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

FIJI ISLANDS
COUNTRY REPORT:

PROFILES AND RESULTS FROM SURVEY WORK AT DROMUNA, MUAIVUSO, MALI, AND LAKEBA

(September to November 2002, April to June 2003,
June and July 2007, and February 2009)

by

Kim Friedman, Mecki Kronen, Aliti Vunisea, Silvia Pinca, Kalo Pakoa, Franck Magron,
Lindsay Chapman, Samasoni Sauni, Laurent Vigliola, Emmanuel Tardy, and Pierre Labrosse

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Secretariat of the Pacific Community
Coastal Fisheries Programme
BP D5, 98848 Noumea Cedex, New Caledonia
Tel: +687 26 00 00
Fax: +687 26 38 18
Email: spc@spc.int; http://www.spc.int/

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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.

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.

The team is made up of:
- Lindsay Chapman, Coastal Fisheries Programme Manager
- Kim Friedman, Senior Reef Fisheries Scientist (invertebrates)
- Mecki Kronen, Community Fisheries Scientist
- Franck Magron, Reef Fisheries Information Manager
- Silvia Pinca, Senior Reef Fisheries Scientist (finfish)
- Ribanataake Awira, Reef Fisheries Officer (finfish)
- Kalo Pakoa, Reef Fisheries Officer (invertebrates)
- Pierre Boblin, Reef Fisheries Officer (finfish)
- Emmanuel Tardy, Reef Fisheries Officer (invertebrates)
- Marie-Therese Bui, Project Administrator
- Ferral Lasi, previous Reef Fisheries Officer (invertebrates)
- Aliti Vunisea, previous Community Fisheries Scientist
- Samasoni Sauni, previous Senior Reef Fisheries Scientist (finfish)
- Laurent Vigliola, previous Senior Reef Fisheries Scientist (finfish).

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APPENDICES

EXECUTIVE SUMMARY

The coastal component of the Pacific Regional Oceanic and Coastal Fisheries Development Programme (PROCFish/C) conducted fieldwork in four locations around Fiji Islands in June and July 2007, and February 2009. This followed previous work funded by the MacArthur Foundation at locations in Fiji Islands in September to November 2002, and April to June 2003 under "The joint application of demography and ecology in evaluating the role of coastal fisheries resources in Pacific Island: the DemEcoFish project". Fiji Islands is one of 17 Pacific Island countries and territories being surveyed over a 5–6 year period by PROCFish/C or its associated programme CoFish (Pacific Regional Coastal Fisheries Development Programme)[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 Fiji Islands covered three disciplines (finfish, invertebrate and socioeconomic) in each site, with programme scientists and several local counterparts from the Ministry of Fisheries and Forests (MFF) and the University of the South Pacific (USP). 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.

[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.

In Fiji Islands, the four sites selected for the survey were Muaivuso and Dromuna on Viti Levu, and Lakeba and Mali on Vanua Levu. These were also sites surveyed under the DemEcoFish project, which provided a unique opportunity to do a comparison of results following the six-year period from the initial surveys. These sites were also 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 Ministry of Fisheries and Forests.

Results from fieldwork at Dromuna

Dromuna is a small, traditional community located on a small island off the mainland of Viti Levu, distant one hour by boat followed by a 30–60 minute road trip from Fiji Islands' main market centres, Nausori and Suva. Dromuna is the second of the two villages of Kaba Point. Both communities share the same *qoliqoli* (traditional fishing ground) with Bau, Viwa and Kiuva on the mainland. The lagoon reef of Kaba is extensive, with potential to support a good invertebrate resource. Water flow is dynamic across the barrier reef through passes to the east, southeast and south of Dromuna.

Socioeconomics in Dromuna

People in the Dromuna community have only a few options for generating income and earning salaries. Arable land allows crops to be produced, both for home consumption and, to some extent, for sale. Fisheries, notably finfish and bêche-de-mer collection, are the main income sources for over 85% of all households, and agricultural produce and mat weaving (by females) complement income. Households have a high food dependency, particularly on finfish (74 kg/capita/year), but consume much less invertebrates (4.4 kg/capita/year) and canned fish (2.9 kg/capita/year).

Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further away from shore, while females are more involved in handlining in the nearshore habitats and in collecting invertebrates. Both gender groups participate in the commercial bêche-de-mer fishery, and this is the most important invertebrate fishery by wet weight and for income generation. Other traditionally harvested invertebrate species, including *Pinna bicolor*, *Spondylus* spp., *Lambis lambis*, lobsters, *Scylla serrata* and *Anadara* spp., are important for home consumption and small-scale, local commercial sale.

Finfish resources in Dromuna

The status of finfish resources in Dromuna at the time of surveys was found to be average. Density, biomass and diversity of fish were higher in the outer reefs, but the fish-community composition was dominated by herbivores. Overall, density was fairly good but biomass quite low compared to the country and regional averages. Average size and size ratio were comparable to those in the two other sites Muaivuso and Lakeba, but lower than in Mali. Biodiversity was in the average country range but higher than at Lakeba. At a detailed analysis at family level, Scaridae consistently displayed very high abundance and biomass, but rather small average size. This family was, however, represented by several species. Carnivores were present but in much lower abundance than herbivores. However, piscivores (such as Serranidae) were almost absent. Some families (Lethrinidae, Mullidae, Labridae, Holocentridae and Scaridae) displayed sizes much smaller than 50% of the known maximum values, suggesting a response from heavy fishing. The amount of stock and the health of the fish community increased with distance from shore, from the coastal and intermediate reefs to the back- and outer reefs.

Invertebrate resources in Dromuna

A wide range of reef environments suitable for giant clams was present in the intermediate and outer reaches of the lagoon system at Dromuna. The number of clam species recorded at Dromuna was low in 2003 and critically low in 2009. The elongate clam (*Tridacna maxima*) and the fluted clam (*T. squamosa*) were the only two species noted. The true giant clam *T. gigas* and the horse-hoof or bear's paw clam *Hippopus hippopus* are considered extinct in Fiji Islands. This situation may have been due partially to the nature of the reef environment (sandy with high levels of algae, with the potential for episodic periods of heavy runoff from land sources), but fishing has undoubtedly played a major role in this depletion.

The reefs at Dromuna offered a range of hard-benthos intermediate and barrier-reef structures that could potentially support commercial quantities of the topshell *Trochus niloticus*. From the limited data available on trochus distribution and abundance in 2003, we suggest that the stock in Dromuna was present but sparsely distributed and at low density. In 2009, wider assessment confirmed the low density level, which seems to have declined even further since 2003. From the preliminary surveys conducted, the fishery for trochus at Dromuna appears to be depleted. Other mother-of-pearl stocks, such as blacklip pearl oysters *Pinctada margaritifera* and green topshells *Tectus pyramis* (of low commercial value), were recorded in survey at medium density in 2003 but at low density in 2009.

The high total of 21 species of sea cucumbers recorded at this site (adding 2003 and 2009 survey numbers) reflects the diversity of environments present in Dromuna, including a predominantly land-influenced lagoon system. In 2003, the presence and density of sea cucumbers were considered relatively healthy for some medium- and low-value species such as curryfish (*Stichopus hermanni*), brown sandfish (*Bohadschia vitiensis*) and blackfish (*Actinopyga miliaris*), while the presence and density of some medium/high- to high-value species, such as greenfish (*Stichopus chloronotus*), surf redfish (*Actinopyga mauritiana*), black teatfish (*Holothuria nobilis*) and sandfish (*H. scabra*), were more of a concern, and these species were considered impacted by fishing. In 2009, all species of low/medium- to high-value species were scarcely distributed and at low to critically low density. The densities of all species of commercial interest are among the weakest observed across all the sites assessed in the Pacific.

Recommendations for Dromuna

- There is an urgent need to manage the finfish and invertebrate resources at Dromuna, with community-based management the best approach and the most likely to succeed.

- Rigorous awareness programmes need to be developed and implemented to educate people and communities on the need for management to sustain resources on a long-term basis.

- The community is advised to allocate certain areas of the coastal reef and associated mangrove areas as management or reserve sites.

- A monitoring system needs to be set in place as part of management arrangements to follow any further changes in finfish and invertebrate resource status.

- Strong management of giant clam stocks is needed to enable sufficient recruitment to maintain the current status.

- If a marine reserve is established, larger clams should be collected and placed in the reserve for protection to allow them to spawn and regenerate stocks over time.

- If the horse-hoof or bear's paw clam *Hippopus hippopus* is to be re-introduced, Dromuna should be considered as a potential release site, as the broken (patchy) bottom sandy reef areas found inshore at Dromuna are well suited to this free-standing species.

- A total ban on fishing the trochus stocks is required for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered. This ban should be enforced at the village level, as well as at the provincial and national levels.

- Reintroduction of trochus to the Dromuna outer-reef front is highly recommended, especially if the total ban is imposed.

- The subsistence use of trochus shell for food or handicrafts should be banned in the village.

- The management of sea cucumbers needs to be strengthened, and a total national ban implemented for at least 10 years (with no exceptions) and enforced to allow all of the commercial species to recover.

- Harvesting of juvenile lobsters and egg-bearing female lobsters was observed in 2009. We recommend that regulations on harvestable size limitations and on the harvest of egg-bearing lobsters or crustaceans in general be urgently developed and adopted.

Results from fieldwork at Muaivuso

Muaivuso is a small, traditional community located close to Fiji Islands' capital, Suva on the island of Viti Levu. Muaivuso is a coastal fishing village, where people have relatively good access to alternative income sources, including employment in the close-by urban areas. Public transport is easily accessible from the village. Fishers from the community sell their finfish catch to middlemen, shopkeepers, restaurants and at the two major markets, Lami and Suva. Invertebrates are caught and sold at the Suva markets at weekends, but some commercial species, including lobsters, are caught for restaurants or, in the case of bêche-de-mer, sold directly to Suva-based exporters. Most of the available reef was too shallow to cross at low tide. Water flow across the barrier and the shallow lagoon was dynamic and originated from the east. The outer reef was exposed and the reef slope shelved steeply. Muaivuso is a study site for USP students and is often referred to as being well or over-studied, considering the smallness of the area. A community marine protected area (MPA) covers 60% of the reef from the middle of the reef flat up to the reef edge.

Socioeconomics in Muaivuso

Muaivuso is close to the capital city Suva and, with the available public transport and short distance, people in the community have several options available for earning income, particularly salary-based income in the greater urban Suva area. Arable land allows for crop production, both for home consumption and, to a smaller extent, for sale. Fisheries, notably finfish and bêche-de-mer collection, are the main income sources for 40% of all households, and salaries provide another 40% with first income. Fisheries, agricultural produce, and mat weaving (by females) also complement income. The Muaivuso community has a high finfish consumption (68 kg/capita/year), but consumes far less invertebrates (10 kg/capita/year) and canned fish (3 kg/capita/year).

Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further away from shore, while females are more involved in handlining and gillnetting in the nearshore habitats and in collecting invertebrates. Both gender groups participate in the commercial bêche-de-mer fishery, as this is the most important invertebrate fishery by wet weight and for income generation. Other traditional species, including sea urchins and octopus, are important for home consumption and small-scale local commercial sale.

Finfish resources in Muaivuso

The status of finfish resources in Muaivuso appeared to be average to low, with density, average size and biodiversity comparable to values at Dromuna and Lakeba but much lower than at Mali. The site is, however, limited in reef habitats (only back- and outer reefs are present), and this creates a natural disadvantage in terms of production and richness of resources. There was a slight dominance of herbivores over carnivores, mainly due to the high abundance of Scaridae and Acanthuridae. Carnivores displayed very small sizes. Kyphosidae, Labridae, Lethrinidae, Mullidae and Scaridae displayed size ratios much lower than the maximum values recorded for these families, indicating a selective impact from fishing. The overall habitat was composed of a complex proportion of hard and soft bottom, offering niches to different families. Therefore, the scarcity or lack of carnivores and especially piscivores (Serranidae) is to be related to fishing impact.

Invertebrate resources in Muaivuso

The shallowness of the lagoon and the lack of extensive protected areas of hard benthos at Muaivuso limited the area of habitat suitable for giant clams. Two species of clams were noted and clams were uncommon at Muaivuso in both the 2003 and 2009 surveys. The density of giant clams recorded at Muaivuso represents a very low abundance; giant clams have undoubtedly been affected by fishing. The marine protected area (MPA) in Muaivuso seems to have provided efficient protection to giant clams as density was higher inside than outside the MPA. Though clams are still at critically low density, the area outside the MPA will benefit from the future population increase inside the MPA.

The barrier reefs at Muaivuso provided suitable habitat for the commercial topshell *Trochus niloticus* but conditions were somewhat limited due to the small scale of the area, its exposure, the sandy nature of the lagoon and reefs, and the lack of shoaling on the outer reef. Other mother-of-pearl stocks, such as blacklip pearl oysters, *Pinctada margaritifera*, and green topshells, *Tectus pyramis* (of low-commercial value), were recorded in survey and are considered to be at low-to-medium density.

Habitat suitable for sea cucumbers around Muaivuso was limited in scale and subject to daily fishing pressure. Stocks were varied, but the density of individual species groups was generally depleted in 2003 and totally overfished in 2009. The exceptions in 2003 were the high-density aggregations of deep-water redfish (*Actinopyga echinites*) on the back-reef and the promising settlement of the higher-value black teatfish (*Holothuria nobilis*). However, in 2009 not a single specimen was recorded and, in general, most of the bêche-de-mer stocks were at a critical level of depletion with continued fishing activity leading to local extinction of several species in the near future. Some species within the MPA showed increases in abundance, which indicates the positive impact of the MPA.

Recommendations for Muaivuso

- Other giant clam species be introduced.
- The community-based management and monitoring in place in Muaivuso be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.
- The community continue to support the marine protected area (MPA) and expand the area covered if possible.
- The community consider the development of land-based activities for income generation given the current fishing pressure and poor state of the resources.
- A ban be placed on fishing for giant clams to conserve the remaining populations.
- Some larger clams be collected and placed in the MPA to boost the stocks and allow them to spawn and regenerate over time.
- If the horse-hoof or bear’s paw clam *Hippopus hippopus* is to be re-introduced, Muaivuso be considered as a potential release site, as the broken (patchy) bottom sandy reef areas found in the area are well suited to this free-standing species.

- The trochus stocks be protected for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- The management of sea cucumbers be strengthened, and a total ban implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

- A clean-up campaign be implemented to control the current outbreak of the crown-of-thorns starfish (*Acanthaster planci*).

Results from fieldwork at Mali

Mali is a traditional community located on a small island off Labasa on Vanua Levu. Half of the Vuata reef in front of the island was set aside as an MPA some years ago by the community, with the support of Macuata Province and the Fiji Locally Managed Marine Area (FLMMA) group. Voro voro passage was added recently into the MPA area as a fish-spawning aggregation site, with plans to declare the passage a national marine reserve. This allowed for sampling stations to be located inside and outside the MPA. The second village surveyed, Nakawaqa, was selected for its coverage under the 1999 World Bank study "voices from the village".

Socioeconomics in Mali

Due to the short distance by boat to markets, people in the community of Mali have good access for marketing their fisheries produce, almost the sole means of generating income (providing 87.5% of households with first income), and one of the most important food sources. In addition, females earn complementary income from handicrafts (mat weaving). There are almost no opportunities to earn salaries on the island, or for agricultural production. Salaries provide only 12.5% of households with first income. The Mali community has a high finfish (81 kg/capita/year) and invertebrate (13.1 kg/capita/year) consumption, but little canned fish is consumed (1.8 kg/capita/year).

Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further from shore, while females are more involved in handlining and gillnetting in the nearshore habitats, mainly the lagoon and permitted sheltered coastal reef areas. Female fishers are heavily engaged in traditional invertebrate collection, but male fishers who free-dive for invertebrates account for the highest impact by wet weight. Bêche-de-mer is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including *Scylla serrata*, giant clams and lobsters, are important for home consumption and small-scale, local commercial sale.

Finfish resources in Mali

The status of finfish resources in the Mali survey site was found to be relatively healthy, with much higher density, size, size ratio and biomass compared to the other three sites. Biodiversity was similar to the values at Muaivuso and Dromuna. Detailed assessment at the trophic and family level revealed a clear dominance of herbivores over carnivores. The average family composition was dominated, as at Lakeba, by Scaridae, Acanthuridae and

Siganidae. The coastal and intermediate reefs displayed a similar family composition, with Acanthuridae and Scaridae equally important and dominating. The back-reefs (representing the majority of all reefs) displayed also a high presence of Siganidae. In the outer reefs, Lutjanidae were also well represented. The habitat was mainly composed of hard bottom, offering little favourable habitat for carnivores of the Mullidae and Lethrinidae families. Kyphosidae, Labridae, Lethrinidae and Mullidae displayed size ratios much lower than the maximum known for these families, indicating a selective impact from fishing. Lethrinidae, together with Serranidae, often very rare, were among the most frequently caught fish in all the four villages.

Invertebrate resources in Mali

A wide range of reef environments suitable for giant clams was present in the coastal, intermediate and outer reaches of the lagoon system at Mali island, both in 2003 and 2009. The double set of barrier reefs (one pseudo-barrier) provided extensive and varied hard benthos at a range of exposure grades for giant clams. However, only two clam species were recorded at Mali both in 2003 and 2009: *Tridacna maxima* and *T. squamosa*. In 2003, the clam distribution and abundance showed that stocks were somewhat depleted, although the presence and abundance of *T. squamosa* were relatively good. In 2009, *T. maxima* was sparsely distributed and quite depleted. However, the *T. squamosa* population seemed healthy, especially inside the MPA, where it locally reached the density of 167 /ha.

The barrier reefs at Mali provided extensive habitat suitable for the commercial topshell, *Trochus niloticus*. Data on trochus distribution, density and shell size suggest that stocks in Mali were not abundant, perhaps heavily impacted by fishing prior to 2003. However, trochus were still spawning and recruiting, and small numbers of trochus were recorded across the intermediate reef, back-reef, and reef slope. Other mother-of-pearl stocks, such as blacklip pearl oysters, *Pinctada margaritifera*, and green topshells, *Tectus pyramis* (of low-commercial value), were recorded in survey at moderate density.

Habitat for sea cucumbers around Mali island was both extensive in scale and varied in structure and environment. The large lagoon system was predominantly protected and land-influenced (suitable for these deposit-feeding resources), but more exposed, oceanic areas were also found near the barrier and on the reef slope. The number of species of sea cucumbers recorded at Mali in 2003 and 2009 (n = 11), was low for a lagoonal site in Fiji Islands, especially since the site supported such a wide range of environments. In 2003, the abundance of sea cucumbers was low, without exception. In 2009, the abundance was critically low for all species; most of the species were recorded at only one or very few specimens. The MPA seems to have had a positive impact, with densities higher than on the open-access reefs.

Recommendations for Mali

- The community-based management and monitoring in place in Mali be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.

- The community continue to support the marine protected area (MPA) and expand the area covered if possible, especially to cover the potential giant clam (*Tridacna maxima*) habitat on the back-reefs of the barrier reef.

- The Fisheries Department provide support to increase the capacity of local people to protect their fishing grounds from poaching, which is substantial in the case of Mali.

- An awareness programme be developed and implemented to educate people and communities on the need for management to sustain their resources on a long-term basis.

- Strong management of giant clam stocks be implemented to enable sufficient recruitment to maintain the current status.

- Introduction of other giant clam species be considered.
- Some larger clams be collected and placed in the MPA to boost the stocks and allow them to spawn and regenerate stocks over time.

- Trochus be re-introduced to the reefs of Mali to develop a stronger spawning stock. Suitable habitat is provided on the northwestern reef front between Mali and Kia islands.

- The trochus stocks be protected from fishing for at least five years (with no exceptions) so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- The management of sea cucumbers be strengthened, and a total ban on fishing implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

Results from fieldwork at Lakeba

Lakeba is a rural, coastal village located in the Macuata Province at the northernmost tip of the island of Vanua Levu at 16º 12' S latitude and 179º 44' E longitude. Lakeba is not far in distance from the island's main centre, Labasa; however, road conditions and transport are poor, making marketing and exchange with the urban centre difficult. Due to the transport problem the community is heavily dependent on buyers who come to the village, and these visits are not necessarily regular. The reef system is productive, with all the suitable habitats present (mangroves, seagrass beds, mudflats, lagoons, back-reefs and outer reef slopes). The lagoon is extensive but mainly sandy, with scattered patches of dead coral. Water flow is dynamic through most of the outer lagoon and across the barrier reef. The more exposed reef front and slope are largely oceanic. A community-based MPA, established in 2003 through the help of FLMMA, was opened in 2007 to harvest sea cucumbers (mainly *Actinopyga miliaris*) to raise funds for the 2007 Methodist Church Conference. The MPA was re-established in January 2009.

Socioeconomics in Lakeba

Lakeba is a rural, coastal community that is highly dependent on fisheries resources for food and income. Despite difficulties in transportation, fishing still offers the main source of income, providing 65% of households with first and 35% with second income, reflecting a lack of alternative options for generating income due to the isolation of the community. The Lakeba community is highly dependent particularly on finfish for food (73 kg/capita/year), followed by invertebrates (10.5 kg/capita/year), with a low canned fish consumption (1.9 kg/capita/year). The community also benefits from good local food production.

Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further away from shore, while females are more involved in handlining and gillnetting in the nearshore habitats, mainly the sheltered coastal reef and lagoon areas. Female fishers are heavily engaged in traditional invertebrate collection, but male fishers who free-dive for invertebrates account for the highest impact by wet weight. This is also true for bêche-de-mer fishing, which is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including *Anadara*, giant clams and octopus, are important for home consumption and small-scale, local commercial sale.

Finfish resources in Lakeba

Overall, the reefs of Lakeba appeared to be in average condition, with the highest fish density, and average size and size ratio similar to values at Dromuna and Muaivuso, but lower than at Mali. Biomass was second only to the value at Mali (104 g/m^2). However, biodiversity was the lowest recorded among the four sites. Detailed assessment at the family level confirmed a rather low diversity in the fish community, composed mainly of herbivores, with a very small proportion of carnivores. In all three habitats, the fish community was dominated by three herbivore families, Scaridae, Acanthuridae and Siganidae. In the outer reefs, however, the picture was slightly different, showing a heavy numerical dominance of Acanthuridae, mainly represented by *Ctenochaetus striatus* and *Acanthurus lineatus*. This trophic composition, heavily dominated by herbivores (especially in density terms), was probably a consequence of the type of substrate, mainly bare rock. Although the general status of the fish stocks was average, some families displayed what could be the first sign of fishing impact: size ratios were below the 50% threshold for Labridae, Lethrinidae and Scaridae. Lethrinidae, similarly to in the other villages, was one of the most frequently caught fish families.

Invertebrate resources in Lakeba

A wide range of reef environments suitable for giant clams was present in the coastal, intermediate and outer reaches of the lagoon system at Lakeba island. Three clam species were recorded: *Tridacna maxima*, *T. squamosa* and *T. derasa*. Clam distribution and abundance showed significant depletion of stocks. Despite the extensive reef area in the lagoon and the good exchange of lagoon and oceanic water, the distribution of clams was sparse, and abundance in the most suitable areas was low. Fishing has undoubtedly played a major role in this depletion.

The reef habitats at Lakeba support the commercial topshell *Trochus niloticus*. Both the reef slopes and more sheltered back-reefs provided suitable habitat for adult and juvenile trochus. The area was extensive and there was a reasonable amount of shoaling of the reef slope (in front of the barrier reef). The type and scale of habitat provided potential for a large fishery for trochus at Lakeba island. However, the density of trochus was low to moderate, with only 6% of stations having a density higher than the 500–600 shell/ha threshold. The data available on trochus distribution, abundance and size suggested that stocks at Lakeba were heavily impacted by fishing. Other mother-of-pearl stocks, such as blacklip pearl oysters, *Pinctada margaritifera*, and green topshells, *Tectus pyramis* (of low-commercial value) were recorded in survey at medium density.

Sheltered lagoon habitat suitable for deposit-feeding sea cucumbers was extensive at Lakeba island, especially facing Nukunuku. However, the marine environment experienced a coral bleaching event (in the early 2000s) and the effects of crown-of-thorns starfish outbreaks in the late 1990s were evident. The range of sea cucumbers recorded was varied but not large, with 13 species and one indicator species recorded during in-water surveys. The presence and density of sea cucumbers were considered depleted for most species recorded. Apart from the very small and difficult-to-process peanutfish, *Stichopus horrens*, which is often recorded in dense patches in seagrass, most species were recorded at densities too low for commercialisation at this time.

Recommendations for Lakeba

- The community-based management and monitoring in place in Lakeba be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.

- The community continue to support the marine protected area (MPA) and expand the area covered if possible, especially to cover the habitats of the giant clams *Tridacna maxima* and *T. squamosa* on the eastern side of Tilagica passage, and the existing trochus stocks.

- An awareness programme be developed and implemented to educate people and communities on the need for management to sustain resources on a long-term basis.

- Strong management of giant clam stocks be implemented to enable sufficient recruitment to maintain the current status.

- Introduction of other giant clam species be considered.

- Some larger clams be collected and placed in the MPA for protection to allow them to spawn and regenerate or rebuild stocks over time.

- The trochus stocks be protected from fishing for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- Trochus be re-introduced to Lakeba reef to develop a stronger spawning stock on the outer reefs of the barrier in front of the village and either side of Tilagica passage.

- The management of sea cucumbers be strengthened, and a total ban on fishing implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

- Regulations on the harvesting of juvenile and egg-bearing female lobsters and crustaceans in general be urgently developed and adopted.

RÉSUMÉ

Les agents de la composante côtière du Programme régional de développement des pêches océaniques et côtières dans les PTOM français et pays ACP du Pacifique (PROCFish/C) ont conduit des travaux de terrain sur quatre sites des Îles Fidji, en juin et juillet 2007, puis en février 2009. Des travaux précédents avaient été financés par la Fondation MacArthur sur certains sites des Îles Fidji, de septembre à novembre 2002 et d'avril à juin 2003, dans le cadre du projet « Évaluation du rôle des ressources issues de la pêche côtière en Océanie, fondée sur l'application de la démographie et de l'écologie : le projet DemEcoFish ». Les Îles Fidji sont l'un des 17 États et Territoires insulaires océaniens visés, sur une période de 5-6 ans, par le projet PROCFish ou le projet CoFish qui lui est associé (Projet de développement de la pêche côtière)[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 Fidji 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 Ministère des ressources marines et forestières (MFF), ainsi que de chercheurs de l'Université du Pacifique Sud. 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.

Les quatre sites retenus aux Îles Fidji étaient : Muaivuso et Dromuna sur l'île de Viti Levu, ainsi que Lakeba et Mali sur l'île de Vanua Levu. Ces sites avaient également fait l'objet d'enquêtes dans le cadre du projet DemEcoFish, ce qui a permis d'établir une comparaison des résultats obtenus au cours des six ans écoulés depuis les premières études. Ces sites ont aussi été choisis en fonction de critères précis :

- 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 Ministère des ressources marines et forestières des Îles Fidji.

Résultats des travaux de terrain conduits à Dromuna

Dromuna est un petit village traditionnel situé sur un îlot au large de la grande île de Viti Levu, à une heure de bateau puis 30 à 60 minutes par la route des grands centres commerciaux des Îles Fidji, Nausori et Suva. Dromuna est le second des deux villages de Kaba Point. Ces deux communautés exploitent le même *qoliqoli* (zone de pêche traditionnelle) que Bau, Viwa et Kiuva sur l'île principale. Le récif du lagon de Kaba est vaste et capable de nourrir des ressources conséquentes en invertébrés. L'hydrodynamisme du récif barrière est assuré par des passes, à l'est, au sud-est et au sud de Dromuna.

Enquêtes socioéconomiques : Dromuna

Les habitants de Dromuna n'ont que quelques possibilités de se faire des revenus et d'avoir des emplois salariés. Les terres cultivables permettent une production agricole destinée à la consommation domestique et, dans une certaine mesure, à la vente. La pêche, en particulier celle de poissons et d'holothuries, est la principale source de revenus pour plus de 85 pour cent des ménages ; elle est complétée par la production agricole et le tissage de nattes (par les femmes). Les ménages sont dans une large mesure tributaires des poissons pour leur nourriture (74 kg par habitant et par an), et consomment beaucoup moins d'invertébrés (4,4 kg/ habitant/an) et de poissons en conserve (2,9 kg/ habitant/an).

Les hommes et les femmes participent à la pêche de poissons et la collecte d'invertébrés, mais les rôles sont répartis selon le sexe. Ce sont surtout les hommes qui vont pêcher les poissons, en ciblant les habitats plus éloignés du littoral, tandis que les femmes pêchent à la ligne à main près du rivage et ramassent des invertébrés. Hommes et femmes participent à la pêche commerciale d'holothuries, principale ressource par poids humide, qui constitue une part importante des revenus. Parmi les autres espèces d'invertébrés traditionnellement récoltés figurent *Pinna bicolor*, *Spondylus* spp., *Lambis lambis*, les langoustes, *Scylla serrata* et *Anadara* spp., importants pour la consommation domestique et la vente commerciale à petite échelle sur les marchés locaux.

