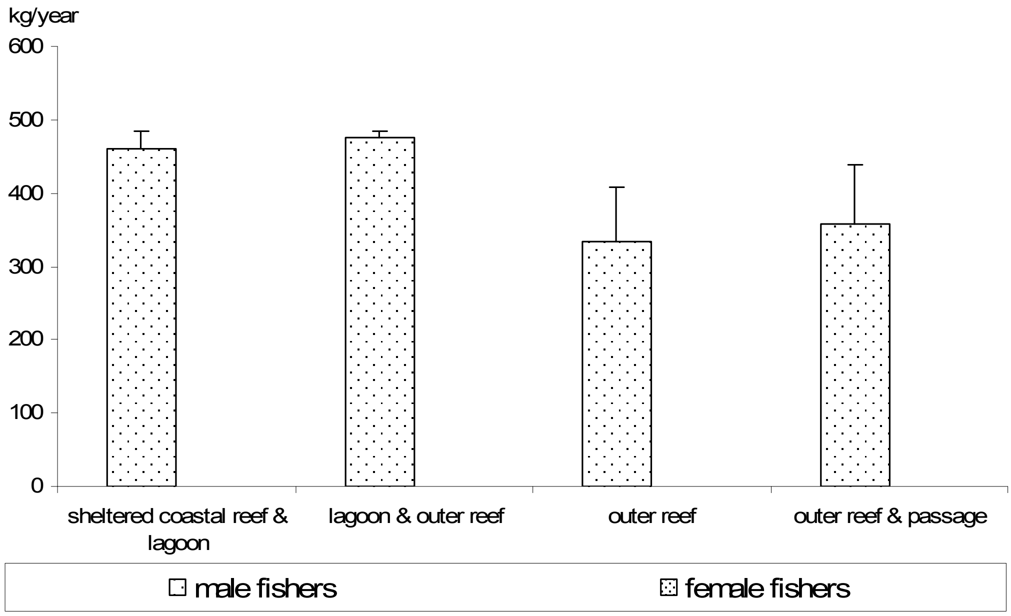

Figure 5.10: Average annual finfish catch (kg/year) per fisher by habitat and gender in Laura.
Bars represent standard error (+SE).

Comparing productivity rates between genders and among habitats (Figure 5.11), there are surprising and significant differences among the habitats fished. Overall, CPUEs are low at 0.6–1.2 kg/hour fished, but much higher for the closer habitats fished as compared to the outer reef and passages.

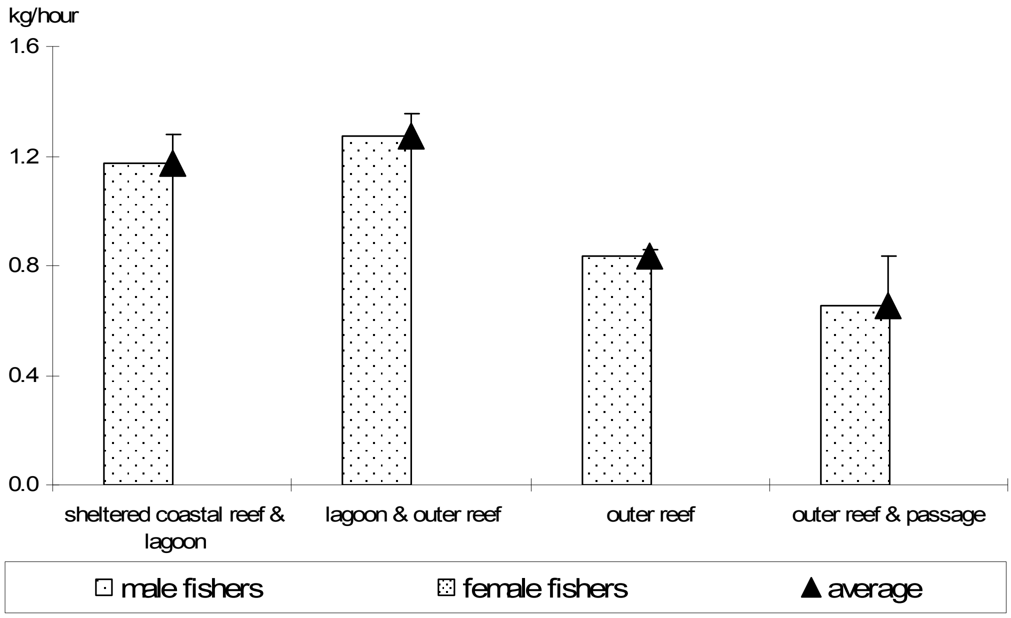

Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Laura.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

The importance of both subsistence and commercial fishing for Laura clearly shows in Figure 5.12. As observed earlier, fishers target the combined habitats of the sheltered coastal reef and lagoon and the lagoon and outer reef mainly for subsistence purposes, but the outer reef and outer reef and passages mostly for sale. Fishing for gifts is associated with subsistence fisheries rather than commercial fishing.

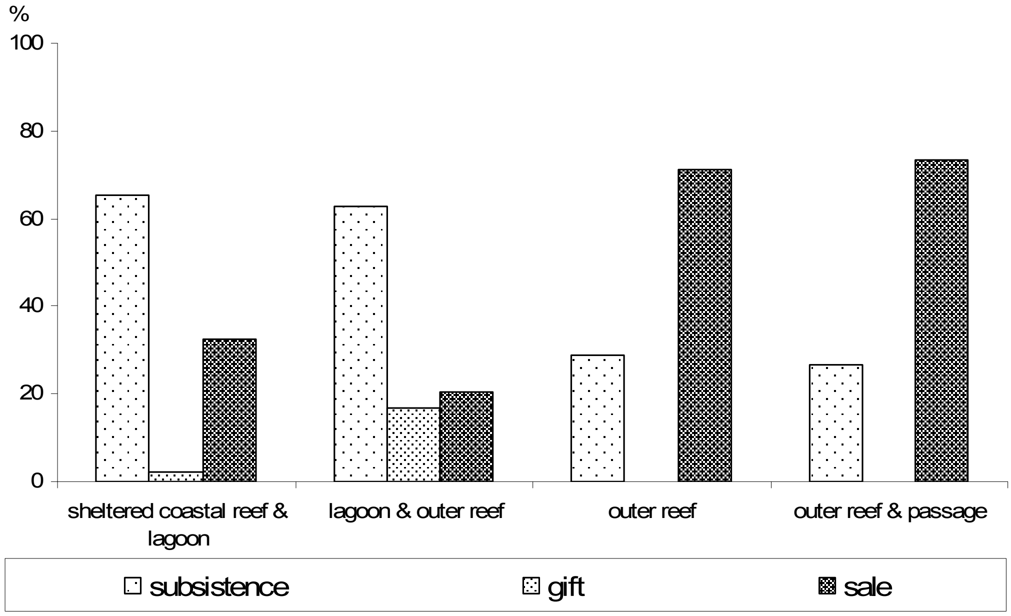

Figure 5.12: The use of finish catches for subsistence, gift and sale, by habitat in Laura. Proportions are expressed in % of the total number of trips per habitat.

The overall finfish fishing productivity is low but higher in the habitats closer to shore than in the more distant habitats (Figure 5.11). This result is surprising and opposite to the generally expected increased productivity of the outer reef and passages. Similarly, one would expect that average reported fish size will increase with distance from shore, thus clearly showing larger average fish sizes for catches from the distant lagoon and outer reef as compared to those caught at the sheltered coastal reef and lagoon. This assumption is true for fish sizes reported by Laura fishers, i.e. the average reported sizes of Acanthuridae, Kyphosidae, Lethrinidae, Lutjanidae and Serranidae increase from the sheltered coastal reef and lagoon to the outer reef and passages. Siganidae, however, show the opposite trend, with smaller average fish sizes reported for catches at the outer reef as compared to catches at the sheltered coastal reef and lagoon (Figure 5.13). Overall, average reported fish sizes are moderate, most ranging around 25 cm.

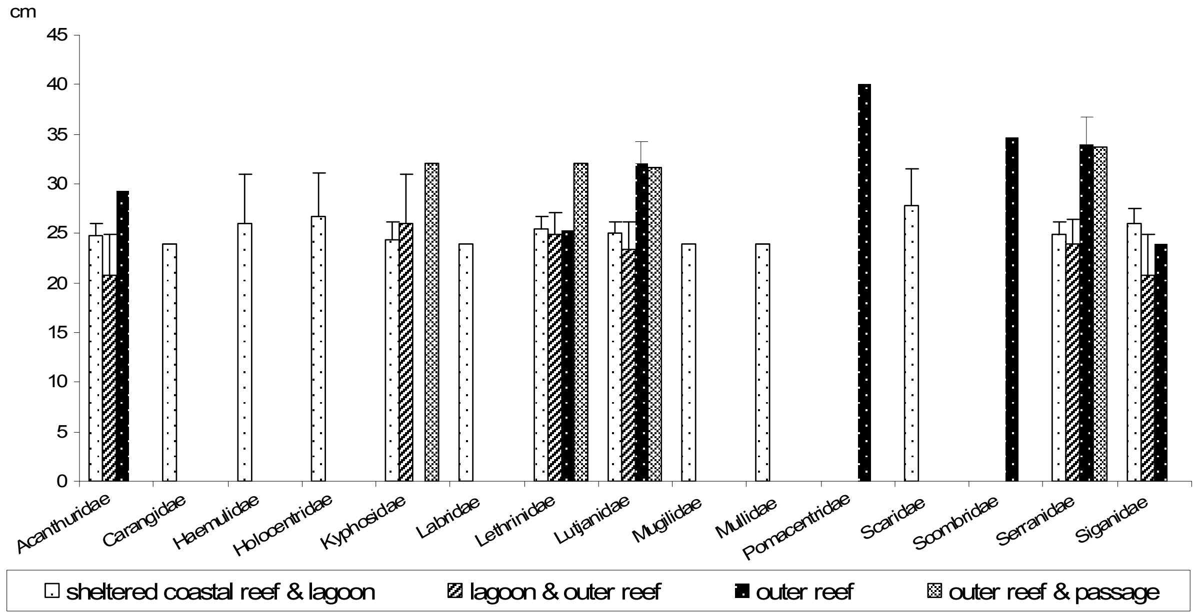

Figure 5.13: Average sizes (cm fork length) of fish caught by family and habitat in Laura.
Bars represent standard error (+SE).

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

Parameters	Habitat					
	Sheltered coastal reef & lagoon	Lagoon & outer reef	Outer reef	Outer reef & passage	Total reef area	Total fishing ground
Fishing ground area (km^2)		lagoon=135.04	5.04	7.64	39.94	142.68
Density of fishers (number of fishers/km^2 fishing ground) (1)	n/a	n/a	8	7	8	2
Population density (people/km^2) (2)					34	9
Average annual finfish catch (kg/fisher/year) (3)	460.61 (±24.02)	475.05 (±9.12)	332.87 (±75.02)	356.83 (±80.75)		
Total fishing pressure of subsistence catches (t/km^2)					2	1
Number of fishers	198	40	40	53	331	331

Figures in brackets denote standard error; n/a = no information available; (1) total number of fishers (= 331) is extrapolated from household surveys; (2) total population = 1343; total subsistence demand = 96.23 t/year; (3) catch figures are based on recorded data from survey respondents only.

The parameters selected to assess current fishing pressure on Laura reef and lagoon resources are shown in Table 5.4. Due to the fact that fishers always combine two habitats in one fishing trip, calculation of total impact per habitat is difficult. However, overall, if we consider the available total reef surface and total fishing ground, population density is moderate, while fisher density and catch rates per unit areas of reef and fishing ground are all low. The catch rates still remain low even if we take into account the additional 29% of annual catch externally sold for the total fishing ground, i.e. the ratio increases to 1.1 mt/km^2. However, in the case of the total reef area, the total annual catch rate increases to a considerable 4.1 mt/km^2 reef surface. In addition, fishers reported that they now need to fish in fishing grounds much further away than before in order to bring home the catch needed.

Also, the fishing grounds that are here considered as belonging to the community of Laura are subject to the open-access system and are therefore fished by a much larger proportion of Laura's total population and fishers. Therefore, the current catch rate is presumably misleading as it does not take into account any previous impact from fishing, nor any current fishing pressure accounted for by fishers from communities other than Laura.

5.2.4 Catch composition and volume – invertebrates: Laura

Analysis of the catches reported by invertebrate fishers by wet weight shows that four-to-five species (*Conus* spp., *Cerithium* spp., *Cypraea tigris*, *Hippopus hippopus* and *Panulirus* spp.) account for most of the total annual reported catch. The fact that three species (*Conus* spp., *Cerithium* spp. and *Cypraea tigris*) are more important than clams, lobsters or octopus supports the earlier argument that invertebrate fishing is not of major importance but is more of a complementary activity, reportedly mainly due to the decline in resources. If we consider that only lobster collection and diving for clams and octopus are reported as fisheries that are done on purpose and for particular target species, the reported annual catch (wet weight) is low, i.e. ~600 kg for lobster, ~1400 kg for clams, and about 450 kg for octopus. As shown in Figure 5.14, there are several other invertebrates caught, such as *Strombus* spp. and *Thais* spp.; however, the proportion of catch they comprise is rather insignificant.

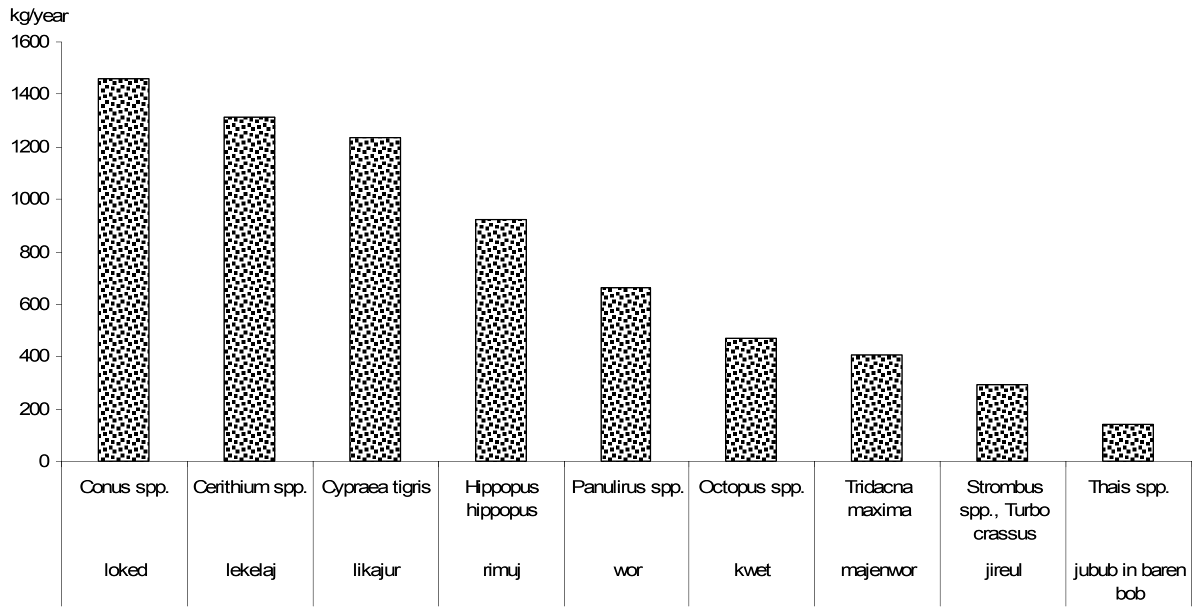

Figure 5.14: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Laura.

The fact that invertebrates are targeted and collected much less than is observed elsewhere in RMI shows in Figure 5.15, with very few vernacular names reported for any fishery or habitat targeted. It was also observed that people from Laura had much less knowledge about invertebrates, and knew far fewer vernacular names than elsewhere. This observation suggests either that invertebrates have never played an important role for this community, or that resource depletion has been ongoing for a long time, hence resulting in a loss of local knowledge.

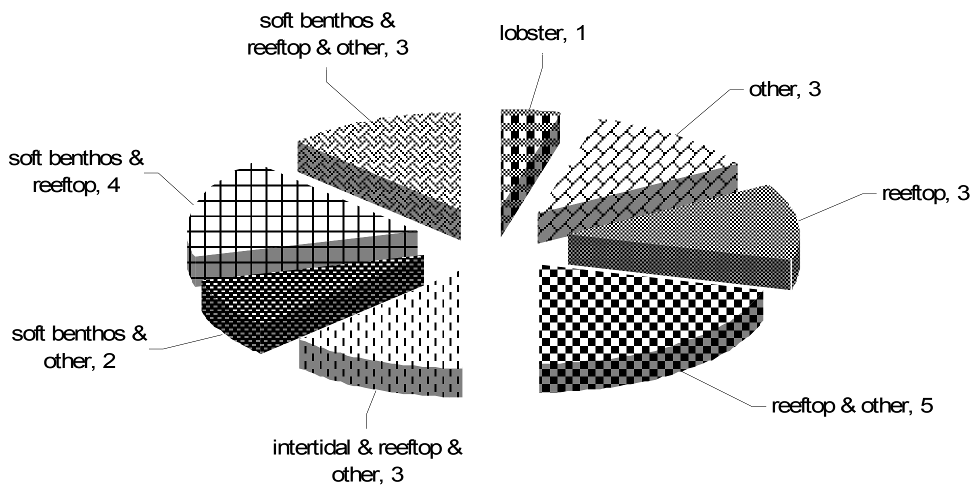

Figure 5.15: Number of vernacular names recorded for each invertebrate fishery in Laura.
'Other' refers to octopus, clam and lobster fisheries.

The average annual catch per fisher by gender and fishery (Figure 5.16) underlines the low importance of invertebrate fishing and the great range of habitats where invertebrates may be collected on purpose or on occasion. Our sample size does not allow thorough comparison between genders and among fisheries. However, overall, the annual average catch rates are low, ~500 kg/fisher (excluding any data that are based on one interview only). Figure 5.16 also shows that males are more actively involved in fishing, as a result of occasionally collecting invertebrates while finfish fishing. Males collect invertebrates from a much broader range of habitats than do female invertebrate fishers.

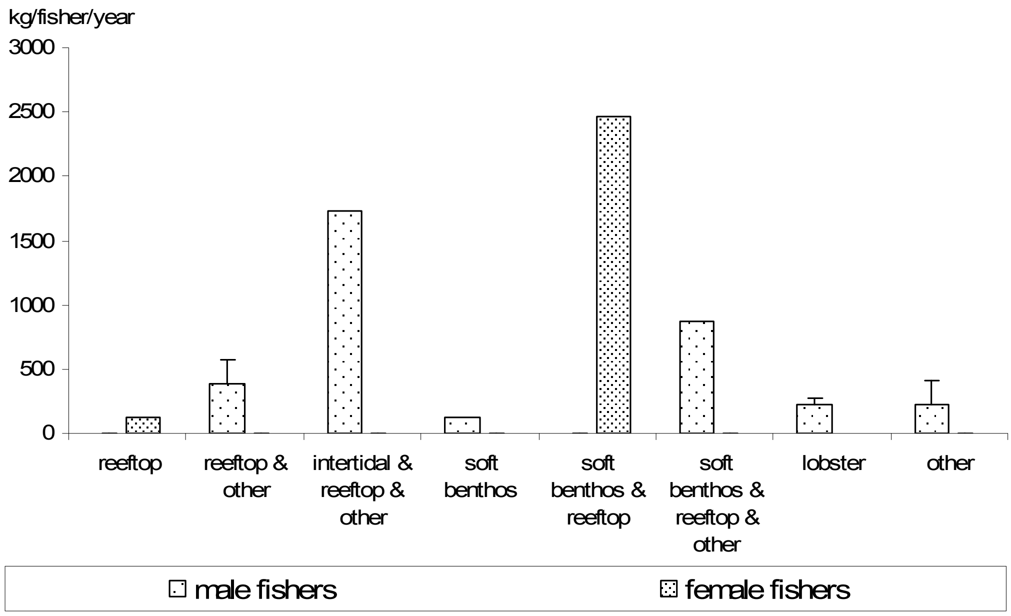

Figure 5.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Laura.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 7 for males, n = 8 for females). Bars represent standard error (+SE). 'Other' refers to octopus, clam and lobster fisheries.

The fact that the Laura community is highly dependent on marine resources for income is also true for invertebrates. As shown in Figure 5.17, almost half of the invertebrates are caught for home consumption, and about 54% may be sold. Commercial invertebrates are mainly represented by the specific fisheries for lobsters and ‘others’, including clams and octopus.

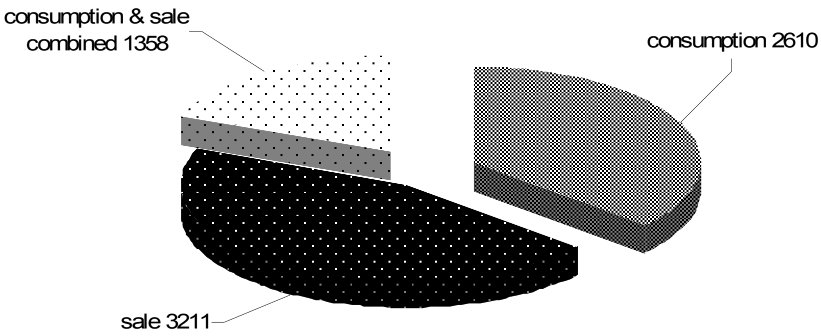

Figure 5.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Laura.

As mentioned earlier, male fishers from Laura are the main invertebrate fishers, accounting for ~64% of the total catch (wet weight) (Figure 5.18). Most Laura invertebrate fishers target reef-associated species by diving (‘others’: octopus, clams and lobsters) and in combination with reeftops or soft benthos. Less impact (~36%) is imposed by female fishers gleaning on the soft-benthos and reeftop resources, mostly for home consumption.

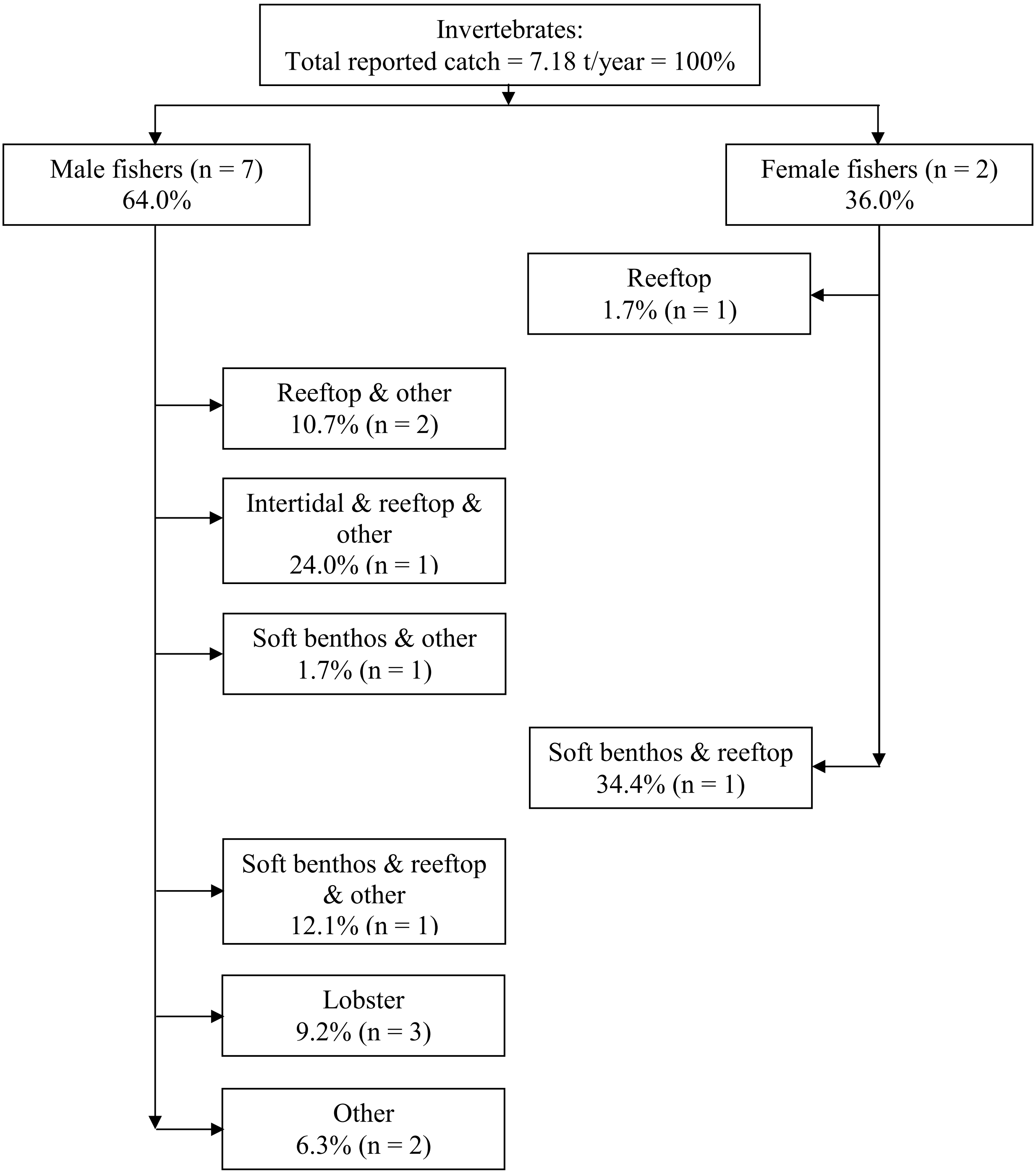

Figure 5.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Laura.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to octopus, clam and lobster fisheries.

Table 5.5: Selected parameters (±SE) used to characterise the current level of fishing pressure of invertebrate fisheries in Laura

Parameters	Fishery / Habitat							
	Reeftop	Reeftop & other	Intertidal & reeftop & other	Soft benthos & other	Soft benthos & reeftop	Soft benthos & reeftop & other	Lobster	Other
Fishing ground area (km^2)	21	21.04	n/a	n/a	n/a	n/a	39.09	21.04
Number of fishers (per fishery) [(1)]	11	32	16	16	11	16	48	32
Density of fishers (number of fishers/km^2 fishing ground)	1	2	n/a	n/a	n/a	n/a	1	2
Average annual invertebrate catch (kg/fisher/ year) [(2)]	119.93 (n/a)	383.51 (±192.42)	1726.29 (n/a)	119.43 (n/a)	2466.74 (n/a)	869.52 (n/a)	219.88 (±52.89)	225.25 (±190.02)

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; 'other' refers to octopus, clam and lobster fisheries; [(1)] number of fishers extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only.

Taking into account available figures on the reef surface areas, fisher density is low for any of the fisheries considered to be supported by reef areas. Also, average annual catch rates given for fishers participating in any of the fisheries (Table 5.5) are low. Although area surfaces are unavailable for soft-benthos fisheries, none of the parameters shown in Table 5.5 give any reason to assume that current fishing pressure causes any detrimental effects on resources. However, taking into account the local knowledge of invertebrate fisheries in the other three sites studied and the reported perception that the invertebrate resources in the Laura fishing grounds have declined, these low parameters reflect a low resource status.

5.2.5 Management issues: Laura

Laura has not been included in any fisheries management activity. Given the high population density on Laura, the open-access system, and the high dependency on finfish resources for both subsistence and income, presumably both previous and current fishing pressure is high and requires immediate interventions. Such interventions should include the demarcation and surveillance of marine protected areas in the wider fishing area of Laura and adjacent communities. The College of the Marshall Islands (CMI) has a research station close to Laura, which could initiate co-management planning by college staff, MIMRA, other NGOs and the community. It also seems that awareness is low; action needs to be taken to inform the local population about the urgent need for fisheries management and conservation of resources in both the short- and long-term future.

MIMRA strategies for fisheries management at the national level should give priority to Laura and its fishing grounds. This applies in particular to the Coastal Management Advisory Council (CMAC) that MIMRA endorsed for establishment during the first quarter of the fiscal year 2005. It has been stated that this advisory council would ultimately broaden and institutionalise the former inter-agency committee that assisted with the community-based fisheries management initiative. The former inter-agency committee, which comprised various government agencies, institutions and non-governmental organisations was set up to assist MIMRA with the planning, research and implementation of community projects with local governments. The aim was to improve the sustainable use of coastal marine resources for small-scale economical development and subsistence use. Thus, this former structure for supporting fisheries management in Laura should be used again and immediately made effective.

Fisheries management strategies, together with their implementation and monitoring, will be a challenge due to the open-access system in place and the high population density of the island. However, management could target gear restrictions, the setting of quotas for full-time commercial fishers, and the demarcation of protected areas. The geographical situation of Marshall Islands and Laura calls for an integrated ecosystem approach in order to take into account the limited land resources for agricultural production and the limited alternative income sources in general. In the case of Laura, focus should be given to finding alternative income-generation activities within a semi-urban to urban structure, and to using marine resources mainly for subsistence and controlled commercial purposes only.

5.2.6 Discussion and conclusions: socioeconomics in Laura

The Laura community is large, semi-urban in character and in close proximity to Laura. The community benefits from access to salary-based income but is still dependent on marine resources for both subsistence and income generation. In addition, about one-third of the Laura population benefits from external financial input (remittances) and the basic household expenditure level is high. Fishing is governed by an open-access system and, given the high population density, this results in high fishing pressure and a subsequent decline in resources. This decline was reported by finfish fishers and invertebrate collectors alike. MIMRA and the established CMAC should urgently commence fisheries management for Laura, and establish gear regulations, quota systems and marine protected areas.

In summary:

- Laura's population is highly dependent on marine resources for subsistence and, to some extent, also for income. Salaries are the most important income source, complemented by fishing and other small-business activities. The easy access to the major urban market on Laura, the availability of cars in the community, regular bus transport, local shops that buy fisheries produce, and the presence of agents in the community, all support the view that the current fishing pressure is not likely to decrease unless fisheries regulation or management is put in place.

- The per capita consumption of fresh fish is high; however, invertebrates and canned fish are consumed to a much smaller extent.

- Gender roles call for males to be responsible for all kinds of fishing; any involvement by females in finfish or invertebrate fishing is not expected and is hardly acknowledged or mentioned. In fact, males are responsible for all commercial fishing activities (finfish and invertebrates); the data collected on female invertebrate fishers indicates that they collect only for home consumption.

- Most finfish (by weight) is sourced from the sheltered coastal reef and lagoon, and the lagoon and outer reef. Male fishers targeting the outer reef and the outer reef and passages combined mainly fish for commercial purposes.

- The average annual catches and CPUEs are low, and the CPUEs for fishing the habitats close to shore are higher than those reported for outer-reef and passage fishing.

- Techniques vary according to the habitat targeted and mainly include gillnetting, handlining and spear diving in the sheltered coastal reef and lagoon habitat, and may also include deep-bottom lining if the outer reef and passages are fished. Average fish sizes are smaller than found elsewhere (~25 cm), and reported average fish sizes do not increase with distance from shore for all the families compared.

- Results from the invertebrate fisher surveys show that: people do not target invertebrates as rigorously as found elsewhere; resources are perceived to be depleted; and males mainly dive for clams, octopus and lobster for commercial purposes.

- Half of the reported annual catch of invertebrates (wet weight) is taken for home consumption, and the other half for commercial purposes.

- The parameters calculated for both finfish and invertebrate fisheries suggest that fishing pressure on all resources and habitats is rather low due to the large available reef and overall fishing ground area, the low fisher densities and average annual catch rates, and low catches per unit areas. However, if we consider the open-access system, the high population density and hence the large number of fishers who have access to fish in Laura's fishing grounds, as well as the reported perceptions of resource decline, the previous and current levels of fishing pressure are high and have imposed, and may continue to impose detrimental effects on the resources.

Given the overall situation in Laura, it is recommended that fisheries management in Laura fishing grounds be urgently addressed, including the establishment of protected areas, fishing gear restrictions and quota systems for commercial reef fisheries activities. This objective also includes a programme to raise awareness in the local population, the involvement of governmental, non-governmental and community stakeholders, and a more comprehensive planning approach to include further development of alternative income sources.

5.3 Finfish resource surveys: Laura

Finfish resources and associated habitats were assessed between 4 and 10 September 2007, from a total of 18 transects (6 intermediate-reef, 6 back-reef and 6 outer-reef transects; see Figure 5.19 and Appendix 3.4.1 for transect locations and coordinates respectively).

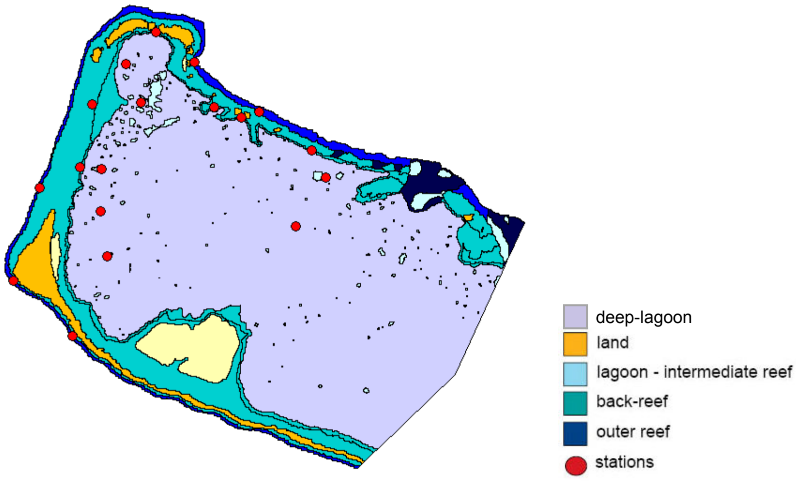

Figure 5.19: Habitat types and transect locations for finfish assessment in Laura.

4.3.1 Finfish assessment results: Laura

A total of 20 families, 56 genera, 162 species and 8920 fish were recorded in the 18 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, 147 species and 7550 individuals.

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

Parameters	Habitat			
	Intermediate reef (1)	**Back-reef (1)**	**Outer reef (1)**	**All reefs (2)**
Number of transects	6	6	6	18
Total habitat area (km^2)	1.9	29.3	5.0	36.2
Depth (m)	9 (1-20) (3)	8 (1-19) (3)	8 (2-11) (3)	8 (1-20) (3)
Soft bottom (% cover)	8 ±2	36 ±7	2 ±1	30
Rubble & boulders (% cover)	8 ±2	17 ±6	3 ±1	14
Hard bottom (% cover)	56 ±7	22 ±9	52 ±10	28
Live coral (% cover)	24 ±8	22 ±4	41 ±11	25
Soft coral (% cover)	0 ±0	0 ±0	0 ±0	0
Biodiversity (species/transect)	39 ±3	30 ±4	47 ±2	38±3
Density (fish/m^2)	0.4 ±0.1	0.4 ±0.1	0.5 ±0.1	0.4
Size (cm FL) (4)	17 ±1	18 ±1	16 ±1	17
Size ratio (%)	54 ±2	53 ±3	52 ±2	53
Biomass (g/m^2)	65.0 ±15.7	73.6 ±27.3	73.9 ±20.9	73.2

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

Finfish resources varied slightly among the three reef environments found in Laura (Table 5.6). The outer reefs displayed the highest values of density, biomass and biodiversity but the lowest size and size ratios, while the back-reefs displayed the lowest density and biodiversity and the intermediate reefs the smallest biomass and highest size ratio among the three habitats.