Enquêtes sur les poissons : Dromuna

L'état des ressources en poissons à Dromuna, au moment des enquêtes, est moyen. La densité, la biomasse et la diversité des espèces de poissons sont supérieures sur les récifs extérieurs, mais la composition par espèce dominée par les herbivores. Dans l'ensemble, la densité est assez bonne, mais la biomasse très faible par rapport aux moyennes du pays et de la région. La taille moyenne et le rapport de tailles sont comparables à ceux des autres sites, Muaivuso et Lakeba, mais inférieurs à ceux de Mali. La biodiversité est comprise dans la fourchette moyenne du pays, mais supérieure à celle de Lakeba. Selon une analyse détaillée au niveau de la famille, les Scaridés affichent constamment une abondance et une biomasse très élevées, mais une taille moyenne plutôt petite. Cette taille est cependant représentée par plusieurs espèces. Des carnivores sont présents, mais en bien moindre abondance que les herbivores. Toutefois, les piscivores (les Serranidés, par exemple) sont quasiment absents. Certaines familles (Lethrinidés, Mullidés, Labridés, Holocentridés et Scaridés) affichent des tailles beaucoup plus petites que 50 % des valeurs maximales connues, ce qui dénote une réaction à une forte pêche. Le volume du stock et la santé de la population de poissons augmentent en fonction de la distance du littoral, depuis les récifs côtiers et intermédiaires vers les arrière-récifs et les récifs extérieurs.

Ressources en invertébrés : Dromuna

Un large éventail d'environnements récifaux convenant aux bénitiers est observé dans les zones intermédiaires et extérieures du système lagonaire de Dromuna. Le nombre d'espèces enregistrées, faible 2003, est dangereusement faible en 2009. Les bénitiers *Tridacna maxima* et *T. squamosa* sont les deux seules espèces observées. Le bénitier *T. gigas* et le bénitier tacheté *Hippopus hippopus* sont considérés comme disparus des Îles Fidji. Cette situation s'explique en partie par la nature de l'environnement récifal (sablonneux, avec des algues épaisses, avec éventuellement des épisodes de fort ruissellement de sources terrestres), mais la pêche a très certainement joué un grand rôle dans l'appauvrissement de ces ressources.

Les récifs de Dromuna présentent diverses structures de récif barrière et de récif intermédiaire à benthos dur qui pourraient éventuellement accueillir des quantités de trocas *Trochus niloticus* intéressantes pour le commerce. D'après les données limitées dont on dispose sur la distribution et l'abondance du troca en 2003, nous estimons qu'il existe un stock à Dromuna, mais dispersé et à faible densité. En 2009, une évaluation plus large confirme le faible niveau de densité, qui semble avoir baissé encore depuis 2003. D'après les premières enquêtes conduites, le stock de trocas à Dromuna semble épuisé. D'autres stocks de nacres, par exemple l'huître perlière à lèvres noires *Pinctada margaritifera* et le troca *Tectus pyramis* (de faible valeur marchande) ont été enregistrés lors de l'enquête ; leur densité, moyenne en 2003, est faible en 2009.

Le total élevé de 21 espèces d'holothuries observé sur ce site (en cumulant les quantités des enquêtes de 2003 et de 2009) reflète la diversité des environnements présents à Dromuna, notamment un système lagonaire surtout influencé par les facteurs terrestres. En 2003, la présence et la densité des holothuries étaient considérées comme relativement bonnes pour certaines espèces de moyenne et faible valeur marchande telles que *Stichopus hermanni*, *Bohadschia vitiensis* et *Actinopyga miliaris*, tandis que celles d'espèces de moyenne à grande valeur marchande (*Stichopus chloronotus*, *Actinopyga mauritiana*, *Holothuria nobilis* et *H. scabra*) étaient plus préoccupantes, ces espèces étant considérées comme touchées par la pêche. En 2009, toutes les espèces de faible/moyenne à grande valeur marchande sont dispersées et présentent une densité faible à dangereusement faible. Les densités de toutes les espèces d'intérêt commercial sont parmi les plus faibles observées sur tous les sites évalués dans le Pacifique.

Recommandations pour Dromuna

- Il est urgent de gérer les ressources en poissons et invertébrés de Dromuna selon la méthode de la gestion communautaire, la meilleure et la plus apte à être couronnée de succès.

- Il faut élaborer des programmes rigoureux de sensibilisation et les mettre en œuvre pour faire prendre conscience aux personnes et aux populations de la nécessité d'une gestion des ressources pour les conserver à long terme.

- Il est conseillé à la communauté d'aménager des sites gérés ou des réserves dans certaines zones du récif côtier et des mangroves associées.

- Un système de surveillance doit être mis en place, dans le cadre des mesures de gestion, pour suivre l'évolution de l'état des ressources en poissons et invertébrés.

- Une solide gestion des stocks de bénitiers est indispensable pour faire en sorte que le recrutement soit suffisant pour maintenir le statu quo.

- Si une réserve marine est aménagée, de grands bénitiers devraient être collectés et placés dans cette réserve pour les protéger et leur permettre de se reproduire et de reconstituer les stocks au fil du temps.

- Si l'on veut réintroduire le bénitier tacheté *Hippopus hippopus*, il faut considérer Dromuna comme un site de repeuplement potentiel, car les zones de récif sablonneux à fond irrégulier, proches du littoral de Dromuna, conviennent bien à cet espèce autonome.

- Il faut totalement interdire, pendant au moins cinq ans, la pêche des stocks de trocas, de manière qu'ils puissent bénéficier du regain d'activité de reproduction que permet une population plus dense, ce qui permettrait aux stocks de se reconstituer pour atteindre au moins 500-600 coquilles/ha avant que l'on puisse envisager une récolte commerciale. Cette interdiction devrait être décidée à l'échelon du village, ainsi qu'aux échelons provincial et national.

- La réintroduction de trocas sur le front du récif extérieur de Dromuna est vivement recommandée, surtout si l'interdiction totale est imposée.

- L'usage vivrier de coquilles de trocas à des fins artisanales ou alimentaires devrait être interdit dans le village.

- Il faut renforcer la gestion des holothuries et décréter une interdiction totale nationale pendant au moins dix ans (sans exceptions) et l'appliquer de manière à permettre à toutes les espèces d'intérêt commercial de reconstituer leurs stocks.

- La récolte de langoustes juvéniles et de langoustes femelles gravides a été observée en 2009. Nous recommandons d'élaborer et d'adopter d'urgence des règlements concernant les tailles limites pouvant être récoltées et sur la récolte de langoustes gravides ou de crustacés en général.

Résultats des travaux de terrain conduits à Muaivuso

Muaivuso est une petite communauté traditionnelle implantée à côté de la capitale, Suva, sur l'île de Viti Levu. Les habitants de ce village de pêche côtier ont un accès relativement aisé à d'autres sources de revenus, notamment l'emploi dans les zones urbaines proches. Les transports publics sont facilement accessibles depuis le village. Les pêcheurs de la communauté vendent leurs prises de poissons à des intermédiaires, des commerçants, des restaurants, et sur les deux grands marchés, Lami et Suva. Les invertébrés sont capturés et vendus sur les marchés de Suva le week-end, mais certaines espèces commerciales, telles que les langoustes, sont destinées aux restaurants ou, dans le cas des holothuries, sont vendues directement à des exportateurs installés à Suva. La majeure partie des récifs est trop peu profonde pour être traversée en bateau à marée basse. L'hydrodynamisme sur la barrière et le lagon peu profond est grand et provient de l'est. Le récif extérieur est exposé et le tombant du récif est en pente abrupte. Muaivuso est un site fréquenté par les étudiants de l'Université du Pacifique Sud, et il est souvent jugé bien ou trop étudié, vu l'exiguïté de sa superficie. Une aire marine protégée couvre 60 pour cent du récif, depuis le milieu du platier jusqu'au bord du récif.

Enquêtes socioéconomiques : Muaivuso

Muaivuso est proche de la capitale, Suva, et, grâce aux transports publics et aux courtes distances, les habitants du village ont plusieurs moyens de gagner de l'argent, notamment les salaires perçus à Suva et sa périphérie. Les terres arables permettent une production agricole, destinée à la consommation domestique et, dans une moindre mesure, à la vente. La pêche, notamment celle de poissons et d'holothuries, est la principale source de revenus pour 40 pour cent des ménages, et les salaires représentent la première source de revenus pour 40 pour cent autres ménages. La pêche, la production agricole et le tressage de nattes (par les femmes) complètent ces revenus. La communauté de Muaivuso consomme beaucoup de poissons (68 kg/habitant/an), et beaucoup moins d'invertébrés (10 kg/habitant/an) et de poisson en conserve (3 kg/habitant/an).

Les hommes et les femmes pratiquent la pêche de poissons et la collecte d'invertébrés, mais les rôles sont répartis selon le sexe. Ce sont surtout les hommes qui pêchent du poisson et ciblent les habitats plus éloignés du rivage, tandis que les femmes pêchent à la ligne à main et au filet maillant dans les habitats proches du littoral et collectent des invertébrés. Hommes et femmes participent à la pêche commerciale d'holothuries, principale espèce d'invertébrés par poids humide et principale source de revenus. D'autres espèces traditionnelles, notamment les oursins et les poulpes, sont importantes pour la consommation domestique et la vente commerciale à petite échelle, sur les marchés locaux.

Ressources en poissons : Muaivuso

L'état des ressources en poissons à Muaivuso semble être moyen à faible ; la densité, la taille moyenne et la biodiversité sont comparables aux valeurs relevées à Dromuna et Lakeba, mais bien inférieures à celles de Mali. Ce site se limite toutefois aux habitats récifaux (il n'y a qu'un arrière-récif et des récifs extérieurs), ce qui crée un handicap naturel en termes de production et de richesse des ressources. Il y a une légère prédominance des herbivores sur les carnivores, ce qui s'explique principalement par la grande abondance de Scaridés et d'Acanthuridés. Les carnivores affichent de très petites tailles. Les Kyphosidés, Labridés, Lethrinidés, Mullidés et Scaridés présentent des rapports de tailles beaucoup plus faibles que les valeurs maximales enregistrées pour ces familles, ce qui dénote un impact sélectif dû à la pêche. L'habitat est composé dans l'ensemble d'un assortiment complexe de fonds durs et meubles, offrant des niches à différentes familles. C'est pourquoi la rareté ou l'absence de carnivores, notamment de piscivores (Serranidés) est à imputer à l'impact dû à la pêche.

Ressources en invertébrés : Muaivuso

La faible profondeur du lagon et l'absence de grandes zones protégées de benthos dur à Muaivuso limitent la superficie de l'aire habitable par des bénitiers. Deux espèces ont été observées, et les bénitiers ne figurent pas couramment dans les enquêtes de 2003 et de 2009. La densité des bénitiers enregistrée à Muaivuso dénote une très faible abondance, ce qui est très certainement l'effet de la pêche. L'aire marine protégée de Muaivuso semble avoir offert une protection efficace aux bénitiers, car la densité y est plus élevée qu'à l'extérieure de l'AMP. Bien que la densité des bénitiers soit encore dangereusement faible, la zone située à l'extérieur de l'AMP profitera de l'augmentation de cette population à l'intérieur de l'AMP.

Les récifs barrières de Muaivuso offrent un habitat approprié au troca d'intérêt commercial *Trochus niloticus*, mais les conditions sont limitées par l'exiguïté de la zone, son exposition, la nature sablonneuse du lagon et des récifs, et l'absence de petites profondeurs sur le récif extérieur. D'autres stocks de nacres (huîtres perlières à lèvres noires *Pinctada margaritifera,* et trocas *Tectus pyramis* de faible valeur marchande, par exemple), enregistrés au cours de l'enquête, sont considérés comme présentant une densité faible à moyenne.

Autour de Muaivuso, l'habitat convenant aux holothuries est limité en surface et exposé à la pression quotidienne de la pêche. Les stocks sont variés, mais la densité des différents groupes d'espèces témoigne d'un appauvrissement en 2003 et d'une surpêche totale en 2009. Les exceptions notées en 2003 concernent les concentrations d'holothuries brunes *Actinopyga echinites* sur l'arrière-récif et la colonisation prometteuse d'holothuries noires à mamelles *Holothuria nobilis*, de grande valeur marchande. Toutefois, en 2009, pas un seul spécimen n'a été observé, et, en général, la plupart des stocks d'holothuries ont atteint un niveau critique d'appauvrissement, et la poursuite des activités halieutiques entraînera l'extinction locale de plusieurs espèces dans un proche avenir. Certaines espèces trouvées à l'intérieur de l'AMP ont une abondance croissante, ce qui traduit l'impact positif de l'AMP.

Recommandations pour Muaivuso

- Il convient d'introduire d'autres espèces de bénitiers.
- La gestion communautaire et le suivi en vigueur à Muaivuso devraient être renforcés de manière à pérenniser les ressources en poissons et invertébrés.
- La communauté devrait conserver l'AMP et élargir la superficie couverte, si possible.
- La communauté devrait envisager de mener d'autres activités à terre, génératrices de revenus, vu la pression de pêche actuelle et l'état médiocre des ressources.

- Il faudrait interdire la pêche de bénitiers afin de conserver les populations restantes.

- Certains grands bénitiers devraient être récoltés et placés dans l'AMP afin de faciliter la reconstitution des stocks et leur permettre de se reproduire et de se régénérer au fil du temps.

- Si l'on veut réintroduire le bénitier tacheté *Hippopus hippopus*, il faut considérer Muaivuso comme un site de repeuplement potentiel, car les zones récifales sablonneuses à fond irrégulier conviennent bien à cette espèce autonome.

- Les stocks de trocas devraient être protégés pendant au moins cinq ans, pour pouvoir bénéficier de l'augmentation de l'activité de reproduction qu'entraîne une population plus dense, ce qui permettrait aux stocks de se reconstituer pour atteindre au moins 500-600 coquilles/ha avant qu'une récolte commerciale ne puisse être envisagée.

- Il faut renforcer la gestion des holothuries et décréter et appliquer une interdiction totale (sans exception) de leur récolte, pour permettre le rétablissement de toutes les espèces d'intérêt commercial.

- Il faut conduire une campagne de nettoyage pour lutter contre l'invasion actuelle d'étoiles de mer corallivores *Acanthaster planci.*

Résultats des travaux de terrain conduits à Mali

Mali est une communauté traditionnelle située sur un îlot au large de Labasa, sur l'île de Vanua Levu. La population a aménagé la moitié du récif de Vuata, en face de l'îlot, en aire marine protégée, il y a quelques années, avec le soutien de la province de Macuata et le FLMMA (réseau fidjien d'aires marines protégées sous gestion locale). La passe de Voro voro, site de concentration de poissons reproducteurs, a été récemment incluse dans l'AMP, et il est prévu de déclarer la passe réserve marine nationale. Cela a permis d'installer des stations d'échantillonnage au sein de l'AMP et en dehors. Le second village étudié, Nakawaqa, a été choisi parce qu'il a été couvert par l'étude conduite en 1999 par la Banque mondiale, « le village s'exprime ».

Enquêtes socioéconomiques à Mali

Vu la courte distance des marchés par bateau, les habitants de Mali n'ont pas de difficulté pour vendre les produits de la pêche, ce qui est pratiquement le seul moyen pour eux d'avoir des revenus (premiers revenus de 87,5 pour cent des ménages) et l'une de leurs principales sources de nourriture. En outre, les femmes se font des revenus complémentaires grâce à l'artisanat (tressage de nattes). Il n'y a quasiment pas de possibilité d'emploi salarié sur l'île ni de production agricole. Des salaires ne sont perçus, en tant que première source de revenus, que par 12,5 % des ménages. La communauté de Mali consomme beaucoup de poissons (81 kg/habitant/an) et d'invertébrés (13,1 kg/habitant/an), mais peu de poisson en conserve (1,8 kg/habitant/an).

Les hommes et les femmes participent à la pêche de poissons et à la collecte d'invertébrés, mais leurs rôles sont différenciés selon le sexe. Ce sont surtout des hommes qui pêchent des poissons et ciblent des habitants plus éloignés du rivage, tandis que les femmes pratiquent la pêche à la ligne à main et au filet maillant dans les habitats proches du littoral, principalement dans le lagon et les zones du récif côtier abrité autorisées. Les femmes sont fortement impliquées dans la collecte traditionnelle d'invertébrés, mais les hommes qui pratiquent la pêche d'invertébrés en plongée libre exercent l'impact le plus fort par poids humide. Les holothuries sont les principales espèces d'invertébrés par poids humide. En dehors de cette source de revenus, des espèces traditionnelles telles que *Scylla serrata*, les bénitiers et les langoustes, entrent aussi pour une part importante dans la consommation domestique et la vente commerciale à petite échelle sur les marchés locaux.

Ressources en poissons : Mali

L'état des ressources en poissons observé sur le site d'enquête à Mali est relativement bon. La densité, la taille, le rapport de tailles et la biomasse de ces ressources sont beaucoup plus élevés que sur les trois autres sites. La biodiversité est similaire à celle observée à Muaivuso et à Dromuna. Une évaluation détaillée au niveau trophique et à celui de la famille révèle une nette prédominance des herbivores sur les carnivores. La composition moyenne par famille est dominée, comme à Lakeba, par les Scaridés, les Acanthuridés et les Siganidés. Les récifs côtiers et intermédiaires affichent une composition similaire, les Acanthuridés et les Scaridés ayant une importance égale et dominante. Les arrière-récifs (représentant la majorité des récifs) affichent également une forte présence de Siganidés. Sur les récifs extérieurs, les Lutjanidés sont également bien représentés. L'habitat est principalement composé d'un fond dur, offrant un habitat peu favorable à des carnivores des familles des Mullidés et Lethrinidés. Les Kyphosidés, Labridés, Lethrinidés et Mullidés présentent des rapports de tailles inférieurs au maximum connu pour ces familles, ce qui dénote un impact sélectif de la pêche. Les Lethrinidés, ainsi que les Serranidés, souvent très rares, comptent parmi les poissons les plus fréquemment capturés par les quatre villages.

Ressources en invertébrés : Mali

On a observé une grande diversité d'environnements récifaux appropriés aux bénitiers dans les zones côtières, intermédiaires et extérieures du système lagonaire de l'île de Mali, tant en 2003 qu'en 2009. Le double ensemble de récifs-barrières (ou pseudo-barrières) présente un benthos dur, vaste et varié, à divers degrés d'exposition pour les bénitiers. Toutefois, deux espèces seulement ont été observées à Mali en 2003 et en 2009 : *Tridacna maxima* et *T. squamosa*. En 2003, la distribution et l'abondance des bénitiers montraient que les stocks étaient appauvris, mais que la présence et l'abondance de *T. squamosa* étaient relativement bonnes. En 2009, *T. maxima* est dispersé et épuisé. La population de *T. squamosa* semblait toutefois en bonne santé, en particulier à l'intérieur de l'AMP, où elle atteint la densité de 167 individus/ha.

Les récifs-barrières de Mali offrent un vaste habitat, convenant au troca d'intérêt commercial *Trochus niloticus*. Les données relatives à la distribution, la densité et la taille de coquille des trocs suggèrent que les stocks de Mali ne sont pas abondants, la pêche ayant peut-être eu un fort impact avant 2003. Toutefois, les trocas continuent de se reproduire et de recruter, et de petites quantités de trocas ont été enregistrées sur le récif intermédiaire, l'arrière-récif et le tombant récifal. D'autres stocks de nacres, par exemple l'huître perlière à lèvres noires *Pinctada margaritifera*, et le troca *Tectus pyramis* (de faible valeur marchande), ont été observés à densité modérée.

L’habitat des holothuries, autour de l’île de Mali, est à la fois étendu et varié par sa structure et son environnement. La majeure partie du grand système lagonaire est protégée et soumise à des influences terrestres (convenant à ces ressources détritivores), mais des zones océaniques plus exposées se trouvent aussi près de la barrière et sur le tombant récifal. Le nombre d’espèces d’holothuries enregistré à Mali en 2003 et 2009 (n = 11) est faible pour un site lagonaire des Îles Fidji, d’autant plus que le site comporte un large éventail d’environnements. En 2003, l’abondance des holothuries était faible, sans exception. En 2009, elle est dangereusement faible pour toutes les espèces ; la plupart des espèces observées n’étant représentées que par un spécimen ou très peu. L’AMP semble avoir eu un impact positif, les densités y étant supérieures à celles des récifs à accès libre.

Recommandations pour Mali

- Le système de gestion et suivi communautaire en vigueur à Mali devrait être renforcé pour assurer la pérennité des ressources en poissons et en invertébrés à l’avenir.

- La communauté devrait continuer à apporter son soutien à l’AMP et élargir si possible sa superficie, de manière à inclure l’habitat potentiel des bénitiers *Tridacna maxima* sur les arrière-récifs du récif-barrière.

- Le Service des pêches devrait s’employer à renforcer la capacité des habitants de protéger leurs zones de pêche contre le braconnage, qui est important dans le cas de Mali.

- Une campagne de sensibilisation devrait être conçue et menée pour faire prendre conscience aux personnes et aux communautés de la nécessité de gérer leurs ressources pour les conserver à long terme.

- Un système solide de gestion des stocks de bénitiers devrait être mis en place pour permettre un recrutement suffisant et les maintenir à leur niveau actuel.

- Il faudrait envisager d’introduire d’autres espèces de bénitiers.

- Certains spécimens de bénitiers de grande taille devraient être collectés et placés dans l’AMP pour favoriser la reproduction et la régénération des stocks au fil du temps.

- Le troca devrait réintroduit sur les récifs de Mali, afin d’avoir un stock de reproducteur plus important. Il existe un habitat approprié sur le front récifal nord-ouest, entre les îles de Mali et de Kia.

- La pêche des stocks de troca devrait être interdite pendant au moins cinq ans (sans exception), de manière à ce qu’ils puissent bénéficier du regain d’activité de reproduction qu’entraîne une population plus dense, ce qui permettrait aux stocks de se reconstituer pour atteindre au moins 500-600 coquilles/ha avant qu’une récolte commerciale ne puisse être envisagée.

- La gestion des holothuries devrait être renforcée, et une interdiction totale de la pêche mise en œuvre (sans exception) et appliquée pour permettre au stock d’espèces commerciales de se reconstituer.

Résultats des travaux de terrain conduits à Lakeba

Lakeba est un village côtier rural situé dans la province de Macuata, à l'extrémité nord de l'île de Vanua Levu, par 16º12' de latitude sud et 179º44' de longitude est. Il n'est pas éloigné du centre principal de l'île, Labasa, mais l'infrastructure routière et les transports sont médiocres, ce qui rend difficiles la vente et les échanges avec le centre urbain. Du fait du problème des transports, les habitants sont fortement tributaires des acheteurs qui viennent au village et dont les visites ne sont pas nécessairement régulières. Le système récifal est riche, et offre tous les habitats appropriés (mangroves, herbiers, vasières, lagons, arrière-récifs et tombants externes). Le lagon est vaste mais principalement sablonneux, avec des pâtés dispersés de coraux morts. L'hydrodynamisme est intense dans la majeure partie du lagon extérieur et au-delà du récif-barrière. Le front récifal et le tombant, plus exposés, sont largement exposés aux influences océaniques. Une AMP sous gestion communautaire, établie en 2003 avec l'aide du FLMMA, a été ouverte en 2007 à la pêche d'holothuries (en majorité, *Actinopyga miliaris*) afin de réunir des fonds au profit de la Conférence de l'Église méthodiste, tenue en 2007. L'AMP a été rétablie en janvier 2009.

Enquêtes socioéconomiques : Lakeba

Lakeba est une communauté côtière rurale dont la nourriture et les revenus dépendent fortement des ressources halieutiques. Malgré des difficultés de transport, la pêche reste l'une des principales sources de revenus, revenu primaire pour 65 % des ménages, secondaire pour 35 %, ce qui traduit l'absence de toute autre possibilité du fait de l'isolement de la communauté. La population de Lakeba est fortement tributaire du poisson (la consommation s'élève à 73 kg/habitant/an), suivi des invertébrés (10,5 kg/habitant/an), la consommation de poisson en conserve étant faible (1,9 kg/habitant/an). La communauté bénéficie aussi d'une bonne production alimentaire locale.

Les hommes et les femmes participent à la pêche de poissons et à la collecte d'invertébrés, les rôles étant différenciés par sexe. Ce sont surtout les hommes qui pêchent le poisson et ciblent des habitats plus éloignés du rivage, tandis que les femmes participent davantage à la pêche à la ligne à main et au filet maillant près du littoral, principalement sur le récif côtier abrité et dans le lagon. Les femmes pratiquent activement la collecte traditionnelle d'invertébrés, mais les hommes qui pêchent des invertébrés en plongée libre sont responsables du plus fort impact par poids humide. Il en va de même pour la pêche d'holothuries, principale ressource en invertébrés par poids humide et principale source de revenus. Des espèces traditionnelles, telles que *Anadara*, les bénitiers et les poulpes, sont également importantes pour la consommation domestique et la vente commerciale à petite échelle sur les marchés locaux.

Ressources en poissons : Lakeba

Dans l'ensemble, les récifs de Lakeba semble être dans un état moyen ; la densité de poissons y est maximale ; la taille moyenne et le rapport de tailles similaires aux valeurs enregistrées à Dromuna et Muaivuso, mais inférieurs à celles de Mali. La biomasse vient au second rang après Mali (104 g/m²). La biodiversité est toutefois la plus faible des quatre sites. Une évaluation détaillée par familles confirme une diversité assez faible de la population de poissons, composée principalement d'herbivores, avec une très petite proportion de carnivores. Dans les trois habitats, la communauté de poissons est dominée par trois familles d'herbivores : Scaridés, Acanthuridés et Siganidés. Sur les récifs extérieurs, en revanche, le tableau est légèrement différent, avec une forte prédominance numérique d'Acanthuridés, surtout représentés par *Ctenochaetus striatus* and *Acanthurus lineatus*. Cette composition trophique, dans laquelle dominent les herbivores (surtout en termes de densité) est probablement la conséquence du type de substrat, généralement composé de roches nues. Bien que l'état général des stocks de poissons soit moyen, certaines familles manifestent ce qui pourrait être le premier signe d'un impact de la pêche : les rapports de tailles sont inférieurs au seuil de 50 % pour les Labridés, Lethrinidés et Scaridés. Les Lethrinidés, comme dans les autres villages, sont l'une des familles les plus fréquemment capturées.

Ressources en invertébrés : Lakeba

Les zones côtières, intermédiaires et extérieures du système lagonaire de l'île de Lakeba recèlent un large éventail d'environnements récifaux appropriés pour les bénitiers. Trois espèces ont été observées : *Tridacna maxima, T. squamosa* and *T. derasa*. La distribution et l'abondance des bénitiers dénotent un appauvrissement important des stocks. Malgré la vaste zone récifale située dans le lagon et les bons échanges d'eau entre le lagon et l'océan, les bénitiers sont dispersés et l'abondance faible dans les zones les plus appropriées. La pêche a très certainement joué un grand rôle dans cet appauvrissement.

Les habitats récifaux de Lakeba sont favorables au troca d'intérêt commercial *Trochus niloticus*. Les tombants et les arrière-récifs plus abrités offrent un habitat approprié aux trocas juvéniles et adultes. La superficie est très vaste, et le tombant récifal (devant le récif barrière) présente une quantité raisonnable de hauts fonds. Le type et l'échelle de l'habitat permettent l'existence d'une grande pêcherie de trocas sur l'île de Lakeba. Toutefois, la densité des trocas est faible à modérée, 6 pour cent seulement des stations ayant une densité supérieure au seuil des 500-600 coquilles/ha. Les données existantes relatives à la distribution, l'abondance et la taille des trocas laissent à penser que les stocks de Lakeba subissent fortement l'impact de la pêche. D'autres stocks de nacres, telles que l'huître perlière à lèvres noires *Pinctada margaritifera* et le troca *Tectus pyramis* de faible valeur marchande, ont été observés à densité moyenne.

L'habitat lagonaire protégé convenant aux holothuries détritivores est étendu, sur l'île de Lakeba, surtout en face de Nukunuku. L'environnement marin a toutefois subi un phénomène de blanchissement corallien (au début des années 2000), et les effets d'invasions d'étoiles de mer corallivores à la fin des années 90 sont évidents. Le nombre d'espèces d'holothuries observées est varié mais assez faible : 13 espèces et une espèce témoin ont été observées dans les enquêtes en plongée. La présence et la densité des holothuries montrent que la plupart des espèces sont épuisées. Hormis *Stichopus horrens*, très petite et difficile à traiter, souvent observée dans des herbiers denses, la plupart des espèces ont été enregistrées à des densités trop faibles pour une commercialisation à l'heure actuelle.

Recommandations pour Lakeba

- Le système de gestion et suivi communautaire en vigueur à Lakeba devrait être renforcé pour assurer la pérennité des ressources en poissons et invertébrés.

- La communauté devrait continuer à gérer l'AMP et élargir sa superficie, si possible, afin de couvrir les habitats de bénitiers *Tridacna maxima* and *T. squamosa* du côté est de la passe de Tilagica, ainsi que les stocks existants de trocas.

- Une campagne de sensibilisation devrait être conçue et appliquée pour faire prendre conscience aux personnes et aux communautés de la nécessité de gérer les ressources pour les conserver à long terme.

- Des mesures rigoureuses de gestion des stocks de bénitiers devraient être appliquées pour permettre un recrutement suffisant et assurer le maintien des stocks à leur niveau actuel.

- Il faudrait envisager d'introduire d'autres espèces de bénitiers.

- Certains spécimens de bénitiers de grande taille devraient être collectés et placés dans l'AMP, pour les protéger, leur permettre de se reproduire et de reconstituer les stocks au fil du temps.