Intermediate-reef environment: Laura

The intermediate-reef environment of Laura was strongly dominated by one family of herbivores: Acanthuridae (Figure 5.20) and, to a lesser extent, by Scaridae and, only for biomass, by Lutjanidae. These three families were represented by 23 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus nigricauda*, *Lutjanus gibbus*, *Chlorurus sordidus*, *A. lineatus*, *A. nigricans*, *A. blochii*, *L. monostigma* and *L. fulvus* (Table 5.7). This reef environment presented a large surface covered by hard bottom (56%), good live-coral cover (24%) and very little soft bottom (Table 5.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.137 ±0.047	10.9 ±4.2
	Acanthurus nigricauda	Epaulette surgeonfish	0.011 ±0.010	8.1 ±8.0
	Acanthurus lineatus	Lined surgeonfish	0.016 ±0.016	3.6 ±3.6
	Acanthurus nigricans	Whitecheek surgeonfish	0.028 ±0.016	2.8 ±1.9
	Acanthurus blochii	Ringtail surgeonfish	0.004 ±0.003	2.5 ±2.5
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.008 ±0.008	5.1 ±4.9
	Lutjanus monostigma	Onespot snapper	0.003 ±0.003	2.1 ±1.7
	Lutjanus fulvus	Flametail snapper	0.005 ±0.005	2.1 ±2.1
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.038 ±0.008	4.2 ±0.6

The density of finfish in the intermediate reefs of Laura was the second-lowest (0.4 fish/m^2), only slightly higher than in the back-reefs. Biomass was, however, the lowest of the three habitats (65 g/m^2). Biodiversity (39 species/transect) and size (17 cm FL) were intermediate between the two other habitats, while size ratio was the highest of the three (54%). When compared to the other country sites, Laura values of density and biomass were lower only than the Arno values. Biodiversity, comparable to Arno, was lower only than in the Ailuk intermediate reefs. Size ratio, the highest at the site, was also the highest among the four atolls. Herbivores heavily dominated the trophic structure, due to the extremely high abundance of Acanthuridae. Carnivores, mainly Lutjanidae, were present in small numbers and contributed a minor share of the biomass composition of the fish community. Size ratios were particularly low for Scaridae (37%) and Serranidae (41%), suggesting an impact from fishing. Serranidae were, in fact, highly targeted by fishers. The substrate was dominated by hard bottom and live coral, with little cover of rubble and soft bottom (Mullidae and Lethrinidae). Families usually associated with soft bottom were, therefore, almost nonexistent, while the dominance of hard bottom may explain, at least partially, the dominance of surgeonfish.

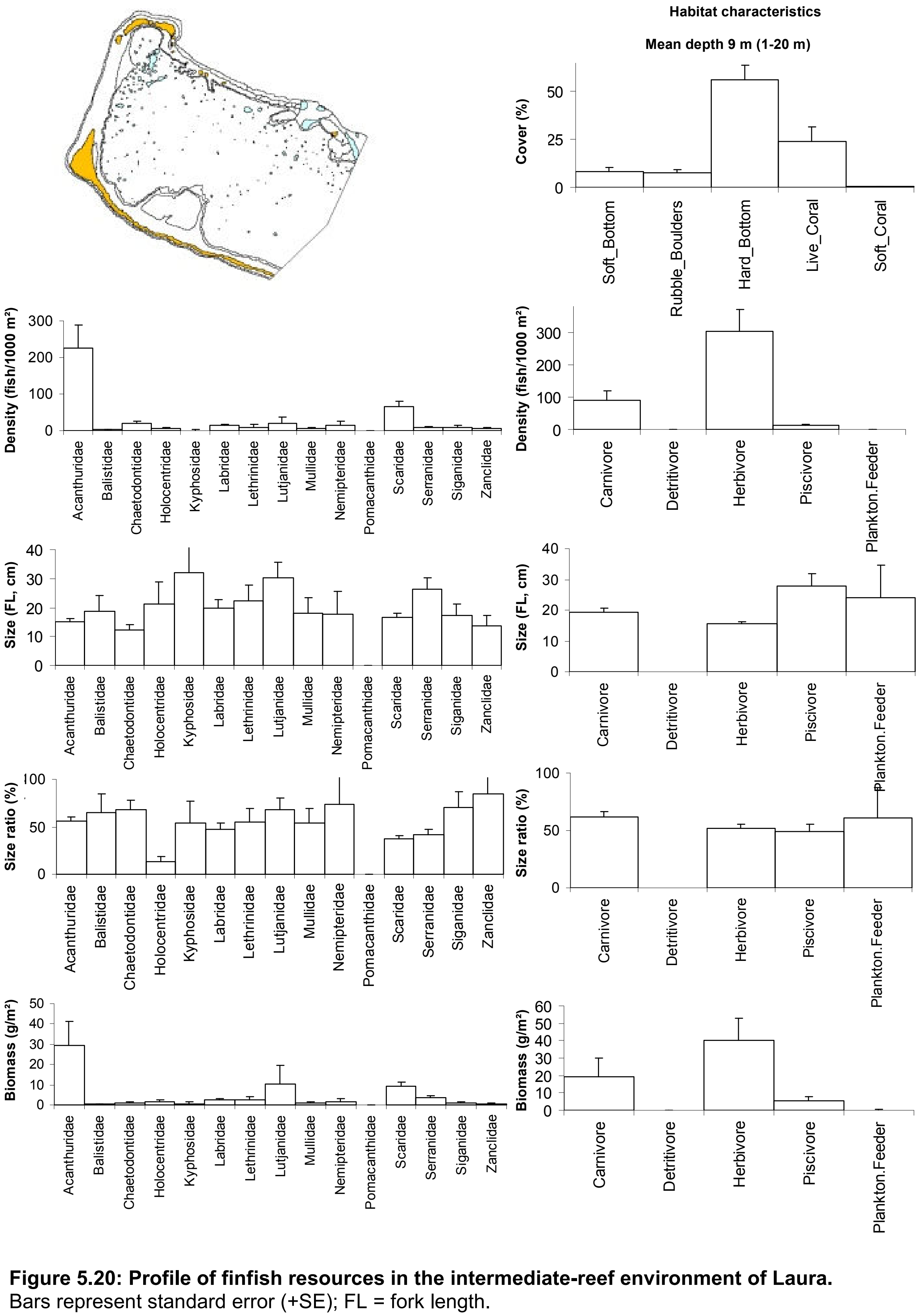

Figure 5.20: Profile of finfish resources in the intermediate-reef environment of Laura.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Laura

The back-reef environment of Laura was dominated by two families of herbivores: Acanthuridae and Scaridae and, to a lesser extent, and only in terms of biomass, by Lethrinidae and Mullidae (Figure 5.21). These four major families were represented by 27 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Naso unicornis*, *Monotaxis grandoculis*, *Parupeneus barberinus*, *Chlorurus sordidus*, *Acanthurus nigricauda* and *Lethrinus xanthochilus* (Table 5.8). This reef environment presented a substrate composition dominated by soft bottom (36% of total reef surface), and with a similar composition of hard bottom and live coral (22% each) with a small amount of rubble (17%, Table 5.6 and Figure 5.21).

Table 5.8: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Laura

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.071 ±0.026	8.6 ±3.7
	Naso unicornis	Bluespine unicornfish	0.009 ±0.008	7.0 ±6.4
	Acanthurus nigricauda	Epaulette surgeonfish	0.005 ±0.003	2.6 ±1.8
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.016 ±0.012	7.0 ±5.3
	Lethrinus xanthochilus	Yellowlip emperor	0.003 ±0.003	2.2 ±2.2
Mullidae	*Parupeneus barberinus*	Dash-and-dot goatfish	0.008 ±0.003	3.7 ±2.2

The density of finfish in the back-reef of Laura was the lowest at the site (0.37 fish/m^2). Average size was, however, the largest (18 cm FL); therefore, the biomass was similar to the top value, recorded at the outer reefs (74 g/m^2). Biodiversity was the lowest of the site. When comparing these results to parameters recorded in the other three back-reefs in the country, the Laura back-reefs showed the highest density and size but the second-highest biomass (surpassed only by Arno) and a biodiversity lower than both values in Likiep and Ailuk, but higher than in Arno. Size ratio was slightly lower than 50% for Lutjanidae, Scaridae and Serranidae, probably a first sign of impact from fishing. Trophic composition was dominated by herbivores in terms of density, while total biomass was equally composed of herbivores and carnivores. Carnivores were essentially represented by Lethrinidae and Mullidae, for which the habitat here with a good amount of soft bottom (36%) was ideal. The abundance of certain species of Acanthuridae, such as *A. nigricauda*, was also related to the large amount of soft-bottom cover.

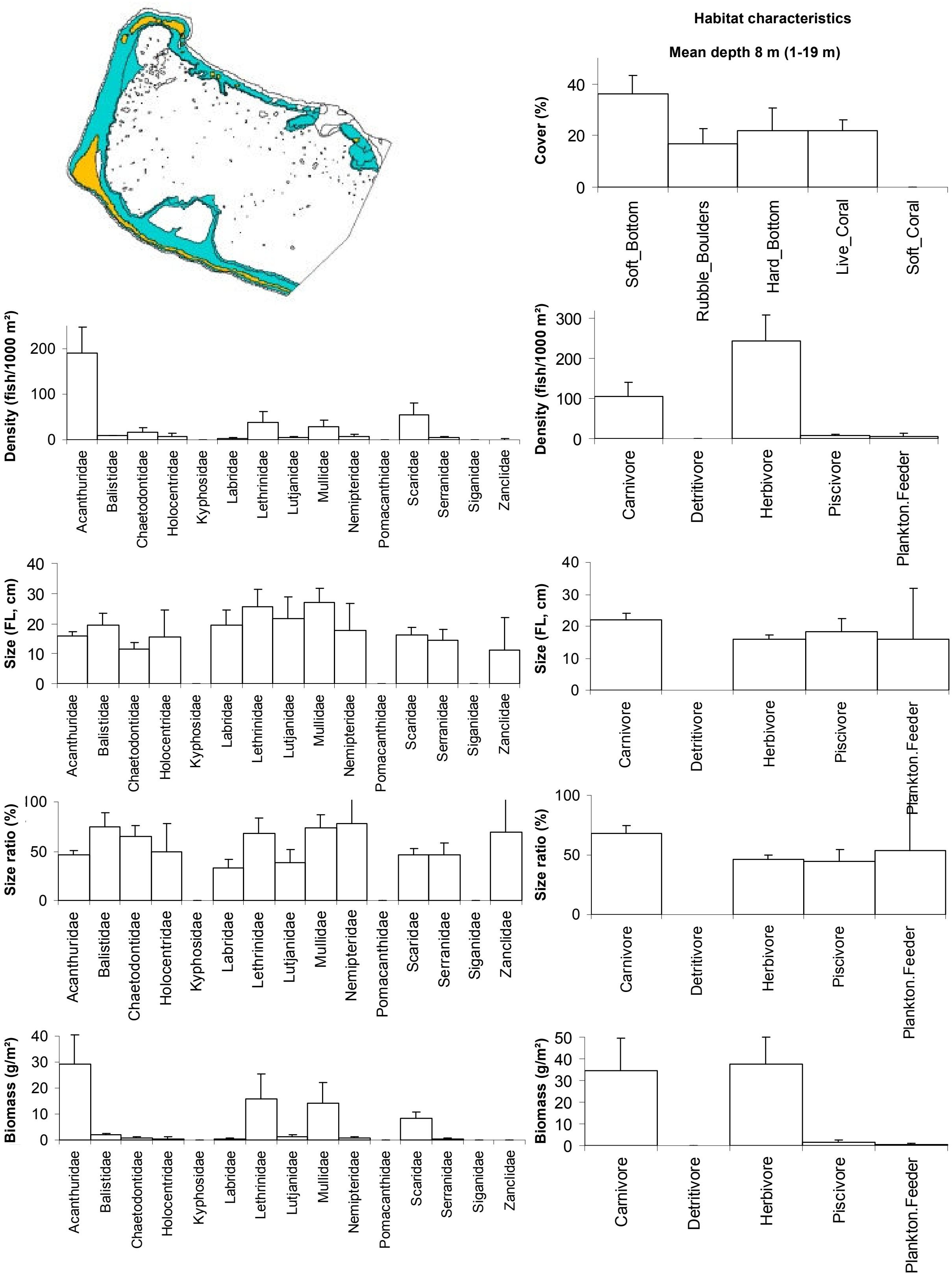

Figure 5.21: Profile of finfish resources in the back-reef environment of Laura.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Laura

The outer-reef environment of Laura was dominated by two families of herbivores, Acanthuridae and Scaridae, in terms of density and biomass (Figure 5.22) and by Lutjanidae and Lethrinidae in terms of biomass only. These four major families were represented by 28 species; particularly high biomass and abundance were recorded for *Scarus niger*, *Ctenochaetus striatus*, *Acanthurus nigricans*, *Lutjanus gibbus*, *Chlorurus sordidus*, *Lutjanus fulvus*, *Monotaxis grandoculis* and *Gnathodentex aureolineatus* (Table 5.9). This reef environment presented a substrate composition dominated by hard bottom (52%), high coral cover (41%), and little soft bottom and rubble (5%, Table 5.6 and Figure 5.23).

Table 5.9: Finfish species contributing most to main families in terms of densities and biomass in the outer-reef environment of Laura

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.179 ±0.049	11.3 ±2.9
	Acanthurus nigricans	Whitecheek surgeonfish	0.114 ±0.030	8.0 ±2.4
Scaridae	*Scarus niger*	Black parrotfish	0.017 ±0.017	12.9 ±12.7
	Chlorurus sordidus	Daisy parrotfish	0.029 ±0.008	3.6 ±1.6
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.014 ±0.009	5.3 ±3.3
	Lutjanus fulvus	Flametail snapper	0.011 ±0.009	3.5 ±2.7
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.008 ±0.004	3.4 ±1.6
	Gnathodentex aureolineatus	Goldlined seabream	0.017 ±0.017	1.8 ±1.8

The density, biomass and biodiversity of finfish in the outer reef of Laura were the highest of the values at the site habitats. However, size and size ratio were the lowest. When comparing these values to values recorded in the other three country outer reefs, Laura showed the highest density, but the second-lowest biomass (below Likiep and Arno values), the second-lowest size and the lowest size ratio. Holocentridae, Mullidae and Scaridae displayed very low size ratios, indicating a probable impact from fishing. Trophic composition was dominated by herbivores in both density and biomass. Carnivores were essentially represented by Lethrinidae and Lutjanidae. The habitat was dominated by hard bottom and live coral, which normally favours Acanthuridae and Scaridae among the herbivores and Lutjanidae and Serranidae among the carnivores. However, Serranidae were almost absent but, at the same time, they represented one of the most commonly fished families. Their absence appears to be a signal of a declining resource.

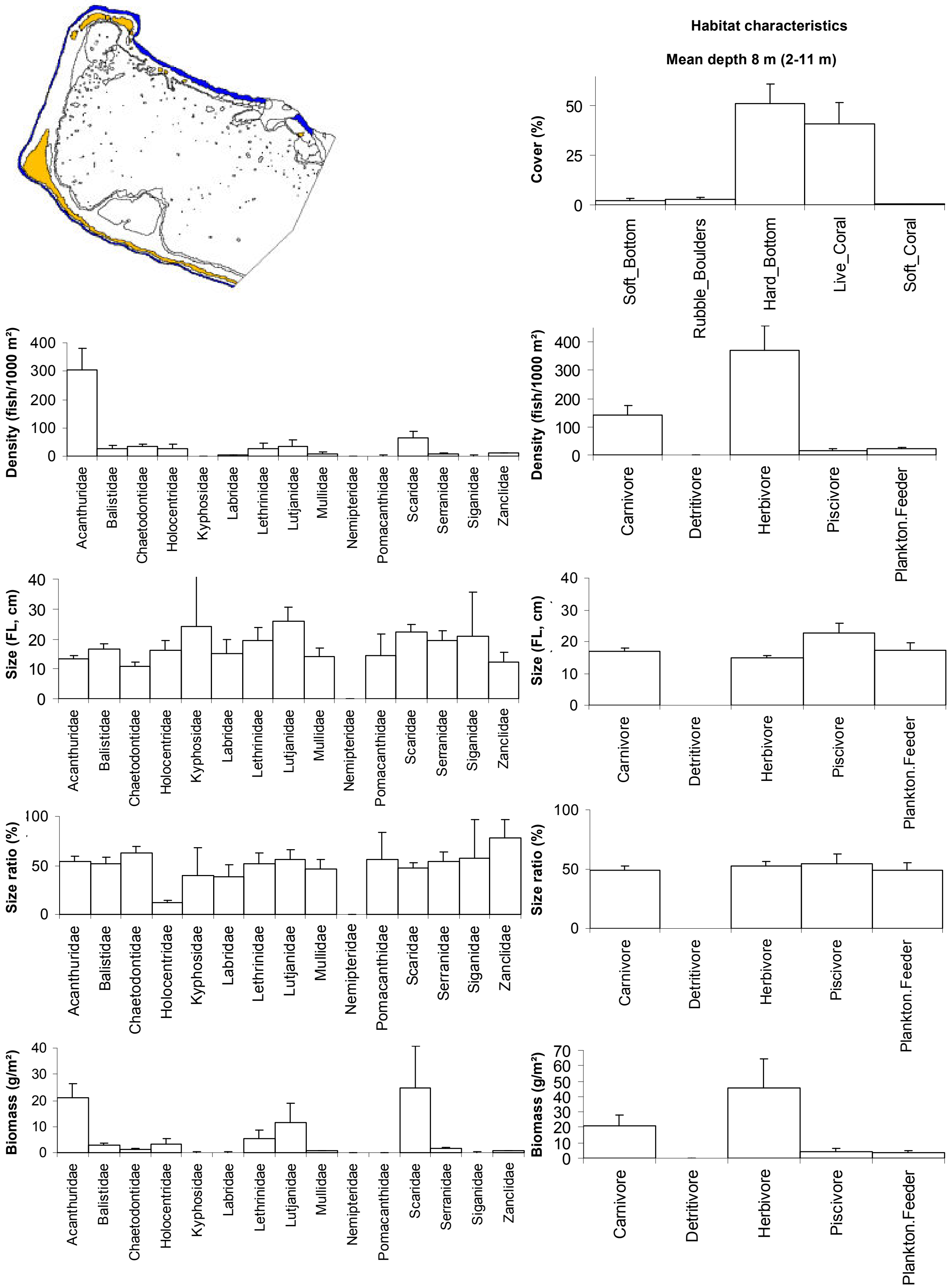

Figure 5.22: Profile of finfish resources in the outer-reef environment of Laura.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Laura

Overall, the fish assemblage of Laura was dominated by the herbivores Acanthuridae and Scaridae and, only in terms of biomass, by the carnivores Lethrinidae and Lutjanidae (Figure 5.23). These four major families were represented by a total of 47 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Parupeneus indicus*, *Gnathodentex aureolineatus*, *Lethrinus harak*, *Monotaxis grandoculis*, *Naso brevirostris*, *Chlorurus microrhinos*, *Parupeneus barberinus*, *Acanthurus nigricans*, *A. blochii* and *C. sordidus* (Table 5.10). The average substrate was dominated by hard bottom (40%), and composed of a smaller proportion of soft bottom and rubble (31%) and a good but not exceptional cover of live coral (24%). The overall fish assemblage in Laura shared characteristics of primarily back-reefs (81% of total habitat), then outer reefs (14%) and, only to a very small extent, intermediate reefs (5%).

Table 5.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Arno (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.125	9.4
	Naso brevirostris	Spotted unicornfish	0.012	2.7
	Acanthurus nigricans	Whitecheek surgeonfish	0.028	2.1
	Acanthurus blochii	Ringtail surgeonfish	0.006	1.9
Lethrinidae	*Gnathodentex aureolineatus*	Goldlined seabream	0.021	7.2
	Lethrinus harak	Thumbprint emperor	0.006	3.6
	Monotaxis grandoculis	Bigeye bream	0.008	2.8
Mullidae	*Parupeneus indicus*	Indian goatfish	0.012	7.5
	Parupeneus barberinus	Dash-and-dot goatfish	0.005	2.5
Scaridae	*Chlorurus microrhinos*	Steephead parrotfish	0.003	2.7
	Chlorurus sordidus	Daisy parrotfish	0.019	1.9

Overall, Laura appeared to support an average-to-poor finfish resource with the highest density, size, size ratio and biomass among the highest values of the four atolls, but biodiversity only higher than the values at Arno. However, when compared to the regional averages these values were low, placing Laura towards the mid-to-low end of the range for density, biomass and biodiversity. A detailed assessment at the trophic and family level revealed a clear dominance of herbivores over carnivores in terms of density but a comparative contribution of both carnivores and herbivores in terms of biomass. The representation of carnivores in the biomass composition was mainly due to Lethrinidae and Mullidae. Holocentridae, Lutjanidae, Scaridae and Serranidae displayed small size ratios (below 45% of their maximum sizes), probably suggesting an impact from fishing. Lutjanidae, Serranidae and Scaridae composed the majority of catches from both the lagoon and outer reefs. The composition of the habitat was rather complex, including hard bottom, live coral and soft bottom in similar proportions, reflecting the conditions at the back-reef.

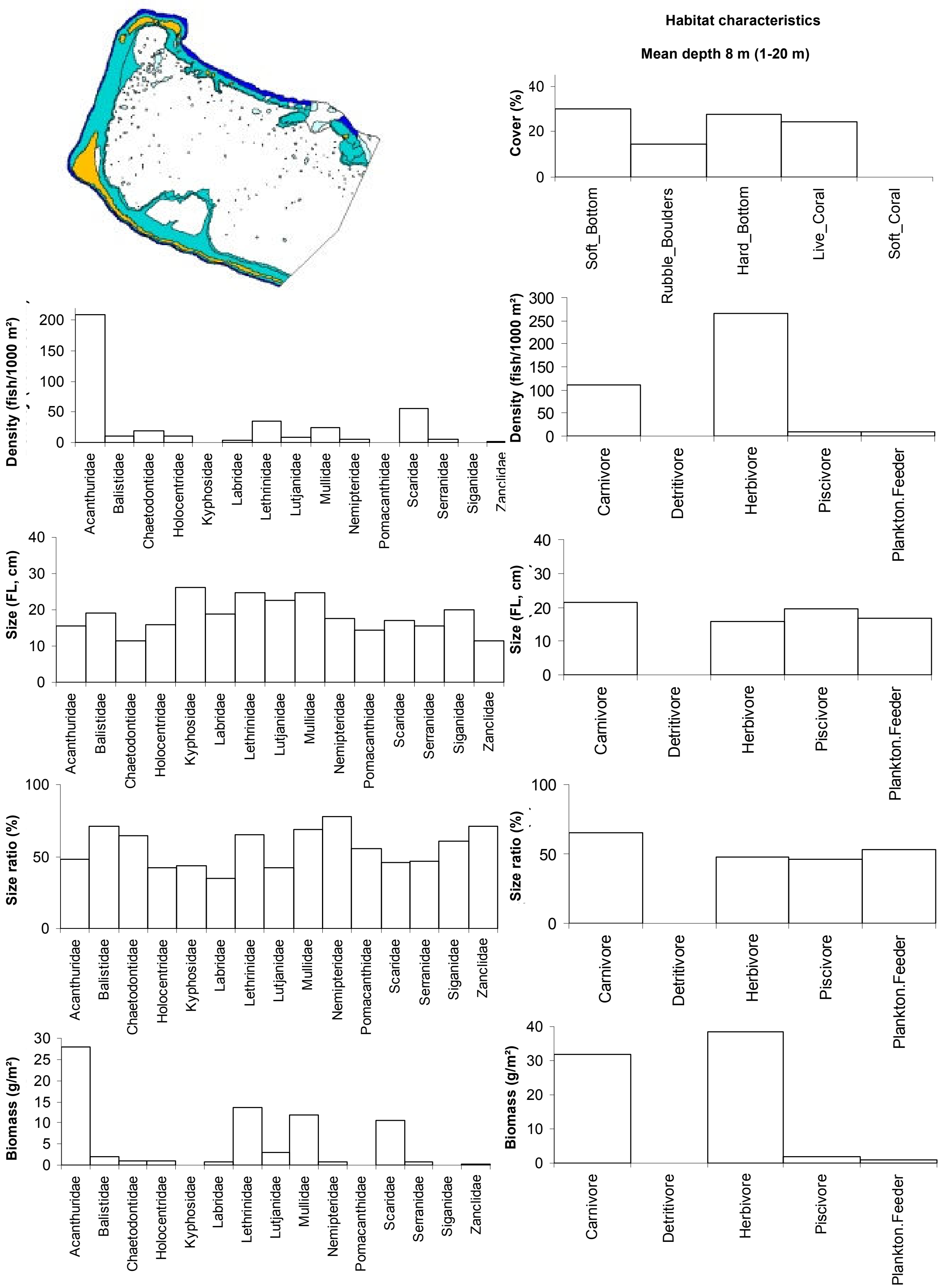

Figure 5.23: Profile of finfish resources in the combined reef habitats of Laura (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Laura

The assessment indicated that the status of finfish resources in Laura was rather meagre. The habitat was not rich everywhere and fish resources were scarce, displaying parameters lower than the regional average although comparable to the other three country sites.

- Corals were less abundant compared to corals in the other sites, especially in the lagoon and back-reef; they were slightly more abundant on the outer reefs but still less than in Likiep and Arno.

- Fish density, biomass and size were comparable to values in the other country sites, but biodiversity was low and comparable to the low value from Arno. However, these values ranked average-to-low in the regional range.

  Moreover,

  - The finfish community was everywhere dominated by herbivores. Only in the back-reefs was biomass composed almost equally of herbivores and carnivores. The general numerical dominance of herbivores, especially Acanthuridae and Scaridae, could not simply be explained by the type of environment, since even in the habitats dominated by hard bottom, such as the outer and intermediate reefs, carnivores such as Serranidae and Lutjanidae and some Lethrinidae were lacking. Fishing may be a contributing factor to the poverty of the fish community, and especially to the shortage of large carnivores (Serranidae, Lutjanidae, Lethrinidae and Labridae). At this site, fishing was mostly concentrated on Lethrinidae, Serranidae and Lutjanidae, and mainly carried out in the intermediate reefs.

  - Apex predators were rare and sharks were less abundant than at the other atolls (a total of eight sharks were sighted during surveys in Laura compared to 41 in Likiep, 17 in Arno, and 48 in Ailuk). Average sizes were rather small, especially in the outer reefs, and large-sized fish were almost absent. Size ratios of carnivores (Serranidae, Lutjanidae and Holocentridae) were low.

  - Fish were rather wary and distant from divers, which suggests an overuse of spear diving.

When analysed at the reef habitat level, the resources displayed some disparities, although the variability was lower than at the other sites.

- At the intermediate reefs the coral coverage was slightly better than at the back-reef, but lower than at Ailuk and Likiep, and dominated by digitate, submassive, table and branching corals with local high coral coverage (40–60%). In some stations, dead table corals covered with algae were very frequent, suggesting that there may have been massive bleaching of these forms in this area a few years ago. The back-reef system of Laura displayed a low live-coral cover (22%) compared to the back-reefs at the other sites, and was dominated by submassive and massive corals. Soft bottom was present in a good amount (36%). The outer reef of Laura had a much richer live-coral coverage (41%), with some areas showing high peaks of percentage cover (80–100%). Tabulate corals were very common in the west, close to Rongorong Island. For the remaining stations, massive and submassive corals were dominant, with patches of digitate, foliose and branching corals.

The finfish resources also displayed disparities among the habitats, especially in terms of community composition:

- At the intermediate reefs a school of snappers (*Lutjanus gibbus* and *L. bohar*) was observed along with juvenile coral trouts (*Plectropomus laevis* and *P. areolatus*). A few groupers (*Epinephelus polyphekadion*) were observed in some of the stations. However, overall, the abundance and biomass of Serranidae and Lutjanidae were low. Moreover, this habitat, highly exploited in terms of fisheries and mainly for commercial purposes, showed signs of impact as the small size ratios of some families, particularly Holocentridae, Scaridae and Serranidae. Density and biomass displayed the lowest values of this site.

- In the back-reefs, finfish populations, numerically dominated by Acanthuridae, were also composed of fish species associated with rubble and sand, such as Lethrinidae (emperors) and Mullidae (goatfish) due to the high percentage of soft bottom (36%); schools of *Mulloidichthys vanicolensis* were observed in almost all stations. Larger fish were quite wary of divers, which may indicate that spear fishing and human disturbances were high.

- Finfish resources in the outer-reef system of Laura were dominated by Acanthuridae in numbers (*Ctenochaetus striatus* and *A. nigricans*) and Scaridae in biomass. Large *Cheilinus undulatus* (70–80 cm) were observed at several stations.

These observations, along with the overall analysis of the data collected, suggest that Laura can be considered as a fairly impacted site.

5.4 Invertebrate resource surveys: Laura

The diversity and abundance of invertebrate species at Laura were independently determined using a range of survey techniques (Table 5.11), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 5.24) and finer-scale assessment of specific reef and benthic habitats (Figures 5.25 and 5.26).

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

Table 5.11: Number of stations and replicates completed at Laura

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	22	132 transects
Soft-benthos transects (SBt)	1	6 transects
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches (RFs)	4	24 search periods
Reef-front search by walking (RFs_w)	0	0 search period
Sea cucumber day searches (Ds)	3	18 search periods
Sea cucumber night searches (Ns)	0	0 search period

Figure 5.24: Broad-scale survey stations for invertebrates in Laura.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 5.25: Fine-scale reef-benthos transect survey stations in Laura.
Black circles: reef-benthos transect stations (RBt).

Figure 5.26: Fine-scale survey stations for invertebrates in Laura.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey stars: sea cucumber day search stations (Ds);
grey circles: sea cucumber night search stations (Ns).

Forty-seven species or species groupings (groups of species within a genus) were recorded in the Laura invertebrate surveys. These included 5 bivalves, 21 gastropods, 8 sea cucumbers, 4 urchins, 4 sea stars, 1 cnidarian and 2 lobsters (Appendix 4.4.1). Information on key families and species is detailed below.

5.4.1 Giant clams: Laura

The site surveyed at Laura covers roughly the western half of Laura atoll. Shallow-reef habitat that is suitable for giant clams within the atoll and on the outer slope was quite extensive (31.3 km^2); however, for the relatively large lagoon (The atoll is ~40 km long and 12 km wide, with a total area of 318 km^2.), shallow reef was not always common along shorelines and within the lagoon (inner shoreline and intermediate reef only ~21 km^2). There were large areas of sandy benthos and limestone platforms of flat pavement (without life), as well as some reeftops that were partially exposed, which limited the amount of suitable reef benthos across the atoll. The inner part of the lagoon was rather deep, with few intermediate reefs and pinnacles. Outside the lagoon and around the passages, more exposed reef of the barrier-reef front and reef slope (10.3 km^2) supported more live coral.

As in most atolls, nutrient inputs from low-lying land were limited at Laura and, in general, the system appeared to be nutrient-poor in areas close to the settlements. As in the neighbouring atoll of Arno, the main passages were situated at the northern central part of the atoll, facing the prevailing winds. This part of the lagoon has the most dynamic water flow, whereas the more protected areas (due to the continuous land in the south and southwest) have the lowest water circulation with more depositional conditions.

Broad-scale sampling provided an overview of giant clam distribution at Laura. Reefs at this site held three species of giant clams: the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa* and the horse-hoof or bear's paw clam *Hippopus hippopus*. The true giant clam (*T. gigas*), which occurs in Marshall Islands, was not noted in these surveys. Records from broad-scale sampling revealed that *T. maxima* had the widest distribution (found in 11 of 12 stations and 32 of 72 transects), followed by *H. hippopus* (in 10 stations and 15 transects) and then *T. squamosa* (7 stations and 10 transects).

The average station density in broad-scale assessments was 30.0 /ha ±7.8 for *T. maxima*, 4.1 /ha ±1.0 for *H. hippopus* and 2.3 /ha ±0.7 for *T. squamosa* (Figure 5.27).

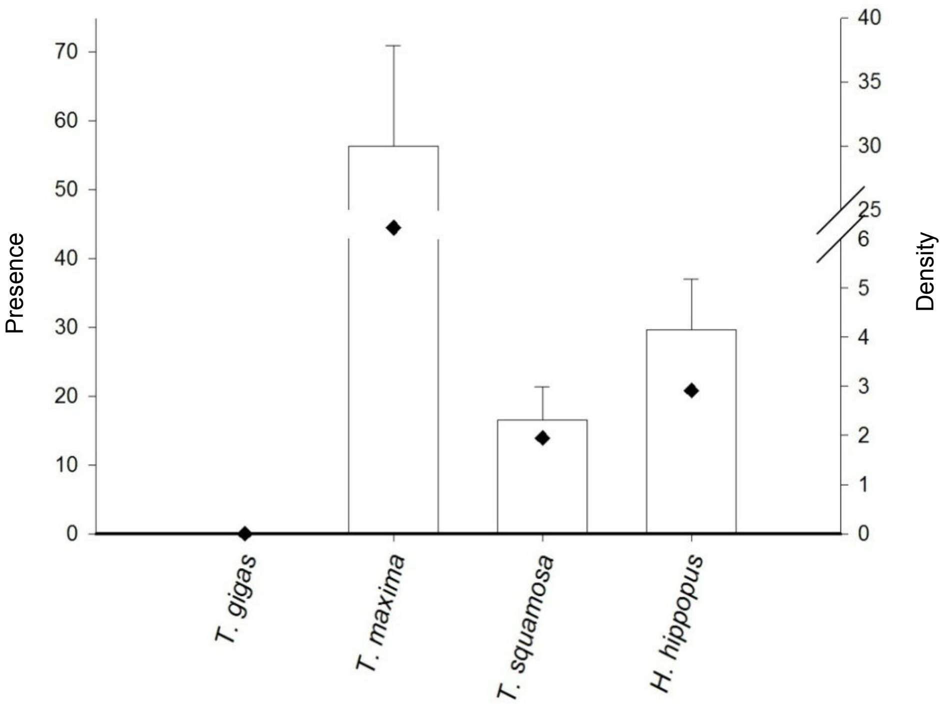

Figure 5.27: Presence and mean density of giant clam species at Laura based on broad-scale survey.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

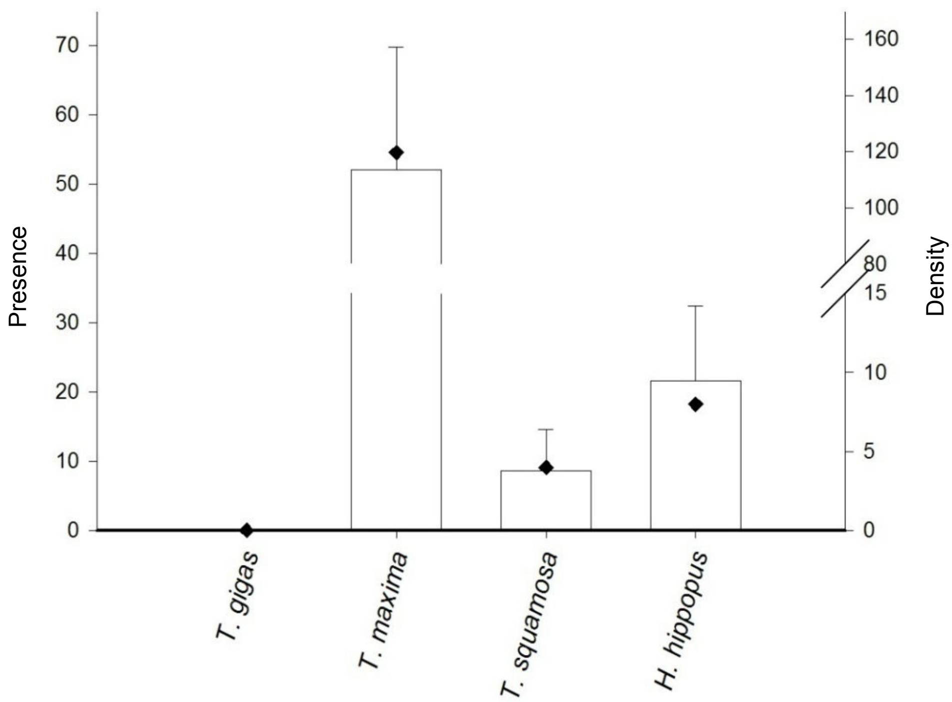

Figure 5.28: Presence and mean density of giant clam species at Laura based on reef-benthos transect assessments.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Based on the findings of the broad-scale survey, finer-scale surveys targeted specific areas of clam habitat (Figure 5.28). In these reef-benthos assessments (RBt), *T. maxima* was present in 55% of stations at a mean density of 113.6 /ha ±43.5, far below the 583.3 /ha ± 126.4 average recorded at the neighbouring island of Arno.

The highest densities for *T. maxima* were recorded on the northern reef and on the outer slope west of the site. The maximum density recorded on one RBt station reached 833.3 specimen/ha. Across the site, the *T. maxima* resource was relatively depleted, especially in areas close to human settlements. *H. hippopus* was sparsely distributed, with most of the specimens found on the inner side of the back-reef north and west of the site. The population of the cryptic *T. squamosa* was sparsely distributed, mostly on the inner side of the back-reef, to the north of the site.

Of the 219 *T. maxima* recorded during all assessment techniques, 129 were measured and had an average length of 10.4 cm ±0.3. *T. squamosa* and *H. hippopus* had an average size of 18.9 cm ±3.1 (n = 11) and 20.2 cm ±1.7 (n = 16) respectively. A full range of lengths was recorded for all three clam species; however, the largest *T. maxima* were, in general, small, and the larger size classes for this species were not well represented. *T. maxima* clams larger than 16 cm comprised only 7% of the measured stock. Despite the rather small number of *H. hippopus* recorded, the population size profile seemed quite healthy, with a large range of sizes recorded (from juvenile to large adults). The scarcity of *T. squamosa*, evident from the low numbers of clams noted, did not seem to limit reproduction given the percentage of juveniles recorded (Figure 5.29). This species can be found at depths ≥20 m and it is possible that reproduction from some deeper-water areas is sustaining the population at this time.

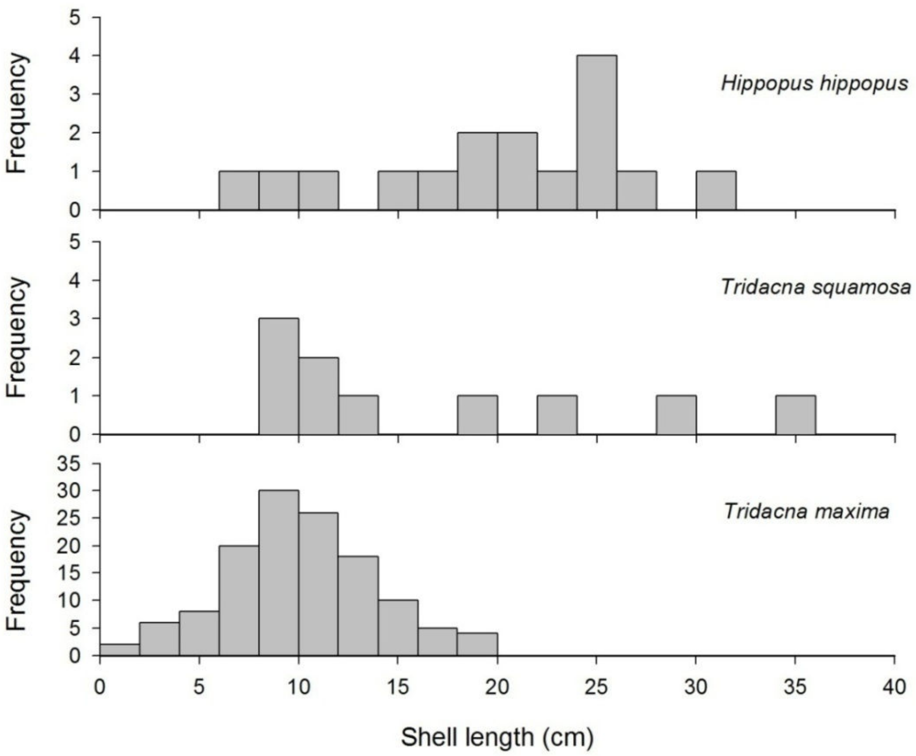

Figure 5.29: Size frequency histograms of giant clam shell length (cm) for Laura.

5.4.2 Mother-of-pearl species (MOP) – trochus and pearl oysters: Laura

The commercial topshell, *Trochus niloticus*, was introduced into RMI by the Japanese during the 1930s, with introductions to Jaluit, Laura, Ailinglaplap and apparently also Ailuk, Kwajalein and Enewetak (Asano and Inenami 1939, McGowan 1958 cited in Wright *et al.* 1989).

Figure 5.30: *Trochus niloticus* abundance (numbers of shell) at sites across Laura.

Logistic problems and rough seas prevented a complete assessment of the trochus resource. The survey team was unable to cover the outer reef of the north shore and could only assess the western and southern outer slope for half a day. Therefore, the observations are mostly based on the assessment of the inner reefs and back-reefs.

Across the site, the habitat was suitable for trochus, especially on the outer slope of the western reef, where a few trochus were recorded while free-diving. The steeper slope in the west and south does not provide a very suitable or extensive habitat, while the northern shoal has a more complex habitat, which is more suitable for these grazing gastropods. As mentioned earlier, part of the site could not be accessed but, from the similar reef structure observed on the neighbouring island of Arno, it is suggested that this would provide better habitat for trochus, as a more gentle slope and a large back-reef provides both substrate and food for adult and juvenile trochus (Figure 5.30).

Table 5.13: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Laura
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
Pinctada margaritifera				
B-S	2.8	1.9	4/12 = 25	4/72 = 6
RBt	1.9	1.9	1/22 = 5	1/132 =1
RFs	0	0	0/4 = 0	0/24 = 0
Tectus pyramis				
B-S	0.2	0.2	1/12 = 8	1/72 = 1
RBt	0	0	0/22 = 0	0/132 = 0
RFs	4.9	2.4	2/4 = 50	4/24 = 17
Trochus niloticus				
B-S	2.1	0.7	4/12 = 33	8/72 = 11
RBt	49.2	13.8	7/22 = 32	16/132 = 12
RFs	14.7	4.4	3/4 = 75	9/24 =38

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

Despite the limited number found (n = 50), trochus were well distributed across the site, even in the calm, shallow, south section of the lagoon (Figure 5.31). Several RBt stations surveyed in the back-reef area revealed an unusual number of juvenile trochus, which represents promising recruitment for the coming years. In one particular RBt station surveyed on the back-reef south of the northern islet, density reached 417 ±123.6 specimens/ha, with the size of 10 individuals averaging 4.4 cm ±0.4. Overall, a lower average density was recorded for all RBt stations (49.2 /ha ±13.8), showing that the reefs inside the lagoon did not hold a fishable stock, based on the recommended minimum threshold of 500–600 /ha before fishing can be considered.

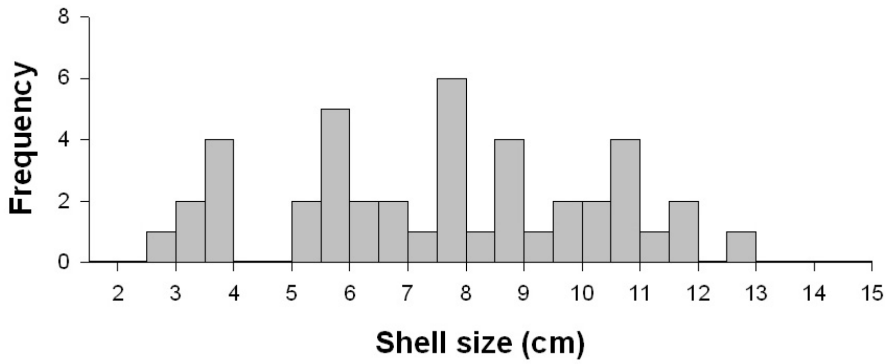

Figure 5.31: Size frequency histogram of trochus (*Trochus niloticus*) shell base diameter (cm) for Laura.

From the 50 specimens recorded, 43 basal widths were measured and the recorded sizes ranged from 2.9 to 12.8 cm, with an average of 7.7 cm ±0.4. This size record includes almost all sizes, from juvenile to large, mature adults, and shows that the trochus population, even though not at high density in the lagoon, has ongoing successful spawning and settlement.

Tectus pyramis, an algal-grazing gastropod with a similar life history to trochus, was rare and at low density at Laura (n = 6 recorded in survey). The mean size (basal width) was 6.4 cm ±0.5.

Blacklip pearl oysters, *Pinctada margaritifera*, a normally cryptic and sparsely distributed oyster in open-lagoon systems, were not uncommon in Laura. This atoll lagoon was relatively enclosed despite the large northern passages, and thirteen blacklip pearl oysters were noted in survey (mean shell height: 10.9 cm ±5.1).

5.4.3 Infaunal species and groups: Laura

Only a single, fine-scale soft-benthos survey and no infaunal stations (quadrat surveys) were made at Laura. The soft-benthos coastal margin of the shallow-water lagoon was mostly sandy without extensive areas of seagrass with the exception of a pool, east of Laura village. This pool did have good seagrass cover but was too deep for standard assessment and had no concentrations of in-ground resources (shell 'beds'), such as arc shells (*Anadara* spp.) or venus shells (*Gafrarium* spp.).

5.4.4 Other gastropods and bivalves: Laura

The edible common spider conch (*Lambis lambis*) was commonly found inside the lagoon (n = 24) and was at low-to-moderate density in RBt stations (26.5 /ha ±10.8). The larger Seba's spider conch (*L. truncata*) was also recorded but was at low density inside the lagoon (n = 3 individuals). Eleven *L. chiragra* specimens were noted.

The edible strawberry or red lipped conch (*Strombus luhuanus*) was commonly noted (n = 92). It was recorded at 32% of the RBt stations, reaching a density of 1125 /ha ±1125 at one station (Appendices 4.4.1 to 4.4.7).

One species of turban shell, the edible silver-mouthed turban (*Turbo argyrostomus*), was recorded during surveys. It was present in 18% of the RBt stations at the low average density of 13.3 /ha ±6.9. It was also recorded on RFs at low density (2.9 /ha ±2.9).

Other resource species targeted by fishers (e.g. *Astralium*, *Chicoreus*, *Conus*, *Cypraea*, *Mitra*, *Thais* and *Vasum*) were also recorded during independent surveys (Appendices 4.4.1 to 4.4.7). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Beguina* spp. and *Spondylus* spp. are also in Appendices 4.4.1 to 4.4.7. No creel surveys were conducted at Laura.

5.4.5 Lobsters: Laura

The site surveyed at Laura had 39.1 km (lineal distance) of exposed reef front (barrier reef). This exposed reef, with passages and areas of submerged back-reef, represents a large amount of habitat for lobsters.

There was no dedicated night reef-front assessment of lobsters (See Methods.), but two lobster species (the pronghorn spiny lobster, *Panulirus penicillatus* (n = 1), and the painted spiny lobster, *P. versicolor* (n = 1)), were recorded in other surveys. No sand lobsters (*Lysiosquillina maculata*) were noted, but mud lobsters (*Thalassina* spp.) were commonly recorded (n = 28).

5.4.6 Sea cucumbers[9]: Laura

Laura has an extensive shallow lagoon system (317.7 km²), which is surrounded by low-lying *motu* (sand islands – around 16 km² total land area). 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, rubble and limestone pavement, with no noticeable inputs of nutrients or epiphytic growth that could support large populations of sea cucumbers, other than directly in front of the main settlements (Sea cucumber species eat organic matter and detritus in the upper few mm of bottom substrates.).

In general, the system was predominantly oceanic-influenced. Outside the barrier reef, the reef slope was impacted by large swells in the north and even in the west and south the reef slope was not extensive as it shelved off relatively steeply into deeper water.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Table 5.14, Appendices 4.4.2 to 4.4.6; also see Methods). At Laura, seven commercial species of sea cucumber were recorded during in-water assessments, plus one indicator species (Table 5.14). This is a similar amount to that recorded in the other atoll CoFish sites in Marshall Islands. The range of sea cucumber species recorded in Laura reflected the isolated and easterly position of these dispersed atolls and the largely exposed, oceanic-influenced nature of the habitats present.

Sea cucumber species associated with shallow-reef areas, e.g. leopardfish (*Bohadschia argus*), were not common (found in 14% of broad-scale transects and 4% of RBt stations) and were at low average density (3.2 /ha ±1.2 in B-S survey and 3.8 /ha ±2.6 in RBt survey).

Black teatfish (*Holothuria nobilis*), a high-value sea cucumber that is commonly found in shallow water and is highly susceptible to fishing pressure, was rarely recorded (n = 5 individuals) and was at low average density (0.9 /ha ±0.6) in broad-scale surveys. The average density was similarly low (0.9 /ha ±0.9) in shallow-water on RBt surveys.

Sea cucumber species associated with reef crests, such as the medium-value surf redfish (*Actinopyga mauritiana*), were also not common (n = 7 individuals noted) and occurred at low density (average of 4.9 /ha ±4.9 at RFs stations), despite the suitability of the pools, reef platform and reef slope at Laura. This species has been recorded at commercial densities of 500–600 /ha in other oceanic-influenced and atoll islands in French Polynesia, Cook Islands and Tonga.

The fast-growing and medium/high-value greenfish (*Stichopus chloronotus*) was not recorded in Marshall Islands and, since it was absent from all the four CoFish sites, it may be absent from the whole country.

More protected areas of reef and soft benthos at embayments in the lagoon were not very influenced by land (no river inputs) and the habitat did not reflect the high-island systems found in regions such as Melanesia. No blackfish (*Actinopyga miliaris*), stonefish

[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.

(*A. lecanora*), elephant trunkfish (*Holothuria fuscopunctata*) or curryfish (*Stichopus hermanni*) were recorded.

Lower-value species, e.g. pinkfish (*Holothuria edulis*) were noted at low densities, while lollyfish (*H. atra*) was recorded at moderate-to-high densities (174.4 /ha ±37.6 on B-S stations, 4500 /ha ±3626 on RBt stations and 65,250 /ha on SBt stations). The single SBt station was made on the main seagrass bed, just east of Laura village, where the species was very abundant (n = 1566 individuals noted).

Deep-water assessments (18 searches of 5 mins, average depth 20.8 m, max depth 29 m) were completed to obtain a preliminary abundance estimate for white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*), amberfish (*T. anax*) and partially for elephant trunkfish (*H. fuscopunctata*). Oceanic-influenced lagoon benthos near the passages had suitably dynamic water movement for these species.

The high-value *H. fuscogilva* was not recorded close to the passage nor in the two survey stations made in more calm areas of the lagoon, despite environmental conditions being suitable (good water flow and substratum). Amberfish (*T. anax*) was a common species, with 43 specimens noted in survey. The average density (28.6 /ha ±8.19 in deep-water surveys) is relatively high for this species. Prickly redfish was also detected, but only at moderate densities in broad-scale transects (3.2 /ha ±1.1) and on Ds (8.7 /ha ±4.2). Elephant trunkfish was not recorded at all in Laura and was also absent from the other CoFish sites in Marshall Islands suggesting that the archipelago might be outside the range of this species.

5.4.7 Other echinoderms: Laura

The edible collector urchin (*Tripneustes gratilla*) was not formally identified (only one specimen of *Tripneustes* sp. seen on a broad-scale station) and the slate urchin (*Heterocentrotus mammillatus*) was absent. Other urchins that can be used as a food source or potential indicators of habitat condition (*Echinothrix* spp. and *Echinometra mathaei*) were recorded, but at low levels. The large, black *Echinothrix* species (*E. diadema*) was noted in 9% of RBt stations at a mean station density of 9.5 /ha ±7.7. In RFs stations, the density was similar (7.8 /ha ±3.6) (See Appendices 4.4.1 to 4.4.7.).

Starfish were sparsely distributed at Laura; the common starfish (*Linckia laevigata*) and the coralivore pincushion star (*Culcita novaeguineae*) were recorded in moderate numbers (17 and 25 individuals respectively). Eleven individuals of another coral-eating star, the crown-of-thorns (*Acanthaster planci*, COTS) were noted. COTS were evenly distributed and not concentrated in any one place in the lagoon, and are not of any concern at this density (See presence and density estimates in Appendices 4.4.1 to 4.4.7.).

Table 5.14: Sea cucumber species records for Laura

Species	Common name	Commercial value [5]	B-S transects n = 72			Reef-benthos stations n = 22			Other stations SBt = 1; RFs = 4; MOPs = 6			Other stations Ds = 3		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga mauritiana	Surf redfish	M/H	0.5	16.4	3				4.9	19.6	25 RFs			
Bohadschia argus	Leopardfish	M	3.2	23.3	14	3.8	41.7	9				1.6	4.8	33
Holothuria atra	Lollyfish	L	174.4	570.7	31	4500	16,500	27	65,250	62,250	100 SBt	0.8	2.4	33
Holothuria edulis	Pinkfish	L				18.9	416.7	5				0.8	2.4	33
Holothuria nobilis [4]	Black teatfish	H	0.9	22.2	4	1.9	41.7	5						
Synapta spp.	-	-				5.7	125	5						
Thelenota ananas	Prickly redfish	H	3.2	23.3	14							8.7	26.2	33
Thelenota anax	Amberfish	M	1.4	100.0	1							28.6	28.6	100

[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; SBt = soft-benthos transect; RFs = reef-front search; MOPs = mother-of-pearl search; Ds = day search.

5.4.8 Discussion and conclusions: invertebrate resources in Laura

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

In summary, data on giant clam distribution, density and shell size suggest that:

- The lagoon and part of the barrier reef were suitable for the full range of giant clams found in Marshall Islands. Much of the reef in the lagoon and the reef platform of the barrier were mostly constituted of dead substrate, not suitable for Tridacnidae. Water movement was more dynamic to the north of the site, where most of the atoll is constituted of reef and is open to the ocean through large passages. Oceanic influence was less marked in the south, where the continuous narrow land constitutes a barrier to water exchange. Land influence was noticeable on the southwest corner and along the south coast as well as in front of the human settlement at the northern islet. The increasing population and number of piggeries provided an unusually large amount of organic matter in front of the settlements but in general the system was mostly oceanic-influenced.

- Three species of giant clam were recorded at Laura (the elongate clam *Tridacna maxima*, the fluted clam *T. squamosa*, and the horse-hoof or bear's paw clam *Hippopus hippopus*). No true giant clam (*T. gigas*) was recorded, although this species naturally occurs in Marshall Islands.

- The most suitable areas for *T. maxima* were located on the western and northern part of the atoll, were water flow was good. *H. hippopus* was sparsely distributed, with the best location along the inner drop-off of the barrier reef or the reef flat.

- Giant clam distribution and density were indicative of an impacted clam fishery, and clam stocks near to the main settlement were depleted. Coverage and densities of *T. maxima* were low to moderate. *H. hippopus* was less common and at lower density but still recorded in reasonable numbers. The larger *T. squamosa* was the most rare, but was still receiving recruitment, possibly from adults protected by living in deeper waters.

- Giant clams are broadcast spawners that only mature as females at larger size classes (protandric hermaphrodites). This means that, for successful stock management, clams need to be maintained at higher density and include larger-sized individuals to ensure sufficient spawning takes place to produce new generations.

- A 'full' range of size classes was noted for the three giant clam species, which indicates successful spawning and recruitment. Nevertheless, *T. maxima* clams of large size were relatively sparse, and the small numbers of the larger species support the assumption that all clam stocks are impacted by fishing.

In summary, the distribution, density and length recordings of sea cucumbers at Laura reveal that:

- A restricted range of seven commercial sea cucumber species was present at Laura. This is possibly due to biogeographical influences: the isolated easterly position of Laura in the Pacific, the poverty of the primary production, and the limited range of protected, shallow-water habitats available in this largely oceanic-influenced atoll lagoon system.

- The easily accessed high-value black teatfish (*Holothuria nobilis*) and the medium-value prickly redfish (*Thelenota ananas*) were recorded, as was the lower-value leopard or tigerfish (*Bohadschia argus*); however, distribution was sparse and densities were too low to warrant commercial interest.

- In more protected areas, no blackfish (*Actinopyga miliaris*), stonefish (*A. lecanora*), elephant trunkfish (*H. fuscopunctata*) or curryfish (*Stichopus hermanni*) were recorded, but the low-value lollyfish (*H. atra*) was common.

- In deeper-water surveys, the high-value white teatfish (*H. fuscogilva*) was not recorded, although the low-to-medium value amberfish (*T. anax*) was recorded at good density on the sandy bottom of the lagoon.

- It is unknown whether the sea cucumber stocks at Laura were over-fished during previous periods and have failed to recover, or whether Laura is just naturally deficient in both the range and density of these commercial species due to environmental factors and periodic stressors. However, what can be deduced is that there is very little potential for developing a commercial sea cucumber fishery based on the stocks existing at Laura at this time.

Data on MOP distribution, density and shell size suggest that:

- Marshall Islands is outside the normal range of the commercial topshell, *Trochus niloticus*, but reefs at Laura do hold trochus, which were initially introduced by the Japanese in the 1930s. The local reef conditions constitute excellent habitat for both juvenile and adult trochus. Juveniles have extensive, suitable back-reef habitat, especially north of the site, while the main adult habitat (barrier and outer-reef slope) is predominantly in the north.

- Within the site, trochus was well distributed but recorded at low density within the lagoon. Due to poor weather and lack of access to a survey boat, the full site (especially the outer slope) was not adequately surveyed; therefore the record of density is not complete. However, from the current records, it is suggested that there is no potential for commercially fishing trochus at this time. The density records suggest that MOP stocks are below the level at which consideration of commercial fishing is possible, and stocks are in need of ongoing protection to enable them to build until the main aggregations reach a minimum of 500–600 shells/ha.

- Trochus at Laura comprise a full range of size classes, holding both juveniles and large adults. The size-class frequency revealed a high percentage of small juveniles, which suggests that recruitment into the fishery should be good in the coming years.

- The false trochus or green topshell (*Tectus pyramis*) was present at low density and the blacklip pearl oyster (*Pinctada margaritifera*) was relatively common at Laura.

5.5 Overall recommendations for Laura

- The community-based fisheries management projects and activities be further developed and strengthened in Laura.

- The use of community-managed conservation areas (marine reserves) be applied, and sites selected in accordance with the communities' requirements, along with the recommendations issued by scientists.

- More awareness be provided at the village level to increase the understanding of the functions of MPAs and to alleviate concerns among landowners.

- The continued support of the Coastal Management Advisory Committee be required to ensure that any recommendations from scientists are fully considered in future management plans and measures for Laura and Majuro.

- A monitoring system be set in place to follow further any changes in finfish resources and monitor other land and marine sources of impact affecting the reefs, in particular, dredging, lagoon pollution, garbage disposal, etc.

- Controls be put in place to limit the use of spearfishing, especially in the lagoon and at night, and gillnetting, mostly in the lagoon.

- Some larger clams be placed in marine reserves, if these are established in Laura, to ensure that clam stocks remain protected from fishing.

- There is no potential for commercial fishing of trochus at this time, and stocks are in need of on-going protection to build until the major aggregations reach a minimum of 500–600 shells/ha.

- There is no potential for developing a commercial sea cucumber fishery based on the existing stocks at Ailuk at this time.

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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).

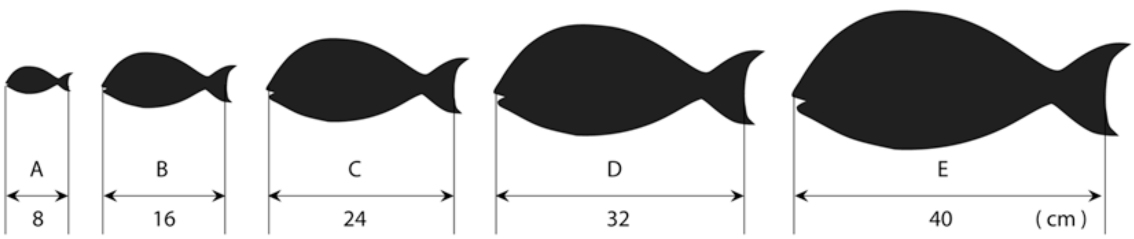

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

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$_i$

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Invertebrate per capita consumption:

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

Inv_{pcj} = Invertebrate weight consumption (kg edible meat/capita/year) for $household_j$

Inv_{wj} = Invertebrate weight consumption (kg edible meat/household/year) for $household_j$

n = number of age-gender classes

AC_{ij} = number of people for age class i and household j

C_i = correction factor of age-gender $class_i$

Canned fish per capita consumption:

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

CF_{pcj} = canned fish net weight consumption (kg/capita/year) for $household_j$

CF_{wj} = canned fish net weight consumption (kg/household/year) for $household_j$

n = number of age-gender classes

AC_{ij} = number of people for age $class_i$ and $household_j$

C_i = correction factor of age-gender $class_i$

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

Total finfish consumption:

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

F_{pcj} = finfish net weight consumption (kg/capita/year) for $household_j$

n_{ss} = number of people in sample size

n_{pop} = number of people in total population

Total invertebrate consumption:

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

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

Total canned fish consumption:

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

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

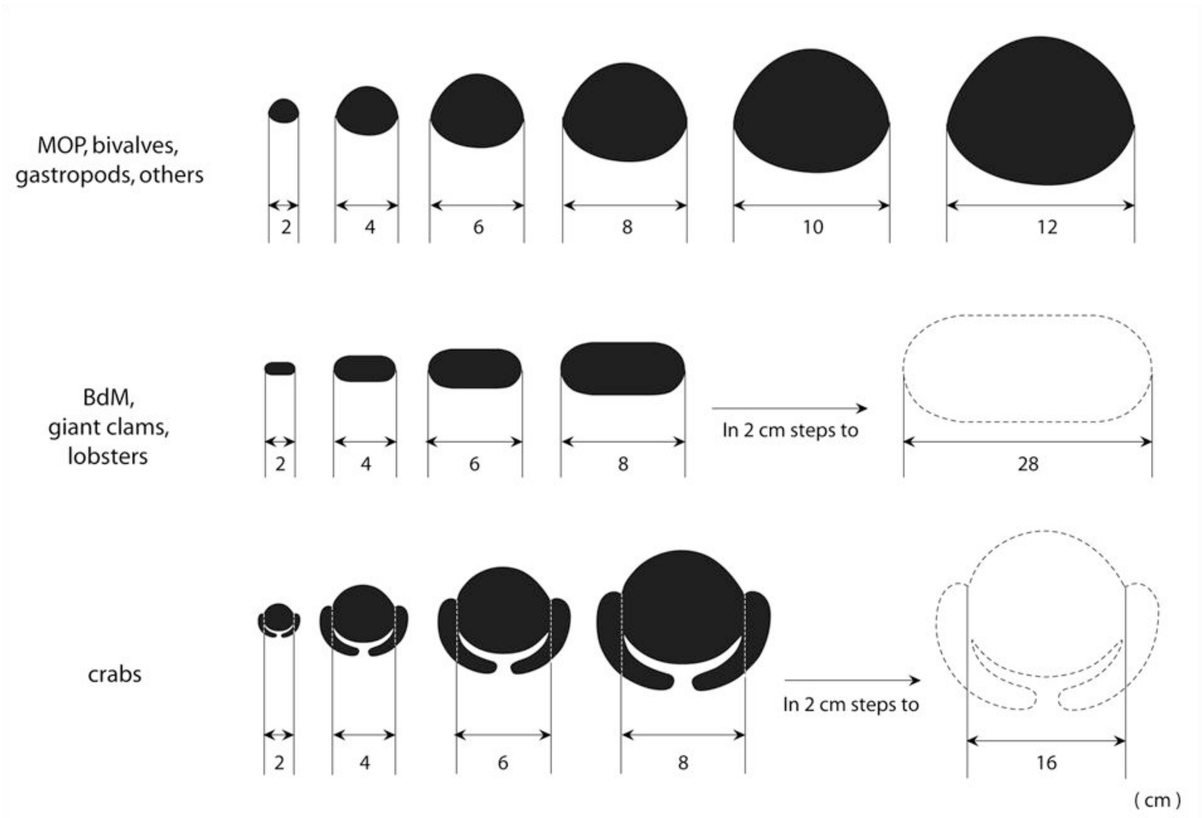

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

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Finfish fisher survey

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

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

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

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

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

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

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

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

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

Determination of fishing strategies includes:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Where:

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

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

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

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

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

Total annual finfish export:

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

Where:

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

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

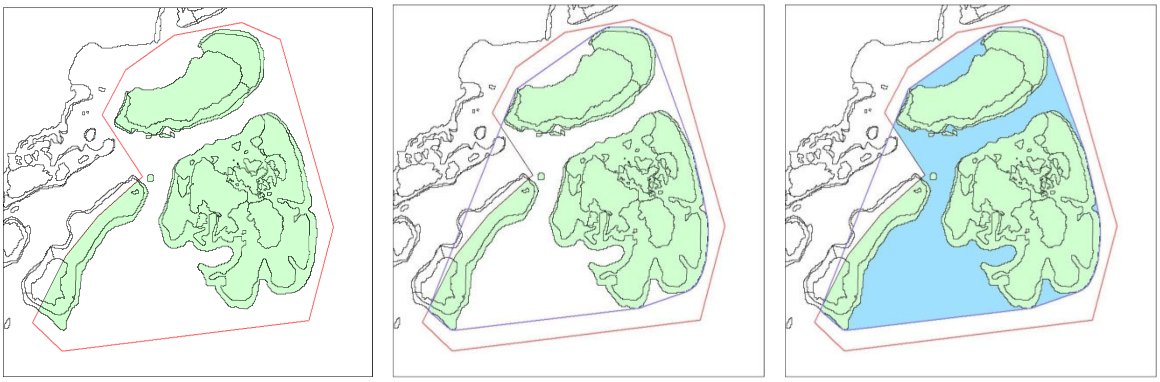

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as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

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

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

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

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

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

Invertebrate fisher survey

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

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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:

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

TACj = total annual catch t/year for species_j

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

$Ac_{inv}f_{hj}$ = average annual catch by female invertebrate fishers (kg/year) for habitat_h and species_j

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

$Ac_{inv}m_{hj}$ = average annual catch by male invertebrate fishers (kg/year) for habitat_h and species_j

N_h = number of habitats

Where:

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

$I_{inv}f_h$ = 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? male ☐ female ☐
   (must be living there; tick box)

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

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

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

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

5. Does this household have any agricultural land?

   yes ☐ no ☐

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

   for permanent/regular cultivation ☐ (unit)

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

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

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

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

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

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

Fishing/seafood collection ☐

Agriculture (crops & livestock) ☐

Salary ☐

Others (handicrafts, etc.) ☐ specify: ____________________

11. Do you get remittances? yes ☐ no ☐

12. How often?

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

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

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

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

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

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

CONSUMPTION SURVEY

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

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

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

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

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

Other seafood

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

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

☐ medium

☐ big

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

Fish:

☐ caught by myself/member of this household

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

☐ buy it at ______________

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

Invertebrates:

☐ caught by myself/member of this household

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

☐ buy it at ______________

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

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

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

–THANK YOU–

FISHING (FINFISH) AND MARKETING SURVEY

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

Name of head of household: ______________________ Village: ______________

Surveyor's name: _____________________ Date: ______________

1. Which areas do you fish?

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

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

Yes ☐ no ☐

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

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

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

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

5. Do you use a boat for fishing?

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

6. If you use a boat, which one?

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

coastal reef ☐ lagoon ☐ outer reef ☐

2 { canoe (paddle) ☐ sailing ☐
motorised ☐ HP outboard ☐ 4-stroke engine ☐ }

coastal reef ☐ lagoon ☐ outer reef ☐

3 { canoe (paddle) ☐ sailing ☐
motorised ☐ HP outboard ☐ 4-stroke engine ☐ }

coastal reef ☐ lagoon ☐ outer reef ☐

7. How many fishers ALWAYS go fishing with you?

Names:____
____
____
____

Appendix 1: Survey methods
Socioeconomics

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

coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

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

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

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

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

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

4. Do you go all year?

Yes ☐ no ☐

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

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

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

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep bottom line ☐ poison: which one? _____________

☐ other, specify: ____

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

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

____

8. Do you use ice on your fishing trips?

☐ always ☐ sometimes ☐ never

☐ is it homemade? ☐ or bought?