- La pêche des stocks de troca devrait être interdite pendant au moins cinq ans (sans exception), de manière à ce qu'ils puissent bénéficier du regain d'activité de reproduction qu'entraîne une population plus dense, ce qui permettrait aux stocks de se reconstituer pour atteindre au moins 500-600 coquilles/ha avant qu'une récolte commerciale ne puisse être envisagée.

- Des trocas devraient être réintroduits sur les récifs de Lakeba pour avoir un stock plus important de reproducteurs sur les récifs extérieurs de la barrière, en face du village et de chaque côté de la passe de Tilagica.

- La gestion des holothuries devrait être renforcée et la pêche totalement interdite (sans exception) de façon que les stocks de toutes les espèces d'intérêt commercial se reconstituent.

- Des règlements sur la récolte de langoustes juvéniles et de femelles gravides, et celle des crustacés en général, devraient être élaborés et adoptés d'urgence.

ACRONYMS

ACP	African, Caribbean and Pacific Group of States
BdM	bêche-de-mer (or sea cucumber)
B-S	broad-scale
CMT	customary marine tenure
CoFish	Pacific Regional Coastal Fisheries Development Programme
COTS	crown-of-thorns starfish
CPUE	catch per unit effort
Ds	day search
D-UVC	distance-sampling underwater visual census
EDF	European Development Fund
EEZ	exclusive economic zone
FAO	Food and Agricultural Organization (UN)
FJD	Fijian dollar
FL	fork length
FLMMA	Fiji Locally Managed Marine Areas network
GPS	global positioning system
ha	hectare
HH	household
IRD	Institut de Recherche pour le Développement
LMMA	Locally Managed Marine Area
MAF	Ministry of Agriculture and Fisheries
MAFF	Ministry of Agriculture, Fisheries and Forests
MCRMP	Millennium Coral Reef Mapping Project
MFF	Ministry of Fisheries and Forests
MIRAB	Migration, Remittances, Aid and Bureaucracy (model explaining the economies of small island nations)
MOP	mother-of-pearl
MOPs	mother-of-pearl search
MOPt	mother-of-pearl transect
MPA	marine protected area
MPI	Ministry of Primary Industries
MSA	medium-scale approach
NASA	National Aeronautics and Space Administration (USA)
Ns	night search
OCT	Overseas Countries and Territories
PICTs	Pacific Island countries and territories
PROCFish	Pacific Regional Oceanic and Coastal Fisheries Development Programme
PROCFish/C	Pacific Regional Oceanic and Coastal Fisheries Development Programme (coastal component)

RBt	reef-benthos transect
RFID	Reef Fisheries Integrated Database
RFs	reef-front search
RFs_w	reef-front search by walking
SBq	soft-benthos quadrat
SBt	soft-benthos transect
SCUBA	self-contained underwater breathing apparatus
SD	standard deviation
SE	standard error
SPC	Secretariat of the Pacific Community
TFROs	Traditional Fishing Rights Owners
USD	United States dollar(s)
USP	University of the South Pacific

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: Fiji Islands, Wallis and Futuna, and New Caledonia, and is funded under European Development Fund (EDF) 8.
The CoFish programme works with the Cook Islands, Federated States of Micronesia, Marshall Islands, Nauru, Niue and Palau, and is funded under EDF 9.

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

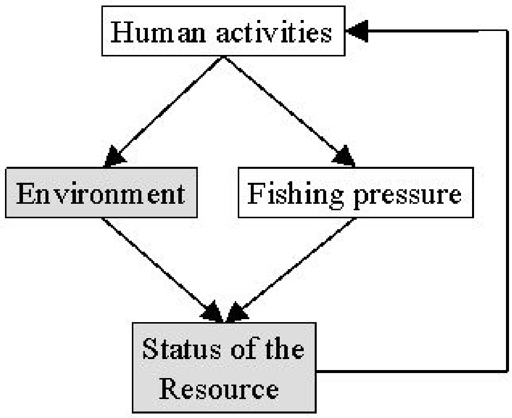

Figure 1.1: Synopsis of the PROCFish/C* multidisciplinary approach.
PROCFish/C conducts coastal fisheries assessment through simultaneous collection of data on the three major components of fishery systems: people, the environment and the resource. This multidisciplinary information should provide the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

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

Expected outputs of the project include:

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

1.2 PROCFish/C and CoFish methodologies

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

1.2.1 Socioeconomic assessment

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

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

Socioeconomic assessments also relied on additional complementary data, including:

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

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

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

1.2.2 Finfish resource assessment

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

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

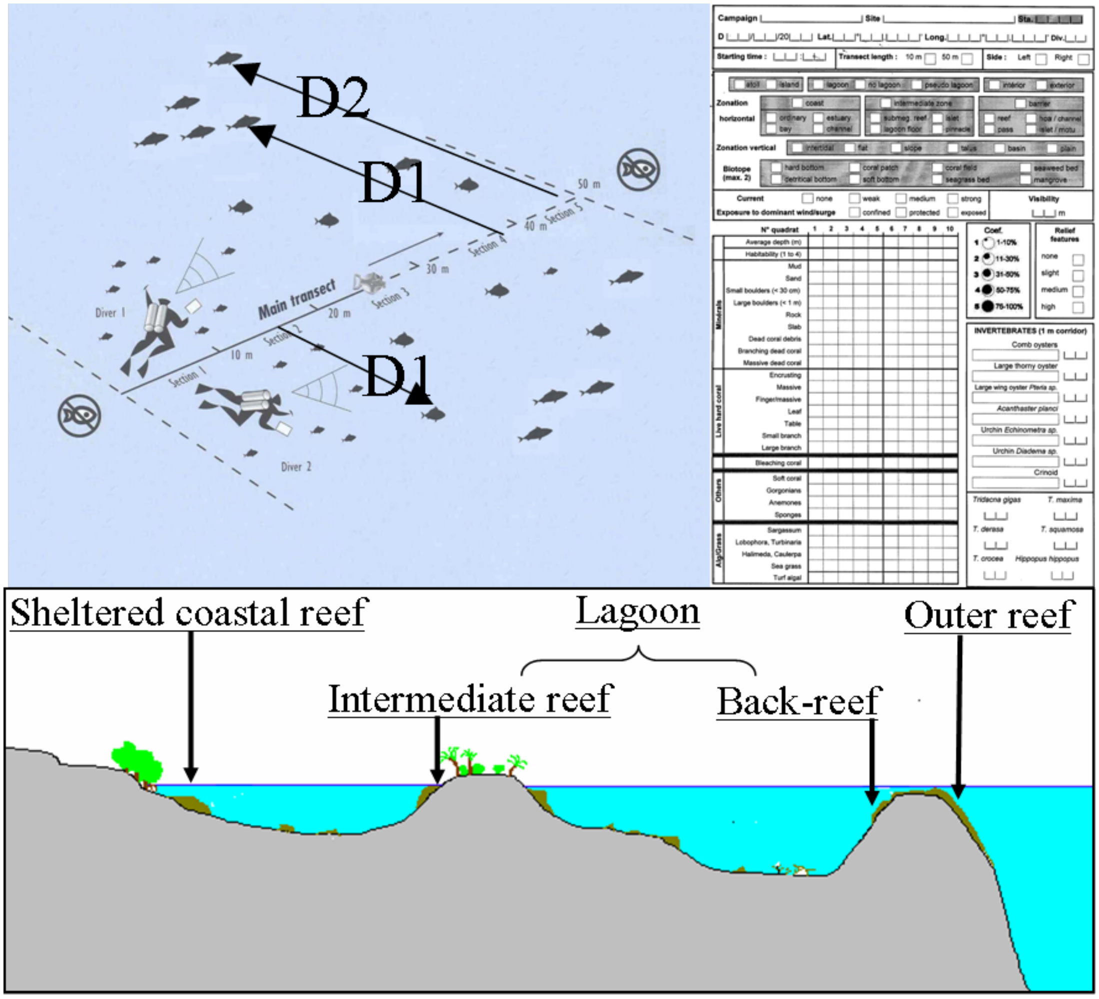

Figure 1.2: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver recorded the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys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

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

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

1.2.3 Invertebrate resource assessment

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

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

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

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

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

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

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

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

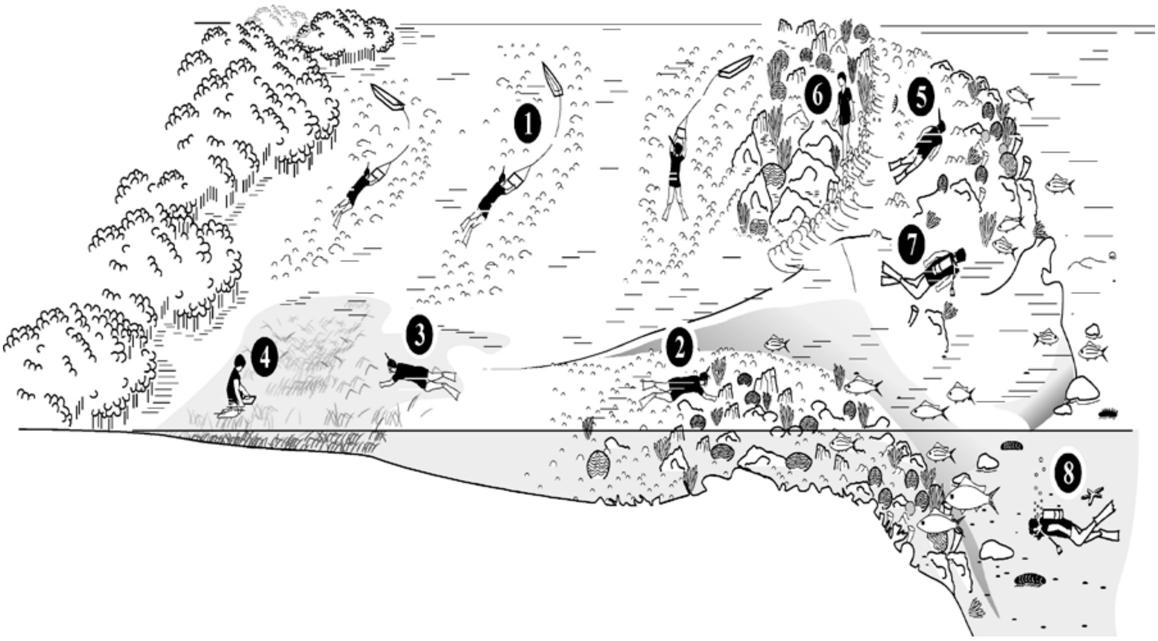

Figure 1.3: Assessment of invertebrate resources and associated environments.
Techniques used include: broad-scale assessments to record large sedentary invertebrates (1); fine-scale assessments to record epi-benthic resources and potential indicator species (2) and (3); quadrats to count targeted infaunal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

1.3.1 General

Fiji Islands comprises about 844 islands and islets (approximately 106 of which are inhabited) scattered in the area 12–23º S and 177ºE–178º W (Figure 1.4). The country is divided into 14 provinces plus Rotuma, and the islands may be divided into several distinct groups: Rotuma; Vanua Levu and associated islands, including Taveuni and the Ringgold Islands; the Lau Group; the Lomaiviti Group; the Yasawa Group; Viti Levu and associated islands; and Kadavu and associated islands (Turner 2008). The main archipelago comprises a total land area of 18,333 km^2, of which 87 per cent is accounted for by Viti Levu (10,386 km^2) and Vanua Levu (5,534 km^2). Other large islands are Taveuni, Kadavu and Gau. The shelf area to 200 m is approximately 15,000 km^2. The country has a surrounding Exclusive Economic Zone (EEZ) of about 1.3 million km^2 (Gillett 2002). Apart from the Eastern Division, the islands consist almost entirely of volcanic and plutonic rocks of various ages, which have been subjected to degeneration and soil formation under typical tropical conditions of intense weathering (Richards *et al.* 1994, Turner 2008, FAO 2008).

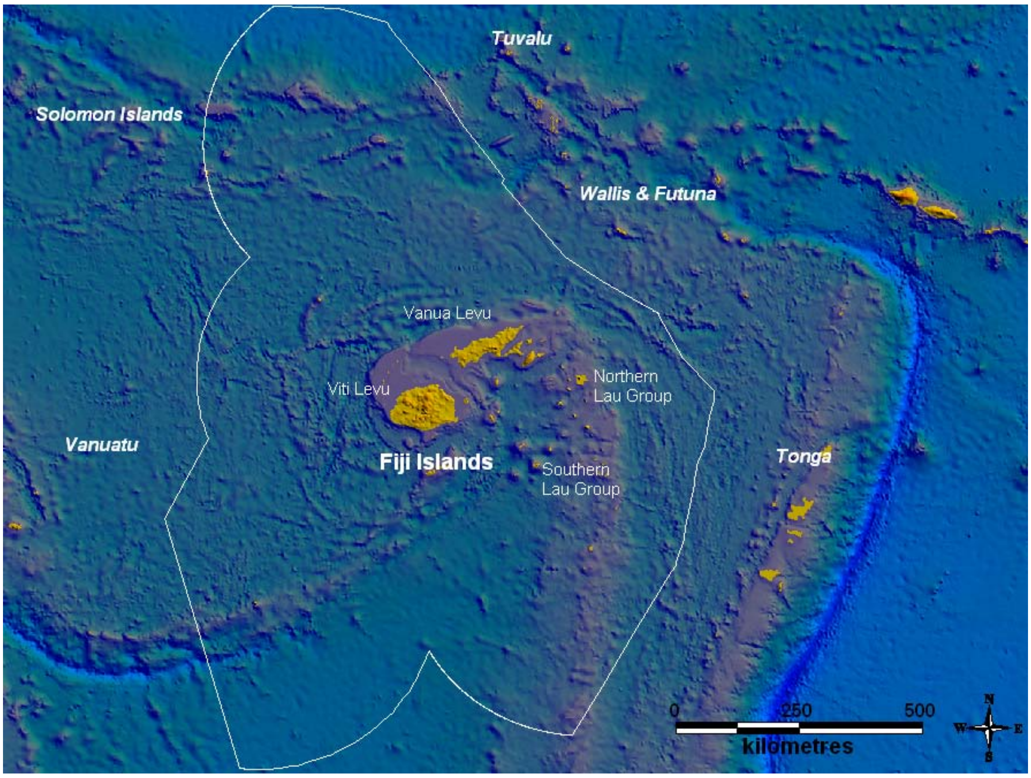

Figure 1.4: Map of Fiji Islands.

The climate is tropical, with high humidity. Temperatures may rise to 35º C, but these are modified by the southeast trade winds from May to November resulting in cool nights and low rainfall. Spells of northerly and northwesterly winds occur during the hurricane season from December to March, when light and variable winds predominate (Turner 2008). The summer is hot and wet with several tropical cyclones, while the winter months are drier and cooler. In Suva (the capital), temperatures range from 22.8°C in July to 26.7°C in January. Annual rainfall is 2974 mm (UNEP/IUCN 1988, Turner 2008).

Provisional figures for the 2007 census show a population of 835,230 people, with an annual growth rate of 0.6%. The 2008 mid-year figure for population density was 46 persons per km^2 (SPC 2008a). The population of Suva is 172,948 people according to the provisional 2007 census figures. Other large towns are Lautoka (52,742), Nausori (48,111), and Nadi (42,717) (Turner 2008).

Fiji Islands became independent in 1970, after nearly a century as a British colony. Democratic rule was interrupted by two military coups in 1987. Free and peaceful elections in 1999 resulted in a new government but a civilian-led coup in May 2000 ushered in a prolonged period of political turmoil. Parliamentary elections held in August 2001 provided Fiji Islands with a democratically elected government until the December 2006 military coup installed an Acting President from the militia. In January 2007, the Acting President was appointed interim Prime Minister (CIA 2008).

Endowed with forest, mineral, and fish resources, Fiji Islands has one of the most developed of the Pacific Island economies, although it still has a large subsistence sector. Sugar exports, remittances from Fijians working abroad, and a growing tourist industry – with 400,000 to 500,000 tourists annually – are the major sources of foreign exchange. Natural resources include timber, fish, gold, copper, offshore oil potential, and hydropower. Agricultural products include sugarcane, coconuts, cassava (tapioca), rice, sweet potatoes, bananas, cattle, pigs, horses, goats, and fish. The main industries are tourism, sugar, clothing, copra, gold, silver, lumber, and small cottage industries. According to 2001 estimates, approximately 70% of the labour force is employed in agriculture while 30% is employed in industry and services (Turner 2008). The Gross Domestic Product (GDP) for 2004 was estimated as comprising 8.9% agriculture, 13.5% industry, and 77.6% services. In 2006, USD 3.12 billion was spent on the import of manufactured goods, machinery and transport equipment, petroleum products, food, and chemicals. Import partners for 2006 were Singapore (29.5%), Australia (21.5%), New Zealand (17.2%), and China (4.1%). In 2006, USD 1.202 billion f.o.b. was acquired from the export of sugar, garments, gold, timber, fish, molasses, and coconut oil. Export partners in 2006 were the United States of America (16.6%), United Kingdom (13%), Australia (10.6%), Samoa (5.2%), Tonga (4.5%), and New Zealand (4.4%) (CIA 2008).

1.3.2 The fisheries sector

The fisheries sector is divided into three sub-sectors: subsistence, coastal commercial, and offshore/industrial. The distinction between subsistence and coastal commercial fishing in the larger, less isolated islands is often blurred, as small-scale fishing activity is becoming increasingly monetised in these areas (Gillett 2002). The Asian Development Bank in 2001 estimated that the catches by subsistence fishing were worth USD 24,675,061, by coastal commercial fishing USD 15,231,519, and by locally based offshore fishing USD 25,639,724 (Gillett 2002). The same study also calculated that this fishing is responsible for about 2.4% of Fiji Islands' GDP. Because fish processing and other post-harvest activities are considered in other sectors of Fiji Islands' economy for GDP calculation purposes, the contribution of fisheries to the economy of Fiji is substantially larger than the 2.4% from fishing alone (Gillett 2002, FAO 2008).

The subsistence fishery targets mainly finfish, bêche-de-mer, octopus, seaweed, lobsters, mud crabs, and various bivalve molluscs. Few figures are available on this fishery, but it accounts for at least 50% of the fish landed from Fiji Islands' waters, and a large proportion of the rural population engages in some form of non-commercial fishing activity. The figure is not documented but in 1990 it was estimated at 15,000 mt per annum (MPI&C 1990). According to Fisheries Division data, 1012 vessels and 2304 fishers participated in the coastal commercial fishery in 1999. It is estimated that 9320 t of finfish and non-finfish were harvested by this component of the fishery in 1999. The most important exports from the coastal commercial fishery are bêche-de-mer, trochus, aquarium fish, coral, snapper, and live food fish (Gillett 2002, FAO 2008).

Offshore fisheries

There is little written on the traditional role of Fijians being involved in fishing for tuna, and it is thought that, apart from some islands where paddling and sailing canoes were used outside the reef with bamboo poles and pearl shell lures, fishing for tuna is a more recent event. The second half of the 20th century saw the development of large- and medium-scale tuna fishing, tuna processing and deep-water snapper fishing activities, along with the use of fish aggregating devices (FADs) for small-scale tuna fishing and gamefishing activities. Trials have also been conducted for flying fish and deep-water shrimps.

1: Introduction and background

Offshore tuna fishery and tuna processing

The first attempt to develop a commercial fishery for tuna in Fiji Islands was made in 1948 by an American company; however, this was unsuccessful and it was not until the 1970s that the next attempt was made (Kearney 1984). In 1974 a survey of the tuna and baitfish resource in Fiji Islands' waters confirmed a seasonal abundance of tuna and the potential for live bait (Anon. 1974).

Tuna longlining activity in the waters around Fiji Islands can be traced back to the early 1950s, when Japanese longline vessels started to fish south of the equator. Part of this expansion saw the Japanese fleet establish supply bases. They also stationed longliners at these bases, one of which was established in 1953 (Chapman 2002). The Japanese longline fleet continued to expand during the 1950s and 1960s, with albacore tuna being the target species. The catch was landed at the bases and freighted to American Samoa, Hawaii and the US west coast for canning. In 1963, PAFCO (Pacific Fishing Company Limited) was formed and granted a licence under the Protected Industries Ordinance, with a joint venture established between C. Itoh and Company of Japan, Daiwa Corporation of Japan, and the Government of Fiji. A freezing plant and a 2400 t capacity cold store were built in 1964.

Taiwanese and Korean longline vessels entered the Pacific albacore fishery in the mid-1970s, also shipping their catch to canneries. In the late 1970s, Taiwanese and Korean vessel numbers increased as the Japanese fleet switched from longlining for albacore for canning, to longlining for yellowfin and bigeye tuna for the sashimi market in Japan (Chapman 2002). The introduction of super-cold freezers (–60°C) saw Japan close their shore bases (The Fiji base closed in 1977.) and cease using mother ships.

In 1970, a pilot cannery was constructed to process 10 t/day of tuna. At this time, frozen loins were produced for export and canned tuna flakes for the domestic market. A small fish-meal plant was also established to process the offal from the canning process. The pilot cannery proved to be successful and led to the establishment of a larger cannery, 15,000 t/year capacity, with construction starting in 1974. Also at this time, the Government of Fiji discussed and finally established in late 1975 a national fishing company, the Ika Corporation (Chapman 2002, 2004).

The Ika Corporation commenced its fishing operation in 1976 (landing 625 mt that year) by chartering two pole-and-line vessels from the Japanese Hokuku Fishing Company. Ika Corporation continued this charter arrangement, with up to six Japanese vessels fishing in any one season. Catches continued to increase and, in the 1978/79 season, seven vessels landed 3292 mt of tuna (Kearney 1984). The SPC Skipjack Survey and Assessment Programme conducted tagging research in 1978, with 8497 skipjack, 840 yellowfin and one bigeye tagged over 25 fishing days (Kearney 1978). A second tagging cruise was made in 1980, with 11,597 skipjack, 1274 yellowfin and 1 bigeye tagged over 24 fishing days (Kearney 1984).

The late 1970s also saw the number of Taiwanese and Korean longline vessels increase in the waters that are now the Fiji Islands EEZ. In 1978 there were 38 Taiwanese and 4 Korean longliners fishing this area, landing their fish under contract to PAFCO in Levuka. In the 1980s and 1990s, the vessel numbers fluctuated between 10 and 23, with most of the vessels being Taiwanese. These vessels also fished for part of the time in the EEZs of neighbouring countries, such as Vanuatu, Tuvalu and Solomon Islands (Chapman 2002).

To meet the growing demand for its product, PAFCO increased production from 15 to 35 t/day during the period 1980 to 1986. Also during this time (1984) the Sainsbury supermarket chain in the UK started buying PAFCO products. Pole-and-line caught tuna was the main product processed by PAFCO to supply the UK market. By the end of the 1980s, the wharf and freezer complex were getting run down and needed to be upgraded. A proposal was put to the Australian Government to fund this upgrading, including the reclamation of land for other structures. Several studies were undertaken before agreement was reached. The work was undertaken, with land reclaimed, and a new cold-storage facility and a new office building constructed. The work was completed by the end of 1992 (Chapman 2002).

To assist the pole-and-line vessels in locating tuna schools and reducing search time and fuel costs, both the Fiji Fisheries Division and Ika Corporation placed a series of anchored fish aggregating devices (FADs) around the country. The first FADs were deployed in 1981, and both the Fisheries Division and Ika Corporation maintained their respective FAD programmes during the 1980s and 1990s (Smith and Tamate 1999). Unfortunately, Ika Corporation experienced financial difficulty from the start, and this continuous poor financial performance saw Ika Corporation taken over by PAFCO in 1994. Low catches in the following seasons resulted in Ika Corporation ceasing operations in May 1997 (Smith and Tamate 1999). One privately owned pole-and-line vessel continued to fish and sell to PAFCO; however, its operations ceased in early 2001, when the company decided to convert its vessels to enter the tuna longline fishery (Chapman 2002).

Also in 1980–1985, purse-seining trials were undertaken by two New Zealand vessels, under an exploratory feasibility fishing trial. The nets used were small and shallow compared to the nets used in other parts of the region, and the New Zealand crew were inexperienced in purse-seining in Fiji Island conditions. To increase their ability to catch tuna, the vessels focused their fishing on pre-dawn sets on FADs, using light attraction. The New Zealand vessels deployed and maintained a series of FADs in the sheltered waters north of Vanua Levu. From 1981 to 1983, both vessels worked in Fiji Islands, reporting total catches of 772 mt, 911 mt, and 1006 mt. Only one vessel returned to fish in Fiji Island waters in 1984 and 1985, but did not subsequently return (Chapman 2002).

Medium-scale tuna longliners using monofilament longline gear were introduced to the Pacific in the mid-to-late 1980s. The introduction of medium-scale longliners provided a real opportunity for domestic tuna longlining operations to be developed in Pacific Island countries and territories. Fiji Islands was one of the first Pacific Island countries to seize this opportunity. The economic climate was good with the devaluation of the Fiji Island dollar by 35% in 1987, a direct flight from Fiji Islands to Japan established in early 1988 by the national airline, Air Pacific, and the strong government support for businesses, especially export industries, following the 1987 coup. One company in particular, Fiji Fish, geared up a vessel, F/V *Sunbird*, and had it operational in June 1988 (Chapman 2002).

Initial trial shipments of Fiji Fish's fresh fish were successful, so several local companies started to develop joint-venture arrangements with Australian and US partners. The Fiji Islands Government quickly stepped in and introduced a licensing system to prevent over-capitalisation of the fishery. In 1990 there were 30 licensed tuna longliners in Fiji Islands; however, only 8–10 actually fished (Chapman 2002). Domestic and joint-venture longline operations continued to expand during the 1990s, with 37 vessels in 1994, increasing to 55 in 2000. In 2001 this number increased again to 95 vessels, with 21 longline companies and five processing or packhouse facilities (Amoe 2002, Chapman 2002).

The main tuna fishing activity in Fiji Island waters in the 2000s has been tuna longlining. Landings in 2000 and 2001 were 11,441 mt and 12,219 mt respectively, with albacore making up around 60–65% of the catch (Amoe 2002). In 2003 there were 28 longline companies and 101 vessels licensed to fish, with the landed catch being 12,205 mt, again with albacore being the main species taken (Amoe 2004). More stringent controls on the vetting of longline licences resulted in the number of vessels licensed dropping to 66 in 2006, with the catch of these vessels increasing to 20,707 mt (Amoe 2007).

Small-scale tuna fishery including fishing around FADs

FADs were first deployed in the waters around Fiji Islands in the second half of 1981, in order to render free-ranging tuna schools available for purse-seining, and their use was then adopted by the industrial pole-and-line fleet. This then flowed on to the commercial, artisanal and subsistence fisheries in the country. From 1984 to 1993, at least 210 FADs were deployed by the Fisheries Division, the purse-seine companies and Ika Corporation. As poor records were kept, the actual number of FADs deployed may be much higher (Beverly and Chapman 1998, Chapman 2002, Smith and Tamate 1999).

The first fisheries development project to introduce tuna fishing techniques for use around FADs to small-scale fishing operations, and to promote this type of fishing, was implemented in the second half of 1982 over a four-month period (Fisheries Division 1985). The fishing methods trialled included trolling, small-scale pole-and-line fishing using live bait, and poling using pearlshell lures. The first month of the project was spent fitting out and rigging the *alia* catamaran and deploying two FADs, one off Beqa Island and the other off Vatulele island. Trolling was the main method used and was very successful, with a catch of 1566 fish weighing 4025 kg. In all, five fisheries staff and 21 local fishers participated in the project and received training in the different fishing methods used. Several local fishers started trolling for tuna as a result of the project; however, they stopped soon after for no obvious reason (Fisheries Division 1985, Chapman 2002, Preston n.d.).

From 1984 to 1986, the Japan International Cooperation Agency (JICA) ran a series of fishing trials that included pole-and-line fishing, trolling and surface gillnetting for tuna, sometimes in association with FADs (JICA 1985, 1986). The pole-and-line fishing was the most successful method, with 215.8 t caught in Fiji Island waters. Surface trolling was conducted 64 times in Fiji Island waters, on free-swimming schools, over seamounts, and around FADs. A catch of 8.1 t of surface pelagics was taken, with the main species being yellowfin tuna and skipjack. The gillnets were set on 62 occasions and the catch amounted to 294 fish weighing 3673 kg (45% of the catch by weight was sharks). The catch recorded during this survey was not split between FAD and non-FAD-associated catch, so it is not known to what extent FADs assisted in the catch taken (JICA 1986, 1987).

Also during 1984 and early 1985, the SPC was requested to provide technical assistance through some experimental fishing and gear development work on mid-water fishing methods used in association with FADs. The main method trialled was vertical longlining, which resulted in the catching of some large individual yellowfin and bigeye tuna from deep in the water column around the FADs off Suva. However, the main catch was of smaller yellowfin tuna, averaging around 15 kg, and a range of shark species. These initial trials were very encouraging (Mead n.d.).

The Fisheries Division has continued to put out FADs when it has funding, with these assisting both the industrial pole-and-line vessels and small-scale fishers (Evening 1993). In 1992 the Fisheries Division requested assistance and training from SPC with the conducting of site surveys and rigging and deploying two FADs off Suva. This was a refresher training for some Fisheries Division staff, with other new staff also being trained (Beverly and Chapman 1998). Again in 1998, SPC was requested to run a workshop in Suva to further introduce mid-water fishing techniques to local fishers. Unfortunately, the two FADs located off Suva were lost just prior to the commencement of the workshop. Therefore, the practical fishing trials were conducted outside the reef for demonstration purposes only (Chapman 2002).

A development project to promote tuna fishing around FADs was developed and implemented by the Fisheries Division under their Commodity Development Framework (CDF) funding. Since September 1999, 36 local fishers from the area around Suva have been subsidised to purchase a 7.2 m fibreglass skiff with a 40 HP outboard engine and fishing equipment (Chapman 2002). The local fishers fish around the FADs off Suva, landing their catch within six hours of it being caught. The main fishing methods used are trolling, vertical longlining and mid-water handlining. The larger yellowfin and bigeye tuna are sold to the local processing facilities for fresh export. The rest of the catch is sold to other markets or direct to the general public (Chapman 2004). The CDF project continued until the mid-2000s, and catches from small-scale fishing around the FAD peaked in 2003 at 91 mt (11 vessels), then dropped to 28 mt in 2004 and 421 mt in 2005 (Amoe 2007).

Gamefishing

There is little documented information on sportfishing and charter gamefishing activity in Fiji Islands. This activity has mainly occurred as an offshoot of the tourism industry, with many of the 20–30 charter vessels associated with the main tourist hotels or tourist locations in Fiji Islands. Billfish are the main species targeted, although mahi mahi and wahoo are more common in the catch. This sector seems to expand and contract based on the number of tourists and charters they undertake, as Fijians do not tend to charter vessels or be a part of this activity (Whitelaw 2001). There are also several gamefishing clubs, the main ones being the Suva Yacht Club and the Pacific Harbour Gamefishing Club. It is estimated that there are over 50 private sportfishing and gamefishing vessels in Fiji Islands. The clubs are well organised and hold regular competitions or tournaments (Whitelaw 2001).

Flying fish

Though several species of flying fish (all of the family Exocoetidae) (*ikavuka*, *malolo*) are thought to be common in the oceanic waters of Fiji Islands, only *Cypselurus* spp. are recorded by Lewis (1984, 1985b). In August 1991, the Fisheries Division, the SPC Fisheries Development Project, and the FAO/UNDP Regional Fishery Support Programme conducted fishing trials outside the Suva harbour entrance. The initial trials yielded approximately 10 fish per hour. The trial programme was sufficiently successful to warrant interest from a commercial perspective, but did not result in the establishment of a viable fishery (Walton 1991, cited in Gillett and Ianelli 1993).

Deep-water snapper

Deep-water snapper fishing techniques were first introduced to fishers in Fiji Islands in 1979–1980 through the SPC Deep Sea Fisheries Development Project (DSFDP). Six fisheries staff and five local fishers were trained in the techniques over the 14 fishing trips, with the total catch amounting to 2161 kg, or 1489 kg excluding shark (Mead 1980). A second request for assistance with developing the deep-water snapper fishery prompted SPC to assist in 1981 and 1982 (Mead 1997). The second visit was targeted at conducting a resource survey and training local fishers in the Lau Group, with 31 trips undertaken, 60 local fishers trained, and a catch of 2669 kg recorded (Mead 1997).

Fishers were slow to take up the fishing techniques for deep-water snapper, partly due to the fact that the species were unknown on the local markets and the sale price was low as a result (Lewis *et al.* 1988). This changed a little in 1985 when the first shipment of chilled deep-water snapper was sent to Hawaii, with encouraging prices paid (Lewis *et al.* 1998, Mead n.d.). The fishery at this stage used mainly 9 m diesel vessels with the Samoan-type handreels fitted. In 1986, several larger vessels entered the fishery following a JICA-funded survey, which set a 1000-hook bottom longline and averaged 328 kg of fish/set (Lewis 1986b, Lewis *et al.* 1988, Dalzell and Preston 1992). These larger vessels adapted the gear by using shorter lines with fewer hooks and setting the lines several times per day. Catches were up to 600 kg/day and, in 1986, 80 mt of deep-water snapper were exported to Hawaii with another 45 mt sold on the local market (Lewis *et al.* 1988).

In 1986/1987, an interim management plan based on an annual catch of 1000 mt was prepared and accepted (Anon. 1987). The fishery continued to develop in 1988, although some of the larger vessels considered converting to surface longlining for tuna (Anon. 1989). An assessment was made of the available data by Lewis *et al.* (1988) with a MSY estimate of 550–1600 mt/year for the deep-water snapper fishery. Further assessments were made by Nath and Sesewa (1990) based on catch data from four seamounts and three coastal areas. Dalzell and Preston (1992) also analysed the available data and concluded the potential yield range at MSY to be 409–1230 mt/year.

Catches from the deep-water snapper fishery halved in 1989 as larger vessels moved out of the fishery and entered the tuna longline fishery (Anon. 1989, Chapman 2004). During the early 1990s the deep-water snapper fishery continued as an *ad hoc* fishery, with boats sometimes fishing for these species (Chapman 2004).

There was a revival in the deep-water snapper fishery in 1997 when a new company (Trans Pacific Seafoods Limited) was established. This company had three vessels supplying deep-water snappers to them, with 19 mt processed in 1998 and over 22 mt in 1999 (Fisheries Division 2002, Chapman 2004). Several vessels continue to target deep-water snappers for both the domestic and export markets.

Deep-water shrimps

Late in 1978 the Fisheries Division undertook intensive surveys of deep-water shrimps to establish the geographic and depth distribution of stock, and to determine the commercial viability of a deep-water trap fishery. Tests of the efficiency of different deep-water shrimp traps were carried out in 1979, southwest of Suva harbour in depths of 360–540 m. Seven species were identified, six being pandalid shrimps of the genera *Heterocarpus*, striped soldier shrimp (*Plesionika edwardsii)* and pyjama shrimp (*Parapandalus serratifrons)*. The species with the greatest commercial potential were the mino nylon shrimp (*Heterocarpus sibogae),* humpback nylon shrimp (*H. gibbosus)*, and smooth nylon shrimp (*H. laevigatus*) (Brown and King 1979, King 1993).

Aquaculture and mariculture

Although aquaculture in Fiji Islands dates back to 1940, it was not until 1962 that the government introduced the Inland Fisheries Programme, which included fish culture. A concerted effort to develop aquaculture began in the mid 1970s, through government programmes for freshwater prawns, tilapia, carp and shrimps (Nandlal 2003). Aquaculture has had little success, especially when commercial aquaculture projects are aimed at exports in competition with countries such as Thailand, with lower transport and labour costs. However, in 1992, the government believed there was potential for domestic niche markets selling tilapia and tiger prawns (MPI 1992b). In 2000, the value of production from the sector was FJD 2.7 million. Freshwater aquaculture commodities contributed about 40% or just less than one million dollars of the total. Freshwater aquaculture has included tilapia, carp, and freshwater prawns (MFF n.d.). Today, aquaculture production, although still quite small, is gaining momentum. Tilapia farming, which has been carried out for several decades at the subsistence level, is now being attempted on a commercial scale. In addition, the production of penaeid shrimps has expanded recently. Attempts have been made to culture various other species, but these have generally been unsuccessful. These have included bass carp, bivalves (*Anadara*, *Gafrarium* and *Batissa* spp.), cockles, mangrove crabs, mollies (*Poecilia mexicana*), mullets, green mussels, eleven species of oysters, freshwater prawns, rabbitfish, tarpon, two species of donor fish (*Puntius* spp.), and two species of turtles (Gillett 2002, FAO 2008).

Tilapia

The Mozambique tilapia (*Oreochromis mossambicus*); Nile tilapia (*O. niloticus*) ‘Chitrilada strain’; Nile tilapia (*O. niloticus*) ‘Israeli strain’; Nile tilapia (*O. niloticus*); *O. hornorum*; and *O. aureus* are all present. None of these fish are native to Fiji Islands (Richards *et al.* 1994). The *O. mossambicus* tilapia was introduced in 1954, while the Nile tilapia was introduced in 1968. During the 1954 trials, 52 fingerlings were imported from Singapore and placed in a small pond at Sigatoka. Within two months, the tilapia had grown from fingerlings to adults and spawned (Van Pel 1954).

In 1980, the first tilapia fish farm was established at Nukuloa village. Research into red hybrid tilapia was conducted but ended in 1990 due to the poor quality of broodstock for rearing purposes (MPI 1990). One of the problems faced by industry at the time was the lack of tilapia fingerlings (MPI 1993). In 1997, Genetically Improved Farmed Tilapia (GIFT tilapia) were introduced (MFF n.d.). It was estimated that, in 1999, subsistence and semi-commercial farmers produced a total of 297 t. According to the Fisheries Division, in 1999 there were 46 ha of tilapia ponds in 16 commercial and 268 subsistence farms (Gillett 2002, FAO 2008). The women of Driti have been successfully involved in tilapia breeding since 2003. The production of tilapia in December 2003 was 2.6 mt, which sold for FJD 9100 (Nandlal 2005).

Milkfish

Trials have been carried out to culture milkfish (*Chanos chanos*) for use as tuna longline bait. Twenty ponds of five hectares each were constructed in 1998 and 22 additional sites were surveyed for development in 1999 (Gillett 2002, FAO 2008). The operations were found to be not viable.

Carp

A grass carp (*Ctenopharyngodon idella*) farm was established in 1974, with the aim of being self-sufficient in carp fry for stocking village ponds (farming for food) and rivers (for weed control and establishment of a subsistence fishery). Natural disasters have prevented the hatchery from being operational, but the grow-out facility using imported fry is well established (MAF 1981). The carps cultured at Naduruloulou include grass carp (*Ctenopharyngodon idella)*, silver carp (*Hypophthalmichthys molitrix)*, bighead carp (*Aristichthys nobilis)* and silver barb (*Puntius gionotus).* Of the 233,000 fry produced, a total of 93,000 fingerlings were released in rivers and dams on Viti Levu (MAFF 1994).

Pearl oysters

The blacklip pearl oyster (*Pinctada margaritifera*) (*civa*) is present. Based on 1992 survey results and interviews with shell dealers, Murray (1992) concluded that there are now no stocks of goldlip pearl oyster (*Pinctada maxima*) in Fiji Islands. Pearl farming is considered a fledgling industry. A single farm cultures *P. margaritifera* for pearl production in northeastern Viti Levu. An experimental pearl farm was set up at Nasavusavu, with funding and technical assistance provided by the Australian Centre for International Agricultural Research (ACIAR) and the International Centre for Living Aquatic Resources and Management (ICLARM). About 3000 pearl shells are under culture at the facility (Gillett 2002, FAO 2008). While the Department of Fisheries initiated the farming and encouraged the current interest in pearl culture in the country, it has slowly devolved most of the activities, including the hatchery, its farm, and seeding house, to the private sector (SPC 2008).

The Pacific oyster (*Crassostrea*) was officially introduced into Fiji Islands by a Japanese pearl oyster farmer in 1969 (Ritchie 1974). The oyster culture project was initiated in 1969 and grow-out trials were conducted in Lami in 1969–1980. In 1981, grow-out trials were carried out at Laucala Bay and Namarai Bay. Unfortunately, due to poor growth rates, the project was temporarily suspended (MAF 1981).

Giant clams

Four species of giant clams occur naturally in Fiji Islands: the rugose giant clam (*Tridacna maxima*), (*katavatu*, *kativatu*), the fluted giant clam (*T. squamosa*) (*cega*), the smooth giant clam (*T. derasa*) (*vasua dina*, *matau*) and the recently described devil clam (*T. tevoroa*). The giant clam (*T. gigas*) is recently extinct in Fiji Islands, and the horse-hoof clam (*Hippopus hippopus*) was present in pre-historic times (Lewis 1985a). Surveys in 1988 showed that the resource was grossly overfished and, as a result, a ban on the export of *vasua* was imposed to enable stock recovery. The Makogai quarantine/mariculture facility was used to spawn two species of giant clam: *T. derasa* (*vasua dina*) and *T. squamosa* (*cega*) (MPI 1988).

T. gigas was successfully re-introduced to Fiji Islands in 1986, 1987 and 1990 as juvenile clams from James Cook University (JCU), Australia. *H. hippopus* was re-introduced from JCU in 1991. *T. derasa* was first spawned locally in 1988, the juveniles being re-stocked on local reefs. This species was also re-introduced in 1985 from the Micronesian Mariculture Demonstration Centre (MMDC), Palau, but the stock died. *T. tevoroa* was re-stocked from Tonga. By mid-1989, juveniles of locally spawned *T. squamosa* were being produced (Gulick 1990). In 1999 about 270,000 clams of various sizes were being maintained at the Makogai ocean and land nurseries (Gillett 2002). In 1984, exploitation guidelines were produced to assist local fishing rights custodians and for clam stock monitoring by the Fisheries Division. Many of the guidelines were superseded in December 1988 when Cabinet passed a new regulation banning the export of giant clam meat (Richards *et al*. 1994). In 1995, 60,000 juvenile clams (shells >3 cm) were maintained in ocean nurseries for growing to 10 cm before reseeding to reef areas in 1996 (MAFF 1995).

Freshwater prawns

The freshwater prawn species which have been used for aquaculture are the giant freshwater prawn (*Macrobrachium rosenbergii*) and the freshwater prawn (*M. lar*) (*uradina*) (Gulick 1990). The prawn grow-out project was established in June 1981 to investigate the growth rate and economics of culturing *M. rosenbergii* from post larvae to a marketable size prawn (MAF 1981). Eight thousands *M. rosenbergii* post larvae were produced in 1990 and 6000 were exported to Samoa, with the rest used for polyculture and feed trials (MPI 1990). In 1993, due to Cyclone Kina, the prawn broodstock was washed away; therefore, no feed trials were carried out.

Marine prawns

The penaeid prawns include the giant tiger prawn (*Penaeus monodon*) (*urakeirasaqa*), kuruma prawn (*P. japonicus*), Indian white prawn (*P. indicus*), banana prawn (*P. merguiensis*) and blue prawn (*P. stylirostris*) (Gulick 1990). The penaeid prawn industry is relatively small compared to that of the freshwater prawn (SPC 2008). Two local companies produced about 150 to 200 t of penaeid shrimp annually in the late 1990s (Gillett 2002, FAO 2008). Hatchery trials producing *P. monodon* have been less successful than those producing *P. stylirostris* and *P. japonicus* (SPC 2008). Prawn production was 3 mt in 1997, increased to 5.3 mt in 2000, and then declined to 1.7 mt in 2004 (MFF n.d.).

Seaweeds

Seaweeds are a part of the Pacific diet. Species commonly used in Fiji Islands include sea grapes (*Caulerpa racemosa*), *lumi wawa* (*Gracilaria maramae*) and *lumi cevata* (*Hypnea pannosa*). These have been identified to have potential as gelling phycolloid, agar or carrageenan. Three species in Fiji Islands, *G. maramae*, *G. edulis*, and *G. arcuata*, have aquaculture potential for agar production. Cultivation techniques are simple but market and price have yet to be established. Other seaweeds, such as *G. racemosa* and *Meristotheca procumbens* (a red alga), have markets in Japan but are highly perishable and difficult to cultivate (SPC 2008).

Commercial species of red seaweed (*Eucheuma* spp.) introduced to Fiji Islands from the Philippines via Tonga for aquaculture trials included *Eucheuma striatum*, *E. alvarezii*, *E. denticulatum* and *E. spinosum* (Gulick 1990). The species used for commercial production since 1985 is a 'cottonii'-type seaweed (*Kappaphyces alvarezii* var *tambalang*) (Richards *et al.* 1994). Farming of *Eucheuma* seaweed took place during the late 1980s but ceased in the early 1990s, mainly as a result of changed market conditions. It was revitalised in the late 1990s under a promotional scheme known as the Commodity Development Fund. In 1999, 632 farms produced seaweed for export (Gillett 2002, FAO 2008http://www.fao.org/countryprofiles).

Reef and reef fisheries (finfish and invertebrates)

Coral reef habitat

Fiji Islands has some of the largest and best developed coral reef systems in the southwest Pacific region. All reef types are represented: fringing reefs, barrier reefs, platform reefs, oceanic ribbon reefs, drowned reefs, atolls and near atolls. Damage to reefs has been caused by pollution, elevated nutrients and outbreaks of crown-of-thorns starfish. Most reefs in Fiji Islands are moderately to heavily fished. Reefs closest to villages and urban areas are subject to heavy fishing pressure because of commercial fishing. Stocks of reef fish and invertebrates such as giant clams, trochus and bêche-de-mer have been reduced. There is generally no systematic reef monitoring to detect early signs of overfishing despite a moderate research effort at the University of the South Pacific (Vuki *et al.* n.d.).

Finfish

Estuary, lagoon and reef fish are important to the subsistence and artisanal fisheries sectors. The predominant families in terms of the artisanal catch are Scombridae, Lethrinidae, Carangidae, Mugilidae, Serranidae and Sphyraenidae (Richards *et al*. 1994). MPI (1992a) lists approximately 99 species from 39 families in the category of 'food fishes'. There are approximately 2000 registered artisanal fishing vessels used full- or part-time in reef and lagoon fisheries (Cavuilati 1993). Women play an important role in nearshore fishing and are probably responsible for a greater proportion of the catch than men (Zann 1981).

Fish from Fiji Island waters reported to be ciguatoxic include: red snapper (*Lutjanus bohar*) (*bati damu*), moray eel (probably *Gymnothorax* sp.) (*boila*), moray eel (*Gymnothorax* sp.) (*dabea*), sardine (*Clupea venenosa*) (*daniva*), mangrove jack (*Lutjanus argentimaculatus*) (*damu*), unidentified long-nosed emperor (*delabulewa*), (*Lethrinus microdon* = *elongatus*) (*dokonivudi*), coral trout (*Plectropomus* spp.) (*donu*), unidentified (*dravu* or *drevu*), black-spot sea perch (*Lutjanus monostigma*) (*kake*, *kwake*), sea bass (*Epinephelus fuscoguttatus*) (kawakawa), barracuda (*Sphyraena barracuda*) (*ogo*), Maori snapper (*Lutjanus rivulatus*) (*regua*), trevally (*Caranx* spp.) (*saqa*) and Spanish mackerel (*Scomberomorus commerson*) (*walu*) (Banner and Helfrich 1964, Singh 1992).

There are probably more than 700 species of fish inhabiting Fiji Islands' extensive coral reefs, many of which are either too small or uncommon to be used as food. However, a very diverse array of fish species is captured for subsistence or commercial purposes, including herbivorous (algae- or coral-eating) families such as parrotfish (Scaridae) (*ulavi*), rabbitfish (Siganidae) (*nuqa*) and surgeonfish (Acanthuridae) (*balagi*); carnivorous families such as groupers (Serranidae) (*kawakawa*, *donu*), snappers (Lutjanidae) (*kake*, *damu*), and moray eels (Muraenidae) (*dabea*); and omnivorous families such as emperors (Lethrinidae) (*sabutu*, *kawago*). The increase in the commercial catch, combined with an unquantified increase in subsistence catch, and the sustained local depletions of species groups such as mullet (*kanace*), rabbitfish (*nuqa*), coral trout (*donu*), and individual species such as the double-headed parrotfish (*Bolbometopon muricatum*) (*kalia*) have prompted some resource owners to limit fishing practices.

There is a general impression that the inshore finfish resources have been over-exploited, due to the increasing population. Concerns about localised overfishing have prompted several customary fishing rights areas (*qoliqoli*) to restrict the use of gillnets or limit the number of commercial fishers (MPI 1991, 1992a, Langi *et al.* 2002). The other measures are a ban on the use of SCUBA diving equipment for spearing fish and a ban on Sunday fishing being a condition of granting a fishing permit (Fong 1994). In November 1991, the section of the Fisheries Act concerning dynamite fishing was amended. Fishers now convicted of catching fish using explosives will face fines of up to FJD 5000 (for a third offence) and mandatory jail terms for all convictions (Richards *et al.* 1994). Richards *et al.* (1994) also note that the legislation controlling the exploitation of reef fish in 1994 included restrictions or bans on gillnets, restricted catch sizes for certain fish species, a ban on SCUBA fishing, and a ban on the use of poisons such as plants to harvest fish.

Sharks

Sharks are not eaten in many areas of Fiji Islands because of traditional *tabu*. The exceptions to this are the Rotuma and Rabi communities, where sharks are readily accepted. A small quantity of longline-caught shark, mainly mako shark, is exported to Japan (Lewis 1985a). The fins of some species are used to produce a high-priced soup base in SE Asian countries, and there is an international trade in dried and frozen shark fins (Richards *et al.* 1994). Interest has grown worldwide in the liver of deep-water sharks as a source of squalene, a fine oil used for medicinal and cosmetic purposes. Between 1985 and 1987, experimental fishing for squalene-rich deep-water sharks was conducted in Fiji Island waters, under the direction of Fiji Fisheries Division. The trials were suspended, principally because of a decline in the squalene price during 1987 (Richards *et al.* 1994 cites T. Adams pers. comm.).

Live reef fish fishery

Fiji Islands is one of the countries in the Pacific that has recently become involved in the live reef food fish trade. This fluctuating trade was introduced by the government in the late 1990s. Approximately 338 mt of coral trout, rock cod and wrasse, valued at FJD 1.35 million on the local markets, were caught from the Bua and Macuata coastal zone annually. These fish were sold to the Labasa and Suva markets. Exporting the same amount of live fish to Asian markets would realise an annual export earning of well over FJD 16.9 million. The Fisheries Department is aware of the fluctuations in the trade but recognises the benefits it has brought to local communities in the short time it has been in operation. The Department is hopeful that, with good facilitation and monitoring, this trade may be one of the best alternative sources of income for coastal communities (Ovasisi 2006). One operator targeting coral trout exported 2 mt in 2005 by air to a US market, while in 2006 there were fortnightly shipments of up to 200 kg. A management plan and monitoring programme is being implemented, including a species quota, an allocated fishing area, and a restriction to allow air freighting only (SPC 2008b).

Aquarium fishery (ornamental fishery)

The collection and marketing of aquarium fish commenced in Fiji Islands in 1976, with a single company involved in the fishery. In 1976, the company caught 33,500 fish; however, the fishery declined and the company ceased operation in 1982 (Lewis 1988). The fishery was re-established in 1984 and from 1985 to 1987 the number of fish increased from 59,404 to 83,109 pieces (Lewis 1988).

There are currently five ornamental fish operators in the country; some of them solely catch and export ornamental fish, while others also farm giant clams, corals and rocks. All the fish are exported to the US and Europe and most of them are held in land-based facilities before export. In 2004 there were around 200,000 aquarium fish exported, with a value of USD 600,000 (SPC 2008b).

There is also a freshwater ornamental industry in Fiji Islands mostly growing goldfish and *koi* carp. The techniques were developed at Naduruloulou research station and extended to private farmers, and the market is mostly local. In 1993–1994, MAFF considered ways to centralise the importations to control the possible introduction of diseases. Only three importers were allowed to bring in their stocks for breeding and distribution in the country. The companies are no longer as active as they were in the beginning. The Ministry introduced stock from Malaysia in 2002 for breeding and to supply to the public. Ornamental fishes have a good market and the government hopes that a private entrepreneur will continue with the business (SPC 2008).

Coral and live rock fishery

Coral harvest for export began in Fiji Islands in 1985 (Viala 1992) and the trade has been an issue that continues to be discussed given the involvement of villagers and the social and environmental impacts the trade can incur (Vunisea 2003). In 2001, over 800,000 kg of live rock was harvested and exported. As a result, the government called for an environmental assessment. The World Wide Fund for Nature (WWF) and the Marine Aquarium Council (MAC) embarked on a project to develop community-based processes for wise coral harvesting and management, and to help the government develop sound policies and legislation to support a sustainable aquarium trade (Owen 2003). In 2004, ~1500 mt of live rock was harvested (SPC 2008b).

Invertebrates

Bêche de mer (sea cucumbers)

There are about 10 species of commercial sea cucumbers, including: white teatfish (*sucuwalu*), black teatfish (*loaloa*), sandfish (*dairo*), blackfish (*driloli*), surf redfish (*tarasea*), stonefish, greenfish, curryfish, lollyfish (*loliloli*), and brown sandfish (*vula*). Some are consumed by local people while the majority are exported to China to be used as food flavouring and medicine. The bêche-de-mer is dried and processed locally and exported to China by 13 licensed companies. Exports peaked in 1988 with 700 mt and declined to 365 mt in 1989. There is a regulation that restricts the export of bêche-de-mer (in natural or processed form) that is less than 7.6 cm in length (Gillett 2002, FAO 2008). The decline in high-value stocks is due to overharvesting (Anon. 1990). In 1999 a bêche-de-mer hatchery was set up for studying the techniques of breeding and re-seeding reefs with juveniles.

Trochus

The commercial topshell (*Trochus niloticus*) (*sici*, *leru*) and the closely related, white-based topshell (*Tectus pyramis*) (*tovu*) is common in Fiji Islands (Lewis 1985a). In the 1970s, exploitation of the trochus resource was entirely carried out by village communities. The animals were collected from reef flats by women at low tide and by men from deeper places. In the 1980s several commercial companies were established, with some employing divers using SCUBA gear to collect trochus. By the 1990s the trochus resource was over-exploited and this affected all sections of the fishery. Two button factories in Fiji Islands closed and the remaining two are on the verge of closing down. Fiji Fisheries has not carried out any assessment of the trochus resource mainly due to lack of expertise in stock assessment methodology. However, an examination of export and local market figures suggests that the trochus resource has been depleted or over-fished throughout the country. Fisheries regulations prescribe a 89 mm minimum harvest size. Exports are required to be licensed and are subject to inspection (Ledua *et al.* 1997).

Green mussels

The green mussel (*Perna viridis*) was first introduced from the Philippines in 1975 and on several subsequent occasions, but has not become established. The most recent importation was from Tahiti, where there is a green mussel hatchery (Hickman 1987). Grow-out trials of green mussels were carried out at Laucala Bay and Namarai Bay. Due to slow growth rates, the project was suspended (MAF 1981).

Freshwater clams

The freshwater clam (*Batissa violacea*) (*kai waidranu*) is the major freshwater species of commercial importance. It has been estimated that market sales of this species are around 1000 t/year (Gillett 2002). The clam provides a source of protein on a subsistence basis but is also a substantial commercial fishery operated mainly by Fiji Island women. A female fisher can earn up to FJD 30 /day from collecting *kai* (Bibi 1991). A 1996 socioeconomic survey carried out on the Ba river *kai* fishery showed that 51–69% of fishers in three neighbouring villages earned an income directly or indirectly from the sale of *kai* (Tuara and Prasad 1996). The value of the fishery in 1996 was estimated to be FJD 1 million (Ledua *et al.* 1996). A June 1996 stock assessment showed that the *kai* stock in the Ba river was still in good shape and the current level of fishing sustainable (Ledua *et al.* 1996).

Arc shells (*Anadara* spp.)

The arc shell (*Anadara* spp.) fishery continues to be an essential fishery in many coastal villages, particularly Ucunivanua in Verata. Although this is primarily a subsistence fishery involving mainly women and children, it has consistently provided for the basic necessities of village households throughout the year. Since 1995, the *Anadara* fishery has been the focus of management efforts by the Ucunivanua people. The communities established *tabu* areas for *Anadara* and other species. In addition, the use of size and catch limits for vulnerable resources and raising public awareness are additional measures that ensure the long-term sustainability of the *Anadara* fishery and other coastal resources (Tawake *et al.* 2007).

Mangrove crabs

The green mangrove or mud crab (*Scylla serrata*) (*qari*) is listed by Lewis (1986a) as present in Fiji Islands. Most fishing for *qari* is done by women, who bundle and bind together 6–8 live crabs for the market or for direct sales to shops, hotels and restaurants. Small quantities (40–400 kg per year) are also exported. Regulation 19 of the Fisheries Regulations provides that: "No person shall kill, take, sell or offer or expose for sale any crab of the species *Scylla serrata* (Swimming Crab or Qari Dina) of less than 125 mm [5 inches] measured across the widest part of the carapace or shell" (Richards *et al.* 1994, MPI n.d.).

Lobsters

The most abundant species of rock lobster in Fiji Islands is the golden rock lobster (*Panulirus penicillatus*) (*uraukula*, *urauvatuvatu*). Smaller quantities occur of the painted rock lobster (*P. versicolor*) (*uraudina*), the whiskered lobster (*P. longipes femoristriga*) and the ornate rock lobster (*P. ornatus*) (*urautamata*, *uraubola*). The slipper lobster (*Parribacus caledonicus*) (*vavaba*, *ivinibila*) is also found (Lewis 1985a). Richards *et al.* (1994) state that there were no restrictions prescribed under the Fisheries Act and Regulations. At that time, the harvesting of lobsters was discussed at length under the Cabinet Guidelines approved in 1984 and still in force.