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

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

10. Do you sell fish? yes ☐ no ☐

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

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

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

kg ☐ <u>OR:</u>

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

and the rest you gift? yes ☐

how much? kg ☐ <u>OR:</u>

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

and/or sell? yes ☐

how much? kg ☐ <u>OR</u>:

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

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

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

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

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

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

technique usually used:____________________ boat type usually used:_______________
habitat usually fished: ____

Specify the number by size

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

20. Do you also fish invertebrates?

Yes ☐ no ☐ <u>if yes</u> for consumption? ☐ sale? ☐

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ______________________________

Gender: ☐ female ☐ male Age: ☐

Village: ______________________________

Date: ______________ Surveyor's name: ________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

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

☐ lobster diving ☐ other, such as clams, octopus

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

☐ one only ☐ several

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

----

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

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

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

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

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

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

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

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

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

FISHERIES (FINFISH AND INVERTEBRATE AND SOCIOECONOMICS) GENERAL INFORMATION SURVEY

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

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

a) legal/Ministry of Fisheries

b) traditional/community/village determined:

2. What do you think – do people obey:

traditional/village management rules?

mostly ☐ sometimes ☐ hardly ☐

legal/Ministry of Fisheries management rules?

mostly ☐ sometimes ☐ hardly ☐

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

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

a) finfishing

gillnets – most-used mesh sizes:

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

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

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

Seasonality of species

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

Vernacular name	Scientific name(s)	Months NOT fished

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.

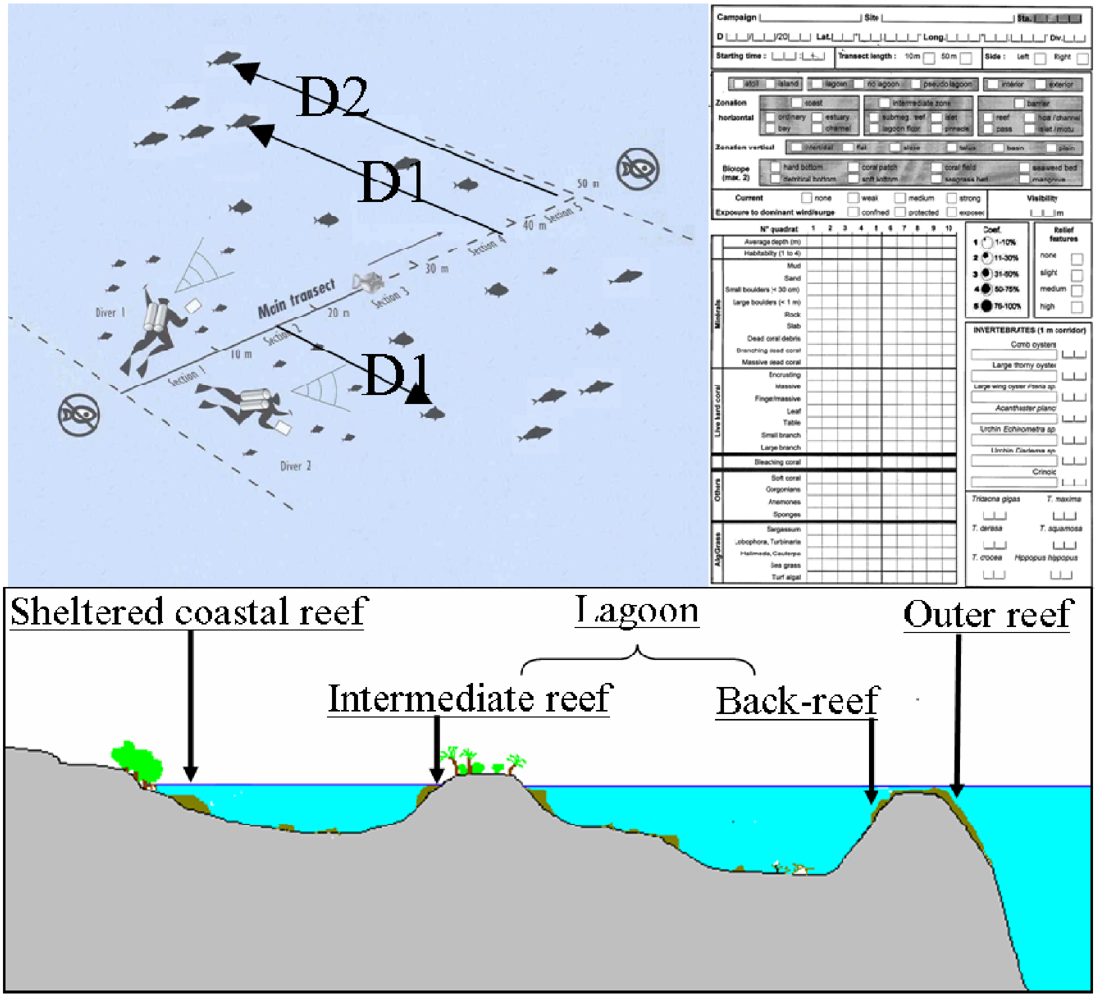


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys 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.

Appendix 1: Survey methods
Finfish

Species selection

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

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

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

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

Appendix 1: Survey methods
Finfish

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

These are:

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

Substrate

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

Parameters of interest

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

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

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

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

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

Sampling design

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

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

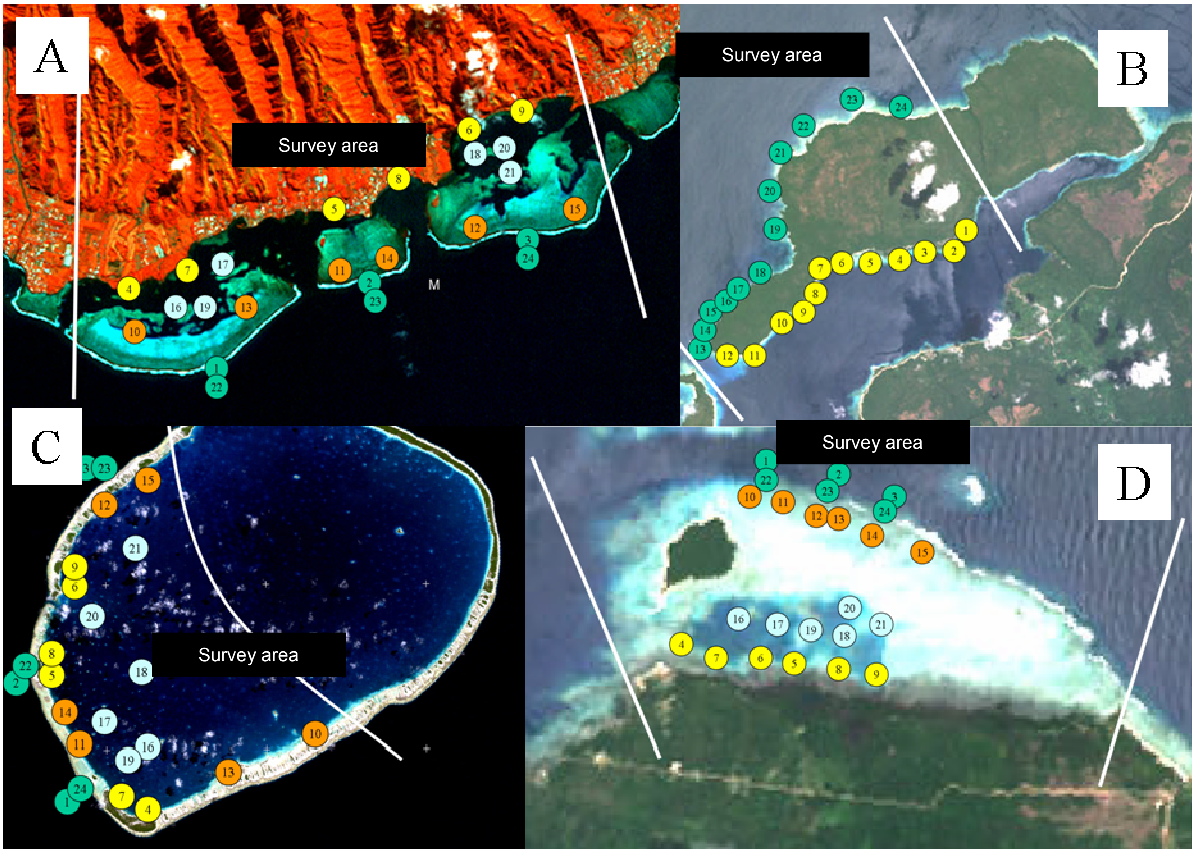


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon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

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

Scaling

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

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

Where:

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

A comparative approach only

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

Campaign |________| Site |______________| Diver |__|__| Transect |__|__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|' Long.|__|__|__|°|__|__|,|__|__|__|' WT |__|__|__|

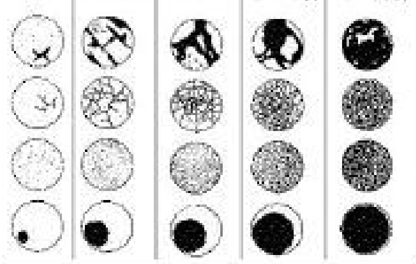
Starting time : |__|__| :|__|__|	Visibility |__|__| m	Side : Left ☐ Right ☐

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

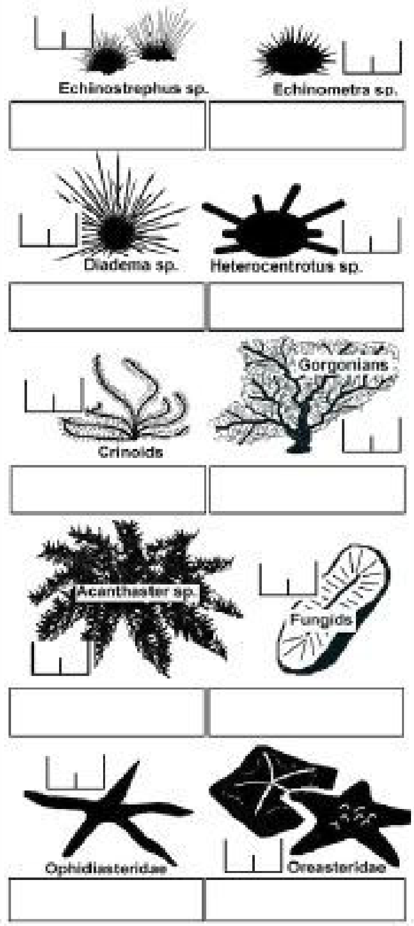
☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

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

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



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



Appendix 1: Survey methods
Finfish

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

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

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).

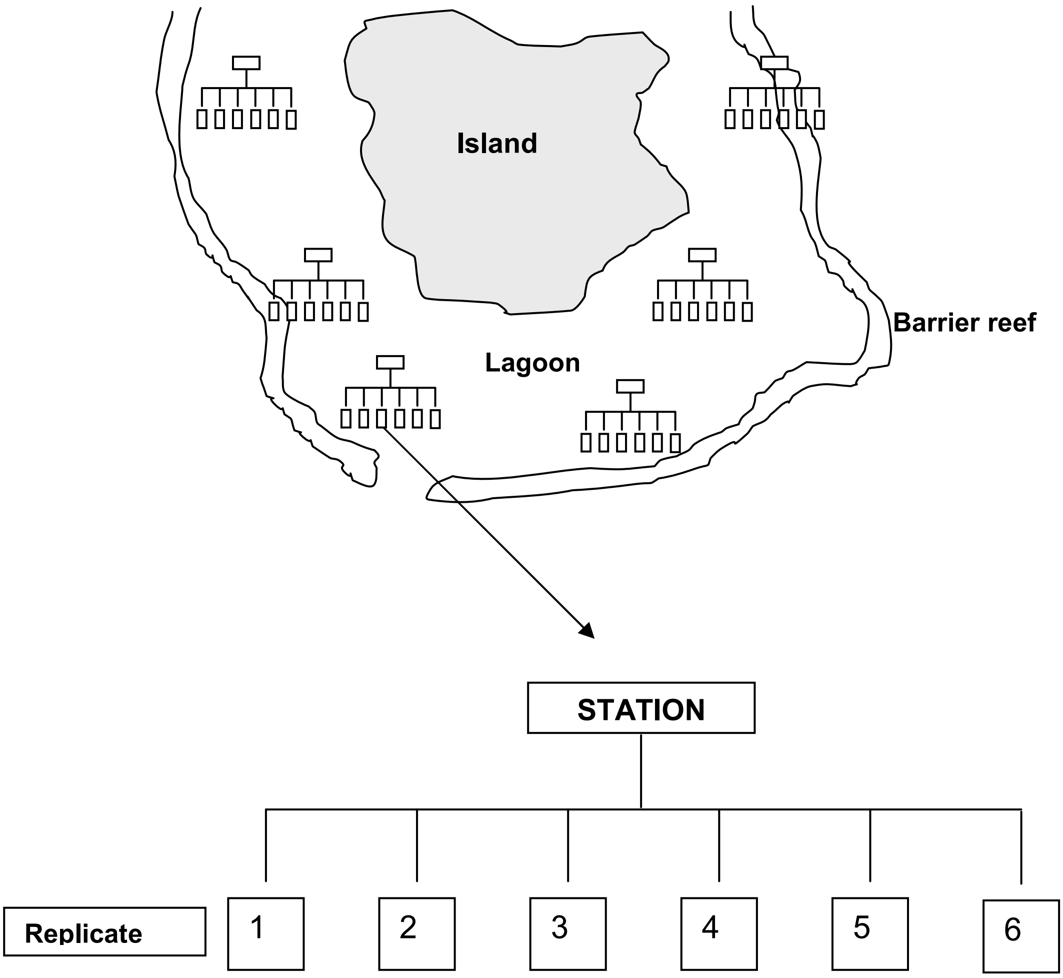


Figure A1.3.1: Stations and replicate measures at a given site.
A replicate measure could be a transect, search period or quadrat group.

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).

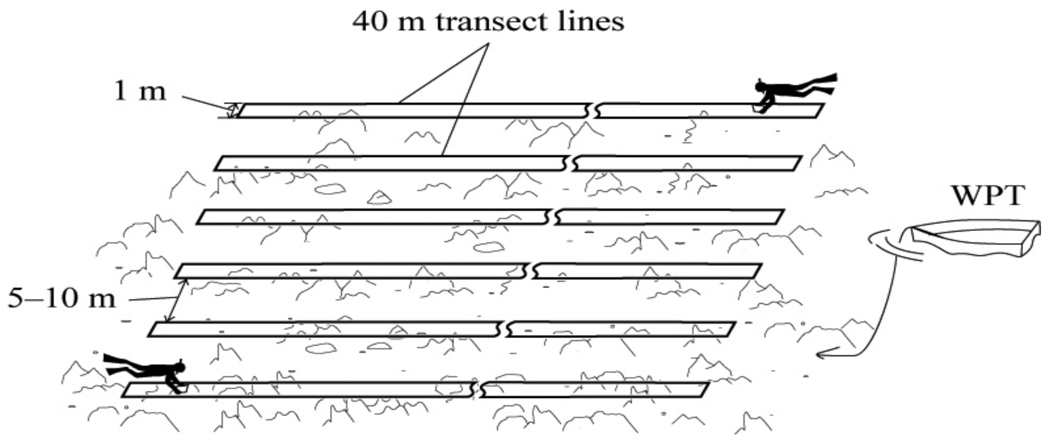


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

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.

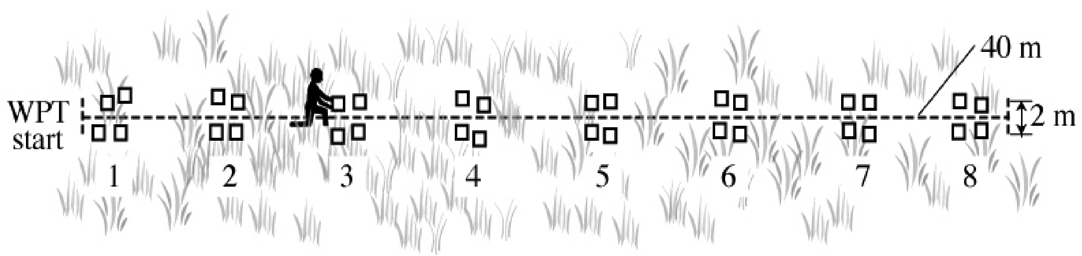


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<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).

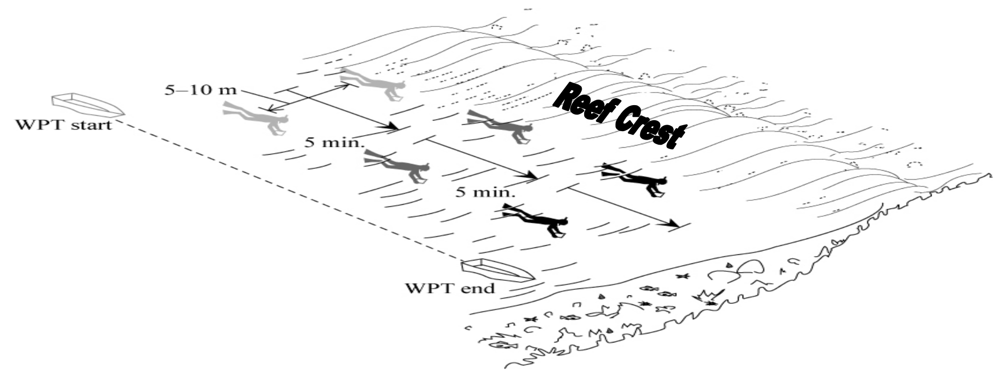


Figure A1.3.4: Reef-front search (RFs) station.

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.

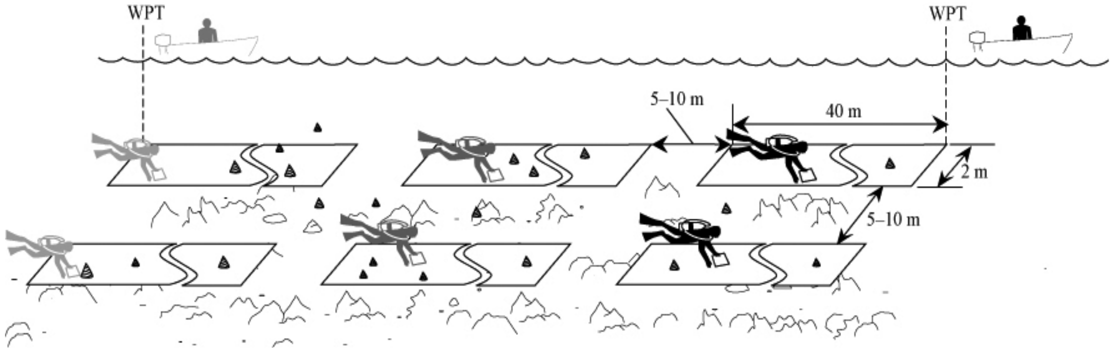


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

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.

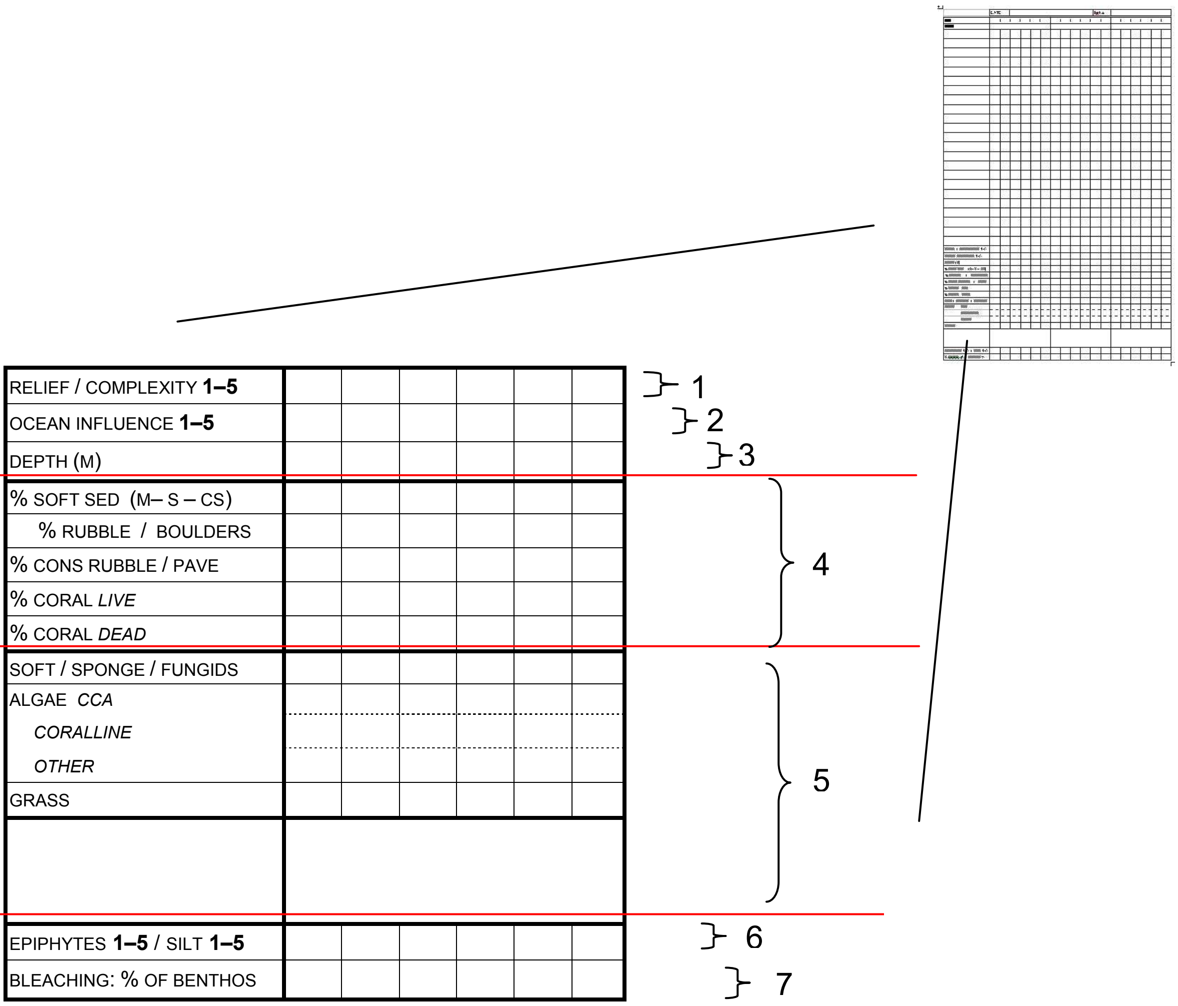


Figure A1.3.7: Sample of the invertebrate habitat part of survey form.

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.

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 Likiep socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat – Likiep

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Gro	Serranidae	*Plectropomus* spp.	1546	12.6
Jato	Lutjanidae	*Lutjanus gibbus*	1535	12.5
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	1152	9.4
Bajrok	Kyphosidae	*Kyphosus cinerascens*	887	7.2
Mole	Siganidae	*Siganus argenteus*	685	5.6
Loom	Lutjanidae	*Aprion virescens*	450	3.7
Baan	Lutjanidae	*Lutjanus bohar*	444	3.6
Jo	Mullidae	*Mulloidichthys flavolineatus*	399	3.2
Dijin	Lethrinidae	*Lethrinus obsoletus*	398	3.2
Berak	Lethrinidae	*Lethrinus* spp.	394	3.2
Kuban	Acanthuridae	*Acanthurus triostegus*	371	3.0
Mamu	Serranidae	*Epinephelus* spp.	328	2.7
Eek mouj	Scaridae	*Scarus* spp.	303	2.5
Mejmej	Lethrinidae	*Gymnocranius audleyi*	295	2.4
	Scaridae	*Scarus* spp.	270	2.2
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	270	2.2
Jutak lola	Lethrinidae	*Lethrinus* spp.	250	2.0
Ikaidik	Carangidae	*Elagatis bipinnulata*	207	1.7
Moramor	Siganidae	*Siganus punctatus*	179	1.5
Momo	Serranidae	*Epinephelus merra*, *Epinephelus* spp.	164	1.3
Teu	Haemulidae	*Plectorhinchus* spp.	151	1.2
Kuro	Serranidae	*Epinephelus fuscoguttatus*	151	1.2
Wolalo	Serranidae	*Variola louti*	129	1.1
Kwi	Acanthuridae	*Acanthurus lineatus*, *Acanthurus lineatus*	129	1.1
Bulak	Acanthuridae	*Naso lituratus*	121	1.0
Ael	Acanthuridae	*Acanthurus* spp.	108	0.9
Bataklaj	Acanthuridae	*Naso* spp., *Naso brevirostris*	108	0.9
Mera	Scaridae	*Chlorurus microrhinos*	107	0.9
Patriuk	Carangidae	*Caranx* spp.	97	0.8
Mone	Acanthuridae	*Naso unicornis*	93	0.8
Katok	Serranidae	*Epinephelus* spp.	93	0.8
Liele	Balistidae	*Pseudobalistes flavimarginatus*, *Pseudobalistes* spp.	76	0.6
Lejebatatak	Serranidae	*Epinephelus* spp.	65	0.5
Iik bwij	Carangidae	*Caranx* spp.	65	0.5
Koko	Coryphaenidae	*Coryphaena hippurus*	65	0.5
Kubkub	Carangidae	*Caranx* spp.	50	0.4
Jera	Holocentridae	*Sargocentron spiniferum*	43	0.4

2.1.1 Annual catch (kg) of fish groups per habitat – Likiep (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)				
Kotale	Serranidae	*Epinephelus* spp.	43	0.4
Korkor	Coryphaenidae	*Coryphaena* spp.	36	0.3
Alkinene	Acanthuridae	*Naso* spp.	22	0.2
Total:			**12,277.0**	**100.0**
Outer reef				
Gro	Serranidae	*Plectropomus* spp.	261	22.6
Dijin	Lethrinidae	*Lethrinus obsoletus*	164	14.2
Wolalo	Serranidae	*Variola louti*	144	12.4
Kuban	Acanthuridae	*Acanthurus triostegus*	137	11.9
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	72	6.2
Jera	Holocentridae	*Sargocentron spiniferum*	72	6.2
Al	Scombridae	*Acanthocybium solandri*	72	6.2
Mera	Scaridae	*Chlorurus microrhinos*	71	6.1
Loom	Lutjanidae	*Aprion virescens*	49	4.3
Koko	Coryphaenidae	*Coryphaena hippurus*	47	4.1
Eek mouj	Scaridae	*Scarus* spp.	43	3.7
Bwebwe	Scombridae	*Thunnus albacares*	25	2.1
Total:			**1156.6**	**100.0**
Outer reef & passage				
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	609	19.6
Gro	Serranidae	*Plectropomus* spp.	515	16.6
Baan	Lutjanidae	*Lutjanus bohar*	452	14.5
Dijin	Lethrinidae	*Lethrinus obsoletus*	232	7.5
Bwebwe	Scombridae	*Thunnus albacares*	215	6.9
Ikaidik	Carangidae	*Elagatis bipinnulata*	177	5.7
Berak	Lethrinidae	*Lethrinus* spp.	144	4.6
Mole	Siganidae	*Siganus argenteus*	140	4.5
Loom	Lutjanidae	*Aprion virescens*	104	3.3
Jutak lola	Lethrinidae	*Lethrinus* spp.	90	2.9
Kuro	Serranidae	*Epinephelus fuscoguttatus*	79	2.6
Bajrok	Kyphosidae	*Kyphosus cinerascens*	49	1.6
Eek mouj	Scaridae	*Scarus* spp.	43	1.4
Katok	Serranidae	*Epinephelus* spp.	43	1.4
Jera	Holocentridae	*Sargocentron spiniferum*	43	1.4
Jauwe	Serranidae	*Plectropomus areolatus*	36	1.1
Jato	Lutjanidae	*Lutjanus gibbus*	35	1.1
Lojabwil	Scombridae	*Katsuwonus pelamis*	33	1.1
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	25	0.8
Boklim	Serranidae	*Epinephelus* spp., *Epinephelus cyanopodus*	25	0.8
Momo	Serranidae	*Epinephelus merra*, *Epinephelus* spp.	11	0.3
Mamu	Serranidae	*Epinephelus* spp.	10	0.3
Total:			**3110.0**	**100.0**

2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Likiep

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Lobster	Wor	*Panulirus* spp.	100.0
Other	Rimuj	*Hippopus hippopus*	24.6
	Barulep	*Birgus latro*	20.2
	Tonale	*Tridacna squamosa*	17.9
	Kabor	*Tridacna* spp.	10.8
	Kwet	*Octopus* spp.	7.7
	Majenwor	*Tridacna maxima*	7.0
	Jebarbar	*Etisus* spp.	6.2
	Konnet	*Cypraea tigris*	2.4
	Maio	*Etisus splendidus*	1.7
	Juke	*Donax cuneatus*	1.6
	Kadmok	*Strombus* spp.	0.0
Reeftop	Lekelaj	*Cerithium* spp.	35.3
	Maio	*Etisus splendidus*	18.2
	Jireul	*Strombus* spp., *Turbo crassus*	12.5
	Nanaeo	*Etisus splendidus*	10.6
	Konnet	*Cypraea tigris*	5.3
	Jirrol	*Turbo crassus*, *Turbo* spp.	5.3
	Jubub in baren bob	*Thais* spp.	4.1
	Aurak	*Lambis lambis*	2.3
	Koi kor	*Asaphis violascens*	2.1
	Karrol	*Nerita polita*	1.5
	Juke	*Donax cuneatus*	1.3
	Kwet	*Octopus* spp.	1.1
	Karred	*Nerita* spp.	0.5
Intertidal	Maio	*Etisus splendidus*	47.1
	Juke	*Donax cuneatus*	12.1
	Albij	*Serpulorbis* spp.	11.1
	Nanaeo	*Etisus splendidus*	7.8
	Jukjukinbrenbob	*Thais* spp.	6.9
	Koi kor	*Asaphis violascens*	5.5
	Jireul	*Strombus* spp., *Turbo crassus*	4.0
	Karred	*Nerita* spp.	3.8
	Karrol	*Nerita polita*	1.7
Intertidal & reeftop	Albij	*Serpulorbis* spp.	54.5
	Aurak	*Lambis lambis*	45.5
Lobster	Wor	*Panulirus* spp.	100.0
Other	Rimuj	*Hippopus hippopus*	24.6
	Barulep	*Birgus latro*	20.2
	Tonale	*Tridacna squamosa*	17.9
	Kabor	*Tridacna* spp.	10.8
	Kwet	*Octopus* spp.	7.7
	Majenwor	*Tridacna maxima*	7.0
	Jebarbar	*Etisus* spp.	6.2
	Konnet	*Cypraea tigris*	2.4
	Maio	*Etisus splendidus*	1.7
	Juke	*Donax cuneatus*	1.6
	Kadmok	*Strombus* spp.	0.0

2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Likiep (continued)

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Reeftop	Lekelaj	*Cerithium* spp.	35.3
	Maio	*Etisus splendidus*	18.2
	Jireul	*Strombus* spp., *Turbo crassus*	12.5
	Nanaeo	*Etisus splendidus*	10.6
	Konnet	*Cypraea tigris*	5.3
	Jirrol	*Turbo crassus*, *Turbo* spp.	5.3
	Jubub in baren bob	*Thais* spp.	4.1
	Aurak	*Lambis lambis*	2.3
	Koi kor	*Asaphis violascens*	2.1
	Karrol	*Nerita polita*	1.5
	Juke	*Donax cuneatus*	1.3
	Kwet	*Octopus* spp.	1.1
	Karred	*Nerita* spp.	0.5
Intertidal	Maio	*Etisus splendidus*	47.1
	Juke	*Donax cuneatus*	12.1
	Albij	*Serpulorbis* spp.	11.1
	Nanaeo	*Etisus splendidus*	7.8
	Jukjukinbrenbob	*Thais* spp.	6.9
	Koi kor	*Asaphis violascens*	5.5
	Jireul	*Strombus* spp., *Turbo crassus*	4.0
	Karred	*Nerita* spp.	3.8
	Karrol	*Nerita polita*	1.7
Intertidal & reeftop	Albij	*Serpulorbis* spp.	54.5
	Aurak	*Lambis lambis*	45.5

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Likiep

Vernacular name	Scientific name	Size class	% of total catch (weight)
Albij	*Serpulorbis* spp.	04-06 cm	99.3
		06-08 cm	0.7
Aurak	*Lambis lambis*	08-12 cm	35.8
		08-14 cm	22.5
		10-12 cm	16.7
		10-14 cm	7.5
		12-14 cm	17.5
Barulep	*Birgus latro*	18-22 cm	33.8
		18-24 cm	8.8
		18-26 cm	22.1
		20-26 cm	17.6
		22-26 cm	17.6
Jebarbar	*Etisus* spp.	08-10 cm	100.0
Jireul	*Strombus* spp., *Turbo crassus*	04-06 cm	84.5
		06 cm	15.5

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Likiep (continued)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Jirrol	Turbo crassus, Turbo spp.	04-06 cm	65.1
		04-08 cm	34.9
Jubub in baren bob	Thais spp.	04-06 cm	36.0
		04-08 cm	24.0
		06-08 cm	40.0
Juke	Donax cuneatus	04-06 cm	11.4
		04-08 cm	88.6
Jukjukinbrenbob	Thais spp.	04-06 cm	100.0
Kabor	Tridacna spp.	18-20 cm	11.0
		18-22 cm	54.8
		18-24 cm	34.2
Kadmok	Strombus spp.	06 cm	100.0
Karred	Nerita spp.	04-06 cm	37.5
		04-08 cm	50.0
		06-08 cm	12.5
Karrol	Nerita polita	04-06 cm	100.0
Koi kor	Asaphis violascens	04-06 cm	81.5
		06 cm	18.5
Konnet	Cypraea tigris	06-08 cm	66.7
		06-09 cm	29.4
		09 cm	3.9
Kwet	Octopus spp.	12-14 cm	7.5
		12-16 cm	70.1
		14-16 cm	5.6
		14-18 cm	16.8
Lekelaj	Cerithium spp.	04-06 cm	66.7
		04-08 cm	33.3
Maio	Etisus splendidus	04-06 cm	13.4
		04-08 cm	56.5
		08-12 cm	14.4
		16-20 cm	10.3
		17-22 cm	5.5
Majenwor	Tridacna maxima	16-18 cm	14.9
		18-24 cm	85.1
Nanaeo	Etisus splendidus	08-12 cm	17.4
		10-12 cm	46.9
		10-14 cm	21.4
		12-14 cm	14.3
Rimuj	Hippopus hippopus	16-22 cm	12.7
		16-24 cm	12.7
		18-20 cm	11.7
		18-22 cm	55.7
		18-26 cm	7.2

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Likiep (continued)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Tonale	Tridacna squamosa	16-20 cm	24.9
		16-22 cm	31.1
		18-22 cm	37.8
		18-24 cm	6.2
Wor	Panulirus spp.	18-22 cm	6.7
		18-24 cm	73.3
		20-26 cm	20.0

2.2 Ailuk socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat – Ailuk
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Gro	Serranidae	*Plectropomus* spp.	1103	18.2
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus, Epinephelus* spp., *Epinephelus macrospilos*	940	15.6
Jato	Lutjanidae	*Lutjanus* spp.	595	9.8
Moamoa	Siganidae	*Siganus vermiculatus*	515	8.5
Baan	Lutjanidae	*Lutjanus bohar*	408	6.8
Loum	Lutjanidae	*Aprion virescens*	324	5.4
Bulak	Acanthuridae	*Naso lituratus*	302	5.0
Mole	Siganidae	*Siganus argenteus*	291	4.8
Jo	Mullidae	*Mulloidichthys flavolineatus*	244	4.0
Net	Lethrinidae	*Lethrinus* spp.	217	3.6
Mojani	Lethrinidae	*Monotaxis grandoculis*	163	2.7
Drijin	Lethrinidae	*Lethrinus* spp.	156	2.6
Motal	Haemulidae	*Plectorhinchus* spp.	132	2.2
Katok	Serranidae	*Epinephelus* spp.	102	1.7
Boklim	Serranidae	*Epinephelus* spp., *Epinephelus cyanopodus*	102	1.7
Muramur	Siganidae	*Siganus punctatissimus, Siganus vermiculatus, Siganus vermiculatus*	61	1.0
Jalia	Lethrinidae	*Lethrinus olivaceus, Lethrinus* spp.	61	1.0
Kuro	Serranidae	*Epinephelus* spp.	61	1.0
Bonej	Lutjanidae	*Lutjanus kasmira*	61	1.0
Mejmej	Lethrinidae	*Gymnocranius audleyi*	51	0.8
Mamu	Serranidae	*Epinephelus* spp.	47	0.8
Okor	Serranidae	*Epinephelus* spp.	41	0.7
Berak	Lethrinidae	*Lethrinus* spp.	41	0.7
Bejrok	Kyphosidae	*Kyphosus vaigiensis, Kyphosus* spp.	30	0.5
Total:			**6046**	**100.0**
Outer reef & passage				
Baan	Lutjanidae	Lutjanus bohar	264	17.6
Gro	Serranidae	Plectropomus spp.	232	15.4
Jato	Lutjanidae	Lutjanus spp.	159	10.6
Bejrok	Kyphosidae	Kyphosus vaigiensis, Kyphosus spp.	156	10.4
Lejebjeb	Serranidae	Epinephelus fuscoguttatus, Epinephelus spp., Epinephelus macrospilos	137	9.1
Loum	Lutjanidae	Aprion virescens	108	7.2
Iik- aidik	Carangidae	Elagatis bipinnulata	93	6.2
Drijin	Lethrinidae	Lethrinus spp.	47	3.2
Bwebwe	Scombridae	Gymnosarda spp.	47	3.2
Katok	Serranidae	Epinephelus spp.	41	2.7
	Scaridae	Scarus spp.	30	2.0
Bulak	Acanthuridae	Naso lituratus	24	1.6

2.2.1 Annual catch (kg) of fish groups per habitat – Ailuk (continued)

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef & passage (continued)				
Mole	Siganidae	*Siganus argenteus*	24	1.6
Liele	Balistidae	*Pseudobalistes flavimarginatus*, *Pseudobalistes* spp.	24	1.6
Eek mouj	Scaridae	*Scarus* spp.	24	1.6
Nituwa	Sphyraenidae	*Sphyraena* spp.	24	1.6
Alkinene	Acanthuridae	*Naso* spp.	24	1.6
Jutak lola	Lethrinidae	*Lethrinus* spp.	24	1.6
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	20	1.4
Total:			**1502**	**100.0**

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Ailuk

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Lobster	Wor	*Panulirus* spp.	100.0
Other	Barulep	*Birgus latro*	28.3
	Majenwor	*Tridacna maxima*	27.0
	Tonale	*Tridacna squamosa*	20.2
	Jeno	*Tridacna maxima*	14.7
	Kwet	*Octopus* spp.	7.2
	Maio	*Etisus splendidus*	2.6
	Karred	*Nerita* spp.	0.0
	Won		
Reeftop	Jiuet	*Charonia tritonis*	37.1
	Likajur	*Cypraea tigris*	25.9
	Jireul	*Strombus* spp., *Turbo crassus*	8.9
	Jirrol	*Turbo crassus*, *Turbo* spp.	5.2
	Loked	*Conus* spp.	4.9
	Konnet	*Cypraea tigris*	4.9
	Kwet	*Octopus* spp.	2.6
	Karrol	*Nerita polita*	2.3
	Maio	*Etisus splendidus*	1.8
	Barulep	*Birgus latro*	1.7
	Karred	*Nerita* spp.	1.4
	Juke	*Donax cuneatus*	0.9
	Aurak	*Lambis lambis*	0.9
	Kukor	*Donax cuneatus*	0.6
	Jubub in baren bob	*Thais* spp.	0.4
	En	*Saccostrea* spp.	0.4
	Tak kor	*Asaphis violascens*	0.3
Intertidal	Jireul	*Strombus* spp., *Turbo crassus*	66.7
	Koi kor	*Asaphis violascens*	18.7
	Albij	*Serpulorbis* spp.	10.8
	Karrol	*Nerita polita*	3.8

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Ailuk

Vernacular name	Scientific name	Size class	% of total catch (weight)
Albij	*Serpulorbis* spp.	04-06 cm	100.0
Aurak	*Lambis lambis*	04-08 cm	28.9
		10-12 cm	32.5
		10-14 cm	31.3
		12-14 cm	7.2
Barulep	*Birgus latro*	17-22 cm	14.8
		18-22 cm	5.6
		18-24 cm	18.3
		18-26 cm	56.0
		20-26 cm	5.3
En	*Saccostrea* spp.	06-10 cm	100.0
Jeno	*Tridacna maxima*	16-20 cm	29.1
		18-20 cm	18.2
		18-22 cm	52.7
Jireul	*Strombus* spp., *Turbo crassus*	04-06 cm	98.3
		06 cm	1.7
Jirrol	*Turbo crassus*, *Turbo* spp.	04-06 cm	71.3
		04-08 cm	12.3
		06-08 cm	16.4
Jiuet	*Charonia tritonis*	04-06 cm	100.0
Jubub in baren bob	*Thais* spp.	04-08 cm	100.0
Juke	*Donax cuneatus*	04-06 cm	66.7
		04-08 cm	33.3
Karred	*Nerita* spp.	04-06 cm	99.4
		08-12 cm	0.6
Karrol	*Nerita polita*	04-06 cm	91.6
		04-08 cm	8.4
Koi kor	*Asaphis violascens*	04-06 cm	88.9
		06 cm	11.1
Konnet	*Cypraea tigris*	04-06 cm	100.0
Kukor	*Donax cuneatus*	04-06 cm	100.0
Kwet	*Octopus* spp.	12-16 cm	3.4
		14-16 cm	8.5
		14-18 cm	88.1
Likajur	*Cypraea tigris*	04-06 cm	100.0
Loked	*Conus* spp.	04-08 cm	100.0
Maio	*Etisus splendidus*	10-14 cm	46.2
		12-14 cm	53.8
Majenwor	*Tridacna maxima*	16-18 cm	16.7
		16-20 cm	21.8
		16-22 cm	41.6
		18-20 cm	7.9
		18-22 cm	11.9
Tak kor	*Asaphis violascens*	04-06 cm	100.0
Tonale	*Tridacna squamosa*	16-20 cm	66.8
		16-22 cm	21.2
		18-22 cm	11.9

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Ailuk (continued)

Vernacular name	Scientific name	Size class	% of total catch (weight)
Wor	Panulirus spp.	18-22 cm	19.3
		18-24 cm	73.9
		20-26 cm	6.8

2.3 Arno socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat – Arno

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Mole	Siganidae	*Siganus argenteus*	843	19.3
Kuro	Serranidae	*Epinephelus fuscoguttatus*	750	17.1
Jera	Holocentridae	*Sargocentron spiniferum*	550	12.6
Bajrok	Kyphosidae	*Kyphosus cinerascens*	543	12.4
Dijin	Lethrinidae	*Lethrinus obsoletus*	388	8.9
Jato	Lutjanidae	*Lutjanus gibbus*	257	5.9
Ael	Acanthuridae	*Acanthurus* spp.	164	3.7
Mone	Acanthuridae	*Naso unicornis*	139	3.2
Bulak	Acanthuridae	*Naso lituratus*	126	2.9
Berak	Lethrinidae	*Lethrinus* spp.	104	2.4
Mera	Scaridae	*Chlorurus microrhinos*	98	2.2
Jauwe	Serranidae	*Plectropomus areolatus*	94	2.2
Labbo	Labridae	*Cheilinus undulatus*	70	1.6
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	56	1.3
Bwebwe	Scombridae	*Thunnus albacares*	56	1.3
Baan	Lutjanidae	*Lutjanus bohar*	35	0.8
Bataklaj	Acanthuridae	*Naso* spp., *Naso brevirostris*	35	0.8
Jo	Mullidae	*Mulloidichthys flavolineatus*	23	0.5
Kwi	Acanthuridae	*Acanthurus lineatus*	23	0.5
Bonej	Lutjanidae	*Lutjanus kasmira*	23	0.5
Total:			**4377**	**100.0**
Lagoon & outer reef				
Jato	Lutjanidae	*Lutjanus gibbus*	1105	18.0
Mole	Siganidae	*Siganus argenteus*	921	15.0
Bilak	Acanthuridae	*Naso lituratus*	768	12.5
Mera	Scaridae	*Chlorurus microrhinos*	718	11.7
Bajrok	Kyphosidae	*Kyphosus cinerascens*	559	9.1
Kuro	Serranidae	*Epinephelus fuscoguttatus*	502	8.2
Ael	Acanthuridae	*Acanthurus* spp.	383	6.2
Dijin	Lethrinidae	*Lethrinus obsoletus*	348	5.7
Momo	Serranidae	*Epinephelus merra*, *Epinephelus* spp.	186	3.0
Jo	Mullidae	*Mulloidichthys flavolineatus*	139	2.3
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	104	1.7
Kwi	Acanthuridae	*Acanthurus lineatus*	104	1.7
Mejmej	Lethrinidae	*Gymnocranius audleyi*	104	1.7
Berak	Lethrinidae	*Lethrinus* spp.	70	1.1
Eek mouj	Scaridae	*Scarus* spp.	70	1.1
Jera	Holocentridae	*Sargocentron spiniferum*	35	0.6
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	35	0.6
Total:			**6151**	**100.0**

2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Arno

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Reeftop & other	Jeno	*Tridacna maxima*	42.1
	Rimuj	*Hippopus hippopus*	37.2
	Kwet	*Octopus* spp.	11.9
	Jireul	*Strombus* spp., *Turbo crassus*	3.9
	Aurak	*Lambis lambis*	1.9
	Kadmok	*Strombus* spp.	1.8
	Jidrul	*Turbo* spp.	1.2
Soft benthos & reeftop	Kwet	*Octopus* spp.	100.0
	Jaibo	*Sipunculus* spp.	
Soft benthos & reeftop & other	Jeno	*Tridacna maxima*	46.2
	Rimuj	*Hippopus hippopus*	19.7
	Kwet	*Octopus* spp.	13.0
	Jireul	*Strombus* spp., *Turbo crassus*	8.6
	Kadmok	*Strombus* spp.	5.9
	Jidrul	*Turbo* spp.	4.7
	Aurak	*Lambis lambis*	2.0

2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Arno

Vernacular name	Scientific name	Size class	% of total catch (weight)
Aurak	*Lambis lambis*	10-12 cm	39.3
		14-16 cm	60.7
Jaibo	*Sipunculus* spp.	06-10 cm	
Jeno	*Tridacna maxima*	16-18 cm	64.0
		16-20 cm	16.8
		18-20 cm	19.2
Jidrul	*Turbo* spp.	04-06 cm	54.5
		06-10 cm	45.5
Jireul	*Strombus* spp., *Turbo crassus*	04-06 cm	73.5
		06 cm	26.5
Kadmok	*Strombus* spp.	06 cm	100.0
Kwet	*Octopus* spp.	14-16 cm	100.0
Rimuj	*Hippopus hippopus*	16-18 cm	8.3
		16-20 cm	13.9
		18-20 cm	22.2
		18-22 cm	55.6

2.4 Laura socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat – Laura
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of total catch
Sheltered coastal reef & lagoon				
Kuro	Serranidae	*Epinephelus* spp.	790	12.0
Mole	Siganidae	*Siganus argenteus*	669	10.2
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	593	9.0
Gro	Serranidae	*Plectropomus* spp.	514	7.8
Drijin	Lethrinidae	*Lethrinus* spp.	483	7.3
Jera	Lutjanidae	*Lutjanus* spp.	450	6.8
Kuban	Acanthuridae	*Acanthurus triostegus*	370	5.6
Jato	Lutjanidae	*Lutjanus* spp.	354	5.4
Momo	Serranidae	*Epinephelus merra*, *Epinephelus* spp.	345	5.3
Bejrok	Kyphosidae	*Kyphosus vaigiensis*, *Kyphosus* spp.	260	3.9
Eek mouj	Scaridae	*Scarus* spp.	258	3.9
Kwi	Acanthuridae	*Acanthurus lineatus*, *Acanthurus lineatus*	141	2.1
Mon	Holocentridae	*Myripristis adusta*	141	2.1
Bilak	Acanthuridae	*Naso lituratus*	137	2.1
Baan	Lutjanidae	*Lutjanus bohar*	115	1.8
Kabro	Carangidae	*Caranx* spp.	112	1.7
Rewa	Carangidae	*Caranx* spp.	112	1.7
Jo	Mullidae	*Mulloidichthys flavolineatus*	106	1.6
Motal	Haemulidae	*Plectorhinchus* spp.	87	1.3
Mera	Labridae	*Choerodon anchorago*	85	1.3
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	64	1.0
Berak	Lethrinidae	*Lethrinus* spp.	64	1.0
Bulak	Acanthuridae	*Naso lituratus*	64	1.0
Autok	Mugilidae	*Mugil* spp.	64	1.0
Jojo	Exocoetidae	*Cypselurus* spp.	64	1.0
Narbok	Acanthuridae	*Naso* spp.	48	0.7
Iik bwij	Carangidae	*Caranx* spp.	43	0.6
Iik- aidik	Carangidae	*Elagatis bipinnulata*	43	0.6
Total:			**6574**	**100.0**

2.4.1 Annual catch (kg) of fish groups per habitat – Laura (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of total catch
Lagoon & outer reef				
Jato	Lutjanidae	*Lutjanus* spp.	276	21.0
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	273	20.8
Drijin	Lethrinidae	*Lethrinus* spp.	179	13.6
Gro	Serranidae	*Plectropomus* spp.	115	8.8
Bejrok	Kyphosidae	*Kyphosus vaigiensis*, *Kyphosus* spp.	115	8.8
Mole	Siganidae	*Siganus argenteus*	76	5.8
Momo	Serranidae	*Epinephelus merra*, *Epinephelus* spp.	76	5.8
Eiro	Acanthuridae	*Naso* spp.	76	5.8
Kuro	Serranidae	*Epinephelus* spp.	64	4.8
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	64	4.8
Total:			**1315**	**100.0**
Outer reef				
Lejebjeb	Serranidae	*Epinephelus fuscoguttatus*, *Epinephelus* spp., *Epinephelus macrospilos*	129	12.9
Jato	Lutjanidae	*Lutjanus* spp.	109	10.9
Jume	Lutjanidae	*Lutjanus* spp.	103	10.2
Jilo	Pomacentridae	*Pomacentrus* spp.	103	10.2
Jalia	Lethrinidae	*Lethrinus olivaceus*, *Lethrinus* spp.	79	7.9
Baan	Lutjanidae	*Lutjanus bohar*	77	7.7
Kuro	Serranidae	*Epinephelus* spp.	77	7.7
Gro	Serranidae	*Plectropomus* spp.	77	7.7
Kuban	Acanthuridae	*Acanthurus triostegus*	52	5.1
Bulak	Acanthuridae	*Naso lituratus*	52	5.1
Lojabwil	Scombridae	*Katsuwonus* spp.	52	5.1
Bwebwe	Scombridae	*Gymnosarda* spp.	51	5.1
Mole	Siganidae	*Siganus argenteus*	21	2.1
Aoinel	Acanthuridae	*Naso* spp.	21	2.1
Total:			**1004**	**100.0**
Outer reef & passage				
Gro	Serranidae	*Plectropomus* spp.	635	44.8
Baan	Lutjanidae	*Lutjanus bohar*	403	28.5
Jato	Lutjanidae	*Lutjanus* spp.	274	19.4
Drijin	Lethrinidae	*Lethrinus* spp.	52	3.6
Bejrok	Kyphosidae	*Kyphosus vaigiensis*, *Kyphosus* spp.	52	3.6
Total:			**1416**	**100.0**

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Laura

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Lobster	Wor	*Panulirus* spp.	100.0
Other	Rimuj	*Hippopus hippopus*	66.6
	Kwet	*Octopus* spp.	29.3
	Jireul	*Strombus* spp., *Turbo crassus*	4.2
Reeftop	Jubub in baren bob	*Thais* spp.	66.7
	Jireul	*Strombus* spp., *Turbo crassus*	20.8
	Aurak	*Lambis lambis*	12.5
Reeftop & other	Lekelaj	*Cerithium* spp.	62.5
	Barulep	*Birgus latro*	17.0
	Majenwor	*Tridacna maxima*	10.4
	Jubub in baren bob	*Thais* spp.	7.9
	Aurak	*Lambis lambis*	2.1
Intertidal & reeftop & other	Likajur	*Cypraea tigris*	71.7
	Majenwor	*Tridacna maxima*	18.9
	Jireul	*Strombus* spp., *Turbo crassus*	9.4
Soft benthos & other	Jireul	*Strombus* spp., *Turbo crassus*	72.7
	Karrol	*Nerita polita*	27.3
Soft benthos & reeftop	Loked	*Conus* spp.	59.2
	Lekelaj	*Cerithium* spp.	33.8
	Kwet	*Octopus* spp.	4.8
	Aurak	*Lambis lambis*	2.2
Soft benthos & reeftop & other	Rimuj	*Hippopus hippopus*	71.8
	Kwet	*Octopus* spp.	25.3
	Aurak	*Lambis lambis*	2.9

2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Laura

Vernacular name	Scientific name	Size class	% of total catch (weight)
Aurak	*Lambis lambis*	10-14 cm	13.6
		12-14 cm	37.3
		12-15 cm	49.1
Barulep	*Birgus latro*	22-26 cm	100.0
Jireul	*Strombus* spp., *Turbo crassus*	06 cm	100.0
Jubub in baren bob	*Thais* spp.	06-08 cm	56.8
		08 cm	43.2
Karrol	*Nerita polita*	08-10 cm	100.0
Kwet	*Octopus* spp.	14-16 cm	100.0
Lekelaj	*Cerithium* spp.	04-06 cm	100.0
Likajur	*Cypraea tigris*	04-06 cm	100.0
Loked	*Conus* spp.	04-10 cm	100.0
Majenwor	*Tridacna maxima*	18-22 cm	100.0
Rimuj	*Hippopus hippopus*	14-18 cm	32.4
		16-20 cm	67.6
Wor	*Panulirus* spp.	22-26 cm	100.0

APPENDIX 3: FINFISH SURVEY DATA

3.1 Likiep finfish survey data

3.1.1 Coordinates (WGS84) of the 20 D-UVC transects used to assess finfish resource status in Likiep

Station name	Habitat	Latitude	Longitude
TRA01	Outer reef	9º49'36.3612" N	169º14'06.6012" E
TRA02	Outer reef	9º49'21.36" N	169º19'01.8012" E
TRA03	Back-reef	9º49'55.92" N	169º13'45.0588" E
TRA04	Back-reef	9º49'38.7588" N	169º16'39.0612" E
TRA05	Back-reef	9º53'20.6412" N	169º16'13.3788" E
TRA06	Lagoon	9º52'52.9212" N	169º13'14.88" E
TRA07	Lagoon	9º52'46.92" N	169º08'37.5" E
TRA08	Lagoon	9º50'13.6788" N	169º09'10.3212" E
TRA09	Outer reef	10º01'58.98" N	168º59'52.1988" E
TRA10	Lagoon	10º01'19.02" N	169º01'06.24" E
TRA11	Back-reef	9º58'25.68" N	169º01'37.3188" E
TRA12	Outer reef	9º58'07.6188" N	169º00'59.94" E
TRA13	Back-reef	10º00'05.4" N	169º06'25.8012" E
TRA14	Lagoon	9º57'46.1988" N	169º05'40.4988" E
TRA15	Lagoon	9º53'28.5612" N	169º07'31.3212" E
TRA16	Back-reef	9º48'18.7812"N	169º09'53.3412" E
TRA17	Outer reef	9º48'37.3212" N	169º06'49.3812" E
TRA18	Back-reef	9º50'21.9588" N	169º05'26.7" E
TRA19	Outer reef	9º49'18.84" N	169º11'28.2012" E
TRA20	Back-reef	9º51'19.1988" N	169º17'20.2812" E

3.1.2 Weighted average density and biomass of all finfish species recorded in Likiep (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus leucocheilus*	0.00014	0.0408
Acanthuridae	*Acanthurus mata*	0.00247	0.9662
Acanthuridae	*Acanthurus nigricans*	0.05007	3.9053
Acanthuridae	*Acanthurus nigricauda*	0.00057	0.1538
Acanthuridae	*Acanthurus nigrofuscus*	0.00427	0.0574
Acanthuridae	*Acanthurus nigroris*	0.00029	0.0212
Acanthuridae	*Acanthurus olivaceus*	0.00066	0.0740
Acanthuridae	*Acanthurus pyroferus*	0.00351	0.4442
Acanthuridae	*Acanthurus thompsoni*	0.00432	0.2603
Acanthuridae	*Ctenochaetus hawaiiensis*	0.00202	0.2256
Acanthuridae	*Ctenochaetus striatus*	0.11244	11.7615
Acanthuridae	*Ctenochaetus strigosus*	0.00202	0.0429
Acanthuridae	*Naso brevirostris*	0.00043	0.0634
Acanthuridae	*Naso caesius*	0.00394	3.7505
Acanthuridae	*Naso lituratus*	0.00072	0.1787
Acanthuridae	*Naso vlamingii*	0.00129	1.1969
Acanthuridae	*Zebrasoma scopas*	0.00333	0.1021
Acanthuridae	*Zebrasoma veliferum*	0.00733	1.1603

3.1.2 Weighted average density and biomass of all finfish species recorded in Likiep (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Balistidae	*Balistapus undulatus*	0.00312	0.3006
Balistidae	*Balistoides viridescens*	0.00087	0.9803
Balistidae	*Melichthys vidua*	0.00129	0.1433
Balistidae	*Pseudobalistes flavimarginatus*	0.00001	0.0190
Balistidae	*Rhinecanthus aculeatus*	0.00001	0.0008
Balistidae	*Sufflamen bursa*	0.00041	0.0333
Balistidae	*Sufflamen chrysopterum*	0.00068	0.0494
Caesionidae	*Caesio teres*	0.02486	6.4785
Caesionidae	*Pterocaesio marri*	0.00015	0.0344
Caesionidae	*Pterocaesio tile*	0.03972	3.6644
Carangidae	*Carangoides ferdau*	0.00015	0.0680
Carangidae	*Carangoides orthogrammus*	0.00029	0.0811
Carangidae	*Caranx lugubris*	0.00014	0.4501
Carangidae	*Caranx melampygus*	0.00580	7.8252
Carangidae	*Decapterus macarellus*	0.00013	0.0364
Carangidae	*Elagatis bipinnulata*	0.00794	32.0336
Carangidae	*Scomberoides commersonnianus*	0.00001	0.0036
Carangidae	*Scomberoides lysan*	0.00161	1.3371
Carangidae	*Scomberoides* spp.	0.00013	0.0252
Carcharhinidae	*Carcharhinus amblyrhynchos*	0.00060	12.5684
Carcharhinidae	*Carcharhinus melanopterus*	0.00041	6.2573
Carcharhinidae	*Triaenodon obesus*	0.00028	2.4503
Chaetodontidae	*Chaetodon auriga*	0.00119	0.0618
Chaetodontidae	*Chaetodon bennetti*	0.00027	0.0058
Chaetodontidae	*Chaetodon citrinellus*	0.00176	0.0050
Chaetodontidae	*Chaetodon ephippium*	0.00241	0.1936
Chaetodontidae	*Chaetodon kleinii*	0.00013	0.0009
Chaetodontidae	*Chaetodon lunula*	0.00126	0.0691
Chaetodontidae	*Chaetodon lunulatus*	0.01057	0.2182
Chaetodontidae	*Chaetodon melannotus*	0.00015	0.0076
Chaetodontidae	*Chaetodon mertensii*	0.00047	0.0169
Chaetodontidae	*Chaetodon octofasciatus*	0.00029	0.0031
Chaetodontidae	*Chaetodon punctatofasciatus*	0.00445	0.0359
Chaetodontidae	*Chaetodon reticulatus*	0.00682	0.1549
Chaetodontidae	*Chaetodon trifascialis*	0.00288	0.1004
Chaetodontidae	*Chaetodon ulietensis*	0.00058	0.0244
Chaetodontidae	*Forcipiger flavissimus*	0.00072	0.0285
Chaetodontidae	*Forcipiger longirostris*	0.00029	0.0085
Chaetodontidae	*Hemitaurichthys polylepis*	0.00086	0.0297
Chaetodontidae	*Heniochus chrysostomus*	0.00186	0.0800
Chaetodontidae	*Heniochus monoceros*	0.00042	0.1030
Chaetodontidae	*Heniochus varius*	0.00041	0.0233
Holocentridae	*Myripristis adusta*	0.00463	1.8719
Holocentridae	*Myripristis berndti*	0.00311	0.9104
Holocentridae	*Myripristis violacea*	0.00027	0.0281
Holocentridae	*Neoniphon opercularis*	0.00013	0.0310

3.1.2 Weighted average density and biomass of all finfish species recorded in Likiep (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Holocentridae	*Neoniphon sammara*	0.00013	0.0360
Holocentridae	*Neoniphon* spp.	0.00013	0.0208
Holocentridae	*Sargocentron spiniferum*	0.00089	0.7402
Kyphosidae	*Kyphosus cinerascens*	0.00013	0.0626
Labridae	*Cheilinus chlorourus*	0.00110	0.1125
Labridae	*Cheilinus fasciatus*	0.00146	0.1681
Labridae	*Cheilinus undulatus*	0.00040	0.0173
Labridae	*Coris aygula*	0.00043	0.3812
Labridae	*Epibulus insidiator*	0.00189	0.3969
Labridae	*Hemigymnus fasciatus*	0.00027	0.0388
Labridae	*Hemigymnus melapterus*	0.00151	0.3208
Labridae	*Oxycheilinus celebicus*	0.00087	0.0569
Labridae	*Oxycheilinus digramma*	0.00057	0.0240
Lethrinidae	*Gnathodentex aureolineatus*	0.00057	0.0729
Lethrinidae	*Gymnocranius* spp.	0.00001	0.0049
Lethrinidae	*Lethrinus erythracanthus*	0.00058	0.1766
Lethrinidae	*Lethrinus microdon*	0.00043	0.5156
Lethrinidae	*Monotaxis grandoculis*	0.00693	1.3060
Lutjanidae	*Aphareus furca*	0.00159	0.3790
Lutjanidae	*Lutjanus bohar*	0.00157	1.0619
Lutjanidae	*Lutjanus gibbus*	0.00186	1.1078
Lutjanidae	*Lutjanus kasmira*	0.00056	0.0807
Lutjanidae	*Lutjanus monostigma*	0.00070	0.1428
Lutjanidae	*Macolor macularis*	0.00297	3.1325
Lutjanidae	*Macolor niger*	0.00212	2.3172
Monacanthidae	*Aluterus scriptus*	0.00027	1.1801
Mullidae	*Mulloidichthys flavolineatus*	0.00134	0.0360
Mullidae	*Parupeneus barberinoides*	0.00002	0.0002
Mullidae	*Parupeneus barberinus*	0.00027	0.1160
Mullidae	*Parupeneus cyclostomus*	0.00054	0.1772
Mullidae	*Parupeneus multifasciatus*	0.00098	0.0377
Myliobatidae	*Aetobatus narinari*	0.00001	0.0765
Pomacanthidae	*Pomacanthus imperator*	0.00027	0.1459
Pomacanthidae	*Pygoplites diacanthus*	0.00215	0.3951
Scaridae	*Cetoscarus bicolor*	0.00170	1.8073
Scaridae	*Chlorurus microrhinos*	0.00722	4.6695
Scaridae	*Chlorurus sordidus*	0.02732	2.4664
Scaridae	*Hipposcarus longiceps*	0.00402	1.5473
Scaridae	*Scarus altipinnis*	0.00362	2.2549
Scaridae	*Scarus chameleon*	0.00203	0.2226
Scaridae	*Scarus festivus*	0.00058	0.1832
Scaridae	*Scarus flavipectoralis*	0.00035	0.0307
Scaridae	*Scarus forsteni*	0.00143	0.2965
Scaridae	*Scarus frenatus*	0.00185	0.4715
Scaridae	*Scarus ghobban*	0.00055	0.1449
Scaridae	*Scarus globiceps*	0.00014	0.0173

3.1.2 Weighted average density and biomass of all finfish species recorded in Likiep (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Scarus niger*	0.00203	0.4118
Scaridae	*Scarus oviceps*	0.00316	0.7742
Scaridae	*Scarus schlegeli*	0.00502	0.4749
Scaridae	*Scarus* spp.	0.00323	0.2554
Scombridae	*Gymnosarda unicolor*	0.00027	1.8622
Scombridae	*Scomberomorus commerson*	0.00014	0.0650
Serranidae	*Anyperodon leucogrammicus*	0.00100	0.2243
Serranidae	*Cephalopholis argus*	0.00223	1.2537
Serranidae	*Cephalopholis urodeta*	0.00113	0.0357
Serranidae	*Epinephelus areolatus*	0.00055	0.1508
Serranidae	*Epinephelus cyanopodus*	0.00001	0.0035
Serranidae	*Epinephelus maculatus*	0.00001	0.0030
Serranidae	*Epinephelus merra*	0.00203	0.0843
Serranidae	*Epinephelus polyphekadion*	0.00051	0.3319
Serranidae	*Gracila albomarginata*	0.00053	0.0773
Serranidae	*Plectropomus areolatus*	0.00113	0.5346
Serranidae	*Plectropomus laevis*	0.00077	4.2233
Serranidae	*Plectropomus maculatus*	0.00042	0.0646
Serranidae	*Plectropomus oligacanthus*	0.00433	0.0097
Serranidae	*Variola albimarginata*	0.00001	0.0024
Serranidae	*Variola louti*	0.00041	0.1866
Siganidae	*Siganus argenteus*	0.00944	2.0405
Siganidae	*Siganus puellus*	0.00013	0.0275
Siganidae	*Siganus punctatus*	0.00130	1.0432
Stegostomatidae	*Stegostoma fasciatum*	0.00014	0.0000
Zanclidae	*Zanclus cornutus*	0.00195	0.2210

3.2 Ailuk finfish survey data

3.2.1 Coordinates (WGS84) of the 19 D-UVC transects used to assess finfish resource status in Ailuk

Station name	Habitat	Latitude	Longitude
TRA01	Outer reef	10º15'57.06" N	169º52'07.5612" E
TRA02	Outer reef	10º14'17.7" N	169º53'05.3988" E
TRA03	Outer reef	10º20'49.0812" N	169º54'32.8788" E
TRA04	Back-reef	10º21'41.6988" N	169º54'47.0988" E
TRA05	Lagoon	10º20'09.78" N	169º54'53.5788" E
TRA06	Lagoon	10º16'49.3212" N	169º56'21.9012" E
TRA07	Back-reef	10º20'21.84" N	169º57'53.82" E
TRA08	Lagoon	10º20'20.5188" N	169º57'22.14" E
TRA09	Lagoon	10º18'39.42" N	169º57'01.8" E
TRA10	Outer reef	10º18'21.42" N	169º52'55.2612" E
TRA11	Back-reef	10º14'03.3612" N	169º53'53.9988" E
TRA12	Back-reef	10º15'17.2188" N	169º58'49.8612" E
TRA13	Outer reef	10º24'24.5412" N	169º54'49.2588" E
TRA14	Outer reef	10º27'27.4212" N	169º55'06.1788" E
TRA15	Back-reef	10º27'24.9588"N	169º55'31.6812" E
TRA16	Back-reef	10º26'49.2" N	169º57'16.6212" E
TRA17	Lagoon	10º23'36.6612" N	169º56'21.1812" E
TRA18	Lagoon	10º21'30.1788" N	169º57'00.54" E
TRA19	Back-reef	10º13'17.4" N	169º58'45.1812" E

3.2.2 Weighted average density and biomass of all finfish species recorded in Ailuk
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus achilles*	0.00083	0.0866
Acanthuridae	*Acanthurus blochii*	0.00019	0.2011
Acanthuridae	*Acanthurus mata*	0.00181	0.6472
Acanthuridae	*Acanthurus nigricans*	0.04832	4.2362
Acanthuridae	*Acanthurus nigricauda*	0.00105	0.3994
Acanthuridae	*Acanthurus nigrofuscus*	0.00641	0.0908
Acanthuridae	*Acanthurus nigroris*	0.00145	0.0253
Acanthuridae	*Acanthurus olivaceus*	0.00003	0.0116
Acanthuridae	*Acanthurus pyroferus*	0.00058	0.0443
Acanthuridae	*Acanthurus thompsoni*	0.01191	0.4425
Acanthuridae	*Ctenochaetus binotatus*	0.00046	0.0203
Acanthuridae	*Ctenochaetus cyanocheilus*	0.00001	0.0000
Acanthuridae	*Ctenochaetus flavicauda*	0.00060	0.0082
Acanthuridae	*Ctenochaetus hawaiiensis*	0.00249	0.4409
Acanthuridae	*Ctenochaetus* spp.	0.00079	0.0522
Acanthuridae	*Ctenochaetus striatus*	0.06285	6.2585
Acanthuridae	*Naso annulatus*	0.00001	0.0099
Acanthuridae	*Naso brevirostris*	0.00194	0.7640
Acanthuridae	*Naso caesius*	0.00018	0.0127
Acanthuridae	*Naso lituratus*	0.00289	0.9196
Acanthuridae	*Naso vlamingii*	0.00017	0.0888