Sea turtles

Two species of sea turtle are present: the hawksbill turtle (*Eretmochelys imbricata*) (*taku*) and the green turtle (*Chelonia mydas*) (*vonu*). The leatherback turtle is occasionally sighted in offshore waters, and the loggerhead turtle (*Caretta caretta*) (*tuvonu*) is sometimes captured (Lewis 1985a). In 1994, 575 turtles were released during the year, of which 75 were tagged using the South Pacific Regional Environment Programme (SPREP) and University of Hawaii tags. A nesting survey was carried out in the Lomaiviti Group from December 1993 to March 1994 (MAFF 1994). In 1995, 29 juvenile hawksbill turtles (*Eretmochelys imbricata*) were tagged and released from Makogai islands. 200 juvenile *E. imbricata* (*taku*) were raised in captivity for tagging (MAFF 1995). Fisheries Regulation 9 places restrictions on the harpooning of turtles. Fisheries Regulation 20 bans any person from collecting or destroying turtle eggs; and bans the killing or sale of turtle for a shell that is less than 45 cm in length. The Regulation restricts the capture of turtles during the months of January, February, November and December (MPI n.d.). A 1995 ban on turtle capture and consumption raised a lot of concerns amongst native Fiji Islanders. Because the turtle is regarded as a chiefly food and part of traditional chiefly functions, Fisheries staff found it impossible to police and enforce the turtle ban. There is a clause in the exploitation guideline which permits the Minister for Agriculture and Fisheries to exempt the molesting and killing of turtles for traditional purposes. The native Fiji Islanders are taking advantage of this exemption and, by June 1995, approximately a number of 23 turtles had been approved by the Minister to be used for traditional purposes (Ledua 1995).

1.3.3 Fisheries research activities

The Fisheries Division plays an active role in research in support of resource assessment, development, management, and aquaculture promotion. The Division has a research section within the Lami headquarters, as well as freshwater aquaculture research stations at Naduruloulou and Dreketi, and a mariculture research station on Makogai island. Previous research activities carried out by the Division include: aquaculture research (bêche-de-mer, tilapia, pearl oysters, carp and milkfish); monitoring of sales of fish, invertebrates and aquatic plants through Fiji Island' main markets; a study of the nature and extent of the subsistence fishery; assessment of baitfish stocks and of the impacts of baitfish harvesting on juveniles of other commercially important species; experimental culture and re-seeding of giant clams (*Tridacna* spp.); and stock assessment of freshwater prawns (*Macrobrachium* spp.), fresh water mussels (*Batissa violacea*) and mud crabs (*Scylla serrata* and allied species) (Gillett 2002, FAO 2008).

The University of the South Pacific (USP) also regularly undertakes marine research activities in Fiji Islands, often focusing on commercially important species. The University has undertaken biological studies on sea cucumbers, deep-water shrimps and marine algae, as well as carrying out social, economic and post-harvest research relevant to fisheries (Gillett 2002, Anon. 1982, Anon. 1986). Many research projects have been carried out in collaboration with regional and international agencies and non-government organisations.

Gender research and women in fisheries support

As in other Pacific Islands, women dominate the subsistence fishing sector (Vunisea 1997). A study conducted on subsistence fisheries showed that over 50% of the rural subsistence catch on the largest islands of Viti Levu was by women, in a fishery where the subsistence sector far outweighed the commercial sector (Rawlinson *et al.* 1994). Several studies show the important role women play, not only in fisheries participation, but also in the provision of food security and contribution to economic livelihoods (Vunisea 1994, 1996, 1997, 2004; Ram-Bidesi 1995, 1997). Both men and women are actively involved in fishing and fish marketing but women dominate the fishing and marketing of crustaceans and molluscs.

The extent of women's involvement in the commercial sector, however, is not known, although a survey carried out by the Fisheries Division in 1978–79 indicated that the subsistence fishery is mainly carried out by women in inshore waters. To determine the involvement of women in commercial fisheries, the Fisheries Division, along with the USP Centre for Applied Studies in Development, participated in an ESCAP-organised project Improving the Socio-Economic Condition of Women in Fisheries (Narsey Lal 1982). Gender research of the tuna industry has been carried out in Fiji Islands. Arama and Associates (2000) examined the gender division of labour in the industry with a view to understanding the issues of access and control over resources and benefits to society. These studies have all contributed to highlighting the participation of women in the fisheries sector. In acknowledgment of this, the Women and Fisheries Network was established in Fiji Islands in the 1990s to support women's development in the fisheries sector in Pacific Islands. The network is intended to link researchers and activists interested in fisheries development issues among women and women's groups who are engaged in fisheries activities in the region.

1.3.4 Fisheries management

The management of living marine resources in Fiji Islands is the responsibility of the Fisheries Division of the Ministry of Fisheries and Forests. The broad objectives for the development of Fiji Islands' fisheries sector are to: further develop fisheries of the EEZ and territorial waters; improve the quality of and increase the value added to exports; and regulate and control all fisheries on the principles of optimum utilisation and long-term sustainability (Ledua 1995). Fisheries regulations cover licences/registration, prohibited fishing methods, mesh limitations, size limits, and exemptions. The Marine Spaces Act (Cap. 158A) establishes the archipelagic waters of Fiji Islands and a twelve-nautical-mile territorial sea. The Act also establishes a 200-nautical-mile exclusive economic zone, over which Fiji Islands has sovereign rights for the purposes of exploring, exploiting, conserving, and managing the natural resources of the seabed, subsoil and superjacent waters (Gillett 2002, FAO 2008).

The colonial administrators who wrote the Fisheries Act in 1941 were careful to recognise the customary right to fish in traditional fishing grounds. Although the ownership of the seabed belongs to the government, all Fiji Islanders have the right to fish in their own fishing rights area to catch fish for their own consumption. In addition, the Act allows the owners of customary fishing rights to advise the District Commissioner and the Fisheries Division as to which commercial fishers shall be allowed to fish in their area, and also to impose restrictions on commercial fishers.

All reefs and lagoons are subject to Fiji Island customary fishing rights. There are 411 customary fishing rights areas (*qoliqoli*) covering all internal waters of Fiji Islands and each is under a separate jurisdiction. In these areas, the local chief has jurisdiction over commercial fishing licences, can ban certain types of fishing gear, and protects the fishery for its own people. Virtually all the resources (including lobsters, giant clams, crabs, reef fish, bêche-de-mer, and other shell fish) fall under this jurisdiction (MPI 1992b).

The management of Fiji Islands' nearshore fisheries, both artisanal and subsistence, will need to be geared toward co-management between traditional owners and the Fisheries Division. Fisheries awareness programmes could be used to emphasise the positive aspects of community-based management, which draws on scientific information about the various resources provided by government officers working closely with resource owners (Ledua 1995). For additional reading on Fiji Island customary marine tenure see Adams (1993), Cooke and Moce (1995), and Bogiva (2003). Reports on co-management by MRAG (1999) and community-based management by Fa'asili *et al.* (2002) and Langi *et al.* (2002) look at merging the work of all community stakeholders in managing Fiji Islands' fisheries resources.

1.4 Selection of sites in Fiji Islands

Six PROCFish/C sites were originally selected in Fiji Islands following consultations with the Ministry of Fisheries and Forests (MFF): Muaivuso and Dromuna on Viti Levu, Lakeba and Mali on Vanua Levu, and Nukunuku and Nasaqalau on Lakeba Island in the Lau Group (Figure 1.5). These sites were selected as they shared most of the required characteristics for our study: they had active reef fisheries, were representative of the country, were relatively closed systems,[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 the MFF. Four of these sites were re-surveyed in 2008 (socioeconomics) and 2009 (invertebrates), with the surveys conducted in Muaivuso and Dromuna on Viti Levu, and Lakeba and Mali on Vanua Levu. This gave a unique opportunity to compare results six-years after the initial surveys.

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

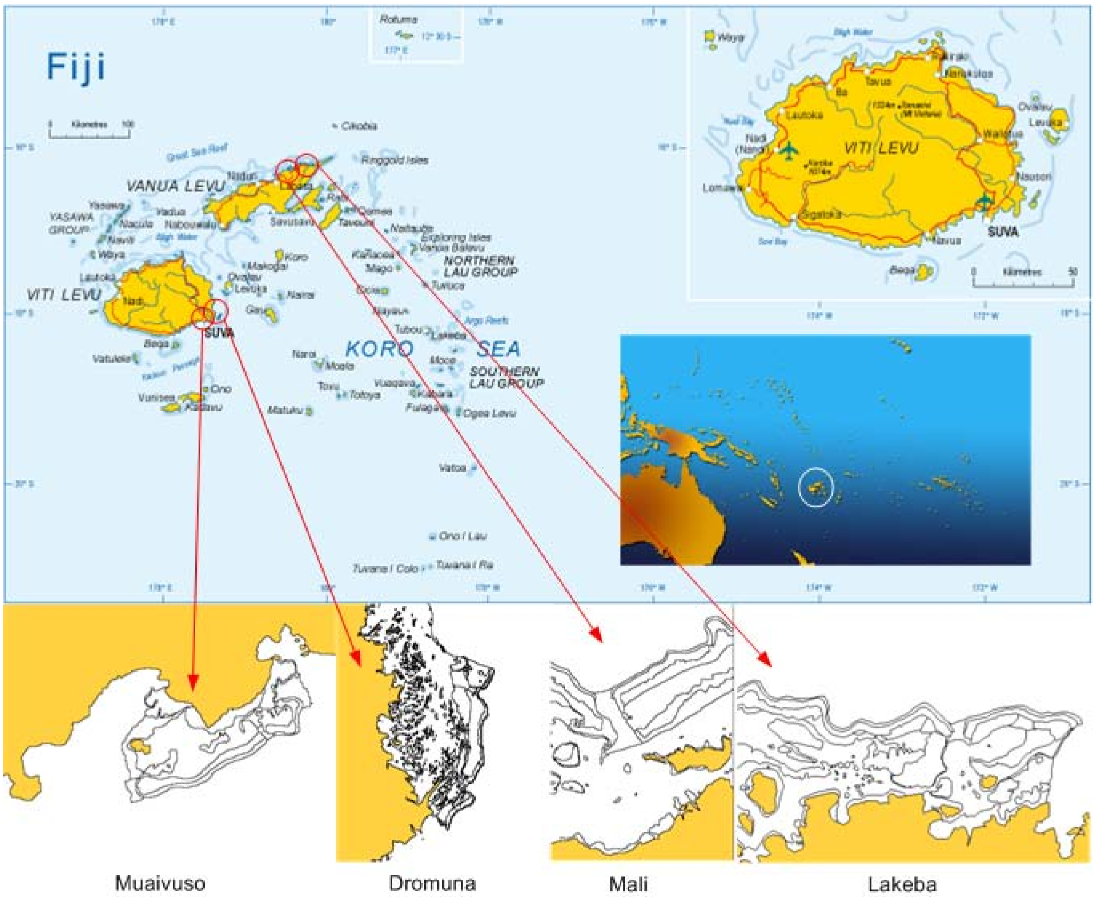

Figure 1.5: Map of the four sites selected in Fiji Islands.

2. PROFILE AND RESULTS FOR DROMUNA

2.1 Site characteristics

Dromuna is a small, traditional community located on a small island off the mainland of Viti Levu, distant one hour by boat followed by a 30–60 minute road trip from Fiji Islands' main market centres, Nausori and Suva. Dromuna is the second of the two villages of Kaba Point. Both communities share the same *qoliqoli* (traditional fishing ground) with Bau, Viwa and Kiuva on the mainland (Figure 2.1). The lagoon reef of Kaba is extensive, with potential to support a good invertebrate resource. Water flow is dynamic across the barrier reef through passes to the east, southeast and south of Dromuna.

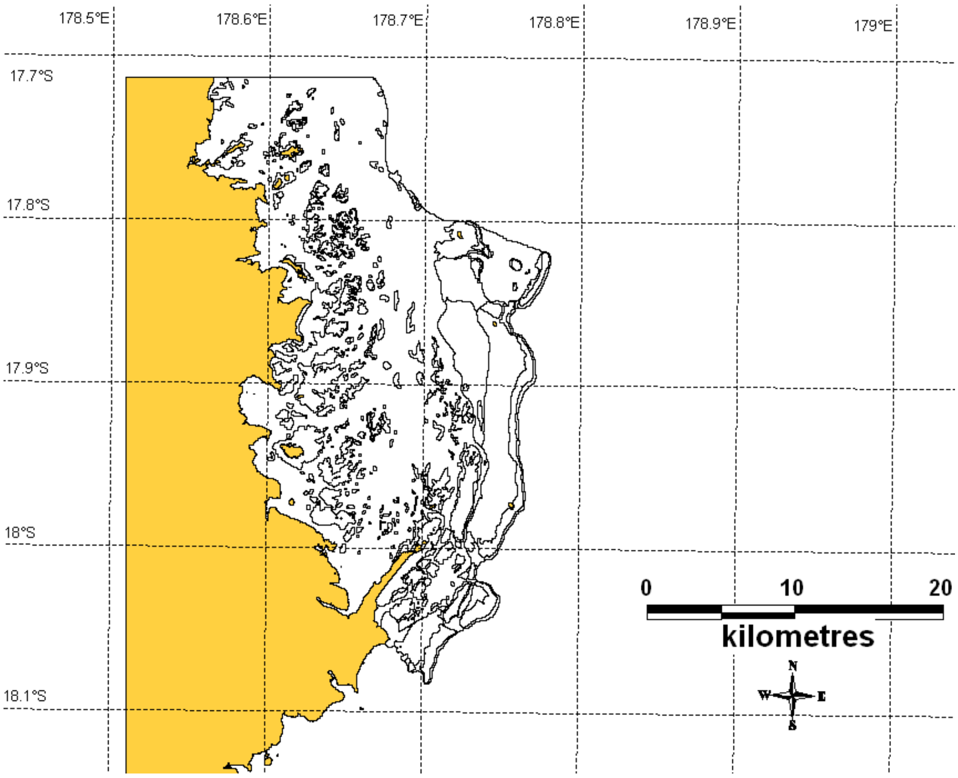

Figure 2.1: Map of Dromuna.

2.2 Socioeconomic surveys: Dromuna

Socioeconomic fieldwork was carried out in Dromuna, Viti Levu, from 23 to 27 June 2007. Dromuna is a coastal fishing village where people have limited access to employment. People are connected by a one-hour boat trip to the mainland, and another 30–60 minutes road travel is required to reach the main markets at Nausori or the capital Suva. Fishers from the community sell their finfish catch to middlemen and shopkeepers upon arrival by boat at the mainland, to restaurants and resorts either reached by boat or boat and road transport, and at the two major markets, Nausori and Suva. Invertebrates are caught and sold upon request to resorts, restaurants or other buyers on the mainland, or sold at the two major markets. The more lucrative species, such as lobsters and bêche-de-mer, are mainly caught in response to requests from buyers (tourist resorts, restaurants, private clients) or, as in the case of bêche-de-mer, to Suva-based exporters.

The Dromuna community has a resident population of 115 people and 25 households. A total of 15 households, which is 60% of the total number of households in the Dromuna community, were surveyed, with all (100%) of these households being engaged in some form of fishing activities. In addition, a total of 24 finfish fishers (20 males and 4 females) and 15 invertebrate fishers (6 males and 9 females) were interviewed. The average household size is small with four people on average, suggesting that the village is subject to major urban migration.

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 consumed was also conducted.

People from Dromuna have access to various habitats; these include large mangrove areas and associated soft benthos, intertidal flats, a lagoon area associated with coastal reefs, outer reefs, channels and passages. Dromuna is located in a densely populated rural area and in comparative close proximity to the country’s capital Suva, and hence its fishing grounds are fished by external fishers.

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

Our results (Figure 2.2) suggest that fisheries play the major role for income generation. Agriculture (crop production) and salaries only supply ~7% of all households with first income. Agriculture, however, is the most important secondary income source (33%), followed by ‘other’ sources. The latter mainly include handicrafts and mat weaving (the second income source for 20% of all households). Salaries as complementary income are of no great importance (~7%). Pigs are not that popularly reared, with 40% of all households having on average two pigs, while chickens are usually not accounted for but run freely around the village. Distribution of fish and seafood produce on a non-monetary basis is of no great importance as almost every household has a member who goes out fishing regularly. However, the ‘share-and-care’ system is an integral component of the Fiji Island culture.

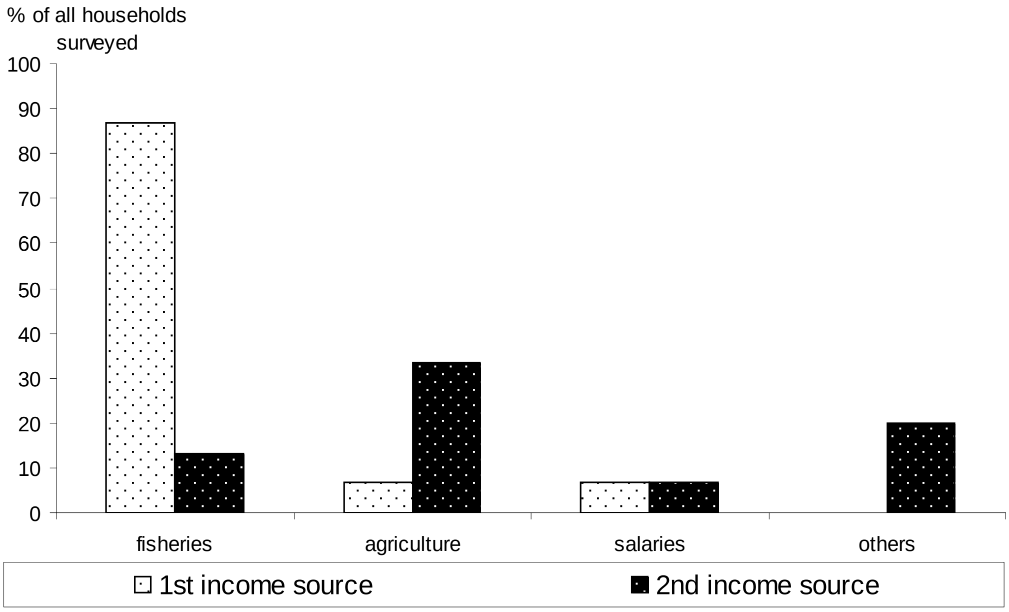

Figure 2.2: Ranked sources of income (%) in Dromuna.
Total number of households = 15 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small businesses.

Our results (Table 2.1) show that annual household expenditures are low, with an average of USD 1291. People are self-sufficient regarding agricultural and marine produce, and they have limited purchasing power due to the limited cash-generating opportunities in the village and its surroundings.

Only a little more than one-quarter (26%) of all households benefit from remittances. The average remittances received are low, on average USD ~360 /household/year, or about 24% of the average annual household expenditure.

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

Survey coverage	Site (n = 15 HH)	Average across sites (n = 66 HH)
Demography		
HH involved in reef fisheries (%)	100.0	98.5
Number of fishers per HH	2.67 (±0.21)	2.47 (±0.11)
Male finfish fishers per HH (%)	25.0	12.9
Female finfish fishers per HH (%)	0.0	0.6
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	20.0	9.8
Male finfish and invertebrate fishers per HH (%)	35.0	41.7
Female finfish and invertebrate fishers per HH (%)	20.0	35.0
Income		
HH with fisheries as 1st income (%)	86.7	69.7
HH with fisheries as 2nd income (%)	13.3	24.2
HH with agriculture as 1st income (%)	6.7	4.5
HH with agriculture as 2nd income (%)	33.3	15.2
HH with salary as 1st income (%)	6.7	13.6
HH with salary as 2nd income (%)	6.7	3.0
HH with other source as 1st income (%)	0.0	12.1
HH with other source as 2nd income (%)	20.0	19.7
Expenditure (USD/year/HH)	1290.63 (±180.65)	1163.72 (±64.04)
Remittance (USD/year/HH) (1)	307.74 (±100.90)	737.10 (±219.95)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	74.13 (±6.33)	74.00 (±2.96)
Frequency fresh fish consumed (times/week)	2.93 (±0.08)	3.20 (±0.07)
Quantity fresh invertebrate consumed (kg/capita/year)	4.40 (±0.74)	9.68 (±2.96)
Frequency fresh invertebrate consumed (times/week)	1.57 (±0.18)	2.11 (±0.13)
Quantity canned fish consumed (kg/capita/year)	2.92 (±0.83)	2.37 (±0.33)
Frequency canned fish consumed (times/week)	0.46 (±0.10)	0.47 (±0.05)
HH eat fresh fish (%)	100.0	98.8
HH eat invertebrates (%)	100.0	98.8
HH eat canned fish (%)	80.0	98.8
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	6.7	6.7
HH eat fresh fish they are given (%)	6.7	6.7
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 (%)	6.7	6.7

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 Dromuna amounts to 67 (40 males and 27 females). Among these are 17 exclusive finfish fishers (males only), 13 exclusive invertebrate fishers (females only), and 36 fishers who fish for both finfish and invertebrates (23 males, 13 females). About 47% of all households own a boat, and all boats are fitted with an outboard engine.

The consumption of fresh fish is high at almost 74 kg/person/year, and average across all the four study sites in Fiji Islands, but about double the regional average of ~35 kg/person/year (Figure 2.3). By comparison, the consumption of invertebrates (edible meat weight only) (Figure 2.4) is low, at ~4.4 kg/person/year. Canned fish (Table 2.1) is not commonly eaten and adds only ~3 kg/person/year to the protein supply from seafood. The consumption pattern of seafood found in Dromuna highlights the fact that people also have access to agricultural produce but limited access to commercially available food items.

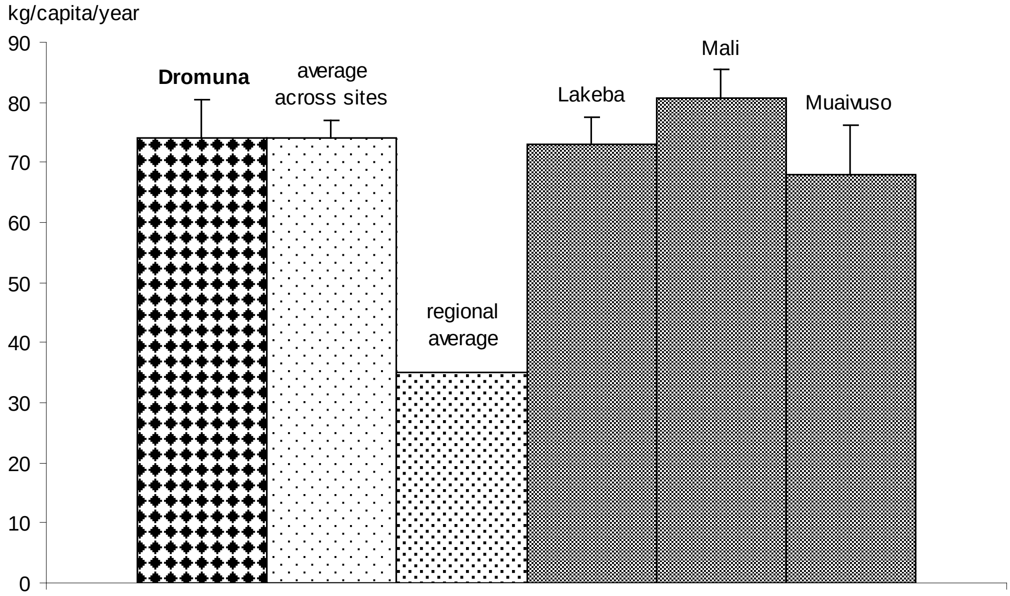

Figure 2.3: Per capita consumption (kg/year) of fresh fish in Dromuna (n = 15) compared to the regional average (FAO 2008) and the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

Comparing results obtained for Dromuna to the average figures across all four study sites surveyed in Fiji Islands, people of the Dromuna community eat fresh and canned fish as often and invertebrates slightly less often than found on average. The per capita consumption of fresh and canned fish is average, while invertebrates are consumed much less than observed elsewhere. Dromuna people conform to the average across all study sites in terms of the proportion of fish and invertebrates caught that they consume, the proportion that they buy and the proportion they are given on a non-monetary basis. It is worth noting that finfish and invertebrates are hardly ever bought. Fisheries play an exceptionally important role for providing income, complemented by agricultural crop production and handicrafts. Salaries and handicrafts are less important for generating income than the average across all PROCFish sites in Fiji Islands. The household expenditure level in Dromuna is slightly above the average. The percentage of households receiving remittances is about average, but the annual average amount of remittances received is low. By comparison, boat ownership is slightly less than elsewhere: however, all the boats reported in all four study sites are motorised.

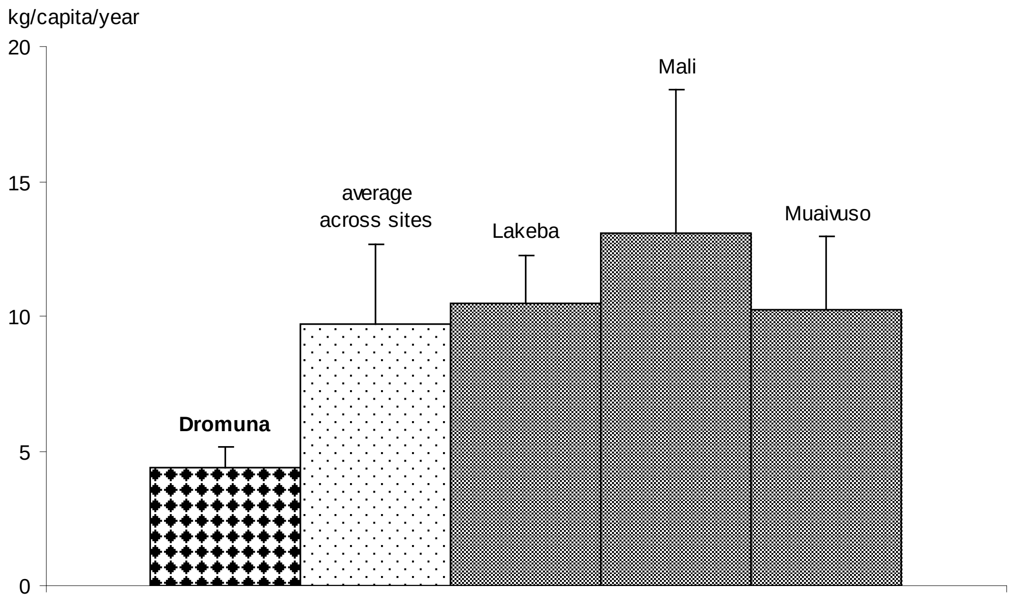

Figure 2.4: Per capita consumption (kg/year) of invertebrates (meat only) in Dromuna (n = 15) compared to the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

2.2.2 Fishing strategies and gear: Dromuna

Degree of specialisation in fishing

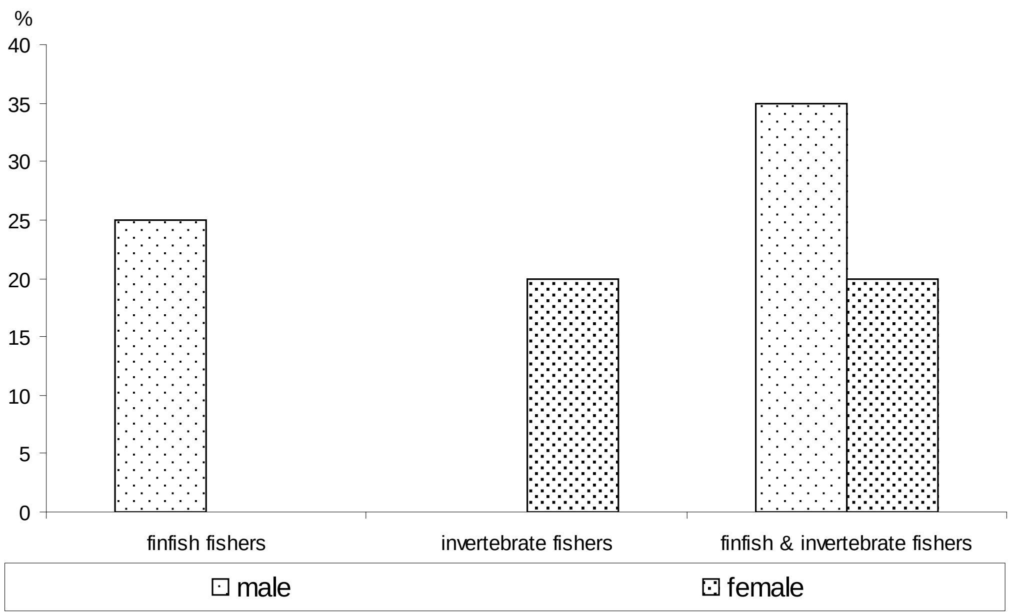

Figure 2.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Dromuna.
All fishers = 100%.

Fishing is done by both gender groups; however, traditional roles are evident from the information shown in Figure 2.5. Males are much more engaged in finfish fisheries, while females are more focused on invertebrates. However, it is worth mentioning that the greatest share of males and about half of all females considered here fish for both finfish and invertebrates.

Targeted stocks/habitat

Considering the low cash flow, the isolation, and the limited commercial opportunities in Dromuna, it is not surprising that finfish fishers mainly target the easily accessible habitats, namely the sheltered coastal reef and 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 frequently as the more easily accessible habitats (Table 2.2). The commercial bêche-de-mer fishery is the most targeted by both female and male fishers. Traditionally, females mainly target seagrass and reeftops, while males focus more on the collection of commercial invertebrates, i.e. lobsters, giant clams and trochus. The huge mangrove areas are not as targeted as one might expect. Overall, most invertebrate collection trips combine several habitats, which is made possible due to the close proximity of habitats surrounding the island.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	80.0	100.0
	Lagoon & outer reef	20.0	0.0
	Outer reef	20.0	0.0
	Outer reef & passage	20.0	0.0
Invertebrates	Reeftop	0.0	22.2
	Intertidal & reeftop	16.7	33.3
	Intertidal & reeftop & other	0.0	11.1
	Seagrass	0.0	11.1
	Seagrass & mangrove	16.7	55.6
	Seagrass & reeftop	0.0	33.3
	Seagrass & reeftop & other	16.7	0.0
	Mangrove	0.0	11.1
	Bêche-de-mer	83.3	44.4
	Lobster	33.3	0.0
	Trochus & lobster	16.7	0.0
	Other	33.3	0.0

'Other' refers to the giant clam and *Lambis lambis* fisheries.
Finfish fisher interviews, males: n = 20; females: n = 4. Invertebrate fisher interviews, males: n = 6; females: n = 9.

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 Dromuna on their fishing grounds (Tables 2.2 and 2.3).

Our survey sample suggests that fishers from Dromuna have a good choice among sheltered coastal reef, lagoon and outer-reef fishing, including access to passages. Because fishing is the major source of cash income, it is not surprising that most fishers target the commercial species, i.e. bêche-de-mer, lobster and trochus, as much as the traditional fisheries on the reeftops, seagrass beds, intertidal areas and mangroves (Figure 2.6). Analysis of gender participation shows that females dominate the gleaning fisheries (reeftop, seagrass, intertidal and mangrove), while males are mainly engaged in diving for lobsters, trochus and other species (giant clams and *Lambis lambis*). Male fishers also dominate the bêche-de-mer fishery, which is, however, also fished by female fishers. Female fishers may occasionally dive for species in shallow water; however, they do not engage in free-diving further from shore (Figure 2.7).

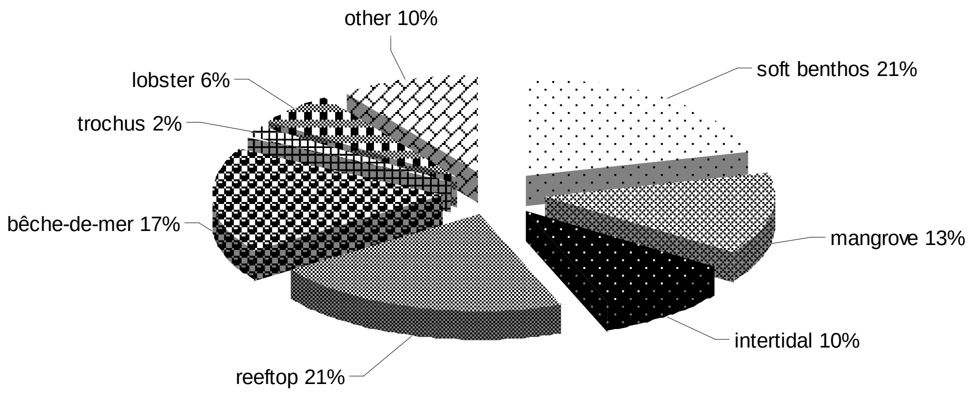

Figure 2.6: Proportion (%) of fishers targeting the eight primary invertebrate habitats found in Dromuna.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to the giant clam and *Lambis lambis* fisheries.

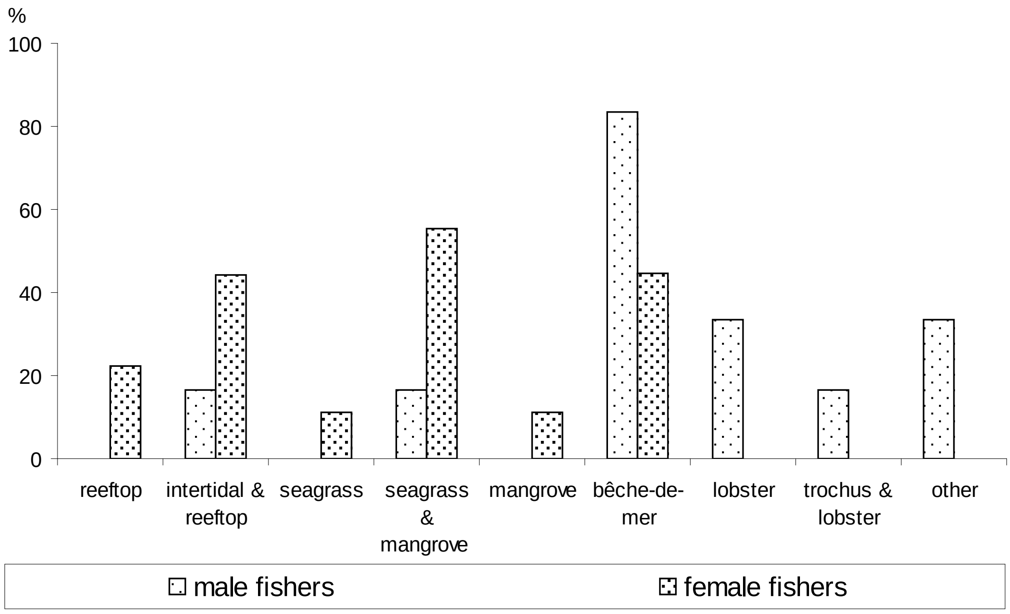

Figure 2.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Dromuna.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 6 for males, n = 9 for females; 'other' refers to the giant clam and *Lambis lambis* fisheries.

Gear

Figure 2.8 shows that Dromuna fishers use a number of fishing techniques during one fishing trip. Most frequently, a combination of gillnets and handlines, perhaps also spear diving and handheld spearing, is used in the sheltered coastal reef and lagoon areas. As distance from shore increases, handlines dominate, combined with all kinds of other techniques. Spear diving is performed by younger male fishers and is preferably done at the outer reef. Trolling and longlining are not that frequent but may be done occasionally by a few male fishers in the village.

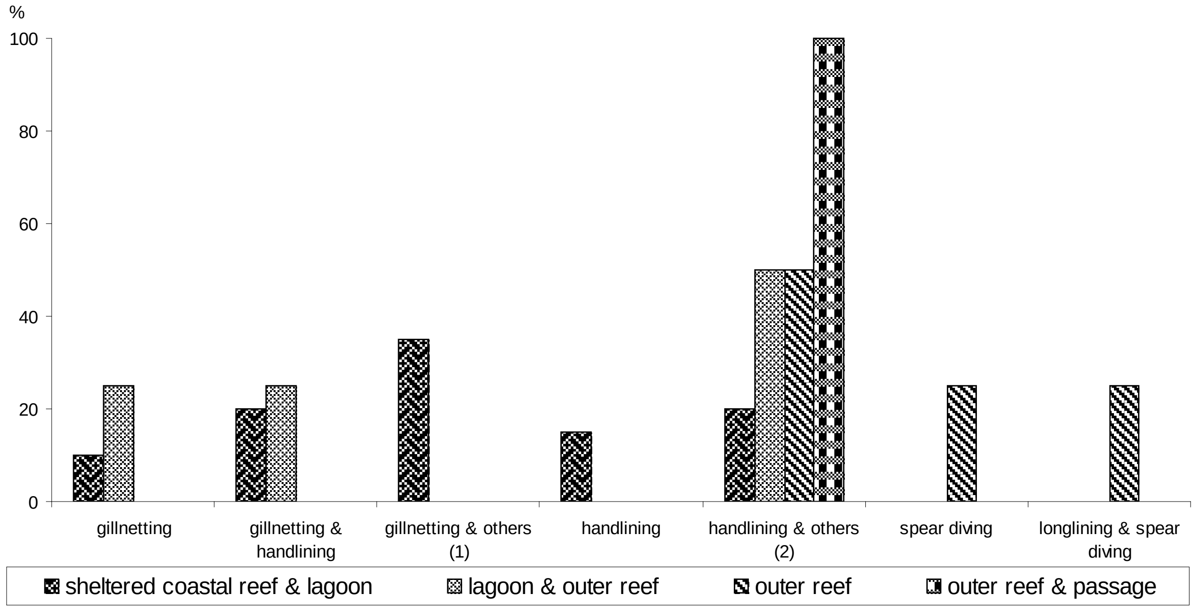

Figure 2.8: Fishing methods commonly used in different habitat types in Dromuna.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.
(1) Handlining, longlining, spear diving & handheld spearing; (2) longlining, spear diving, rod fishing, handheld spearing & trolling.

Frequency and duration of fishing trips

Table 2.3 shows that finfish fishers go out to any of the habitats once or twice per week, with less frequent visits to the further habitats, i.e. the outer reef and passages. Females go fishing about once per week. Invertebrate trips are about the same frequency for male fishers, while female fishers usually collect invertebrates twice per week. The average duration of a finfish fishing trip is about 3 to 5 hours for males, with longer trips to the outer reef and passages, and about 2.5 to 3 hours for females targeting the sheltered coastal reef and lagoon habitats only. A typical invertebrate collection trip takes three hours for both male and female fishers. Bêche-de-mer is collected for at least four if not five hours. Invertebrate diving, i.e. targeting lobsters, clams and trochus, involves travelling a longer distance, and is thus more time consuming, i.e. an average trip may last around five hours.

Most finfish fishing is done according to tidal conditions, i.e. during the day or night, and is performed throughout the year. Female fishers have a preference for daytime finfish fishing. Ice is not always used on finfish fishing trips, but is more regularly used when the outer reef is targeted. Ice is available from the Fisheries Department, which is about an hour by boat from the community. Fishers can, therefore, relatively easily access ice, and trips can easily combine purchasing ice and selling fish to the Fisheries Department or to shops, nearby markets and middlemen.

Fishing in the sheltered coastal reef and lagoon areas does not necessarily require boat transport; however, with increasing distance from shore, boat transport becomes more important and is essential for fishing the passages and outer reef. Gleaning for invertebrates is mostly done by walking, but commercial diving for lobsters, trochus, clams, *Lambis lambis* and bêche-de-mer is done using motorised boat transport. Invertebrates can be collected at day or night time, and this applies to mangroves, bêche-de-mer, soft-benthos and reeftop habitats. Lobster diving is the only fishery that is specifically performed at night.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	1.72 (±0.11)	1.13 (±0.13)	3.44 (±0.24)	2.75 (±0.25)
	Lagoon & outer reef	1.63 (±0.24)	0	4.13 (±0.13)	0
	Outer reef	1.25 (±0.25)	0	5.75 (±0.85)	0
	Outer reef & passage	0.92 (±0.08)	0	5.00 (±1.00)	0
Invertebrates	Reeftop	0	2.50 (±0.50)	0	3.50 (±0.50)
	Intertidal & reeftop	3.00 (n/a)	2.67 (±0.67)	3.00 (n/a)	3.67 (±0.33)
	Intertidal & reeftop & other	0	2.00 (n/a)	0	4.00 (n/a)
	Soft benthos	0	2.00 (n/a)	0	4.00 (n/a)
	Soft benthos & mangrove	3.00 (n/a)	2.00 (±0.32)	3.00 (n/a)	3.40 (±0.24)
	Soft benthos & reeftop	0	2.17 (±0.60)	0	3.33 (±0.67)
	Soft benthos & reeftop & other	2.00 (n/a)	0	4.00 (n/a)	0
	Mangrove	0	0.50 (n/a)	0	4.00 (n/a)
	Bêche-de-mer	1.70 (±0.30)	2.00 (±0.00)	4.40 (±0.24)	3.75 (±0.25)
	Lobster	0.58 (±0.12)	0	5.50 (±0.50)	0
	Trochus & lobster	0.69 (n/a)	0	5.00 (n/a)	0
	Other	1.00 (±0.00)	0	3.00 (±0.00)	0

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to the giant clam and *Lambis lambis* fisheries.
Finfish fisher interviews, males: n = 20; females: n = 4. Invertebrate fisher interviews, males: n = 6; females: n = 9.

2.2.3 Catch composition and volume – finfish: Dromuna

The catches reported from the sheltered coastal reef and lagoon in Dromuna contain a great variety of species, with Lethrinidae, Mugilidae, Balistidae, Acanthuridae and Leiognathidae representing the major species group by reported catch weight. The role (by catch weight) of Carangidae increases with distance from shore. However, catches reported from the combined fishing of the lagoon and outer reef are still dominated by Lethrinidae and Lutjanidae, followed by Carangidae, Mugilidae and others. At the outer-reef, the catch composition is more evenly balanced among Carangidae, Lethrinidae and Haemulidae. Also, Scaridae play a much greater role in catches at the outer reef than elsewhere. If the outer reef and passages are combined in one fishing trip, most weight is reported for Lethrinidae, Haemulidae and Belonidae.

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

Figure 2.9 highlights findings from the socioeconomic survey reported earlier, i.e. that finfish fishing serves mainly income purposes and comparatively little (31%) is consumed by the village people themselves. The total annual catch is estimated to amount to ~43 t.

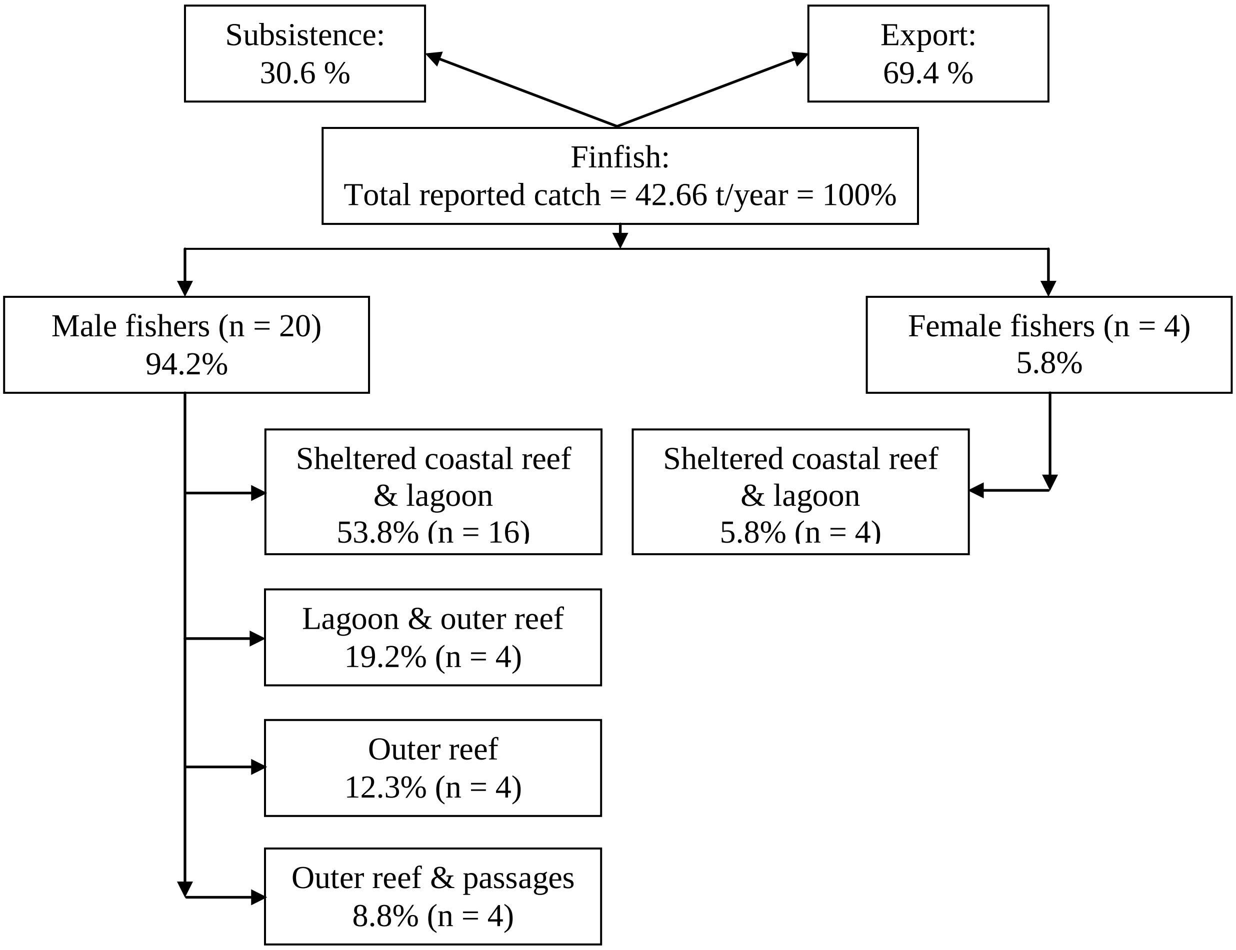

Figure 2.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Dromuna.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The dominance of male fishers by impact and production shows in the proportion of catch that they account for, i.e. 94% of the total annual catch. Thus, it can be concluded that male fishers are mainly in charge of generating the required cash income, but also provide part of their catch as food for the family. Female fishers do contribute to home consumption needs but, by comparison, their share is rather limited (~6%). Most impact (~60–70%) is imposed on the sheltered coastal reef and lagoon resources, and only ~20–30% is accounted for by catches from the outer reef and passages.

The distribution of annual catch weight among the more easily accessible sheltered coastal reef, the lagoon, and the more distant outer reef and passages, is a consequence of the number of fishers and, to some extent, of the annual catch rates. As shown in Figure 2.10, the average annual catch per male fisher is highest if the lagoon and outer reef are combined in one fishing trip (800 kg/fisher/year). By comparison, average annual catch rates for male fishers are about 550 kg/fisher/year for the combined fishing of the sheltered coastal reef and lagoon and the outer reef. Male fishers targeting the outer reef and passages in one fishing trip have the lowest annual production (~400 kg/fisher/year). Female fishers’ productivity is, by comparison, very low, i.e. about 200 kg/fisher/year, which supports the earlier argument that female fishers contribute only to home consumption.

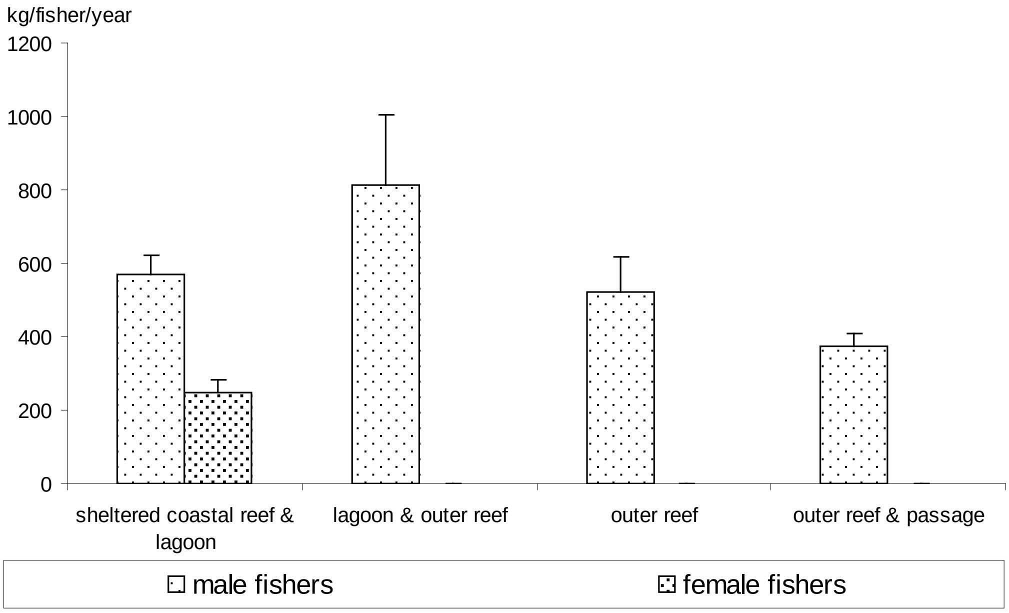

Figure 2.10: Average annual finfish catch (kg/year, +SE) per fisher by gender and habitat in Dromuna (based on reported catch only).

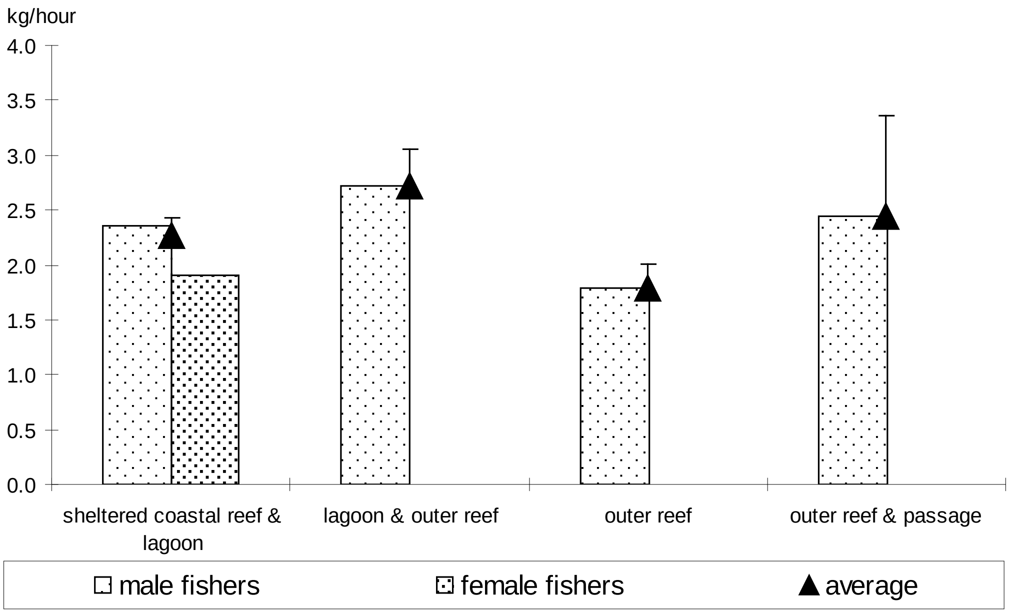

Figure 2.11: Catch per unit effort (kg/hour of total fishing trip) for male and female finfish fishers by habitat in Dromuna.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Comparing productivity rates between genders and among habitats (Figure 2.11), differences among habitats fished are small. Overall, CPUEs are moderate, ranging from 1.8 to 2.5 kg/hour fishing trip. CPUE is comparable for male and female fishers targeting the sheltered coastal reef and lagoon areas in one fishing trip. The highest CPUEs exist for lagoon and outer-reef fishing, the lowest for fishers targeting the outer reef only. The fishing ground of Dromuna is under substantial pressure from neighbouring and external fishers. Results suggest that the resource status does not necessarily improve significantly with distance from shore. The longer travelling time required to reach the outer reef and passages may support this argument as it may cause lower CPUEs as compared to nearshore fishing.

The importance of subsistence fishing for Dromuna clearly shows in Figure 2.12. As observed earlier, fishers target any of the habitats mainly for commercial purposes, with the most accessible habitats (the sheltered coastal reef and lagoon) being the main target areas for home consumption. Dromuna is a community that is dependent upon fishing, with a strong traditional fishing lifestyle. People rely on their knowledge of the species, habitats, winds, moons and tides to guide their daily fishing activities. A few fishing groups that fish and sell fish together were in existence in the village and these groups mostly targeted finfish for sale. Catches in this case were sold at pre-arranged distribution points. There was also a middle buyer in the village who supplied ice and fishing gear and usually bought fish from fishers in the community.

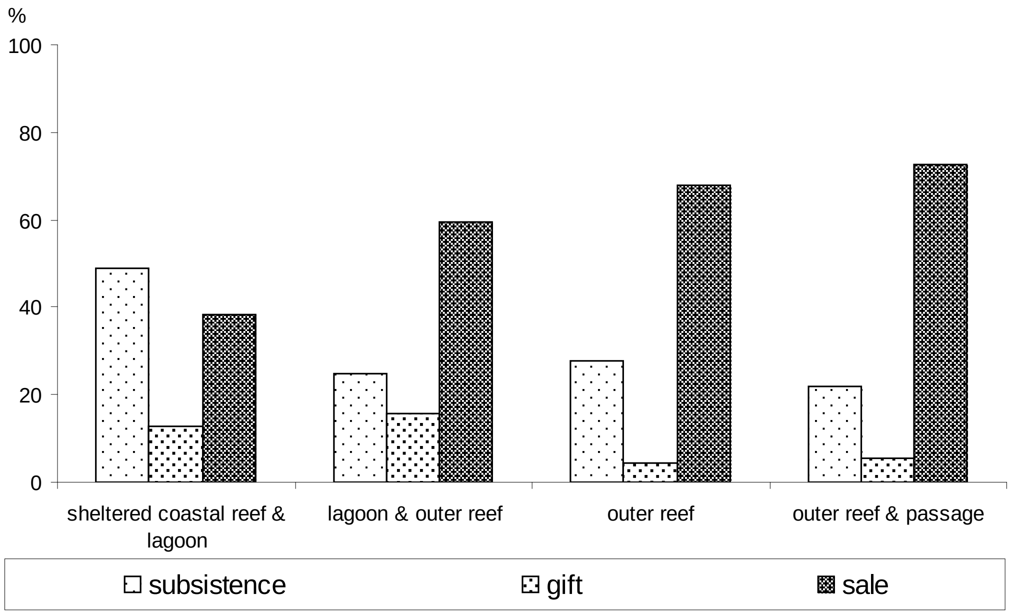

Figure 2.12: The use of finfish catches for subsistence, gift and sale, by habitat in Dromuna. Proportions are expressed in % of the total number of trips per habitat.

Analysis of the overall finfish fishing productivity per habitat did not suggest any major differences in resource status (Figure 2.11) and suggested lower productivity when fishing the outer reef and perhaps passages. This observation does not apply if comparing the reported average fish sizes (fork length) for the major families caught (Figure 2.13). Firstly, average fish sizes are moderate to large and range around 20–35 cm on average. Secondly, and 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, Haemulidae, Lethrinidae and Siganidae. For other families, such as Scaridae, the picture is not conclusive, as the average fish length reported drops from catches at the sheltered coastal reef and lagoon to outer reef, and increases again if the outer reef and passage are combined in one fishing trip. Average fish lengths for Serranidae are similar across all habitats fished.

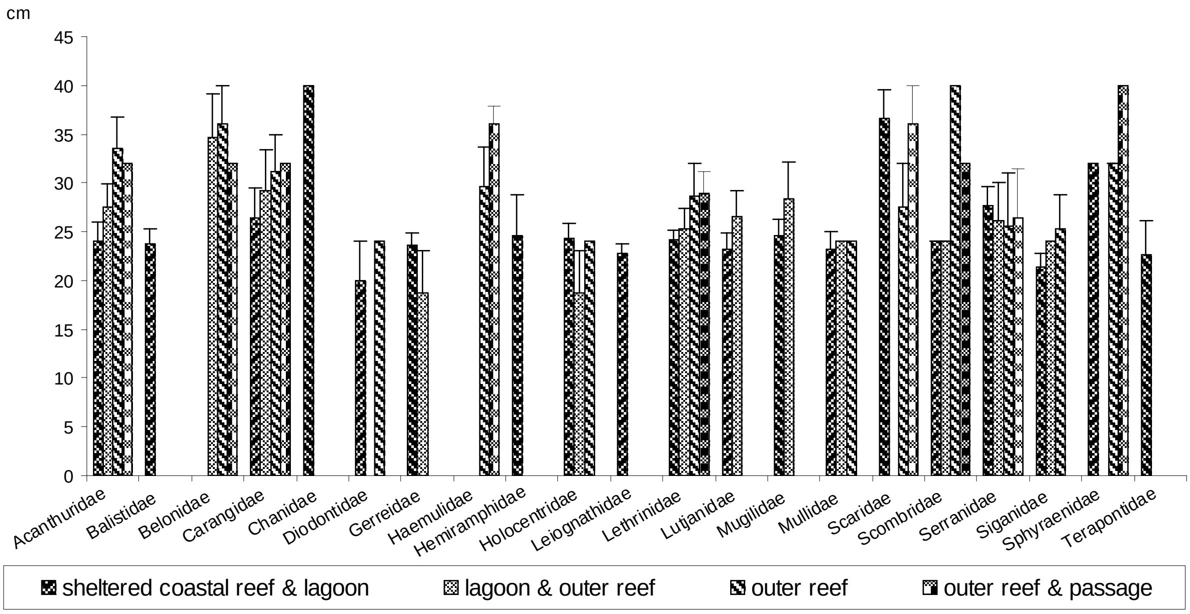

Figure 2.13: Average sizes (cm fork length) of fish caught by family and habitat in Dromuna. Bars represent standard error (+SE).

The parameters selected to assess the current fishing pressure on Dromuna reef and lagoon resources are shown in Table 2.4. Due to the 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. Even if we consider the total annual catch rate from Dromuna fishers, the total fishing pressure on reef and fishing ground areas does not increase drastically given their large size. However, one must take into account that the fishing ground is heavily targeted by fishers from surrounding communities, as well as by external fishers as far away as the Suva area. CPUEs and average reported fish lengths, as discussed above, suggest that fishing impact is already visible.

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

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)	17.4	186.9	4.3	n/a	86.5	208.6
Density of fishers (number of fishers/km^2 fishing ground) (1)	2.1	0.0	1.4	n/a	0.6	0.3
Population density (people/km^2) (2)					1.3	0.6
Average annual finfish catch (kg/fisher/year) (3)	506.45 (±51.32)	815.02 (±189.02)	522.52 (±93.05)	375.27 (±34.76)		
Total fishing pressure of subsistence catches (t/km^2)					0.1	0.0
Total number of fishers	36	6	6	6	54	54

Figures in brackets denote standard error; n/a = no information available; (1) total number of fishers is extrapolated from household surveys; (2) total population = 115; total number of fishers = 54; total subsistence demand = 8.32 t/year; (3) catch figures are based on recorded data from survey respondents only.