3.2.2 Weighted average density and biomass of all finfish species recorded in Ailuk (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Zebrasoma flavescens*	0.00015	0.0007
Acanthuridae	*Zebrasoma scopas*	0.00189	0.0577
Acanthuridae	*Zebrasoma veliferum*	0.00120	0.1299
Balistidae	*Balistapus undulatus*	0.00220	0.1980
Balistidae	*Melichthys vidua*	0.00140	0.2193
Balistidae	*Sufflamen bursa*	0.00017	0.0256
Balistidae	*Sufflamen chrysopterum*	0.00036	0.0133
Caesionidae	*Caesio teres*	0.00047	0.0880
Caesionidae	*Pterocaesio tile*	0.00409	0.4291
Carangidae	*Carangoides orthogrammus*	0.00017	0.0388
Carangidae	*Caranx melampygus*	0.00017	0.2589
Carangidae	*Elagatis bipinnulata*	0.00214	2.6957
Carangidae	*Scomberoides* spp.	0.00017	0.0461
Carcharhinidae	*Carcharhinus amblyrhynchos*	0.00018	2.5027
Carcharhinidae	*Carcharhinus melanopterus*	0.00048	6.7924
Carcharhinidae	*Triaenodon obesus*	0.00017	1.7110
Chaetodontidae	*Chaetodon aureofasciatus*	0.00003	0.0015
Chaetodontidae	*Chaetodon auriga*	0.00200	0.1429
Chaetodontidae	*Chaetodon citrinellus*	0.00135	0.0041
Chaetodontidae	*Chaetodon ephippium*	0.00187	0.1628
Chaetodontidae	*Chaetodon kleinii*	0.00033	0.0014
Chaetodontidae	*Chaetodon lineolatus*	0.00033	0.0854
Chaetodontidae	*Chaetodon lunula*	0.00089	0.1530
Chaetodontidae	*Chaetodon lunulatus*	0.00551	0.1596
Chaetodontidae	*Chaetodon mertensii*	0.00098	0.0166
Chaetodontidae	*Chaetodon punctatofasciatus*	0.00445	0.0358
Chaetodontidae	*Chaetodon reticulatus*	0.00395	0.1410
Chaetodontidae	*Chaetodon semeion*	0.00013	0.0100
Chaetodontidae	*Chaetodon trifascialis*	0.00584	0.0761
Chaetodontidae	*Chaetodon ulietensis*	0.00131	0.0402
Chaetodontidae	*Forcipiger flavissimus*	0.00176	0.0328
Chaetodontidae	*Forcipiger longirostris*	0.00100	0.0392
Chaetodontidae	*Heniochus chrysostomus*	0.00116	0.0485
Chaetodontidae	*Heniochus monoceros*	0.00018	0.0394
Holocentridae	*Myripristis adusta*	0.00035	0.1390
Holocentridae	*Myripristis berndti*	0.00063	0.1367
Holocentridae	*Myripristis kuntee*	0.00063	0.0630
Holocentridae	*Myripristis murdjan*	0.00333	0.4293
Holocentridae	*Myripristis* spp.	0.00212	0.2929
Holocentridae	*Myripristis violacea*	0.00588	1.0595
Holocentridae	*Neoniphon argenteus*	0.00040	0.0190
Holocentridae	*Neoniphon opercularis*	0.00013	0.0268
Holocentridae	*Neoniphon sammara*	0.00031	0.0274
Holocentridae	*Neoniphon* spp.	0.00026	0.0215
Holocentridae	*Sargocentron caudimaculatum*	0.00013	0.0090
Holocentridae	*Sargocentron diadema*	0.00013	0.0015

3.2.2 Weighted average density and biomass of all finfish species recorded in Ailuk (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Holocentridae	*Sargocentron spiniferum*	0.00046	0.3417
Labridae	*Cheilinus chlorourus*	0.00001	0.0024
Labridae	*Cheilinus fasciatus*	0.00062	0.1150
Labridae	*Cheilinus undulatus*	0.00013	0.0036
Labridae	*Coris aygula*	0.00048	0.4509
Labridae	*Coris gaimard*	0.00004	0.0030
Labridae	*Epibulus insidiator*	0.00084	0.1339
Labridae	*Hemigymnus fasciatus*	0.00017	0.0057
Labridae	*Hemigymnus melapterus*	0.00115	0.2143
Labridae	*Oxycheilinus celebicus*	0.00016	0.0104
Labridae	*Oxycheilinus digramma*	0.00018	0.0053
Lethrinidae	*Gnathodentex aureolineatus*	0.00122	0.2089
Lethrinidae	*Gymnocranius* spp.	0.00015	0.3173
Lethrinidae	*Lethrinus microdon*	0.00079	2.5867
Lethrinidae	*Lethrinus xanthochilus*	0.00030	0.5451
Lethrinidae	*Monotaxis grandoculis*	0.01842	7.8909
Lutjanidae	*Aphareus furca*	0.00068	0.1798
Lutjanidae	*Aprion virescens*	0.00030	0.2651
Lutjanidae	*Lutjanus bohar*	0.00062	0.6422
Lutjanidae	*Lutjanus fulvus*	0.00050	0.2232
Lutjanidae	*Lutjanus gibbus*	0.01479	6.1229
Lutjanidae	*Lutjanus monostigma*	0.00246	1.3192
Lutjanidae	*Macolor macularis*	0.00036	0.5284
Lutjanidae	*Macolor niger*	0.00001	0.0029
Mullidae	*Mulloidichthys vanicolensis*	0.00030	0.0062
Mullidae	*Parupeneus barberinus*	0.00013	0.0031
Mullidae	*Parupeneus cyclostomus*	0.00096	0.5137
Mullidae	*Parupeneus multifasciatus*	0.00086	0.0258
Mullidae	*Parupeneus pleurostigma*	0.00430	0.1118
Nemipteridae	*Scolopsis trilineata*	0.00132	0.0171
Pomacanthidae	*Pomacanthus imperator*	0.00017	0.1166
Pomacanthidae	*Pygoplites diacanthus*	0.00220	0.2866
Scaridae	*Cetoscarus bicolor*	0.00168	2.7234
Scaridae	*Chlorurus frontalis*	0.00066	0.3606
Scaridae	*Chlorurus microrhinos*	0.00872	9.3790
Scaridae	*Chlorurus sordidus*	0.01464	1.0545
Scaridae	*Hipposcarus longiceps*	0.00129	0.6512
Scaridae	*Scarus altipinnis*	0.00299	4.1168
Scaridae	*Scarus dimidiatus*	0.00003	0.0012
Scaridae	*Scarus flavipectoralis*	0.00003	0.0038
Scaridae	*Scarus forsteni*	0.00427	1.5822
Scaridae	*Scarus frenatus*	0.00094	0.0968
Scaridae	*Scarus niger*	0.00080	0.3116
Scaridae	*Scarus oviceps*	0.00040	0.0331
Scaridae	*Scarus rubroviolaceus*	0.00018	0.3712
Scaridae	*Scarus schlegeli*	0.00282	0.3172

3.2.2 Weighted average density and biomass of all finfish species recorded in Ailuk (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Scarus* spp.	0.00040	0.1198
Scombridae	*Acanthocybium solandri*	0.00007	0.0060
Serranidae	*Anyperodon leucogrammicus*	0.00100	0.1609
Serranidae	*Cephalopholis argus*	0.00168	0.6085
Serranidae	*Cephalopholis urodeta*	0.00215	0.1320
Serranidae	*Epinephelus areolatus*	0.00044	0.1196
Serranidae	*Epinephelus maculatus*	0.00006	0.0209
Serranidae	*Epinephelus merra*	0.00098	0.0455
Serranidae	*Epinephelus polyphekadion*	0.00019	0.1087
Serranidae	*Epinephelus spilotoceps*	0.00017	0.0254
Serranidae	*Gracila albomarginata*	0.00063	0.1540
Serranidae	*Plectropomus areolatus*	0.00089	0.4067
Serranidae	*Plectropomus laevis*	0.00073	3.4420
Serranidae	*Variola louti*	0.00001	0.0071
Siganidae	*Siganus argenteus*	0.00365	0.9636
Zanclidae	*Zanclus cornutus*	0.00324	0.2920

3.3 Arno finfish survey data

3.3.1 Coordinates (WGS84) of the 18 D-UVC transects used to assess finfish resource status in Arno

Station name	Habitat	Latitude	Longitude
TRA01	Outer reef	7º03'09.6588" N	171º33'26.5212" E
TRA02	Outer reef	7º06'57.78" N	171º33'56.34" E
TRA03	Outer reef	7º02'27.42" N	171º34'12.54" E
TRA04	Outer reef	7º12'16.1388" N	171º38'55.86" E
TRA05	Outer reef	7º10'21.6012" N	171º39'24.5412" E
TRA06	Outer reef	7º08'19.5612" N	171º40'52.68" E
TRA07	Lagoon	7º06'19.8" N	171º38'29.3388" E
TRA08	Back-reef	7º11'12.12" N	171º38'43.0188" E
TRA09	Back-reef	7º10'39.6588" N	171º36'49.2012" E
TRA10	Lagoon	7º09'46.8612" N	171º37'05.4588" E
TRA11	Back-reef	7º08'43.0188" N	171º35'35.2212" E
TRA12	Lagoon	7º08'09.5388" N	171º36'47.4012" E
TRA13	Back-reef	7º09'20.2212" N	171º39'20.7" E
TRA14	Lagoon	7º05'55.7412" N	171º39'43.4412" E
TRA15	Lagoon	7º04'52.6188" N	171º38'23.64" E
TRA16	Lagoon	7º03'59.6412" N	171º35'39.48" E
TRA17	Back-reef	7º07'22.08" N	171º34'36.5412" E
TRA18	Back-reef	7º05'04.1388" N	171º33'36.54" E

3.3.2 Weighted average density and biomass of all finfish species recorded in Arno (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus blochii*	0.00062	0.0576
Acanthuridae	*Acanthurus guttatus*	0.00116	0.0946
Acanthuridae	*Acanthurus lineatus*	0.01045	2.7345
Acanthuridae	*Acanthurus mata*	0.00172	1.3779
Acanthuridae	*Acanthurus nigricans*	0.06653	4.4500
Acanthuridae	*Acanthurus nigricauda*	0.00048	0.0392
Acanthuridae	*Acanthurus nigrofuscus*	0.00135	0.1617
Acanthuridae	*Acanthurus olivaceus*	0.00216	0.3264
Acanthuridae	*Acanthurus pyroferus*	0.00159	0.2121
Acanthuridae	*Acanthurus* spp.	0.00114	0.9797
Acanthuridae	*Acanthurus thompsoni*	0.00444	0.2206
Acanthuridae	*Ctenochaetus* spp.	0.00015	0.0009
Acanthuridae	*Ctenochaetus striatus*	0.17187	11.4211
Acanthuridae	*Naso brevirostris*	0.00740	4.6938
Acanthuridae	*Naso lituratus*	0.00177	0.2774
Acanthuridae	*Naso vlamingii*	0.00049	0.1002
Acanthuridae	*Zebrasoma scopas*	0.00108	0.0215
Acanthuridae	*Zebrasoma veliferum*	0.00053	0.0401
Balistidae	*Balistapus undulatus*	0.00769	0.8573
Balistidae	*Balistoides viridescens*	0.00003	0.0277
Balistidae	*Melichthys niger*	0.00083	0.0620
Balistidae	*Melichthys vidua*	0.00096	0.1162

3.3.2 Weighted average density and biomass of all finfish species recorded in Arno (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Balistidae	*Pseudobalistes flavimarginatus*	0.00015	0.2381
Balistidae	*Rhinecanthus aculeatus*	0.00015	0.0053
Balistidae	*Sufflamen bursa*	0.00018	0.0356
Balistidae	*Sufflamen chrysopterum*	0.00003	0.0042
Caesionidae	*Caesio caerulaurea*	0.00166	0.3433
Caesionidae	*Pterocaesio tessellata*	0.00332	0.5724
Caesionidae	*Pterocaesio tile*	0.00196	0.2057
Carangidae	*Caranx melampygus*	0.00018	0.2331
Carangidae	*Elagatis bipinnulata*	0.05096	120.7656
Carcharhinidae	*Carcharhinus amblyrhynchos*	0.00036	4.1690
Carcharhinidae	*Triaenodon obesus*	0.00047	4.6635
Chaetodontidae	*Chaetodon auriga*	0.00219	0.0745
Chaetodontidae	*Chaetodon citrinellus*	0.00128	0.0201
Chaetodontidae	*Chaetodon ephippium*	0.00176	0.1111
Chaetodontidae	*Chaetodon kleinii*	0.00011	0.0017
Chaetodontidae	*Chaetodon lunula*	0.00103	0.0804
Chaetodontidae	*Chaetodon lunulatus*	0.00632	0.2066
Chaetodontidae	*Chaetodon mertensii*	0.00017	0.0019
Chaetodontidae	*Chaetodon meyeri*	0.00033	0.0097
Chaetodontidae	*Chaetodon ornatissimus*	0.00017	0.0049
Chaetodontidae	*Chaetodon punctatofasciatus*	0.00083	0.0115
Chaetodontidae	*Chaetodon reticulatus*	0.00533	0.2621
Chaetodontidae	*Chaetodon semeion*	0.00003	0.0006
Chaetodontidae	*Chaetodon trifascialis*	0.00117	0.0274
Chaetodontidae	*Chaetodon ulietensis*	0.00053	0.0195
Chaetodontidae	*Chaetodon unimaculatus*	0.00003	0.0010
Chaetodontidae	*Chaetodon vagabundus*	0.00098	0.0394
Chaetodontidae	*Forcipiger flavissimus*	0.00189	0.0841
Chaetodontidae	*Forcipiger longirostris*	0.00139	0.0687
Chaetodontidae	*Hemitaurichthys polylepis*	0.00072	0.0077
Chaetodontidae	*Heniochus chrysostomus*	0.00039	0.0238
Ephippidae	*Platax teira*	0.00001	0.0371
Holocentridae	*Myripristis adusta*	0.00096	0.2686
Holocentridae	*Myripristis* spp.	0.00014	0.0238
Holocentridae	*Neoniphon sammara*	0.00004	0.0034
Holocentridae	*Sargocentron spiniferum*	0.00086	0.2885
Labridae	*Cheilinus chlorourus*	0.00098	0.2083
Labridae	*Cheilinus fasciatus*	0.00098	0.1255
Labridae	*Cheilinus trilobatus*	0.00079	0.0866
Labridae	*Hemigymnus fasciatus*	0.00001	0.0007
Labridae	*Hemigymnus melapterus*	0.00024	0.0217
Lethrinidae	*Gnathodentex aureolineatus*	0.00365	0.3074
Lethrinidae	*Lethrinus amboinensis*	0.00050	0.6167
Lethrinidae	*Lethrinus erythropterus*	0.00066	0.0832
Lethrinidae	*Lethrinus harak*	0.00077	0.1685
Lethrinidae	*Lethrinus olivaceus*	0.00233	1.5645

3.3.2 Weighted average density and biomass of all finfish species recorded in Arno (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Lethrinidae	*Monotaxis grandoculis*	0.00550	2.8661
Lutjanidae	*Aphareus furca*	0.00084	0.1749
Lutjanidae	*Aprion virescens*	0.00048	0.5665
Lutjanidae	*Lutjanus bohar*	0.00519	0.6009
Lutjanidae	*Lutjanus fulvus*	0.00003	0.0070
Lutjanidae	*Lutjanus gibbus*	0.00717	11.8541
Lutjanidae	*Lutjanus monostigma*	0.00171	0.6766
Lutjanidae	*Lutjanus semicinctus*	0.00017	0.0160
Lutjanidae	*Macolor macularis*	0.00294	1.1192
Lutjanidae	*Macolor niger*	0.00050	0.1892
Mullidae	*Mulloidichthys flavolineatus*	0.00058	0.0308
Mullidae	*Mulloidichthys vanicolensis*	0.00004	0.0066
Mullidae	*Parupeneus barberinus*	0.00039	0.0516
Mullidae	*Parupeneus cyclostomus*	0.00035	0.1146
Mullidae	*Parupeneus indicus*	0.00019	0.0396
Mullidae	*Parupeneus multifasciatus*	0.00496	0.2583
Nemipteridae	*Scolopsis bilineata*	0.00062	0.0227
Nemipteridae	*Scolopsis lineata*	0.00001	0.0015
Nemipteridae	*Scolopsis trilineata*	0.00001	0.0015
Pomacanthidae	*Pygoplites diacanthus*	0.00092	0.1129
Scaridae	*Cetoscarus bicolor*	0.00069	0.5204
Scaridae	*Chlorurus microrhinos*	0.00855	8.0638
Scaridae	*Chlorurus sordidus*	0.04210	2.4523
Scaridae	*Hipposcarus longiceps*	0.00750	5.9743
Scaridae	*Scarus flavipectoralis*	0.00017	0.0903
Scaridae	*Scarus niger*	0.00234	0.2218
Scaridae	*Scarus oviceps*	0.00001	0.0060
Scaridae	*Scarus psittacus*	0.00283	0.0740
Scaridae	*Scarus schlegeli*	0.00108	0.1029
Scaridae	*Scarus* spp.	0.00170	0.1103
Serranidae	*Cephalopholis argus*	0.00132	0.3463
Serranidae	*Cephalopholis urodeta*	0.00123	0.0720
Serranidae	*Epinephelus maculatus*	0.00031	0.0917
Serranidae	*Epinephelus merra*	0.00046	0.0189
Serranidae	*Epinephelus polyphekadion*	0.00035	0.1178
Serranidae	*Gracila albomarginata*	0.00050	0.1709
Serranidae	*Plectropomus areolatus*	0.00004	0.0225
Serranidae	*Plectropomus laevis*	0.00133	2.0886
Serranidae	*Plectropomus oligacanthus*	0.00001	0.0052
Serranidae	*Variola albimarginata*	0.00015	0.0663
Siganidae	*Siganus argenteus*	0.00066	0.0659
Siganidae	*Siganus lineatus*	0.00075	0.0834
Siganidae	*Siganus vulpinus*	0.00008	0.0082
Zanclidae	*Zanclus cornutus*	0.00169	0.1708

3.4 Laura finfish survey data

3.4.1 Coordinates (WGS84) of the 18 D-UVC transects used to assess finfish resource status in Laura

Station name	Habitat	Latitude	Longitude
TRA01	Back-reef	7º10'58.44" N	171º07'04.98" E
TRA02	Back-reef	7º11'33.72" N	171º05'47.22" E
TRA03	Back-reef	7º11'45.5388" N	171º05'17.8188" E
TRA04	Back-reef	7º13'07.0212" N	171º04'14.52" E
TRA05	Back-reef	7º11'48.66" N	171º03'04.2012" E
TRA06	Back-reef	7º10'40.3788" N	171º02'50.3988" E
TRA07	Lagoon	7º10'28.56" N	171º07'19.6212" E
TRA08	Lagoon	7º09'35.3412" N	171º06'46.6812" E
TRA09	Lagoon	7º10'37.6212" N	171º03'14.1588" E
TRA10	Lagoon	7º11'50.46" N	171º03'57.3012" E
TRA11	Lagoon	7º09'51.84" N	171º03'13.3812" E
TRA12	Lagoon	7º09'02.8188" N	171º03'20.2212" E
TRA13	Outer reef	7º07'36.2388" N	171º02'43.0188" E
TRA14	Outer reef	7º08'36.24" N	171º01'37.4988" E
TRA15	Outer reef	7º10'17.6412" N	171º02'06.9612" E
TRA16	Outer reef	7º11'40.38" N	171º06'06.7212" E
TRA17	Outer reef	7º12'34.6212" N	171º04'56.0388" E
TRA18	Outer reef	7º12'32.4" N	171º03'41.22" E

3.4.2 Weighted average density and biomass of all finfish species recorded in Laura (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Acanthurus blochii*	0.00612	1.9359
Acanthuridae	*Acanthurus guttatus*	0.00005	0.0050
Acanthuridae	*Acanthurus lineatus*	0.00119	0.2420
Acanthuridae	*Acanthurus nigricans*	0.02814	2.0673
Acanthuridae	*Acanthurus nigricauda*	0.00055	0.4163
Acanthuridae	*Acanthurus nigrofuscus*	0.00005	0.0040
Acanthuridae	*Acanthurus olivaceus*	0.00007	0.0062
Acanthuridae	*Acanthurus pyroferus*	0.00320	0.7690
Acanthuridae	*Acanthurus* spp.	0.00890	8.0433
Acanthuridae	*Acanthurus thompsoni*	0.00002	0.0027
Acanthuridae	*Acanthurus triostegus*	0.00933	0.6399
Acanthuridae	*Ctenochaetus striatus*	0.12544	9.3681
Acanthuridae	*Naso brachycentron*	0.00809	1.3590
Acanthuridae	*Naso brevirostris*	0.01214	2.6951
Acanthuridae	*Naso lituratus*	0.00295	0.1699
Acanthuridae	*Naso unicornis*	0.00083	0.0571
Acanthuridae	*Naso vlamingii*	0.00037	0.1156
Acanthuridae	*Zebrasoma scopas*	0.00126	0.0584
Acanthuridae	*Zebrasoma veliferum*	0.00036	0.0341
Balistidae	*Balistapus undulatus*	0.00418	0.7210
Balistidae	*Melichthys niger*	0.00033	0.1461
Balistidae	*Melichthys vidua*	0.00130	0.0930

3.4.2 Weighted average density and biomass of all finfish species recorded in Laura (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Balistidae	*Pseudobalistes flavimarginatus*	0.00027	0.2794
Balistidae	*Rhinecanthus aculeatus*	0.00216	0.2445
Balistidae	*Sufflamen bursa*	0.00082	0.1233
Balistidae	*Sufflamen chrysopterum*	0.00218	0.3563
Caesionidae	*Caesio caerulaurea*	0.00003	0.0018
Caesionidae	*Pterocaesio pisang*	0.00523	0.4024
Caesionidae	*Pterocaesio* spp.	0.00116	0.1215
Caesionidae	*Pterocaesio tile*	0.00566	0.7149
Caesionidae	*Pterocaesio trilineata*	0.00413	0.2089
Carangidae	*Caranx melampygus*	0.00017	0.1062
Carangidae	*Gnathanodon speciosus*	0.00005	0.0018
Carcharhinidae	*Carcharhinus albimarginatus*	0.00027	4.2656
Carcharhinidae	*Carcharhinus amblyrhynchos*	0.00054	7.5494
Chaetodontidae	*Chaetodon auriga*	0.00664	0.3699
Chaetodontidae	*Chaetodon citrinellus*	0.00144	0.0290
Chaetodontidae	*Chaetodon ephippium*	0.00042	0.0311
Chaetodontidae	*Chaetodon lineolatus*	0.00014	0.0040
Chaetodontidae	*Chaetodon lunula*	0.00011	0.0079
Chaetodontidae	*Chaetodon lunulatus*	0.00394	0.1330
Chaetodontidae	*Chaetodon melannotus*	0.00020	0.0136
Chaetodontidae	*Chaetodon mertensii*	0.00002	0.0002
Chaetodontidae	*Chaetodon meyeri*	0.00009	0.0045
Chaetodontidae	*Chaetodon octofasciatus*	0.00003	0.0010
Chaetodontidae	*Chaetodon ornatissimus*	0.00009	0.0027
Chaetodontidae	*Chaetodon punctatofasciatus*	0.00009	0.0015
Chaetodontidae	*Chaetodon reticulatus*	0.00237	0.0988
Chaetodontidae	*Chaetodon trifascialis*	0.00053	0.0230
Chaetodontidae	*Chaetodon ulietensis*	0.00044	0.0204
Chaetodontidae	*Chaetodon unimaculatus*	0.00036	0.0208
Chaetodontidae	*Chaetodon vagabundus*	0.00094	0.0539
Chaetodontidae	*Forcipiger flavissimus*	0.00034	0.0101
Chaetodontidae	*Forcipiger longirostris*	0.00028	0.0136
Chaetodontidae	*Hemitaurichthys polylepis*	0.00026	0.0040
Chaetodontidae	*Heniochus acuminatus*	0.00054	0.0384
Chaetodontidae	*Heniochus chrysostomus*	0.00068	0.0532
Holocentridae	*Myripristis berndti*	0.00070	0.0806
Holocentridae	*Myripristis* spp.	0.00258	0.4111
Holocentridae	*Neoniphon sammara*	0.00539	0.4477
Holocentridae	*Neoniphon* spp.	0.00050	0.0224
Holocentridae	*Sargocentron* spp.	0.00019	0.0106
Holocentridae	*Sargocentron spiniferum*	0.00032	0.0400
Holocentridae	*Sargocentron tiere*	0.00009	0.0095
Kyphosidae	*Kyphosus vaigiensis*	0.00010	0.0529
Labridae	*Cheilinus chlorourus*	0.00030	0.0067
Labridae	*Cheilinus fasciatus*	0.00054	0.0571
Labridae	*Cheilinus trilobatus*	0.00010	0.0156

3.4.2 Weighted average density and biomass of all finfish species recorded in Laura (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m^2)	Biomass (g/m^2)
Labridae	*Cheilinus undulatus*	0.00002	0.0102
Labridae	*Epibulus insidiator*	0.00008	0.0159
Labridae	*Hemigymnus fasciatus*	0.00011	0.0090
Labridae	*Hemigymnus melapterus*	0.00230	0.5279
Lethrinidae	*Gnathodentex aureolineatus*	0.02149	7.2009
Lethrinidae	*Lethrinus erythropterus*	0.00006	0.0074
Lethrinidae	*Lethrinus harak*	0.00566	3.5689
Lethrinidae	*Lethrinus obsoletus*	0.00002	0.0026
Lethrinidae	*Lethrinus* spp.	0.00006	0.0229
Lethrinidae	*Lethrinus xanthochilus*	0.00002	0.0025
Lethrinidae	*Monotaxis grandoculis*	0.00766	2.7940
Lutjanidae	*Aphareus furca*	0.00055	0.1428
Lutjanidae	*Lutjanus bohar*	0.00171	0.5578
Lutjanidae	*Lutjanus fulvus*	0.00181	0.5905
Lutjanidae	*Lutjanus gibbus*	0.00398	1.1615
Lutjanidae	*Lutjanus lutjanus*	0.00010	0.0372
Lutjanidae	*Lutjanus monostigma*	0.00082	0.3566
Lutjanidae	*Lutjanus semicinctus*	0.00027	0.0982
Lutjanidae	*Macolor macularis*	0.00011	0.0333
Mullidae	*Mulloidichthys flavolineatus*	0.00005	0.0090
Mullidae	*Mulloidichthys vanicolensis*	0.00108	0.6484
Mullidae	*Parupeneus barberinoides*	0.00027	0.1813
Mullidae	*Parupeneus barberinus*	0.00460	2.4695
Mullidae	*Parupeneus indicus*	0.01214	7.5157
Mullidae	*Parupeneus multifasciatus*	0.00692	0.9430
Nemipteridae	*Scolopsis bilineata*	0.00270	0.3594
Nemipteridae	*Scolopsis lineata*	0.00236	0.2448
Nemipteridae	*Scolopsis trilineata*	0.00047	0.0325
Pomacanthidae	*Pygoplites diacanthus*	0.00019	0.0164
Scaridae	*Cetoscarus bicolor*	0.00013	0.0862
Scaridae	*Chlorurus bleekeri*	0.00017	0.0560
Scaridae	*Chlorurus microrhinos*	0.00320	2.7152
Scaridae	*Chlorurus sordidus*	0.01866	1.9385
Scaridae	*Hipposcarus longiceps*	0.00166	0.6626
Scaridae	*Scarus dimidiatus*	0.00032	0.0556
Scaridae	*Scarus flavipectoralis*	0.00003	0.0100
Scaridae	*Scarus forsteni*	0.00006	0.0116
Scaridae	*Scarus frenatus*	0.00005	0.0366
Scaridae	*Scarus globiceps*	0.00432	0.8417
Scaridae	*Scarus niger*	0.00237	1.7893
Scaridae	*Scarus oviceps*	0.00002	0.0094
Scaridae	*Scarus psittacus*	0.02200	1.5701
Scaridae	*Scarus schlegeli*	0.00042	0.0790
Scaridae	*Scarus* spp.	0.00262	0.6585
Scaridae	*Scarus spinus*	0.00005	0.0147
Serranidae	*Anyperodon leucogrammicus*	0.00005	0.0050

3.4.2 Weighted average density and biomass of all finfish species recorded in Laura (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Serranidae	*Cephalopholis argus*	0.00032	0.1073
Serranidae	*Cephalopholis urodeta*	0.00334	0.1717
Serranidae	*Epinephelus fuscoguttatus*	0.00029	0.2803
Serranidae	*Epinephelus merra*	0.00083	0.0220
Serranidae	*Epinephelus polyphekadion*	0.00005	0.0313
Serranidae	*Epinephelus* spp.	0.00002	0.0026
Serranidae	*Gracila albomarginata*	0.00028	0.0523
Serranidae	*Plectropomus areolatus*	0.00009	0.0266
Serranidae	*Plectropomus laevis*	0.00014	0.0902
Serranidae	*Variola louti*	0.00005	0.0163
Siganidae	*Siganus argenteus*	0.00017	0.0234
Siganidae	*Siganus vulpinus*	0.00040	0.0488
Zanclidae	*Zanclus cornutus*	0.00222	0.1609

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Likiep invertebrate survey data

4.1.1 Invertebrate species recorded in different assessments in Likiep

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Holothuria atra*	+	+	+	+
Bêche-de-mer	*Holothuria edulis*		+		+
Bêche-de-mer	*Holothuria nobilis*	+	+		
Bêche-de-mer	*Synapta* spp.		+		
Bêche-de-mer	*Thelenota ananas*	+			+
Bêche-de-mer	*Thelenota anax*	+			+
Bivalve	*Beguina semiorbiculata*	+			
Bivalve	*Hippopus hippopus*	+	+		
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.		+		+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		
Cnidarian	*Entacmaea quadricolor*				+
Cnidarian	*Stichodactyla* spp.		+		
Crustacean	*Gonodactylus* spp.		+		
Crustacean	*Panulirus penicillatus*		+		
Crustacean	*Panulirus versicolor*	+			
Crustacean	*Saron* spp.		+		
Crustacean	*Stenopus hispidus*		+		
Crustacean	*Thalassina sp*		+	+	
Gastropod	*Astralium* spp.		+		
Gastropod	*Bursa bufonia*				+
Gastropod	*Bursa granularis*		+		
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Conus bandanus*	+			
Gastropod	*Conus distans*	+	+		+
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus leopardus*	+			
Gastropod	*Conus lividus*		+		+
Gastropod	*Conus miles*	+	+		+
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus pulicarius*		+		
Gastropod	*Coralliophila* spp.		+		
Gastropod	*Cypraea arabica*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea scurra*		+		
Gastropod	*Cypraea tigris*	+	+		
Gastropod	*Harpa amouretta*		+		
Gastropod	*Lambis chiragra*	+	+		
Gastropod	*Lambis lambis*	+	+		+

+ = presence of the species.

4.1.1 Invertebrate species recorded in different assessments in Likiep (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Lambis scorpius*	+	+		
Gastropod	*Lambis truncata*	+			+
Gastropod	*Mitra mitra*				+
Gastropod	*Rhinoclavis aspera*		+		
Gastropod	*Strombus luhuanus*	+	+		
Gastropod	*Tectus pyramis*	+			+
Gastropod	*Thais aculeata*		+		
Gastropod	*Trochus maculata*		+		+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo argyrostomus*		+		+
Gastropod	*Vasum* spp.		+		
Gastropod	*Vasum turbinellum*	+	+		
Nudibranch	*Phyllidia* spp.		+		
Octopus	*Octopus* spp.	+	+		
Star	*Acanthaster planci*	+	+		+
Star	*Archaster* spp.		+		
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix diadema*	+	+		+
Urchin	*Mespilia globulus*		+		
Urchin	*Tripneustes* spp.	+			

+ = presence of the species.

4.1.2 Likiep broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Actinopyga mauritiana	0.5	0.3	72	16.4	0.3	2	0.5	0.5	12	5.5		1
Beguina semiorbiculata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Bohadschia argus	3.2	1.2	72	23.3	5.1	10	3.2	1.2	12	5.5	1.5	7
Conus bandanus	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Conus distans	1.2	0.6	72	20.8	4.2	4	1.2	0.7	12	4.6	1.9	3
Conus leopardus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus miles	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Culcita novaeguineae	5.1	1.2	72	21.5	2.4	17	5.1	2.0	12	6.8	2.4	9
Cypraea tigris	0.7	0.5	72	25.0	8.3	2	0.7	0.5	12	4.2	1.4	2
Echinothrix diadema	1.4	1.4	72	100.0		1	1.4	1.4	12	16.7		1
Hippopus hippopus	4.1	1.0	72	19.9	1.8	15	4.2	1.0	12	5.0	1.0	10
Holothuria atra	174.4	37.6	72	570.7	69.7	22	173.9	75.3	12	521.8	42.7	4
Holothuria nobilis	0.9	0.6	72	22.2	5.6	3	0.9	0.7	12	5.6	2.8	2
Lambis chiragra	0.9	0.5	72	16.6	0.1	4	0.9	0.5	12	3.7	0.9	3
Lambis lambis	2.1	0.8	72	21.4	3.1	7	2.1	1.0	12	5.0	1.6	5
Lambis scorpius	0.5	0.3	72	16.5	0.1	2	0.5	0.3	12	2.8	0.0	2
Lambis truncata	0.5	0.3	72	16.5	0.1	2	0.5	0.3	12	2.8	0.0	2
Linckia laevigata	2.8	1.1	72	24.8	5.5	8	2.8	1.4	12	5.5	2.3	6
Panulirus versicolor	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Pinctada margaritifera	2.8	1.9	72	50.0	28.1	4	2.8	1.8	12	8.3	4.6	4
Strombus luhuanus	5.8	4.5	72	104.2	71.2	4	5.8	5.5	12	34.7	31.9	2
Tectus pyramis	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Thelenota ananas	3.2	1.1	72	23.3	3.7	10	3.2	1.2	12	6.4	1.4	6
Thelenota anax	1.4	1.4	72	100.0		1	1.4	1.4	12	16.6		1
Tridacna maxima	30.0	7.8	72	67.4	15.4	32	29.9	12.7	12	32.7	13.6	11
Tridacna squamosa	2.3	0.7	72	16.6	0.1	10	2.3	0.9	12	4.0	1.2	7
Tripneustes spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.2 Likiep 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
Trochus niloticus	2.1	0.7	72	18.7	2.1	8	2.1	1.2	12	6.2	2.6	4
Vasum turbinellum	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	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.

4.1.3 Likiep 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	13.3	6.8	132	350.0	100.0	5	13.3	7.9	22	72.9	31.3	4
Archaster spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Astralium spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Bohadschia argus	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Bursa granularis	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Cerithium nodulosum	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Chicoreus brunneus	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1
Conus distans	9.5	4.2	132	250.0	0.0	5	9.5	6.1	22	69.4	27.8	3
Conus flavidus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Conus lividus	5.7	4.2	132	375.0	125.0	2	5.7	4.2	22	62.5	20.8	2
Conus miles	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Conus miliaris	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Conus pulicarius	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Coralliophila spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Culcita novaeguineae	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea arabica	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Cypraea caputserpensis	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea moneta	24.6	8.9	132	361.1	60.5	9	24.6	11.8	22	77.4	29.4	7
Cypraea scurra	1.9	1.9	132	250.0		1	1.9	1.9	22	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.

4.1.3 Likiep 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 tigris	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Echinometra mathaei	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1
Echinothrix diadema	9.5	7.8	132	625.0	375.0	2	9.5	7.7	22	104.2	62.5	2
Gonodactylus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Harpa amouretta	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Hippopus hippopus	9.5	5.0	132	312.5	62.5	4	9.5	4.7	22	52.1	10.4	4
Holothuria atra	4500.0	1858.8	132	23,760.0	8973.0	25	4500.0	3626.2	22	16,500.0	12,763.3	6
Holothuria edulis	18.9	9.6	132	625.0	72.2	4	18.9	18.9	22	416.7		1
Holothuria nobilis	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Lambis chiragra	13.3	8.6	132	583.3	220.5	3	13.3	8.4	22	97.2	36.7	3
Lambis lambis	26.5	9.8	132	350.0	76.4	10	26.5	10.8	22	83.3	22.3	7
Lambis scorpius	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Linckia laevigata	9.5	4.2	132	250.0	0.0	5	9.5	5.4	22	69.4	13.9	3
Mespilia globulus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Octopus spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Panulirus penicillatus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Phyllidia spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Pinctada margaritifera	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Rhinoclavis aspera	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Saron spp.	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Spondylus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Stenopus hispidus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Stichodactyla spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Strombus luhuanus	126.9	58.4	132	1196.4	474.8	14	126.9	63.6	22	398.8	162.6	7
Synapta spp.	5.7	4.2	132	375.0	125.0	2	5.7	5.7	22	125.0		1
Thais aculeata	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Thalassina sp	43.6	12.5	132	410.7	56.3	14	43.6	14.9	22	106.5	24.2	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.

4.1.3 Likiep 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
Tridacna maxima	113.6	26.9	132	500.0	88.1	30	113.6	43.5	22	208.3	69.6	12
Tridacna squamosa	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Trochus maculata	17.0	8.6	132	375.0	125.0	6	17.0	8.1	22	62.5	20.8	6
Trochus niloticus	49.2	13.8	132	406.3	64.0	16	49.2	21.5	22	154.8	48.7	7
Turbo argyrostomus	13.3	5.6	132	291.7	41.7	6	13.3	6.9	22	72.9	19.9	4
Vasum spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Vasum turbinellum	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	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.

4.1.4 Likiep soft-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
Holothuria atra	65,250.0	9853.5	6	65,250.0	9853.5	6	65,250.0		1	65,250.0		1
Thalassina spp.	208.3	100.3	6	416.7	83.3	3	208.3		1	208.3		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.

4.1.5 Likiep reef-front search (RFs) assessment data review
Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	2.9	1.6	24	23.5	0.0	3	2.9	1.0	4	3.9	0.0	3
Actinopyga mauritiana	4.9	3.2	24	39.2	15.7	3	4.9	4.9	4	19.6		1
Bursa bufonia	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Conus distans	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Conus lividus	2.0	1.4	24	23.5	0.0	2	2.0	1.1	4	3.9	0.0	2
Conus miles	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Echinometra mathaei	2.0	1.4	24	23.5	0.0	2	2.0	2.0	4	7.8		1
Echinothrix diadema	7.8	4.2	24	47.1	13.6	4	7.8	3.6	4	10.5	3.5	3
Lambis truncata	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Spondylus spp.	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Tectus pyramis	4.9	2.4	24	29.4	5.9	4	4.9	3.7	4	9.8	5.9	2
Tridacna maxima	28.4	8.3	24	56.9	11.7	12	28.4	13.6	4	28.4	13.6	4
Trochus maculata	2.0	1.4	24	23.5	0.0	2	2.0	1.1	4	3.9	0.0	2
Trochus niloticus	14.7	4.4	24	39.2	5.5	9	14.7	6.9	4	19.6	6.8	3
Turbo argyrostomus	2.9	1.6	24	23.5	0.0	3	2.9	2.9	4	11.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.6 Likiep 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	1.6	1.1	18	14.3	0.0	2	1.6	1.6	3	4.8		1
Culcita novaeguineae	1.6	1.1	18	14.3	0.0	2	1.6	0.8	3	2.4	0.0	2
Entacmaea quadricolor	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Holothuria atra	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Holothuria edulis	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Lambis lambis	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
Spondylus spp.	2.4	1.3	18	14.3	0.0	3	2.4	1.4	3	3.6	1.2	2
Thelenota ananas	8.7	4.2	18	39.3	6.8	4	8.7	8.7	3	26.2		1
Thelenota anax	28.6	8.1	18	34.3	9.0	15	28.6	13.5	3	28.6	13.5	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.7 Likiep species size review – all survey methods

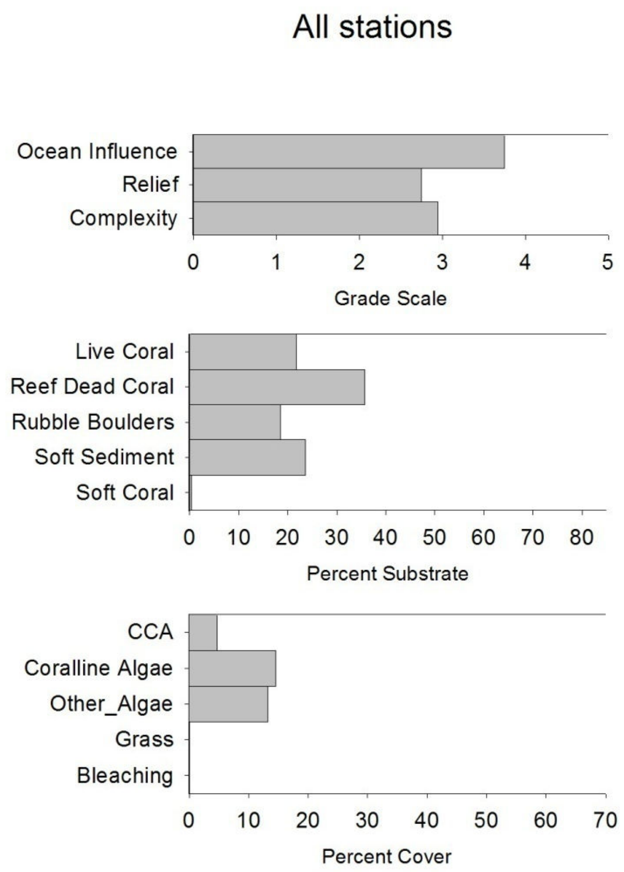
Species	Mean length (cm)	SE	n
Holothuria atra	3.3	0.1	4697
Tridacna maxima	10.4	0.3	219
Strombus luhuanus	5.2	0.2	92
Trochus niloticus	7.7	0.4	50
Thelenota anax	50.4	1.4	42
Thelenota ananas	49.9	1.9	25
Lambis lambis	13.5	0.9	24
Hippopus hippopus	20.2	1.7	23
Bohadschia argus	38.3	1.5	18
Pinctada margaritifera	10.9	5.1	13
Tridacna squamosa	18.9	3.1	12
Holothuria edulis	16.4	1.2	11
Conus distans	8.9	0.4	11
Trochus maculata	2.2	0.1	11
Lambis chiragra	19.6	1.9	11
Turbo argyrostomus	5.8	0.4	10
Actinopyga mauritiana	21.6	1.3	7
Tectus pyramis	6.4	0.5	6
Conus lividus	5.5	1.3	5
Cypraea tigris	7.2	0.6	5
Conus miles	4.6	0.8	4
Lambis truncata	28.7	0.9	3
Cerithium nodulosum	8.3	0.7	2
Conus miliaris	2.7	0.1	2
Cypraea arabica	4.4	0.1	2
Thais aculeata	4.3	0.1	2
Thalassina sp	7.6	0.0	28
Holothuria nobilis	27.1	0.0	5
Vasum turbinellum	5.4	0.0	4
Lambis scorpius	16.1	0.0	3
Rhinoclavis aspera	4.2	0.0	2
Tripneustes spp.	15.0	0.0	1
Astralium spp.	5.7	0.0	1
Conus flavidus	4.0	0.0	1
Conus leopardus	12.0	0.0	1
Conus pulicarius	3.2	0.0	1
Harpa amouretta	3.5	0.0	1
Vasum spp.	4.6	0.0	1
Culcita novaeguineae			25
Echinothrix diadema			19
Linckia laevigata			17
Cypraea moneta			13
Acanthaster planci			11
Octopus spp.			5
Spondylus spp.			5
Echinometra mathaei			4
Saron spp.			4
Synapta spp.			3

4.1.7 Likiep species size review – all survey methods (continued)

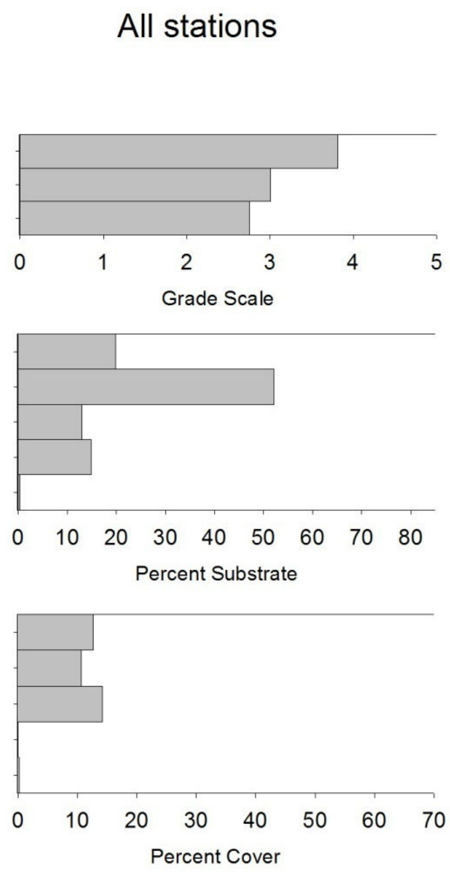
Species	Mean length (cm)	SE	n
Archaster spp.			2
Phyllidia spp.			2
Bursa granularis			2
Chicoreus brunneus			2
Conus bandanus			2
Mespilia globulus			1
Bursa bufonia			1
Coralliophila spp.			1
Cypraea caputserpensis			1
Cypraea scurra			1
Mitra mitra			1
Gonodactylus spp.			1
Panulirus penicillatus			1
Panulirus versicolor			1
Stenopus hispidus			1
Entacmaea quadricolor			1
Stichodactyla spp.			1
Beguina semiorbiculata			1

4.1.8 Habitat descriptors for independent assessment – Likiep

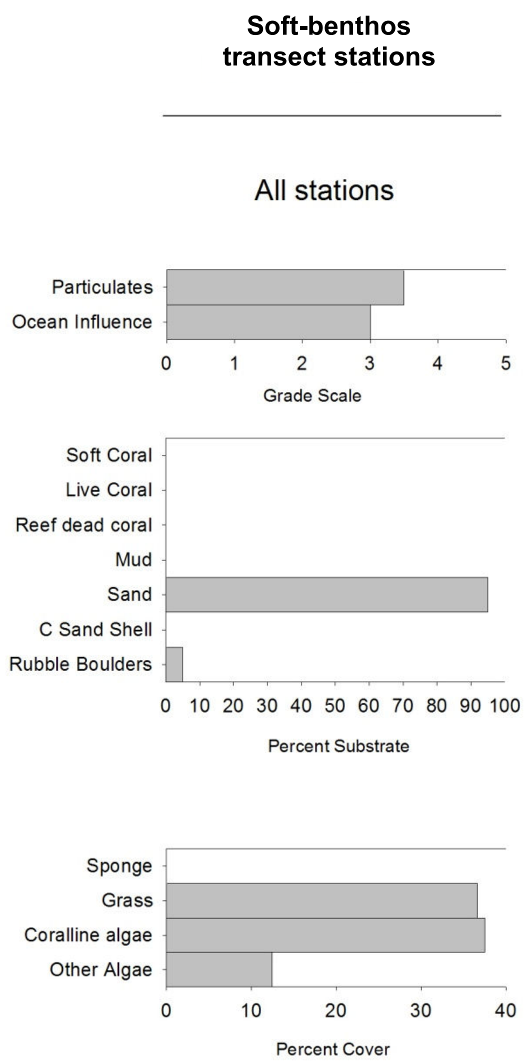
Broad-scale stations



Reef-benthos transect stations



4.1.8 Habitat descriptors for independent assessment – Likiep (continued)



4.2 Ailuk invertebrate survey data

4.2.1 Invertebrate species recorded in different assessments in Ailuk

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Bohadschia argus*	+			+
Bêche-de-mer	*Bohadschia vitiensis*	+			+
Bêche-de-mer	*Holothuria atra*	+	+		+
Bêche-de-mer	*Holothuria edulis*	+	+		+
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria nobilis*				+
Bêche-de-mer	*Synapta* spp.	+			
Bêche-de-mer	*Thelenota ananas*	+			+
Bêche-de-mer	*Thelenota anax*	+	+		+
Bêche-de-mer	*Thelenota* spp.	+			
Bivalve	*Chama* spp.	+	+		+
Bivalve	*Hippopus hippopus*	+	+		+
Bivalve	*Pinctada margaritifera*	+	+		+
Bivalve	*Spondylus* spp.	+			+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		+
Cnidarians	*Stichodactyla* spp.	+	+		+
Crustacean	*Carpilius maculatus*				+
Crustacean	*Etisus* spp.				+
Crustacean	*Panulirus* spp.	+			
Gastropod	*Astralium* spp.		+		
Gastropod	*Cerithium nodulosum*	+	+		
Gastropod	*Charonia tritonis*	+			
Gastropod	*Chicoreus* spp.		+		
Gastropod	*Conus* spp.		+		
Gastropod	*Cypraea annulus*		+		+
Gastropod	*Cypraea caputserpensis*				+
Gastropod	*Cypraea tigris*	+	+		+
Gastropod	*Lambis chiragra*	+	+		+
Gastropod	*Lambis truncata*	+	+		
Gastropod	*Mitra mitra*		+		
Gastropod	*Pleuroploca* spp.				+
Gastropod	*Tectus conus*				+
Gastropod	*Tectus pyramis*	+	+		+
Gastropod	*Trochus maculata*				+
Gastropod	*Trochus* spp.				+
Gastropod	*Turbo argyrostomus*		+		+
Gastropod	*Turbo petholatus*		+		
Octopus	*Octopus* spp.	+	+		+
Star	*Acanthaster planci*	+			+
Star	*Choriaster granulatus*				+
Star	*Choriaster* spp.				+
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia laevigata*	+			
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix diadema*	+	+		
Urchin	*Heterocentrotus mammillatus*				+

+ = presence of the species.

4.2.2 Ailuk 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	0.7	0.4	73	16.7	0.0	3	0.7	0.3	12	2.6	0.1	3
Bohadschia argus	4.1	1.2	73	23.1	3.0	13	3.9	1.5	12	7.9	2.0	6
Bohadschia vitiensis	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Cerithium nodulosum	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Chama spp.	31.7	10.8	73	121.9	34.3	19	32.1	16.8	12	64.3	28.8	6
Charonia tritonis	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Culcita novaeguineae	8.7	1.8	73	27.5	3.1	23	8.6	1.7	12	10.3	1.6	10
Cypraea tigris	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Echinometra mathaei	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Echinothrix diadema	0.4	0.3	73	16.1	0.5	2	0.5	0.3	12	2.8	0.0	2
Hippopus hippopus	5.0	1.2	73	20.4	2.2	18	5.1	0.8	12	5.5	0.7	11
Holothuria atra	643.3	393.7	73	2935.0	1716.3	16	653.3	606.3	12	2613.2	2350.7	3
Holothuria edulis	3.2	1.2	73	25.9	5.6	9	3.0	1.6	12	7.1	3.0	5
Lambis chiragra	1.1	0.6	73	20.8	4.2	4	1.2	0.5	12	3.5	0.7	4
Lambis truncata	0.5	0.5	73	33.3		1	0.5	0.5	12	5.6		1
Linckia laevigata	0.5	0.3	73	16.7	0.0	2	0.5	0.5	12	5.6		1
Octopus spp.	0.5	0.3	73	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Panulirus spp.	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Pinctada margaritifera	5.3	1.3	73	22.5	2.5	17	5.2	1.2	12	6.3	1.2	10
Spondylus spp.	0.5	0.3	73	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Stichodactyla spp.	2.1	0.8	73	21.4	3.1	7	2.1	1.2	12	6.2	2.7	4
Synapta spp.	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Tectus pyramis	0.2	0.2	73	16.7		1	0.2	0.2	12	2.8		1
Thelenota spp.	0.2	0.2	73	16.7		1	0.2	0.2	12	2.4		1
Thelenota ananas	1.8	0.9	73	26.7	6.7	5	1.6	1.4	12	9.7	6.9	2
Thelenota anax	3.9	1.5	73	31.5	7.1	9	3.7	1.7	12	8.9	2.8	5
Tridacna maxima	382.2	50.8	73	416.4	53.4	67	381.0	76.4	12	381.0	76.4	12
Tridacna squamosa	2.3	0.7	73	18.5	1.9	9	2.3	1.0	12	5.5	1.3	5

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3 Ailuk reef-benthos transect (RBt) assessment data review
Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Astralium spp.	6.6	4.9	113	375.0	125.0	2	6.6	4.8	19	62.5	20.8	2
Cerithium nodulosum	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Chama spp.	26.5	10.1	113	375.0	66.8	8	26.3	14.3	19	100.0	40.8	5
Chicoreus spp.	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Conus spp.	8.8	5.4	113	333.3	83.3	3	8.8	5.1	19	55.6	13.9	3
Culcita novaeguineae	33.2	9.2	113	288.5	26.0	13	32.9	13.0	19	89.3	23.1	7
Cypraea annulus	4.4	4.4	113	500.0		1	4.4	4.4	19	83.3		1
Cypraea tigris	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Echinometra mathaei	17.7	8.1	113	333.3	83.3	6	17.5	9.7	19	83.3	29.5	4
Echinothrix diadema	8.8	4.4	113	250.0	0.0	4	8.8	5.1	19	55.6	13.9	3
Hippopus hippopus	24.3	9.4	113	343.8	65.8	8	24.1	13.6	19	91.7	40.4	5
Holothuria atra	389.4	115.8	113	2095.2	474.8	21	386.0	254.1	19	1222.2	729.2	6
Holothuria edulis	28.8	17.4	113	812.5	328.7	4	28.5	28.5	19	541.7		1
Lambis chiragra	6.6	4.9	113	375.0	125.0	2	6.6	4.8	19	62.5	20.8	2
Lambis truncata	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Mitra mitra	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Octopus spp.	4.4	3.1	113	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Pinctada margaritifera	4.4	3.1	113	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Stichodactyla spp.	50.9	18.6	113	638.9	118.7	9	50.4	43.6	19	239.6	197.9	4
Tectus pyramis	4.4	3.1	113	250.0	0.0	2	4.4	3.0	19	41.7	0.0	2
Thelenota anax	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Tridacna maxima	2659.3	234.2	113	3005.0	244.2	100	2663.6	441.9	19	2811.6	440.2	18
Tridacna squamosa	6.6	6.6	113	750.0		1	6.6	6.6	19	125.0		1
Turbo argyrostomus	2.2	2.2	113	250.0		1	2.2	2.2	19	41.7		1
Turbo petholatus	2.2	2.2	113	250.0		1	2.2	2.2	19	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 Ailuk reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	1.0	0.7	48	23.5	0.0	2	1.0	0.6	8	3.9	0.0	2
Chama spp.	6.9	5.9	48	109.8	86.3	3	6.9	6.3	8	27.5	23.5	2
Culcita novaeguineae	7.8	2.5	48	37.6	5.2	10	7.8	2.7	8	12.5	2.3	5
Cypraea annulus	0.5	0.5	48	23.5		1	0.5	0.5	8	3.9		1
Cypraea caputserpensis	0.5	0.5	48	23.5		1	0.5	0.5	8	3.9		1
Echinometra mathaei	85.3	34.4	48	584.9	122.6	7	85.3	55.8	8	227.5	113.5	3
Heterocentrotus mammillatus	1.0	0.7	48	23.5	0.0	2	1.0	0.6	8	3.9	0.0	2
Octopus spp.	0.5	0.5	48	23.5		1	0.5	0.5	8	3.9		1
Spondylus spp.	1.0	0.7	48	23.5	0.0	2	1.0	0.6	8	3.9	0.0	2
Stichodactyla spp.	2.5	1.3	48	29.4	5.9	4	2.5	1.0	8	4.9	1.0	4
Tectus pyramis	0.5	0.5	48	23.5		1	0.5	0.5	8	3.9		1
Tridacna maxima	2733.8	444.8	48	2916.1	461.9	45	2733.8	981.8	8	2733.8	981.8	8
Turbo argyrostomus	0.5	0.5	48	23.5		1	0.5	0.5	8	3.9		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.5 Ailuk mother-of-pearl search (MOPs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Chama spp.	2.2	2.2	42	90.9		1	2.2	2.2	7	15.2		1
Culcita novaeguineae	26.0	4.9	42	54.5	5.3	20	26.0	8.6	7	26.0	8.6	7
Cypraea annulus	2.2	2.2	42	90.9		1	2.2	2.2	7	15.2		1
Cypraea tigris	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Echinometra mathaei	6.5	4.5	42	136.4	0.0	2	6.5	6.5	7	45.5		1
Hippopus hippopus	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Holothuria edulis	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Holothuria nobilis	3.2	2.4	42	68.2	22.7	2	3.2	3.2	7	22.7		1
Octopus spp.	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Pleuroploca spp.	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Stichodactyla spp.	6.5	2.9	42	54.5	9.1	5	6.5	2.6	7	11.4	2.2	4
Tectus conus	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Tectus pyramis	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Thelenota ananas	2.2	2.2	42	90.9		1	2.2	2.2	7	15.2		1
Tridacna maxima	1075.8	233.9	42	1129.5	242.5	40	1075.8	544.7	7	1075.8	544.7	7
Tridacna squamosa	2.2	1.5	42	45.5	0.0	2	2.2	2.2	7	15.2		1
Trochus maculata	1.1	1.1	42	45.5		1	1.1	1.1	7	7.6		1
Trochus spp.	2.2	1.5	42	45.5	0.0	2	2.2	1.4	7	7.6	0.0	2
Turbo argyrostomus	4.3	3.4	42	90.9	45.5	2	4.3	3.2	7	15.2	7.6	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.6 Ailuk 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	8.9	6.0	12	53.3	0.0	2	8.9	8.9	2	17.8		1
Carpilius maculatus	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
Etisus spp.	8.9	8.9	12	106.7		1	8.9	8.9	2	17.8		1
Holothuria atra	151.1	95.1	12	259.0	154.1	7	151.1	106.7	2	151.1	106.7	2
Octopus spp.	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.

4.2.7 Ailuk sea cucumber day search (Ds) assessment data review
Station: Six 5-min search periods.

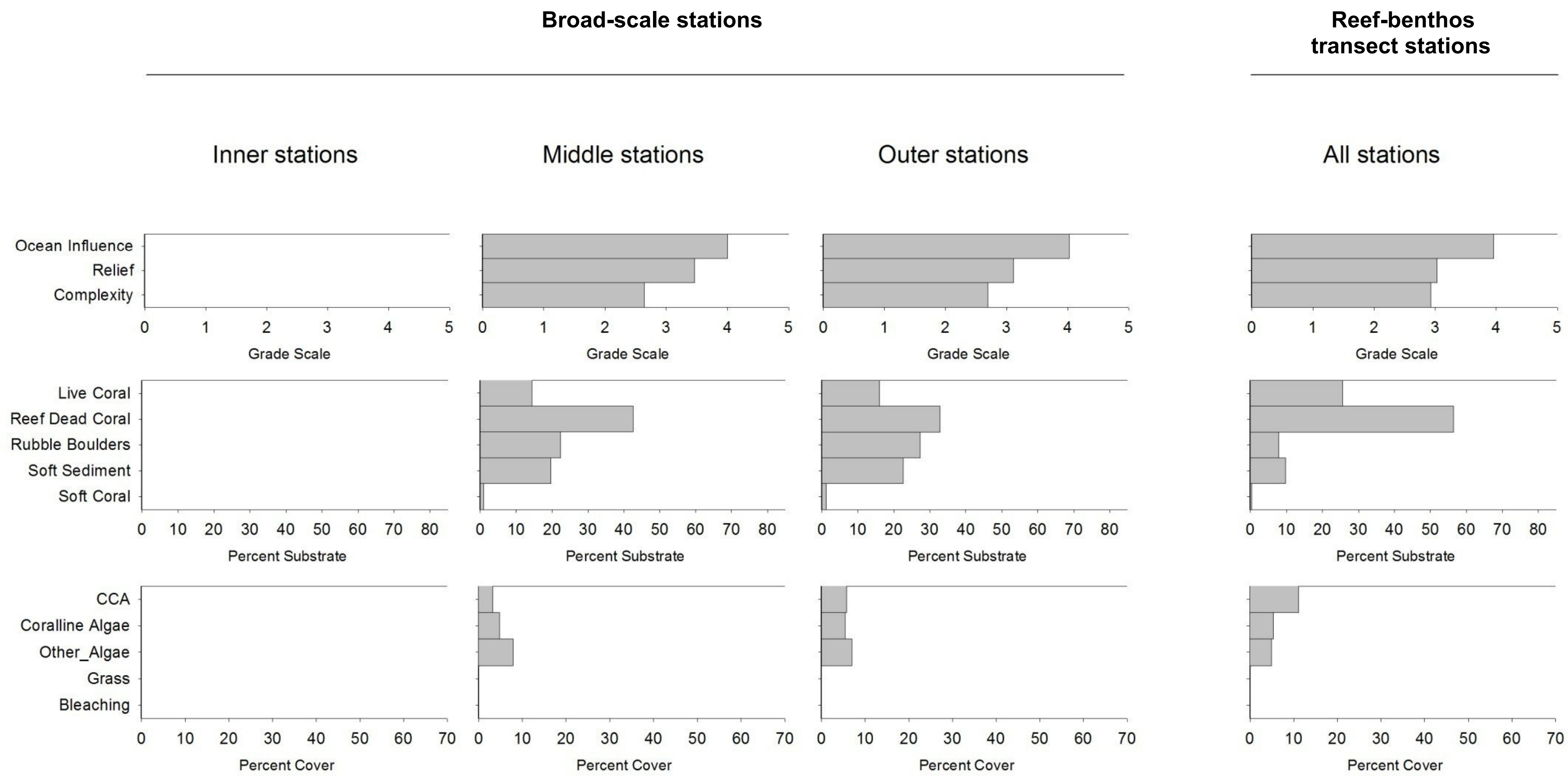
Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	7.1	2.2	30	19.5	4.0	11	7.1	1.5	5	7.1	1.5	5
Chama spp.	38.6	29.8	30	385.7	248.4	3	38.6	38.6	5	192.9		1
Choriaster granulatus	2.9	1.3	30	17.1	2.9	5	2.9	1.7	5	7.1	0.0	2
Choriaster spp.	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Culcita novaeguineae	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Holothuria edulis	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Holothuria fuscogilva	4.3	2.7	30	42.9	14.3	3	4.3	4.3	5	21.4		1
Lambis chiragra	0.5	0.5	30	14.3		1	0.5	0.5	5	2.4		1
Pinctada margaritifera	2.9	1.1	30	14.3	0.0	6	2.9	0.9	5	3.6	0.7	4
Spondylus spp.	1.0	0.7	30	14.3	0.0	2	1.0	0.6	5	2.4	0.0	2
Thelenota ananas	9.0	2.5	30	24.7	3.4	11	9.0	3.0	5	11.3	2.5	4
Thelenota anax	4.3	1.4	30	16.1	1.8	8	4.3	0.9	5	4.3	0.9	5
Tridacna maxima	8.1	2.9	30	24.3	6.0	10	8.1	3.6	5	10.1	3.8	4
Tridacna squamosa	4.8	2.2	30	23.8	7.1	6	4.8	3.1	5	7.9	4.4	3
Trochus maculata	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.

4.2.8 Ailuk species size review – all survey methods

Species	Mean length (cm)	SE	n
Tridacna maxima	10.1	0.1	9470
Holothuria atra	23.3	0.7	3034
Hippopus hippopus	24.3	1.2	34
Bohadschia argus	37.4	0.8	33
Pinctada margaritifera	16.2	0.4	31
Holothuria edulis	28.7	0.8	30
Thelenota ananas	41.6	2.1	29
Thelenota anax	49.1	2.2	27
Tridacna squamosa	28.1	1.6	25
Holothuria fuscogilva	40.6	1.9	9
Lambis chiragra	18.8	1.2	9
Turbo argyrostomus	5.0	0.0	6
Tectus pyramis	5.0	0.6	5
Cypraea tigris	9.1	0.1	4
Conus spp.	3.5	0.0	4
Astralium spp.	3.0	0.1	3
Holothuria nobilis	28.7	3.8	3
Lambis truncata	3.0	0.0	3
Bohadschia vitiensis	30.0	0.0	3
Cerithium nodulosum	11.0	0.0	2
Trochus spp.	2.6	0.0	2
Charonia tritonis	33.0	0.0	1
Chicoreus spp.	3.5	0.0	1
Mitra mitra	8.9	0.0	1
Pleuroploca spp.	10.0	0.0	1
Tectus conus	5.1	0.0	1
Turbo petholatus	4.8	0.0	1
Chama spp.			248
Echinometra mathaei			189
Culcita novaeguineae			95
Stichodactyla spp.			43
Octopus spp.			7
Echinothrix diadema			6
Choriaster granulatus			6
Spondylus spp.			6
Acanthaster planci			5
Cypraea annulus			5
Heterocentrotus mammillatus			2
Linckia laevigata			2
Trochus maculata			2
Etisus spp.			2
Choriaster spp.			1
Cypraea caputserpensis			1
Carpilius maculatus			1
Panulirus spp.			1
Synapta spp.			1
Thelenota spp.			1

4.2.9 Habitat descriptors for independent assessment – Ailuk



4.3 Arno invertebrate survey data

4.3.1 Invertebrate species recorded in different assessments in Arno

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+			
Bêche-de-mer	*Bohadschia argus*	+			
Bêche-de-mer	*Bohadschia vitiensis*	+			
Bêche-de-mer	*Holothuria atra*		+		
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria hilla*		+		
Bêche-de-mer	*Holothuria impatiens*		+		
Bêche-de-mer	*Synapta* spp.		+		
Bêche-de-mer	*Thelenota ananas*	+			
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Arca* spp.		+		
Bivalve	*Hippopus hippopus*	+	+		
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.	+			+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+			
Cnidarian	*Entacmaea quadricolor*				+
Cnidarian	*Stichodactyla* spp.		+		
Crustacean	*Atergatis floridus*		+		
Crustacean	*Lysiosquillina maculata*		+		
Crustacean	*Portunus* spp.		+		
Crustacean	*Saron* spp.		+		
Crustacean	*Thalassina sp*		+		
Gastropod	*Astralium* spp.				+
Gastropod	*Cantharus fumosus*		+		
Gastropod	*Cassis cornuta*	+			
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Conus distans*	+			+
Gastropod	*Conus lividus*				+
Gastropod	*Conus marmoreus*	+			
Gastropod	*Conus miles*	+	+		+
Gastropod	*Conus* spp.	+			
Gastropod	*Cymatium muricinum*		+		
Gastropod	*Cypraea eglantina*		+		
Gastropod	*Cypraea isabella*		+		
Gastropod	*Cypraea maculifera*				+
Gastropod	*Cypraea mappa*		+		
Gastropod	*Cypraea moneta*	+	+		+
Gastropod	*Cypraea scurra*				+
Gastropod	*Cypraea tigris*	+			
Gastropod	*Cypraea vitellus*		+		
Gastropod	*Drupa rubusidaeus*	+			+
Gastropod	*Drupella sp*		+		
Gastropod	*Lambis chiragra*	+	+		
Gastropod	*Lambis lambis*	+			
Gastropod	*Lambis* spp.	+			

+ = presence of the species.

4.3.1 Invertebrate species recorded in different assessments in Arno (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Lambis truncata*		+		+
Gastropod	*Strombus gibberulus gibbosus*	+			
Gastropod	*Strombus luhuanus*	+			
Gastropod	*Tectus pyramis*				+
Gastropod	*Tectus* spp.				+
Gastropod	*Thais armigera*				+
Gastropod	*Trochus maculata*				+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo argyrostomus*		+		+
Gastropod	*Vasum ceramicum*		+		
Gastropod	*Vasum turbinellum*		+		+
Nudibranch	*Phyllidia* spp.		+		
Octopus	*Octopus* spp.	+	+		+
Star	*Acanthaster planci*	+			+
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix calamaris*		+		
Urchin	*Echinothrix diadema*		+		+
Urchin	*Heterocentrotus mammillatus*				+

+ = presence of the species.

4.3.2 Arno 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	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Actinopyga mauritiana	0.9	0.4	72	16.5	0.1	4	0.9	0.9	12	11.0		1
Bohadschia argus	0.9	0.5	72	16.7	0.0	4	0.9	0.7	12	5.6	2.8	2
Bohadschia vitiensis	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Cassis cornuta	0.7	0.4	72	16.7	0.0	3	0.7	0.4	12	2.8	0.0	3
Conus distans	0.9	0.7	72	33.3	0.0	2	0.9	0.6	12	5.6	0.0	2
Conus marmoreus	0.7	0.4	72	16.5	0.2	3	0.7	0.4	12	2.8	0.0	3
Conus miles	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Culcita novaeguineae	1.2	0.5	72	16.7	0.0	5	1.2	0.4	12	2.8	0.0	5
Cypraea moneta	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Cypraea tigris	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Drupa rubusidaeus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Hippopus hippopus	6.5	1.9	72	29.1	5.8	16	6.5	2.0	12	8.6	2.2	9
Lambis chiragra	1.4	0.8	72	24.9	8.4	4	1.4	1.0	12	8.3	2.8	2
Lambis lambis	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	1.6	0.7	72	19.4	2.8	6	1.6	0.7	12	4.8	0.7	4
Octopus spp.	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Pinctada margaritifera	0.5	0.3	72	16.7	0.0	2	0.5	0.3	12	2.8	0.0	2
Spondylus spp.	0.9	0.5	72	16.7	0.0	4	0.9	0.4	12	2.8	0.0	4
Strombus gibberulus gibbosus	0.5	0.5	72	33.3		1	0.5	0.5	12	5.4		1
Strombus luhuanus	3.9	3.5	72	141.7	108.3	2	3.9	3.4	12	23.5	17.9	2
Thelenota ananas	1.9	1.0	72	26.7	10.0	5	1.8	1.2	12	11.1	0.0	2
Tridacna maxima	135.5	16.0	72	147.8	16.6	66	135.5	24.9	12	135.5	24.9	12
Tridacna squamosa	0.9	0.6	72	22.2	5.6	3	0.9	0.5	12	3.7	0.9	3
Trochus niloticus	2.3	1.1	72	27.6	8.3	6	2.3	1.5	12	9.2	4.0	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.