2.2.4 Catch composition and volume – invertebrates: Dromuna

Analysis of reported catches from invertebrate fishers by wet weight suggests that bêche-de-mer species, notably *Holothuria* spp. and *Bohadschia* spp., account for most of the total annual catch volume. However, sampling does not allow exact annual production rates to be calculated. Therefore, Figure 2.14b only displays the reported catch composition by species. In annual catches for traditional species that are mainly targeted for home consumption (Figure 2.14a) and, to some extent, for local sale, *Pinna bicolor*, *Spondylus* spp., *Lambis lambis*, lobsters, *Scylla serrata* and *Anadara* spp. are the most important species, while all others, including octopus, trochus, and clams, are of minor importance by wet weight.

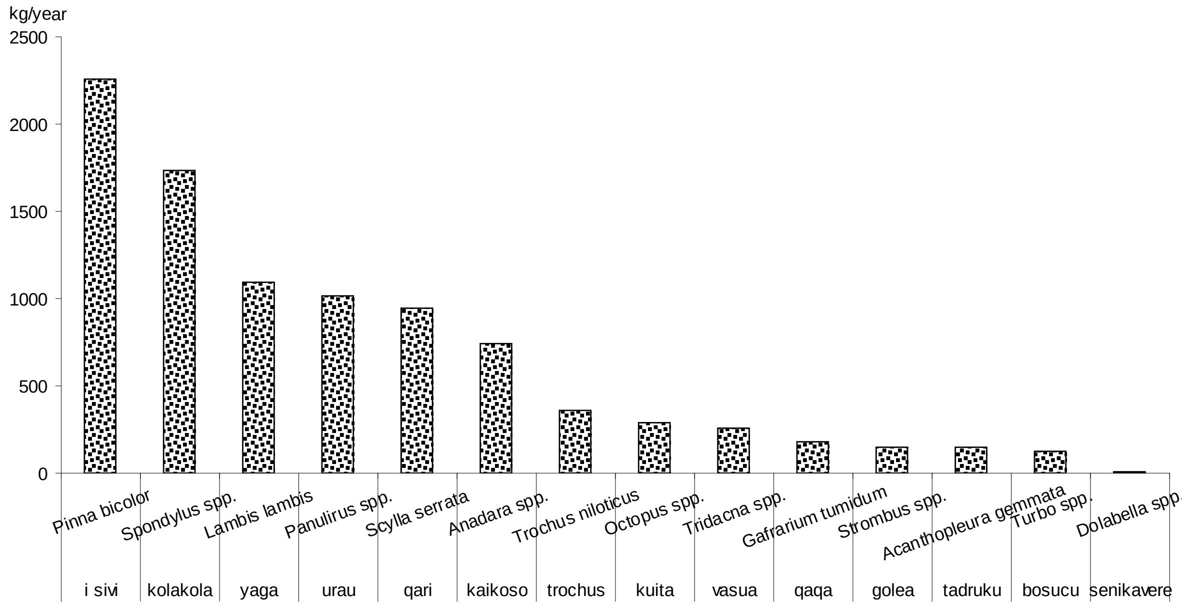

Figure 2.14a: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Dromuna.

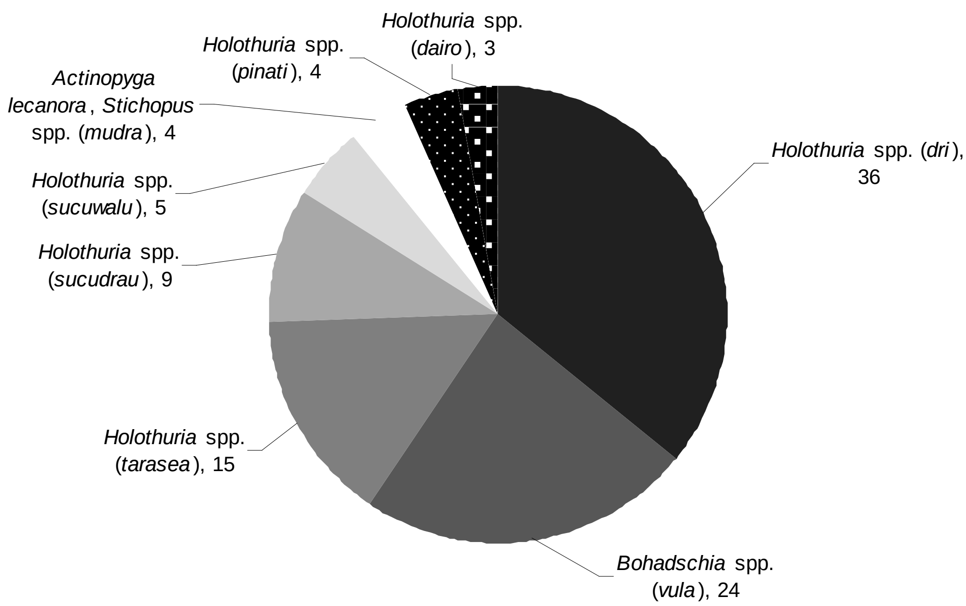

Figure 2.14b: Catch composition of the bêche-de-mer fishery in Dromuna.

Figure 2.15 emphasises that Dromuna has access to a wide range of habitats and that these are often combined in one fishing trip. The number of target species identified by vernacular name, however, is not as varied as one would expect. Among the traditional fisheries, the combination of soft-benthos and intertidal areas and 'others', i.e. diving for reef-associated or submerged species, is represented by the highest number of vernacular names. There are at least seven different species of bêche-de-mer identified by distinct vernacular names.

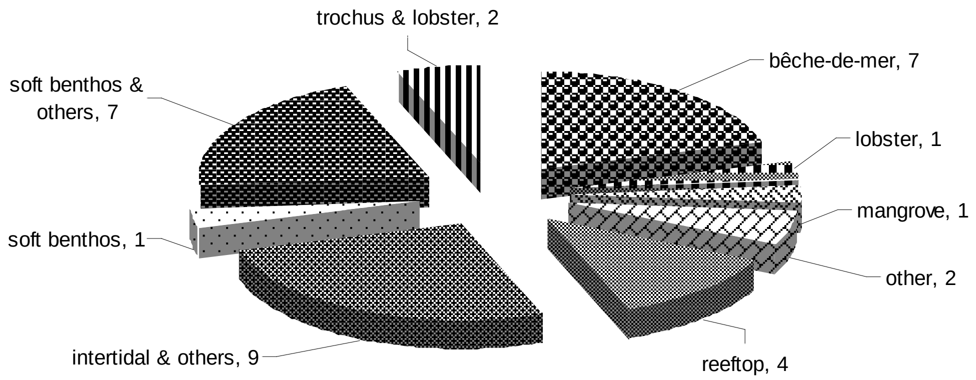

Figure 2.15: Number of vernacular names recorded for each invertebrate fishery in Dromuna.
'Other' refers to the giant clam and *Lambis lambis* fisheries.

Analysis of the average annual catch per fisher by gender and fishery (Figure 2.16) reveals the substantial difference between the commercial bêche-de-mer and all other fisheries but little difference in gender participation. Because the sample data do not allow quantification of the bêche-de-mer fishery, caution is advised in comparing this fishery to the other fisheries.

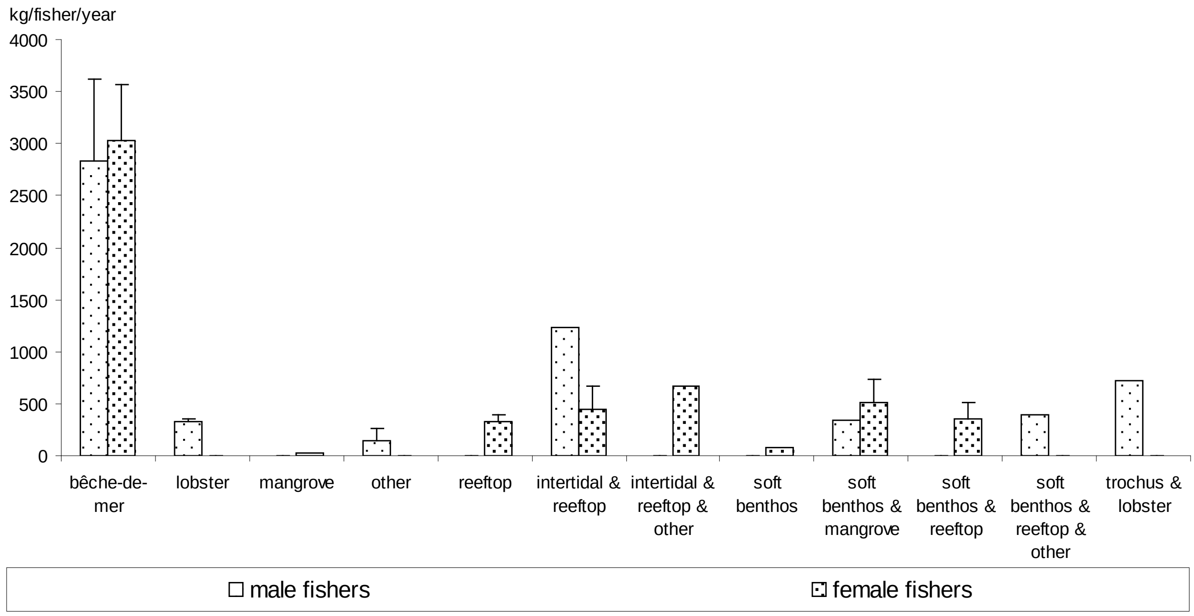

Figure 2.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Dromuna.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 6 for males, n = 9 for females).

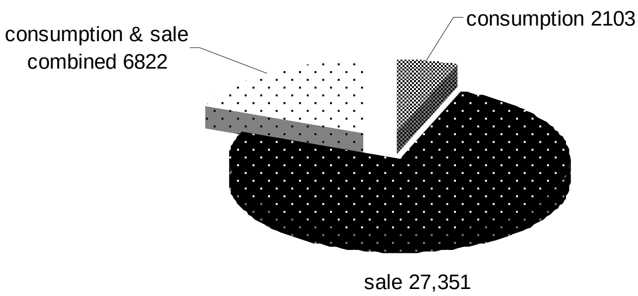

Figure 2.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Dromuna.

The fact that the Dromuna community is highly dependent on marine resources for income also shows in Figure 2.17, which reveals the simple fact that most invertebrates are caught for sale, notably bêche-de-mer and, to a lesser extent, lobsters and trochus. If we assume that half of the catches reported for both sale and home consumption are sold, the proportion of the total invertebrate catch that is sold is about 85%.

As mentioned earlier, male and female fishers from Dromuna are heavily involved in invertebrate fishing, and each gender group accounts for about half of the reported annual catch (wet weight) (Figure 2.18). Most male Dromuna invertebrate fishers target bêche-de-mer, and all other fisheries, including the commercial dive fisheries for lobsters, *Lambis lambis*, clams and trochus, are rather insignificant by comparison. Female fishers also catch bêche-de-mer most by wet weight; however, they also substantially target the soft-benthos and mangrove habitats. Concerning traditional invertebrate fisheries, both male and female fishers have a preference for the species associated with intertidal areas and reeftops.

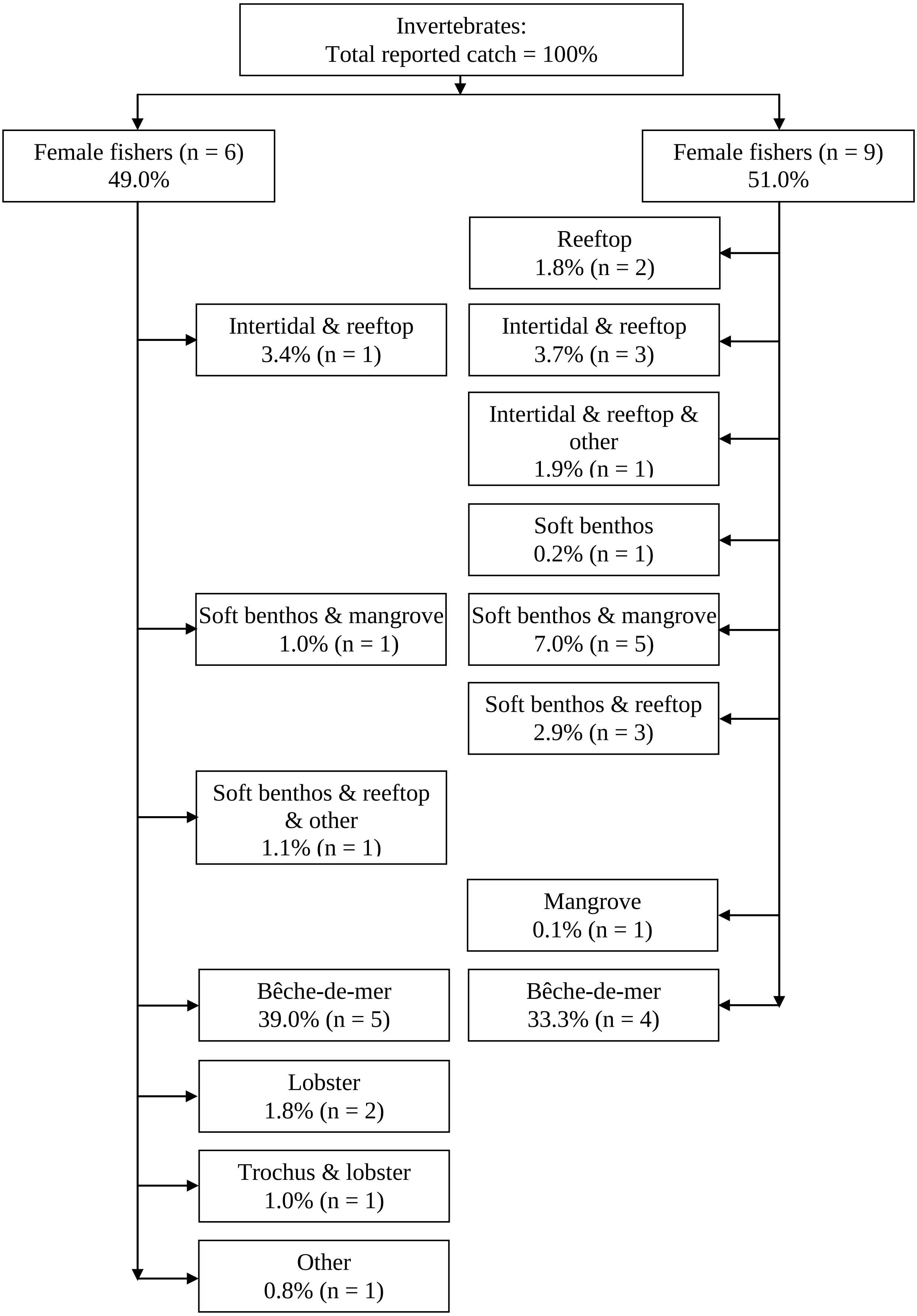

Figure 2.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Dromuna.
'Other' refers to the giant clam and *Lambis lambis* fisheries; n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number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

Taking into account the total area of sheltered coastal reef surface for any reeftop invertebrate fishery, as well as the outer-reef surface area for the trochus (and lobster) fishery, the fisher-density parameters calculated are low. Also, the average annual catch rate for most fisheries is low. Bêche-de-mer fishery data are not reported here, as our sampling does not permit accurate quantitative calculations (Table 2.5). Although the parameters calculated to assess current fishing pressure suggest that there is little, if any, adverse effect to be expected from the current level of fishing activity, this picture may be misleading. The Dromuna fishing ground area is accessed by many fishers from the neighbouring villages, as well as by external fishers as far away as Suva. The bêche-de-mer fishery has a long record in Fiji Islands, it is an open fishery, and resources are widely exhausted due to fishing over the past decades. The argument that suggests the resources are depleted may be supported by the relatively few vernacular names reported for the traditional as well as the commercial fisheries, by a community that is highly dependent on marine resources for both food and income, and that traditionally has a food preference for many invertebrate species.

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

Parameters	Fishery / Habitat						
	Reeftop	Soft benthos	Mangrove	Bêche-de-mer	Lobster	Trochus & lobster	Other
Fishing ground area (km^2)	17.4	n/a	n/a	n/a	n/a	4.3	4.3
Number of fishers (per fishery) (1)	22	3	3	31	8	4	8
Density of fishers (number of fishers/km^2 fishing ground)	1	n/a	n/a	n/a	n/a	1	2
Average annual invertebrate catch (kg/fisher/year) (2)	333.42–671.84 (±61.99)	72.96–483.36 (±184.23)	30.40 (n/a)	n/a	329.82 (±29.98)	719.60 (n/a)	146.57 (±114.00)

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

2.2.5 Fisheries management: Dromuna

The development, exploitation and management of fish stocks in Fiji Islands are subject to the Fisheries Act (Cap 158), the Marine Species Act (Cap 158A) and subsidiary legislation. The Fisheries Act addresses fishing within traditional customary fishing areas (*qoliqoli*). The policy on catching fish within customary fishing rights areas is that no commercial fishing activities are undertaken unless by consent of the traditional owners. These rules plus national legislation have not deterred illegal fishing in the Dromuna fishing area. There also exist customary management strategies in the various communities in Fiji Islands and some of these include bans on fishing upon the death of chiefs, or seasonal closures that are sometimes observed on the harvest of certain species. In Dromuna some of these customary management strategies are all that is being done to manage the fisheries. In Fiji Islands, most of the fishing areas, as in the case of Dromuna, are *vanua*-owned, which means they are either owned by larger groups, similar to districts or traditional groupings of villages, or by smaller groupings, which may be only one or two villages. The ability to give consent to fish within a *qoliqoli* or fishing area rests with the *vanua*, *tikina* (district) or *yavusa* (traditional groupings of villages), depending on the ownership status of that particular *qoliqoli*. For Dromuna, which is in Kaba waters, the paramount chief has rights to grant licences to people to fish within Dromuna waters and, sometimes, the people in the communities themselves are not aware of the licences or the holders of the licences. Modernisation and the market economy have, in many cases, changed the balance of resource use and management in the last few decades, resulting in there being a greater need for management. Under customary marine tenure (CMT), resource owners have jurisdiction over their fishing areas (*qoliqoli*). Ownership of fishing areas up to the high-water mark rests with the state; this, however, is currently being reviewed, with new structures, and ownership to revert to the traditional owners of fishing rights. This will mean that more management authority and decision making rests in the hands of the resource owners.

At the time of the study there was no specific management initiative in existence in Dromuna and no community-organised strategies in place. The Dromuna community was aware of the need to manage the resources and of the state of gradual decline of some species and the move to fish further from the usual fishing grounds. Females were also aware that the invertebrate species were not as plentiful as in the past. However, certain beliefs were held about certain species, e.g. *Lambis lambis*, which remain a challenge for management, e.g. people's belief in the supernatural and the general belief that *Lambis lambis* was always going to be plentiful, despite the high rate of selling that was occurring. The problems of poaching and of other fishers entering fishing grounds without permission are major ones. To address these requires a co-management approach between the community and the Fisheries Department. Community-awareness work is also needed to assist in the implementation of post-harvest activities and quality management of catches. Marketing strategies, value-added processes and the need to include such issues in awareness work are important to ensure a better understanding of the resources, the market and the external influences on resources.

Estimates of fishing pressure, based on the survey responses and extrapolated to the entire population, suggest low figures; however, one must consider the fact that Dromuna shares its fishing waters with Vatani, another immediately adjacent village. Also people from adjoining villages have rights of access to the fishing areas under the traditional *vanua* arrangements. This means that people can fish freely within the collective *qoliqoli* areas without seeking specific permission for so doing. Complicating fishing-area access and adding to the fishing pressure by local fishers was the existence of poachers who frequented the area. With a lack of management mechanisms and personnel trained in monitoring *qoliqoli* or fishing areas, the problem of illegal fishing in the area cannot be addressed. These circumstances, complemented by a history of high exploitation of bêche-de-mer and other commercially exploitable species, suggest that fishing pressure on invertebrate resources remains high, even though it has been reduced in response to resource depletion.

2.2.5 Discussion and conclusions: socioeconomics in Dromuna

Dromuna is a small, traditional community located on a small island off the mainland of Viti Levu, distant one hour by boat and 30–60 minutes by road from Fiji Islands' main market centres, Nausori and Suva. People in the community have only a few options for earning income, and no opportunities for earning salaries. Arable land allows crops to be produced, both for home consumption and, to some extent, for sale. Fisheries, notably finfish and bêche-de-mer collection, provide the main income for over 85% of households, and agricultural produce and mat weaving (by females) complement income. Fishing grounds and fishing rights under customary ownership and rights are huge; however, these are shared with neighbouring villages and illegally fished by outsiders from the wider Suva urban area.

In summary:

- The Dromuna community has the highest dependency on fisheries for income, and a high dependency upon finfish particularly for food, but a much smaller dependency upon invertebrates or canned fish.

- The average household expenditure level is relatively low, and the influx of external finance, i.e. remittances, is not as important as observed elsewhere in the sites studied.

- Finfish and invertebrate fishers target many habitats, and often combine two or more in one fishing trip.

- Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further away from shore, while females are more involved in handlining in the nearshore habitats and in collecting invertebrates. Both gender groups participate most in the commercial bêche-de-mer fishery.

- The highest impact is imposed on the sheltered coastal reef and lagoon habitats; much less is on the outer reef and passages.

- Fishers who fish the lagoon and outer reef combined have the highest annual catch rates; however, their CPUEs are not significantly higher than those calculated for fishers who combine the sheltered coastal reef and lagoon, or the outer reef and passages.

- Average reported fish lengths are moderate to large. While, for most fish families caught, these lengths increase with distance from shore, the average fish lengths of Serranidae were similar across all habitats, and the lengths of Scaridae decreased from the sheltered coastal reef and lagoon to the lagoon and outer-reef habitats.

- Bêche-de-mer is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including *Pinna bicolor*, *Spondylus* spp., *Lambis lambis*, lobsters, *Scylla serrata* and *Anadara* spp., are important for both home consumption and small-scale, local commercial sale.

- Fishing pressure parameters for both finfish and invertebrates suggest that current fishing pressure is low. However, these figures are misleading given that the fishing grounds are shared with neighbouring communities, and given the illegal but high impact imposed by external fishers from the wider urban Suva area.

When the current fishing levels of the community are coupled with the impact imposed by fishers from outside who share the fishing area and by those who fish illegally, there is a lot of pressure on the fishing area. There is a need for some form of management; this could be best addressed through community-based management. This could be achieved through collaborative work or through co-management arrangements with the Fisheries Department or other partners, such as the FLMMA. The two communities that share the fishing ground could be urged to introduce measures to sustain the current levels of resources and seek consensus with all the neighbouring villages that share the fishing ground. This consensus could be reached through rigorous awareness-raising programmes that educate people on the need for management to sustain their resources on a long-term basis.

Traditional mechanisms of resource-use management were no longer effective when implemented and also varied in application. Instead, immediate measures to sustain resources are required. Certain areas of the coastal reef and associated mangrove areas need to be allocated as management or reserve sites. This could be especially viable given the wide range of fisheries habitat; i.e., closing off certain areas in a vast fishing area should not be too onerous.

Implementing management on a wider scale than the Dromuna community alone should also be considered given the shared nature of the fishing rights areas (*qoliqoli).* Thus, management at the district level including several villages should be considered. This should only be done after a proper assessment of the most viable areas to be protected and for which species or for which reasons. Quotas for certain bêche-de-mer species currently harvested could be proposed. Fishing and marketing groups currently operating in the community could be assisted to work on a larger scale, networking with buyers and other sellers to ensure the selling of products at minimal costs. Such measures could help to minimise the consistent harvesting of resources for commercial purposes.

Awareness of the need for sustainable harvests to ensure the long-term sustainability of resources needs to be raised within the community. Other means of earning livelihood need to be assessed, with options for assistance with post-harvest activities also considered. As females dominate the invertebrate fishery, any discussions on management should involve female fishers who have intimate knowledge of habitats and species. Mechanisms to include external buyers in any planned management work should also be considered, because any attempt at management may be undermined by the need for income.

2.3 Finfish resource surveys: Dromuna

Finfish resources and associated habitats were assessed between 15 and 22 April 2003, from a total of 24 transects (6 back-reef, 7 sheltered coastal reef, 5 lagoon reef and 6 outer reef, Figure 2.19).

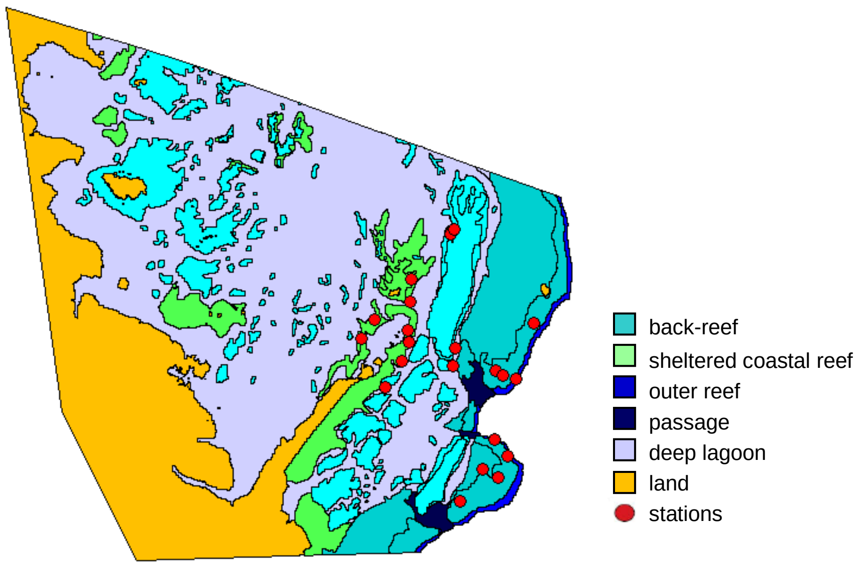

Figure 2.19: Habitat types and transect locations for finfish assessment in Dromuna.

2.3.1 Finfish assessment results: Dromuna

A total of 20 families, 45 genera, 145 species and 8210 fish was recorded in the 24 transects (See Appendix 3.1.2 for list of species.). Only data on the 13 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 36 genera, 133 species and 6759 individuals.

Finfish resources varied greatly among the four reef environments found in Dromuna (Table 2.6). The outer reef contained a greater number of species (49 species/transect), highest density (0.5 fish/m²), highest biomass (98 g/m²), and largest size (19 cm FL) and size ratio (63%) compared to the other reefs. Lowest density (0.5 fish/m²), biodiversity (36 species/transect), size (15 cm FL), size ratio (51%) and biomass (57 g/m²) were recorded in the coastal reefs.

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

Parameters	Habitat				
	Sheltered coastal reef [1]	**Intermediate reef [1]**	**Back-reef [1]**	**Outer reef [1]**	**All reefs [2]**
Number of transects	8	4	6	6	24
Total habitat area (km^2)	17.4	37.3	27.5	2.3	84.4
Depth (m)	3 (1–6) [3]	3 (1–5) [3]	1 (1–2) [3]	9 (5–14) [3]	5 (0–17) [3]
Soft bottom (% cover)	23 ±4	29 ±7	21 ±5	3 ±1	26
Rubble & boulders (% cover)	23 ±4	24 ±4	35 ±8	14 ±7	27
Hard bottom (% cover)	34 ±4	32 ±7	21 ±5	49 ±4	27
Live coral (% cover)	19 ±6	15 ±4	19 ±6	25 ±5	17
Soft coral (% cover)	2 ±2	1 ±0	4 ±2	7 ±2	2
Biodiversity (species/transect)	36 ±2	38 ±2	38 ±5	49 ±1	40 ±2
Density (fish/m^2)	0.5 ±0.1	0.5 ±0.0	0.6 ±0.1	0.5 ±0.1	0.5
Size (cm FL) [4]	15 ±1	17 ±1	17 ±1	19 ±1	17
Size ratio (%)	51 ±2	56 ±2	56 ±2	63 ±2	57
Biomass (g/m^2)	57.3 ±9.9	67.7 ±10.8	80.7 ±18.1	97.6 ±13.0	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.

Sheltered coastal reef environment: Dromuna

The sheltered coastal reef environment of Dromuna was dominated by four major families: herbivorous Scaridae, Acanthuridae and Siganidae, and carnivorous Lutjanidae. Chaetodontidae were important only numerically (Figure 2.20, Table 2.7). The four commercial families were represented by 32 species; particularly high biomass and abundance were recorded for *Scarus rivulatus*, *Ctenochaetus striatus*, *Chlorurus sordidus*, *Siganus doliatus*, *Scarus psittacus*, *Acanthurus blochii* and *Lutjanus fulvus* (Table 2.7). This reef environment was dominated by hard bottom (34%), while rubble and boulders (23%), soft bottom (23%) and live coral (19%) were in lesser proportion (Table 2.6, Figure 2.20).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Scarus rivulatus*	Rivulated parrotfish	0.04 ±0.01	5.6 ±2.0
	Chlorurus sordidus	Daisy parrotfish	0.04 ±0.01	3.5 ±1.0
	Scarus psittacus	Palenose parrotfish	0.03 ±0.01	3.1 ±1.1
Siganidae	*Siganus doliatus*	Barred spinefoot	0.04 ±0.01	3.2 ±1.2
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.04 ±0.02	5.6 ±2.5
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.01	3.8 ±1.9
Lutjanidae	*Lutjanus fulvus*	Flametail snapper	0.01 ±0.01	2.5 ±1.8

The biodiversity, size, size ratio and biomass of finfish in the coastal reefs of Dromuna were the smallest among all the four reef habitats, while density was the second-lowest, higher only than the intermediate-reef value. The trophic structure was only slightly dominated by herbivores in terms of density and biomass. Carnivores were represented especially by Lutjanidae, then Mullidae and Labridae. Size ratios were below 50% of the maximum ever-recorded values for Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae and Siganidae, suggesting impact from fishing. The substrate of coastal reef was composed of hard coral, rubble, soft bottom and live coral in similar amounts, offering suitable habitat for a range of species. Therefore, the total or almost total lack of Holocentridae and Serranidae is probably explained by fishing pressure.