4.3.3 Arno 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
Arca spp.	19.2	10.0	78	375.0	72.2	4	19.2	11.2	13	83.3	24.1	3
Atergatis floridus	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cantharus fumosus	12.8	7.8	78	333.3	83.3	3	12.8	12.8	13	166.7		1
Cerithium nodulosum	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Conus miles	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Culcita novaeguineae	6.4	4.5	78	250.0	0.0	2	6.4	4.3	13	41.7	0.0	2
Cymatium muricinum	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea eglantina	12.8	7.8	78	333.3	83.3	3	12.8	7.3	13	55.6	13.9	3
Cypraea isabella	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea mappa	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Cypraea moneta	44.9	18.7	78	388.9	111.1	9	44.9	25.6	13	116.7	55.0	5
Cypraea vitellus	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Drupella sp	25.6	13.4	78	500.0	102.1	4	25.6	22.4	13	166.7	125.0	2
Echinometra mathaei	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Echinothrix calamaris	16.0	9.5	78	416.7	83.3	3	16.0	8.9	13	69.4	13.9	3
Echinothrix diadema	6.4	4.5	78	250.0	0.0	2	6.4	6.4	13	83.3		1
Hippopus hippopus	44.9	13.5	78	318.2	35.2	11	44.9	19.1	13	97.2	29.8	6
Holothuria atra	22.4	9.3	78	291.7	41.7	6	22.4	15.4	13	145.8	20.8	2
Holothuria hilla	25.6	9.8	78	285.7	35.7	7	25.6	15.3	13	111.1	36.7	3
Holothuria impatiens	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Lambis chiragra	22.4	12.2	78	437.5	119.7	4	22.4	13.8	13	97.2	36.7	3
Lambis truncata	6.4	6.4	78	500.0		1	6.4	6.4	13	83.3		1
Linckia laevigata	12.8	6.3	78	250.0	0.0	4	12.8	7.3	13	55.6	13.9	3
Lysiosquillina maculata	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Octopus spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Phyllidia spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Pinctada margaritifera	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Portunus spp.	9.6	5.5	78	250.0	0.0	3	9.6	5.1	13	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.

4.3.3 Arno 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
Saron spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Stichodactyla spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Synapta spp.	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Thalassina sp	80.1	44.6	78	1562.5	471.9	4	80.1	76.7	13	520.8	479.2	2
Tridacna maxima	583.3	65.7	78	812.5	71.0	56	583.3	126.4	13	689.4	123.9	11
Trochus niloticus	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Turbo argyrostomus	25.6	10.8	78	333.3	52.7	6	25.6	11.1	13	66.7	16.7	5
Vasum ceramicum	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1
Vasum turbinellum	3.2	3.2	78	250.0		1	3.2	3.2	13	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.4 Arno reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Astralium spp.	0.8	0.5	60	23.5	0.0	2	0.8	0.5	10	3.9	0.0	2
Conus distans	0.8	0.5	60	23.5	0.0	2	0.8	0.5	10	3.9	0.0	2
Conus lividus	0.8	0.5	60	23.5		2	0.8	0.5	10	3.9	0.0	2
Conus miles	1.2	0.7	60	23.5	0.0	3	1.2	0.6	10	3.9	0.0	3
Cypraea maculifera	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Cypraea moneta	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Cypraea scurra	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Drupa rubusidaeus	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Echinometra mathaei	20.4	7.0	60	81.6	21.6	15	20.4	11.8	10	34.0	18.0	6
Echinothrix diadema	3.1	1.0	60	23.5	0.0	8	3.1	1.5	10	7.8	2.3	4
Heterocentrotus mammillatus	5.5	2.4	60	41.2	12.4	8	5.5	3.5	10	13.7	7.2	4
Octopus spp.	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Spondylus spp.	0.8	0.5	60	23.5	0.0	2	0.8	0.5	10	3.9	0.0	2
Tectus pyramis	2.4	1.2	60	35.3	6.8	4	2.4	2.0	10	11.8	7.8	2
Tectus spp.	0.8	0.5	60	23.5	0.0	2	0.8	0.5	10	3.9	0.0	2
Thais armigera	0.4	0.4	60	23.5		1	0.4	0.4	10	3.9		1
Tridacna maxima	82.4	22.4	60	117.6	30.5	42	82.4	43.4	10	91.5	47.5	9
Trochus maculata	2.4	1.1	60	28.2	4.7	5	2.4	1.7	10	11.8	3.9	2
Trochus niloticus	5.9	1.8	60	32.1	4.8	11	5.9	3.8	10	19.6	9.1	3
Turbo argyrostomus	0.8	0.5	60	23.5	0.0	2	0.8	0.5	10	3.9	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.

4.3.5 Arno mother-of-pearl search (MOPs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Culcita novaeguineae	7.6	7.6	6	45.5		1	7.6		1	7.6		1
Lambis truncata	7.6	7.6	6	45.5		1	7.6		1	7.6		1
Tridacna maxima	68.2	32.7	6	136.4	26.2	3	68.2		1	68.2		1
Vasum turbinellum	7.6	7.6	6	45.5		1	7.6		1	7.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.3.6 Arno sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Culcita novaeguineae	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Entacmaea quadricolor	1.6	1.6	18	28.6		1	1.6	1.6	3	4.8		1
Holothuria fuscogilva	1.6	1.6	18	28.6		1	1.6	1.6	3	4.8		1
Spondylus spp.	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Thelenota anax	34.1	7.8	18	51.2	8.0	12	34.1	19.9	3	51.2	17.9	2
Tridacna maxima	0.8	0.8	18	14.3		1	0.8	0.8	3	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.

4.3.7 Arno species size review – all survey methods

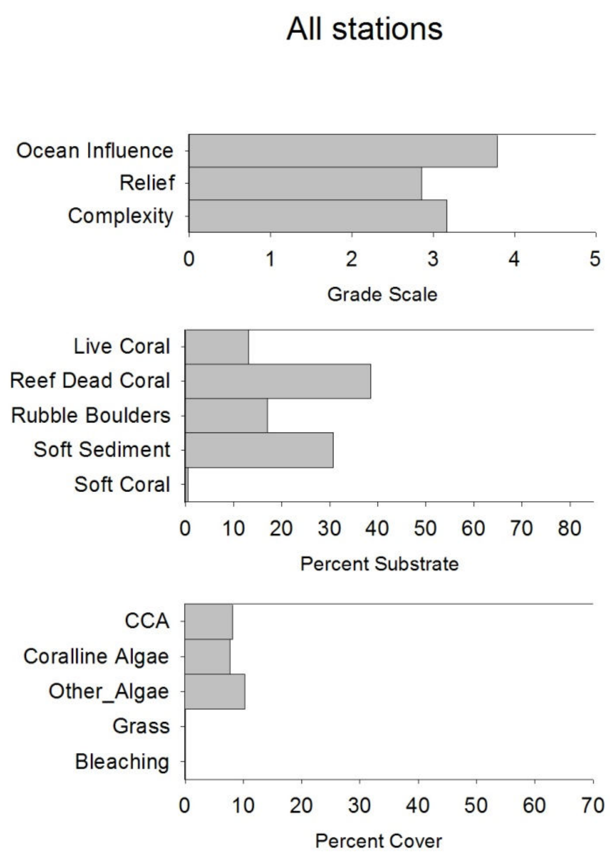
Species	Mean length (cm)	SE	n
Tridacna maxima	8.6	0.2	989
Thelenota anax	55.0	1.1	43
Hippopus hippopus	21.3	1.0	42
Trochus niloticus	9.8	0.4	26
Cypraea moneta	2.5	0.2	16
Lambis chiragra	19.4	0.5	13
Turbo argyrostomus	4.6	0.4	10
Thelenota ananas	43.8	2.4	8
Holothuria atra	12.9	1.0	7
Tectus pyramis	6.1	0.2	6
Trochus maculata	3.7	0.8	6
Conus miles	5.1	0.2	6
Conus distans	4.8	0.7	6
Cypraea eglantina	4.5	0.5	4
Tridacna squamosa	30.3	2.8	4
Bohadschia argus	31.3	1.3	4
Lambis truncata	26.6	0.5	3
Pinctada margaritifera	10.8	1.8	3
Holothuria fuscogilva	30.9	0.4	2
Spondylus spp.	10.0	0.0	7
Cassis cornuta	20.5	0.0	3
Conus lividus	6.3	0.0	2
Tectus spp.	5.8	0.0	2
Vasum turbinellum	6.6	0.0	2
Cerithium nodulosum	8.6	0.0	1
Cypraea scurra	4.3	0.0	1
Cypraea vitellus	4.4	0.0	1
Thais armigera	5.4	0.0	1
Vasum ceramicum	5.6	0.0	1
Atergatis floridus	4.2	0.0	1
Lysiosquillina maculata	21.0	0.0	1
Echinometra mathaei			53
Thalassina sp			25
Strombus luhuanus			17
Heterocentrotus mammillatus			14
Linckia laevigata			11
Echinothrix diadema			10
Culcita novaeguineae			9
Drupella sp			8
Holothuria hilla			8
Arca spp.			6
Echinothrix calamaris			5
Octopus spp.			4
Cantharus fumosus			4
Actinopyga mauritiana			4
Acanthaster planci			3
Conus marmoreus			3
Portunus spp.			3

4.3.7 Arno species size review – all survey methods (continued)

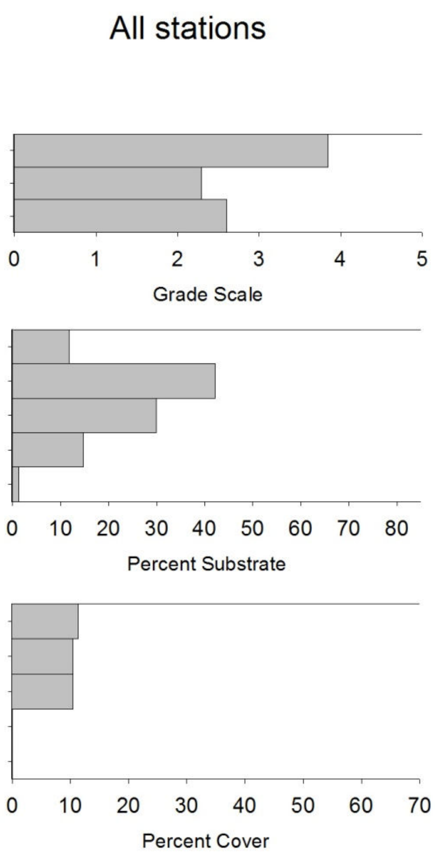
Species	Mean length (cm)	SE	n
Astralium spp.			2
Conus spp.			2
Drupa rubusidaeus			2
Strombus gibberulus gibbosus			2
Entacmaea quadricolor			2
Phyllidia spp.			1
Cymatium muricinum			1
Cypraea isabella			1
Cypraea maculifera			1
Cypraea mappa			1
Cypraea tigris			1
Lambis lambis			1
Lambis spp.			1
Saron spp.			1
Stichodactyla spp.			1
Bohadschia vitiensis			1
Holothuria impatiens			1
Synapta spp.			1

4.3.8 Habitat descriptors for independent assessment – Arno

Broad-scale stations



Reef-benthos transect stations



4.4 Laura invertebrate survey data

4.4.1 Invertebrate species recorded in different assessments in Laura

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*	+	+		
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Holothuria atra*	+	+	+	+
Bêche-de-mer	*Holothuria edulis*		+		+
Bêche-de-mer	*Holothuria nobilis*	+	+		
Bêche-de-mer	*Synapta* spp.		+		
Bêche-de-mer	*Thelenota ananas*	+			+
Bêche-de-mer	*Thelenota anax*	+			+
Bivalve	*Beguina semiorbiculata*	+			
Bivalve	*Hippopus hippopus*	+	+		
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.		+		+
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		
Cnidarian	*Entacmaea quadricolor*				+
Cnidarian	*Stichodactyla* spp.		+		
Crustacean	*Gonodactylus* spp.		+		
Crustacean	*Panulirus penicillatus*		+		
Crustacean	*Panulirus versicolor*	+			
Crustacean	*Saron* spp.		+		
Crustacean	*Stenopus hispidus*		+		
Crustacean	*Thalassina sp*		+	+	
Gastropod	*Astralium* spp.		+		
Gastropod	*Bursa bufonia*				+
Gastropod	*Bursa granularis*		+		
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Chicoreus brunneus*		+		
Gastropod	*Conus bandanus*	+			
Gastropod	*Conus distans*	+	+		+
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus leopardus*	+			
Gastropod	*Conus lividus*		+		+
Gastropod	*Conus miles*	+	+		+
Gastropod	*Conus miliaris*		+		
Gastropod	*Conus pulicarius*		+		
Gastropod	*Coralliophila* spp.		+		
Gastropod	*Cypraea arabica*		+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea moneta*		+		
Gastropod	*Cypraea scurra*		+		
Gastropod	*Cypraea tigris*	+	+		
Gastropod	*Harpa amouretta*		+		
Gastropod	*Lambis chiragra*	+	+		
Gastropod	*Lambis lambis*	+	+		+
Gastropod	*Lambis scorpius*	+	+		
Gastropod	*Lambis truncata*	+			+

+ = presence of the species.

4.4.1 Invertebrate species recorded in different assessments in Laura (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Mitra mitra*				+
Gastropod	*Rhinoclavis aspera*		+		
Gastropod	*Strombus luhuanus*	+	+		
Gastropod	*Tectus pyramis*	+			+
Gastropod	*Thais aculeata*		+		
Gastropod	*Trochus maculata*		+		+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Turbo argyrostomus*		+		+
Gastropod	*Vasum* spp.		+		
Gastropod	*Vasum turbinellum*	+	+		
Nudibranch	*Phyllidia* spp.		+		
Octopus	*Octopus* spp.	+	+		
Star	*Acanthaster planci*	+	+		+
Star	*Archaster* spp.		+		
Star	*Culcita novaeguineae*	+	+		+
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix diadema*	+	+		+
Urchin	*Mespilia globulus*		+		
Urchin	*Tripneustes* spp.	+			

+ = presence of the species.

4.4.2 Laura broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Actinopyga mauritiana	0.5	0.3	72	16.4	0.3	2	0.5	0.5	12	5.5		1
Beguina semiorbiculata	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Bohadschia argus	3.2	1.2	72	23.3	5.1	10	3.2	1.2	12	5.5	1.5	7
Conus bandanus	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	5.6		1
Conus distans	1.2	0.6	72	20.8	4.2	4	1.2	0.7	12	4.6	1.9	3
Conus leopardus	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Conus miles	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Culcita novaeguineae	5.1	1.2	72	21.5	2.4	17	5.1	2.0	12	6.8	2.4	9
Cypraea tigris	0.7	0.5	72	25.0	8.3	2	0.7	0.5	12	4.2	1.4	2
Echinothrix diadema	1.4	1.4	72	100.0		1	1.4	1.4	12	16.7		1
Hippopus hippopus	4.1	1.0	72	19.9	1.8	15	4.2	1.0	12	5.0	1.0	10
Holothuria atra	174.4	37.6	72	570.7	69.7	22	173.9	75.3	12	521.8	42.7	4
Holothuria nobilis	0.9	0.6	72	22.2	5.6	3	0.9	0.7	12	5.6	2.8	2
Lambis chiragra	0.9	0.5	72	16.6	0.1	4	0.9	0.5	12	3.7	0.9	3
Lambis lambis	2.1	0.8	72	21.4	3.1	7	2.1	1.0	12	5.0	1.6	5
Lambis scorpius	0.5	0.3	72	16.5	0.1	2	0.5	0.3	12	2.8	0.0	2
Lambis truncata	0.5	0.3	72	16.5	0.1	2	0.5	0.3	12	2.8	0.0	2
Linckia laevigata	2.8	1.1	72	24.8	5.5	8	2.8	1.4	12	5.5	2.3	6
Panulirus versicolor	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		1
Pinctada margaritifera	2.8	1.9	72	50.0	28.1	4	2.8	1.8	12	8.3	4.6	4
Strombus luhuanus	5.8	4.5	72	104.2	71.2	4	5.8	5.5	12	34.7	31.9	2
Tectus pyramis	0.2	0.2	72	16.4		1	0.2	0.2	12	2.8		1
Thelenota ananas	3.2	1.1	72	23.3	3.7	10	3.2	1.2	12	6.4	1.4	6
Thelenota anax	1.4	1.4	72	100.0		1	1.4	1.4	12	16.6		1
Tridacna maxima	30.0	7.8	72	67.4	15.4	32	29.9	12.7	12	32.7	13.6	11
Tridacna squamosa	2.3	0.7	72	16.6	0.1	10	2.3	0.9	12	4.0	1.2	7
Tripneustes spp.	0.2	0.2	72	16.7		1	0.2	0.2	12	2.8		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.

4.4.2 Laura 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
Trochus niloticus	2.1	0.7	72	18.7	2.1	8	2.1	1.2	12	6.2	2.6	4
Vasum turbinellum	0.5	0.3	72	16.7	0.0	2	0.5	0.5	12	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.

4.4.3 Laura 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	13.3	6.8	132	350.0	100.0	5	13.3	7.9	22	72.9	31.3	4
Archaster spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Astralium spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Bohadschia argus	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Bursa granularis	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Cerithium nodulosum	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Chicoreus brunneus	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1
Conus distans	9.5	4.2	132	250.0	0.0	5	9.5	6.1	22	69.4	27.8	3
Conus flavidus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Conus lividus	5.7	4.2	132	375.0	125.0	2	5.7	4.2	22	62.5	20.8	2
Conus miles	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Conus miliaris	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Conus pulicarius	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Coralliophila spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Culcita novaeguineae	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea arabica	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Cypraea caputserpensis	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Cypraea moneta	24.6	8.9	132	361.1	60.5	9	24.6	11.8	22	77.4	29.4	7
Cypraea scurra	1.9	1.9	132	250.0		1	1.9	1.9	22	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.

4.4.3 Laura 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 tigris	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Echinometra mathaei	3.8	2.7	132	250.0	0.0	2	3.8	3.8	22	83.3		1
Echinothrix diadema	9.5	7.8	132	625.0	375.0	2	9.5	7.7	22	104.2	62.5	2
Gonodactylus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Harpa amouretta	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Hippopus hippopus	9.5	5.0	132	312.5	62.5	4	9.5	4.7	22	52.1	10.4	4
Holothuria atra	4500.0	1858.8	132	23,760.0	8973.0	25	4500.0	3626.2	22	16,500.0	12,763.3	6
Holothuria edulis	18.9	9.6	132	625.0	72.2	4	18.9	18.9	22	416.7		1
Holothuria nobilis	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Lambis chiragra	13.3	8.6	132	583.3	220.5	3	13.3	8.4	22	97.2	36.7	3
Lambis lambis	26.5	9.8	132	350.0	76.4	10	26.5	10.8	22	83.3	22.3	7
Lambis scorpius	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Linckia laevigata	9.5	4.2	132	250.0	0.0	5	9.5	5.4	22	69.4	13.9	3
Mespilia globulus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Octopus spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Panulirus penicillatus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Phyllidia spp.	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Pinctada margaritifera	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Rhinoclavis aspera	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Saron spp.	7.6	3.7	132	250.0	0.0	4	7.6	3.5	22	41.7	0.0	4
Spondylus spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Stenopus hispidus	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Stichodactyla spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Strombus luhuanus	126.9	58.4	132	1196.4	474.8	14	126.9	63.6	22	398.8	162.6	7
Synapta spp.	5.7	4.2	132	375.0	125.0	2	5.7	5.7	22	125.0		1
Thais aculeata	3.8	3.8	132	500.0		1	3.8	3.8	22	83.3		1
Thalassina sp	43.6	12.5	132	410.7	56.3	14	43.6	14.9	22	106.5	24.2	9
Tridacna maxima	113.6	26.9	132	500.0	88.1	30	113.6	43.5	22	208.3	69.6	12

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 Laura 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
Tridacna squamosa	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	41.7	0.0	2
Trochus maculata	17.0	8.6	132	375.0	125.0	6	17.0	8.1	22	62.5	20.8	6
Trochus niloticus	49.2	13.8	132	406.3	64.0	16	49.2	21.5	22	154.8	48.7	7
Turbo argyrostomus	13.3	5.6	132	291.7	41.7	6	13.3	6.9	22	72.9	19.9	4
Vasum spp.	1.9	1.9	132	250.0		1	1.9	1.9	22	41.7		1
Vasum turbinellum	3.8	2.7	132	250.0	0.0	2	3.8	2.6	22	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.

4.4.4 Laura 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
Holothuria atra	65,250.0	9853.5	6	65,250.0	9853.5	6	65,250.0		1	65,250.0		1
Thalassina sp	208.3	100.3	6	416.7	83.3	3	208.3		1	208.3		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.

4.4.5 Laura reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	2.9	1.6	24	23.5	0.0	3	2.9	1.0	4	3.9	0.0	3
Actinopyga mauritiana	4.9	3.2	24	39.2	15.7	3	4.9	4.9	4	19.6		1
Bursa bufonia	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Conus distans	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Conus lividus	2.0	1.4	24	23.5	0.0	2	2.0	1.1	4	3.9	0.0	2
Conus miles	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Echinometra mathaei	2.0	1.4	24	23.5	0.0	2	2.0	2.0	4	7.8		1
Echinothrix diadema	7.8	4.2	24	47.1	13.6	4	7.8	3.6	4	10.5	3.5	3
Lambis truncata	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Spondylus spp.	1.0	1.0	24	23.5		1	1.0	1.0	4	3.9		1
Tectus pyramis	4.9	2.4	24	29.4	5.9	4	4.9	3.7	4	9.8	5.9	2
Tridacna maxima	28.4	8.3	24	56.9	11.7	12	28.4	13.6	4	28.4	13.6	4
Trochus maculata	2.0	1.4	24	23.5	0.0	2	2.0	1.1	4	3.9	0.0	2
Trochus niloticus	14.7	4.4	24	39.2	5.5	9	14.7	6.9	4	19.6	6.8	3
Turbo argyrostomus	2.9	1.6	24	23.5	0.0	3	2.9	2.9	4	11.8		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 Laura 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	1.6	1.1	18	14.3	0.0	2	1.6	1.6	3	4.8		1
Culcita novaeguineae	1.6	1.1	18	14.3	0.0	2	1.6	0.8	3	2.4	0.0	2
Entacmaea quadricolor	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Holothuria atra	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Holothuria edulis	0.8	0.8	18	14.3		1	0.8	0.8	3	2.4		1
Lambis lambis	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
Spondylus spp.	2.4	1.3	18	14.3	0.0	3	2.4	1.4	3	3.6	1.2	2
Thelenota ananas	8.7	4.2	18	39.3	6.8	4	8.7	8.7	3	26.2		1
Thelenota anax	28.6	8.1	18	34.3	9.0	15	28.6	13.5	3	28.6	13.5	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.4.7 Laura species size review – all survey methods

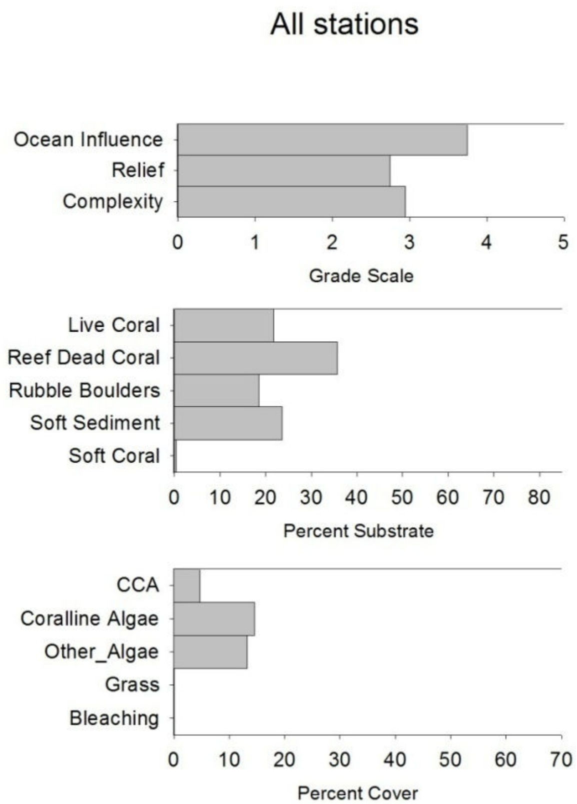
Species	Mean length (cm)	SE	n
Holothuria atra	3.3	0.1	4697
Tridacna maxima	10.4	0.3	219
Strombus luhuanus	5.2	0.2	92
Trochus niloticus	7.7	0.4	50
Thelenota anax	50.4	1.4	42
Thelenota ananas	49.9	1.9	25
Lambis lambis	13.5	0.9	24
Hippopus hippopus	20.2	1.7	23
Bohadschia argus	38.3	1.5	18
Pinctada margaritifera	10.9	5.1	13
Tridacna squamosa	18.9	3.1	12
Holothuria edulis	16.4	1.2	11
Conus distans	8.9	0.4	11
Trochus maculata	2.2	0.1	11
Lambis chiragra	19.6	1.9	11
Turbo argyrostomus	5.8	0.4	10
Actinopyga mauritiana	21.6	1.3	7
Tectus pyramis	6.4	0.5	6
Conus lividus	5.5	1.3	5
Cypraea tigris	7.2	0.6	5
Conus miles	4.6	0.8	4
Lambis truncata	28.7	0.9	3
Cerithium nodulosum	8.3	0.7	2
Conus miliaris	2.7	0.1	2
Cypraea arabica	4.4	0.1	2
Thais aculeata	4.3	0.1	2
Thalassina sp	7.6	0.0	28
Holothuria nobilis	27.1	0.0	5
Vasum turbinellum	5.4	0.0	4
Lambis scorpius	16.1	0.0	3
Rhinoclavis aspera	4.2	0.0	2
Tripneustes spp.	15.0	0.0	1
Astralium spp.	5.7	0.0	1
Conus flavidus	4.0	0.0	1
Conus leopardus	12.0	0.0	1
Conus pulicarius	3.2	0.0	1
Harpa amouretta	3.5	0.0	1
Vasum spp.	4.6	0.0	1
Culcita novaeguineae			25
Echinothrix diadema			19
Linckia laevigata			17
Cypraea moneta			13
Acanthaster planci			11
Octopus spp.			5
Spondylus spp.			5
Echinometra mathaei			4
Saron spp.			4
Synapta spp.			3

4.4.7 Laura species size review – all survey methods (continued)

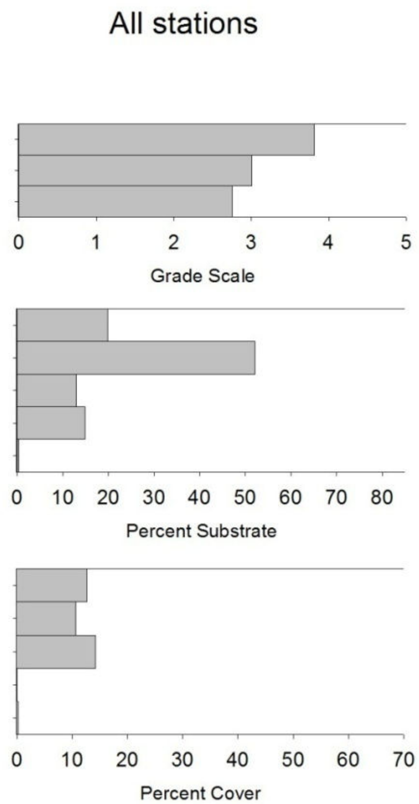
Species	Mean length (cm)	SE	n
Archaster spp.			2
Phyllidia spp.			2
Bursa granularis			2
Chicoreus brunneus			2
Conus bandanus			2
Mespilia globulus			1
Bursa bufonia			1
Coralliophila spp.			1
Cypraea caputserpensis			1
Cypraea scurra			1
Mitra mitra			1
Gonodactylus spp.			1
Panulirus penicillatus			1
Panulirus versicolor			1
Stenopus hispidus			1
Entacmaea quadricolor			1
Stichodactyla spp.			1
Beguina semiorbiculata			1

4.4.8 Habitat descriptors for independent assessment – Laura

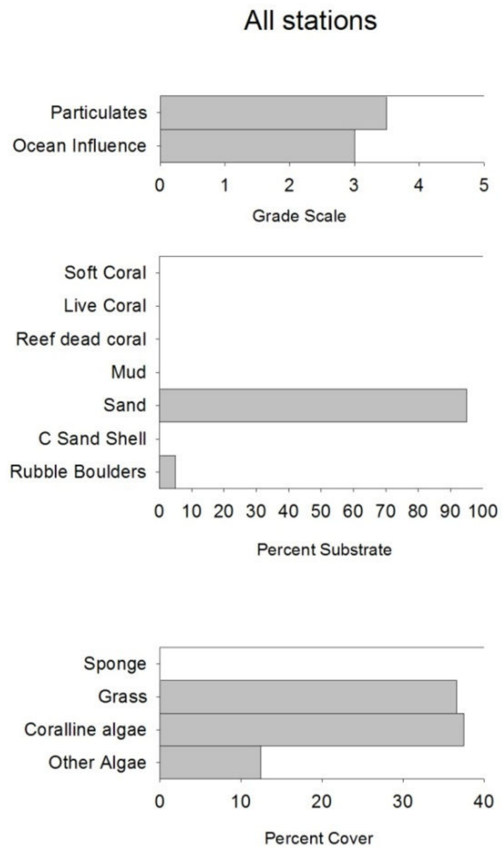
Broad-scale stations



Reef-benthos transect stations



Soft-benthos transect stations

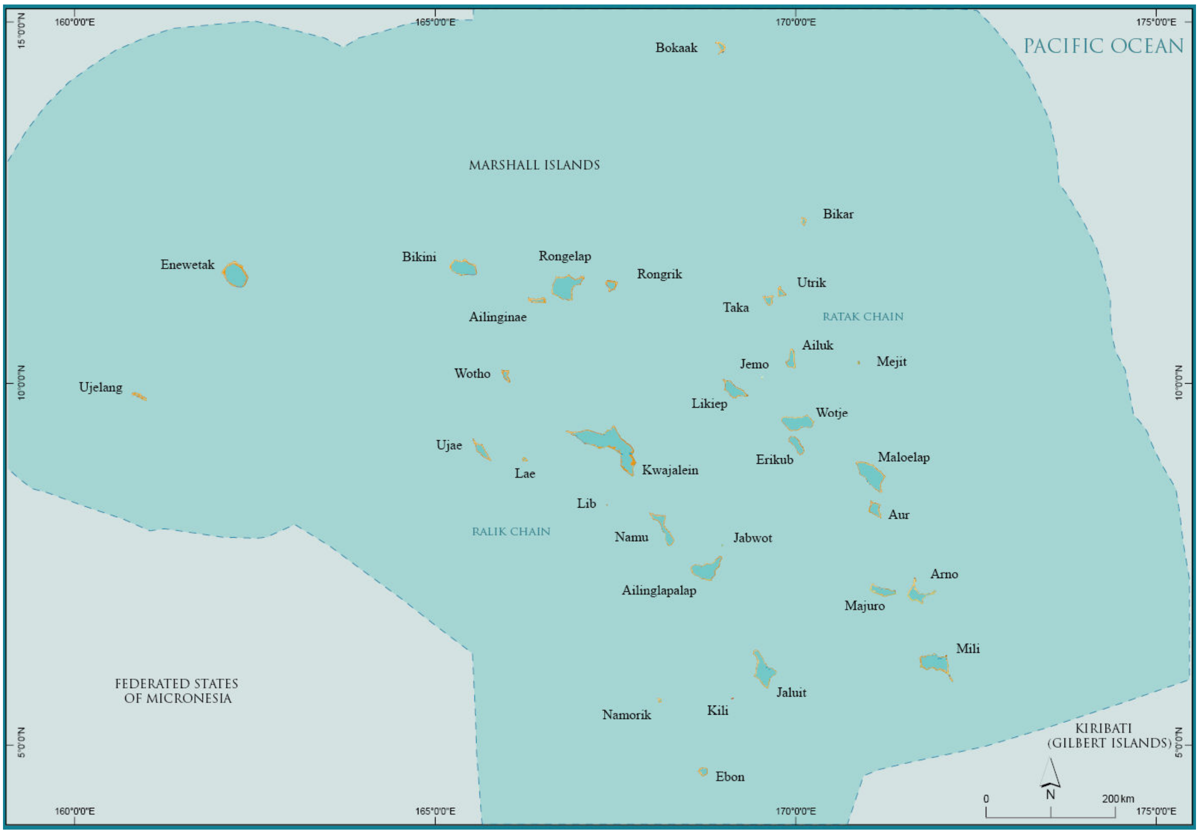


APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – MARSHALL ISLANDS

Institut de Recherche pour le Développement, UR 128 (France)
Institute for Marine Remote Sensing, University of South Florida (USA)
National Aeronautics and Space Administration (USA)

Millennium Coral Reef Mapping Project Marshall Islands

(May 2009)



The Institute for Marine Remote Sensing (IMaRS) of University of South Florida (USF) was funded in 2002 by the Oceanography Program of the National Aeronautics and Space Administration (NASA) to characterize, map and estimate the extent of shallow coral reef ecosystems worldwide using high-resolution satellite imagery (Landsat 7 images at 30 meters resolution). Since mid-2003, the project is a partnership between Institut de Recherche Pour le Développement (IRD, France) and USF. The program aims to highlight similarities and differences between reef structures at a scale never considered so far by traditional work based on field studies. It provides a reliable, spatially well constrained data set for biogeochemical budgets, biodiversity assessment, coral reef conservation programs and fisheries. The PROCFish/Coastal project has been using Millennium products in the last four years to optimize sampling strategy, access reliable reef maps, and further help in fishery data interpretation for all targeted countries. PROCFish/C is using Millennium maps only for the fishery grounds surveyed for the project.

For further inquiries regarding the status of the coral reef mapping of the Federated States of Micronesia and data availability, please contact:

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Reference: Andréfouët S *et al.* (2006), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th Int. Coral Reef Symposium, Okinawa 2004, Japan: pp. 1732-1745.