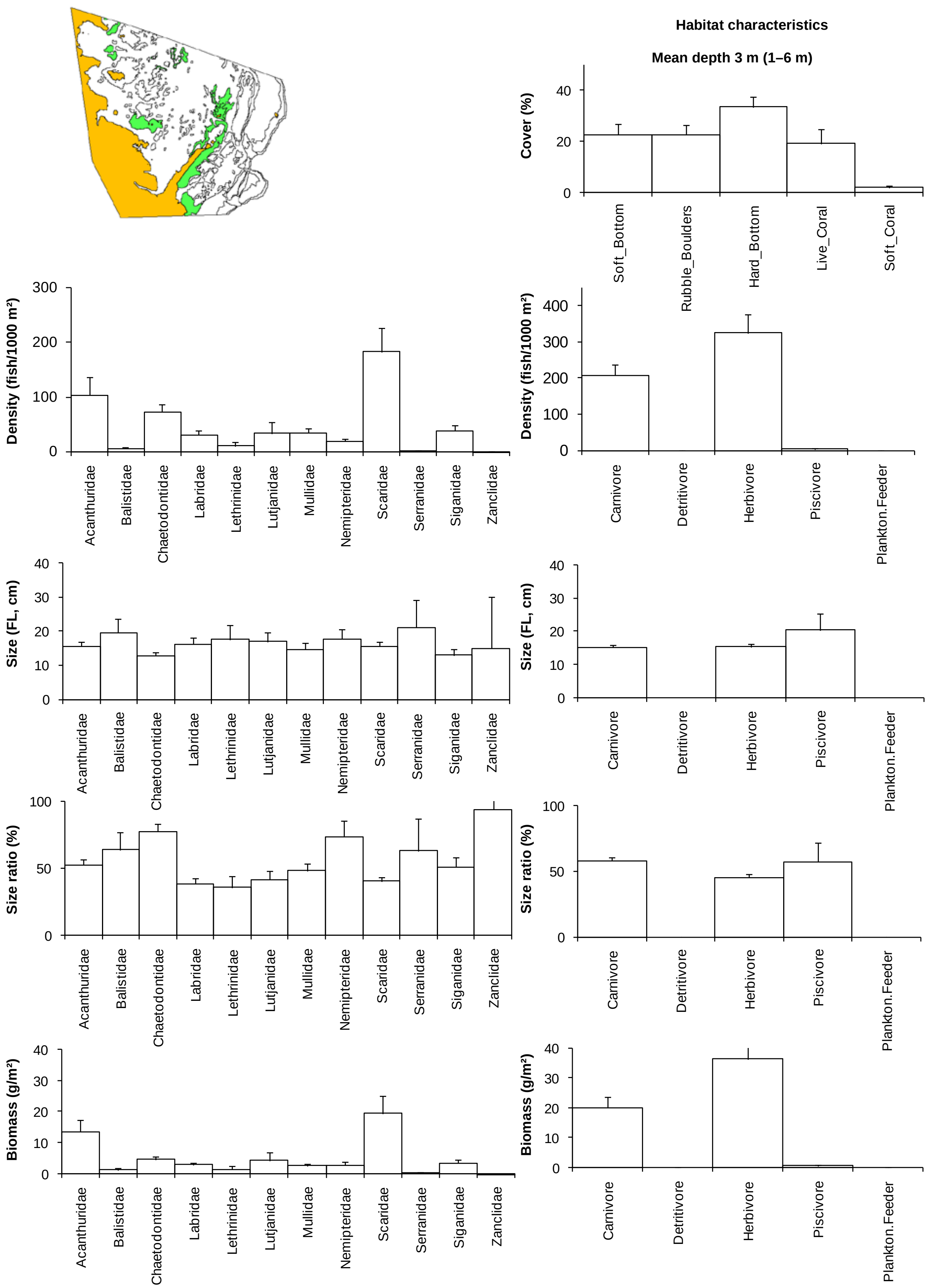

Figure 2.20: Profile of finfish resources in the sheltered coastal reef environment of Dromuna. Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Dromuna

The intermediate reef of Dromuna was dominated, both in terms of density and biomass, by herbivorous Scaridae and Acanthuridae and, to a much lesser extent, by carnivorous Lutjanidae, Mullidae, Lethrinidae and Nemipteridae. Chaetodontidae were important only numerically (Figure 2.21). The major families were present with 41 species, with the most important in terms of biomass and abundance being: *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scolopsis bilineata*, *Scarus schlegeli*, *Acanthurus blochii*, *Lutjanus fulviflamma* and *Monotaxis grandoculis* (Table 2.8). Hard-bottom cover (32%), rubble (24%) and soft bottom (29%) were almost equally important in defining the substrate composition. Live coral was present in lower proportion (15%, Table 2.6, Figure 2.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06 ±0.01	7.3 ±2.1
	Scarus schlegeli	Schlegel's parrotfish	0.02 ±0.01	3.7 ±1.6
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05 ±0.01	11.6 ±3.3
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.01	5.0 ±2.1
Nemipteridae	*Scolopsis bilineata*	Bridled monocle bream	0.03 ±0.01	4.3 ±1.0
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.01 ±0.01	3.5 ±3.2
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.02 ±0.01	3.0 ±1.5

The density of finfish in this reef was the lowest of all habitats. However, biodiversity, size and size ratio were second only to values in the outer reefs, and biomass was intermediate between the coastal-reef and back-reef values. The trophic composition was only slightly dominated by herbivores, where Scaridae and then Acanthuridae represented the largest bulk of density and biomass. Size ratios were much lower than 50% for some families, but especially for Holocentridae, Labridae, Lethrinidae and Scaridae, suggesting impact from fishing on these targeted families. The substrate composition, composed of hard bottom, soft bottom and rubble in similar amounts, provides an environment that naturally supports the recorded abundance of various families, including a good diversity of carnivores.

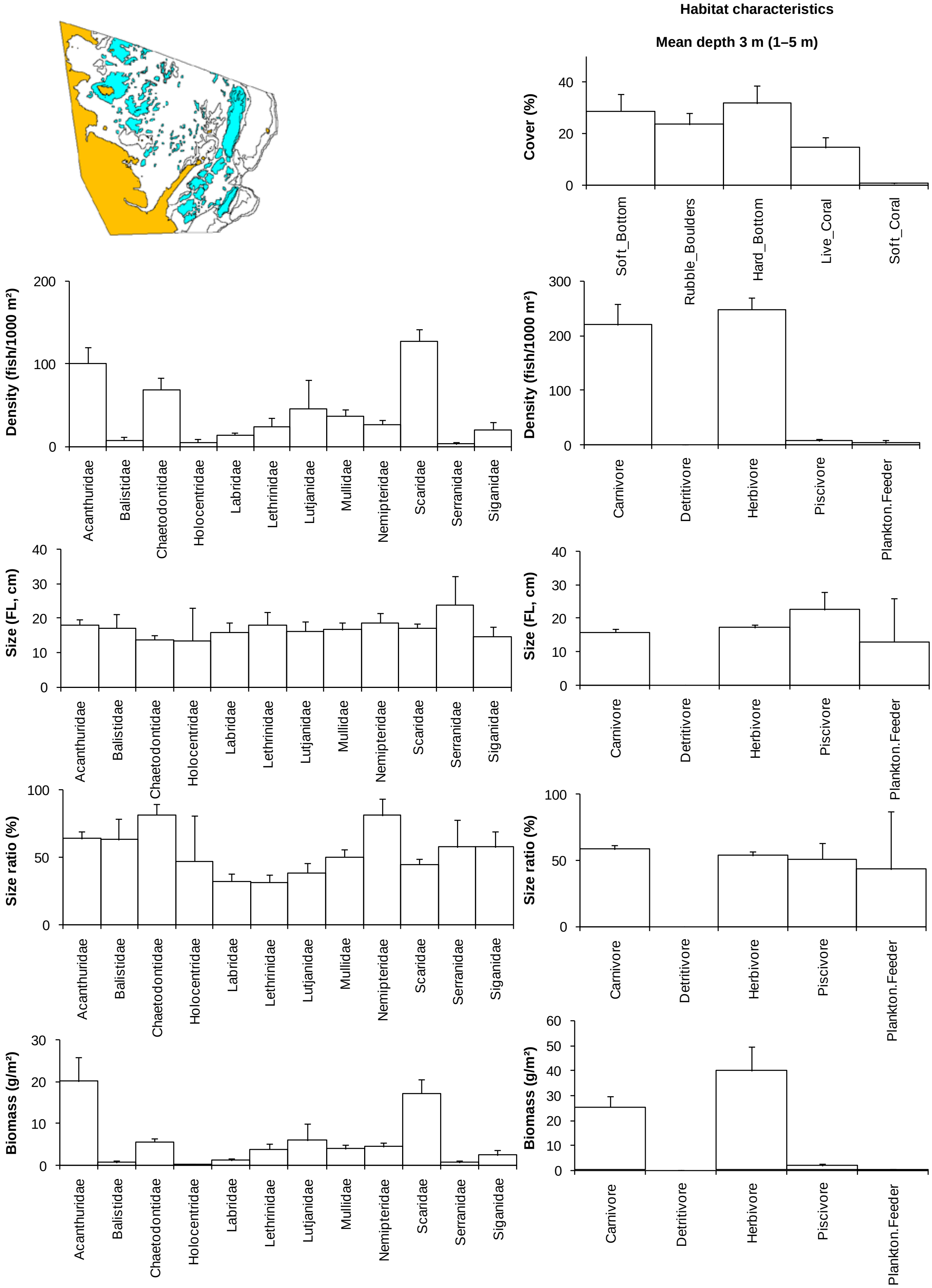

Figure 2.21: Profile of finfish resources in the intermediate-reef environment of Dromuna.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Dromuna

The back-reef of Dromuna was dominated, both in terms of density and biomass, by herbivorous Scaridae and Acanthuridae and, to a much lesser extent, Siganidae, and by carnivorous Lutjanidae and Nemipteridae and, only for density, by Chaetodontidae (Figure 2.22). The five major families were present with 34 species, with the most important in terms of biomass and abundance being: *Chlorurus sordidus*, *Ctenochaetus striatus*, *Scarus psittacus*, *Siganus spinus*, *Scolopsis bilineata*, *Acanthurus triostegus*, *Scarus rivulatus*, *Lutjanus fulviflamma* and *Scarus schlegeli* (Table 2.9). The substrate was dominated by rubble (35%), while hard bottom and soft bottom (21%) had equally important cover, and live coral cover was relatively good (19%, Table 2.6, Figure 2.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.07 ±0.01	12.8 ±3.5
	Scarus psittacus	Palenose parrotfish	0.06 ±0.02	3.5 ±0.6
	Scarus rivulatus	Rivulated parrotfish	0.02 ±0.01	3.9 ±1.3
	Scarus schlegeli	Schlegel's parrotfish	0.01 ±0.01	3.7 ±2.2
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.06 ±0.02	11.6 ±4.6
	Acanthurus triostegus	Convict tang	0.03 ±0.01	2.8 ±1.3
Siganidae	*Siganus spinus*	Little spinefoot	0.05 ±0.01	3.4 ±1.0
Nemipteridae	*Scolopsis bilineata*	Bridled monocle bream	0.03 ±0.01	4.4 ±1.8
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.01 ±0.01	4.7 ±3.9

The density of fish at this reef was the highest among all reefs, while biomass was second only to that in the outer reefs. However, size, size ratio and biodiversity displayed the second-lowest values, intermediate between the coastal and lagoon-reef values. The trophic composition was highly dominated by herbivores, where Scaridae represented the most important group. Size ratios were much lower than 50% for some families, Labridae, Lethrinidae, Mullidae and Scaridae, signalling an impact from fishing on these targeted families. The substrate, composed of hard bottom and soft bottom in equal amounts, with a high cover of rubble (35%) and a good coral cover (19%), naturally supports the relatively high diversity of species.

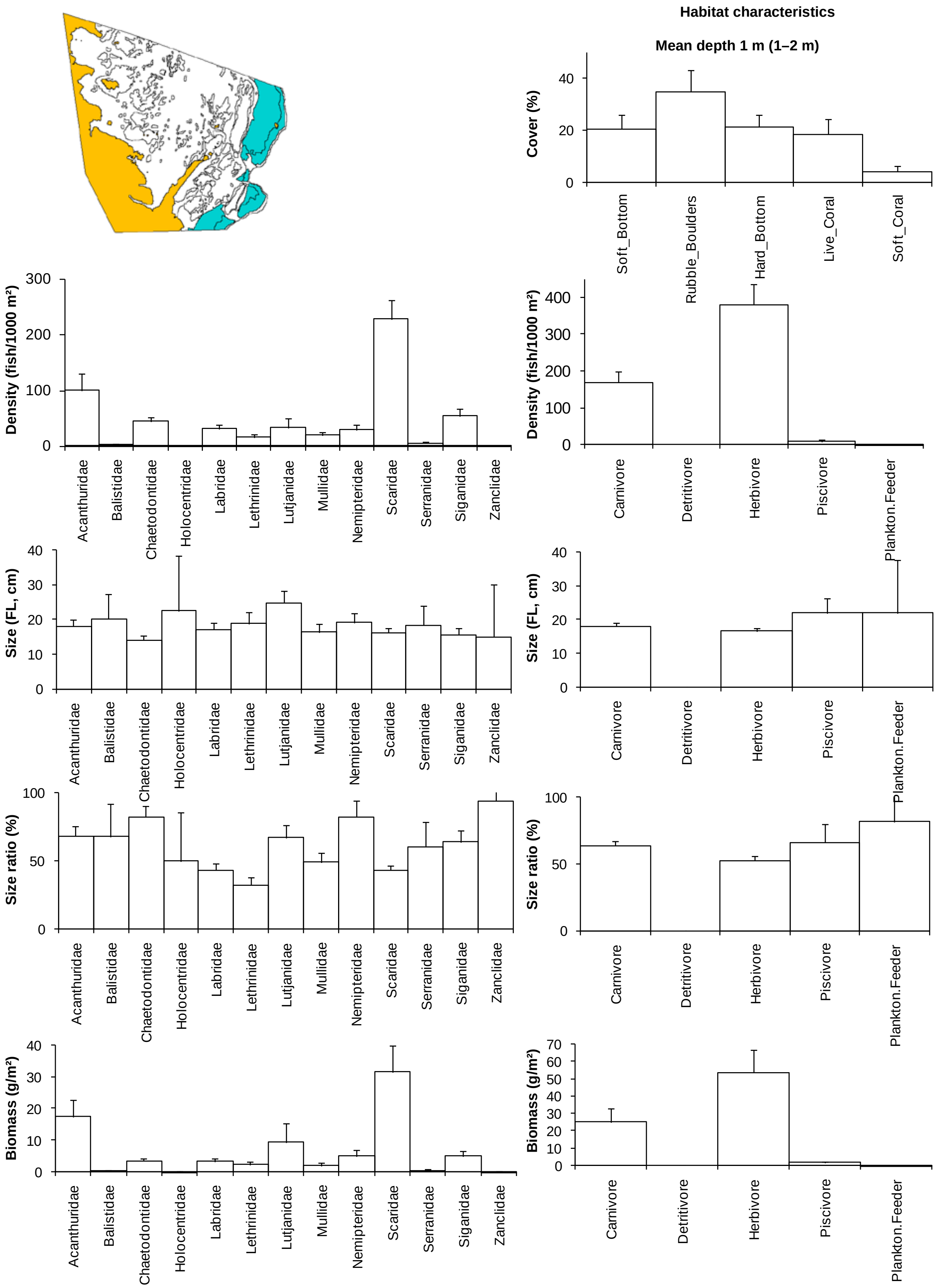

Figure 2.22: Profile of finfish resources in the back-reef environment of Dromuna.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Dromuna

The outer reef of Dromuna was largely dominated, in terms of density and biomass, by herbivorous Acanthuridae and Scaridae, and by carnivorous Chaetodontidae (only in terms of density) and Lutjanidae (Figure 2.23). The three major families were represented by a total of 44 species, dominated by *Chlorurus sordidus*, *Ctenochaetus striatus*, *Zebrasoma scopas*, *Lutjanus fulviflamma*, *Scarus altipinnis* and *Scarus schlegeli* (Table 2.10). Hard-bottom cover (49%) highly dominated the habitat and cover of live coral was fairly good (25%, Table 2.6 and Figure 2.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04 ±0.01	5.0 ±0.9
	Scarus altipinnis	Filamentfinned parrotfish	0.02 ±0.02	7.6 ±6.1
	Scarus schlegeli	Schlegel's parrotfish	0.02 ±0.01	2.6 ±0.7
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.01 ±0.01	2.6 ±0.7
	Zebrasoma scopas	Twotone tang	0.04 ±0.01	2.1 ±0.6
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.03 ±0.02	8.4 ±4.6

The density of fish in the outer reef of Dromuna was lower than in the back-reefs but higher than at the other reef habitats. However, size, size ratio, biomass and biodiversity were the highest at the site. Trophic structure was dominated by herbivores, equally composed of Scaridae and Acanthuridae. Carnivores were less diverse and represented mainly by Lutjanidae and, to a much lesser extent, Labridae. Size ratios were below 50% of maximum for Labridae, Lethrinidae and Mullidae. The composition of the habitat, dominated by hard bottom and live coral (74%), clearly favoured herbivores and disadvantaged soft-bottom associated carnivores, such as Lethrinidae and Mullidae.

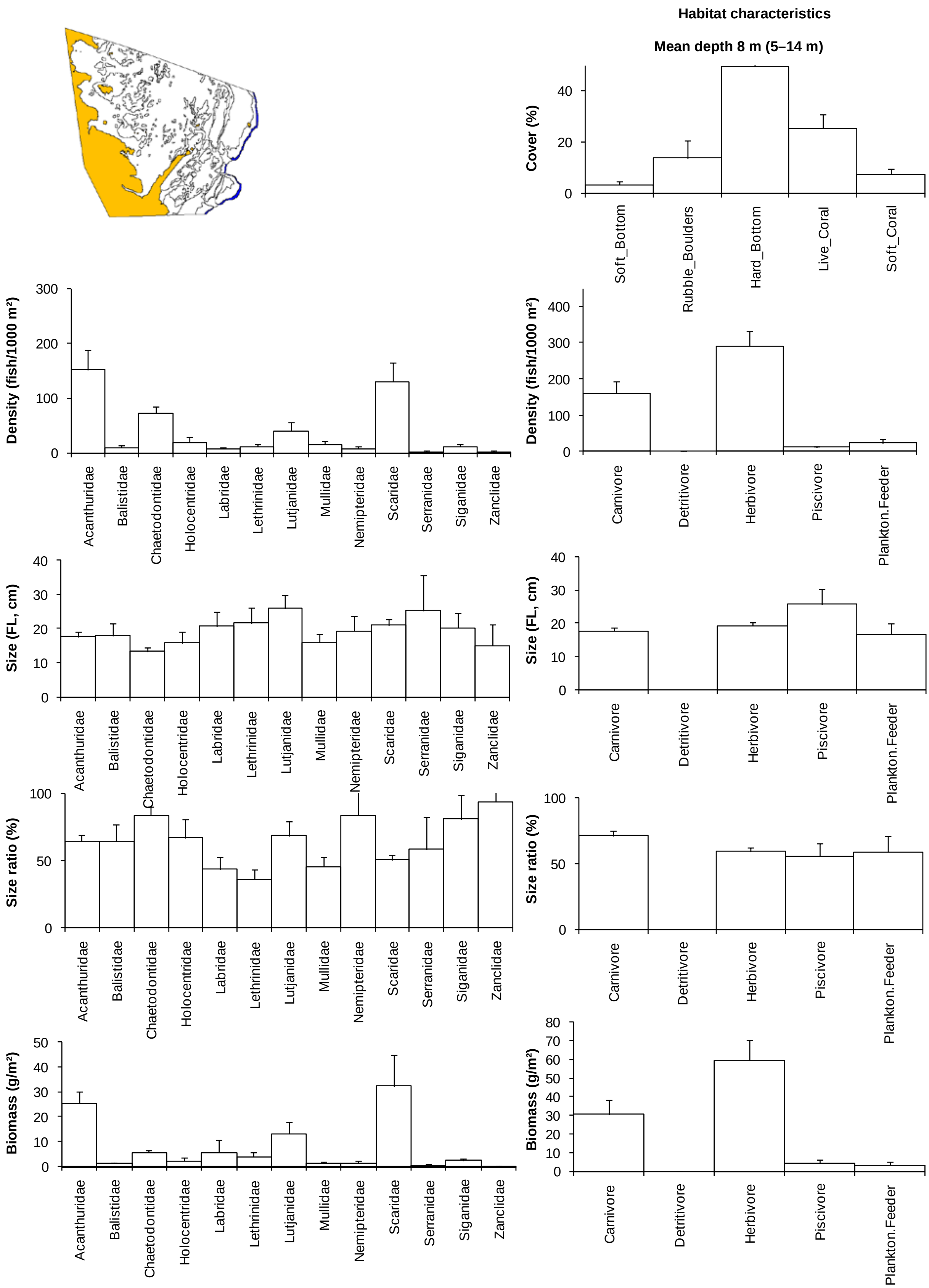

Figure 2.23: Profile of finfish resources in the outer-reef environment of Dromuna.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Dromuna

Overall, the reefs of Dromuna were heavily dominated by two main herbivorous families, Scaridae and Acanthuridae (Figure 2.24). These two families were represented by a total of 42 species, dominated by *Chlorurus sordidus*, *Scarus schlegeli*, *S. rivulatus* and *Ctenochaetus striatus* (Table 2.11). Overall, soft bottom, hard bottom and rubble cover equally composed the substrate and live coral cover was fairly good (17%, Table 2.6 and Figure 2.24). The overall fish assemblage in Dromuna shared characteristics of primarily intermediate reefs (44% of total habitat), then back-reefs (33%), sheltered coastal reefs (20%) and only to a small extent outer reefs (3%).

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

Family	Species	Common name	Density (fish/m²)	Biomass (g/m²)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06	8.9
	Scarus schlegeli	Schlegel's parrotfish	0.02	3.5
	Scarus rivulatus	Rivulated parrotfish	0.02	2.6
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05	11.1

Overall, Dromuna appeared to support an average finfish resource, with biodiversity similar to that found in Muaivuso and Mali and higher than in Lakeba, density and size similar to values in Muaivuso and Lakeba, but biomass lower than the Mali and Lakeba values. However, overall comparisons are more meaningful when Dromuna is compared to Mali and Lakeba, which both present the four reef types. In this context, Dromuna is described as having a low-to-average resource status in the country. The detailed assessment at the level of fish-community composition revealed poorer density and biomass of carnivorous species compared to herbivores, which strongly dominated the fish community. Piscivores and planktivores were basically absent. Few families dominated the community and a general lack or serious scarcity of piscivores was the dominant profile; however, a few carnivorous species were present, although in very low numbers and biomass. The dominance of herbivores cannot be explained by the composition of the habitat, equally composed of soft and hard substrate, which would normally favour many different families with different requirements. The study of size and size ratio trends disclosed the presence of smaller fish in the carnivorous families, indicating an impact from fishing on such a highly preferred target group.

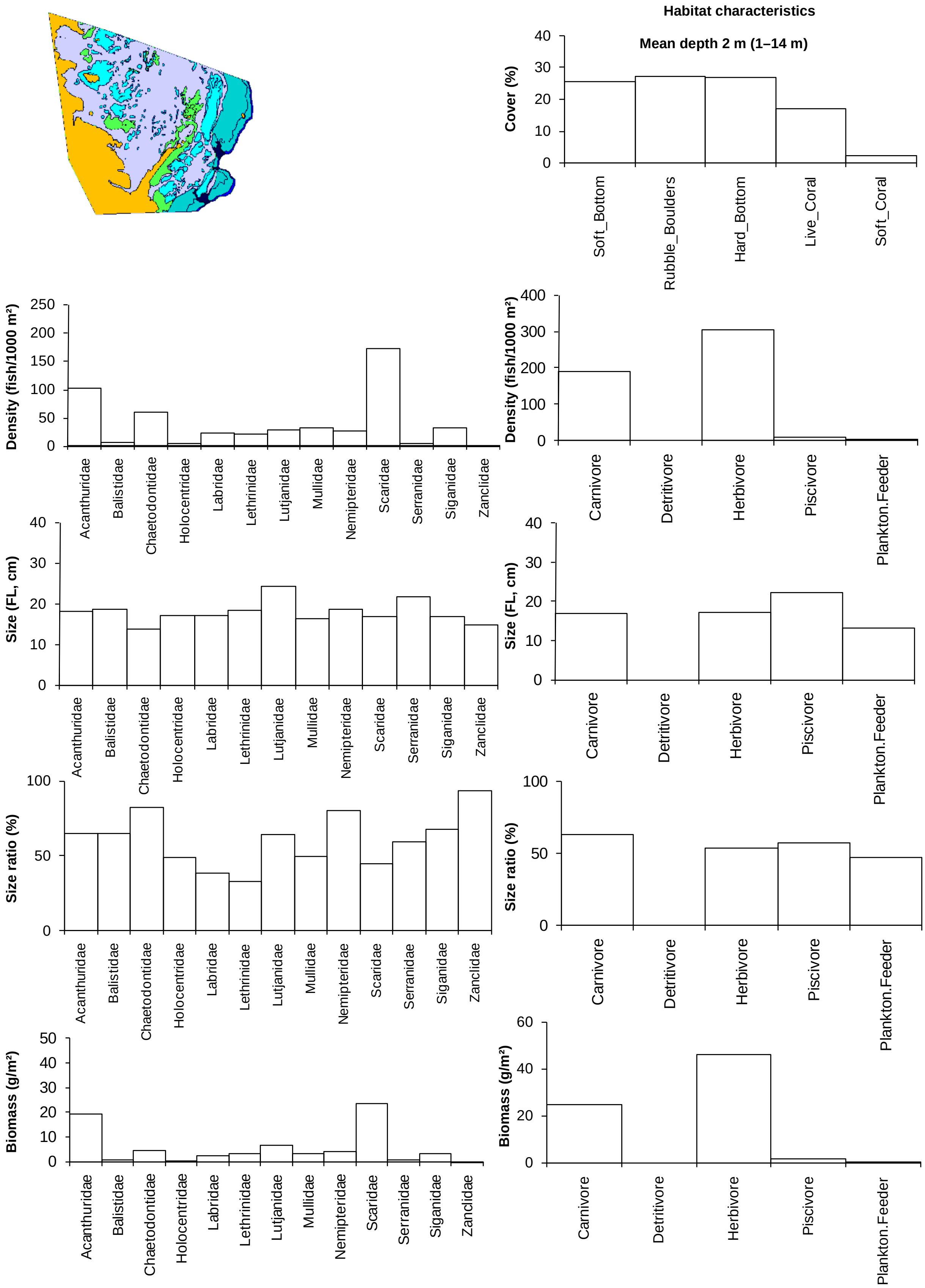

Figure 2.24: Profile of finfish resources in the combined reef habitats of Dromuna (weighted average).
FL = fork length.

2.3.2 Discussion and conclusions: finfish resources in Dromuna

The assessment of finfish resources in Dromuna indicated that the status of finfish resources at the time of surveys was average. Density was fairly good but biomass quite low compared to the country and regional averages. Size and size ratio were comparable to values at the two other sites Muaivuso and Lakeba, but lower than at Mali. Biodiversity was in the country range but higher than at Lakeba. At a detailed analysis at family level, Scaridae consistently displayed very high abundance and biomass, but rather small average size. This family was, however, represented by several species. Carnivores were present but in much lower importance than herbivores. However, piscivores (such as Serranidae) were almost absent. Some families displayed sizes much lower than the maximum ever-recorded values (below 50% of the known maximum values) suggesting a response from heavy fishing. The amount of stock and the health of the fish community increased with the move from the coastal, to the intermediate, back- and outer reefs. Dromuna is one of the most urbanised and populated of the four villages visited, with the highest number of boats but the lowest dependency on fishing for income generation.

- Resources were overall in average condition. The inner reefs were poorer than the outer reefs.

- Density, biomass and diversity of fish were higher in the outer reefs but the fish-community composition was still dominated by herbivores.

- Scaridae was the most abundant family in the coastal, back- and outer reefs.

- Size ratios of several families were below 50% of their maximum known value: Lethrinidae, Mullidae, Labridae, Holocentridae and Scaridae fell into this category, suggesting a response from heavy fishing.

2.4 Invertebrate resource surveys: Dromuna

The diversity and abundance of invertebrate species at Dromuna were independently determined using a range of survey techniques (Tables 2.12a for 2003; 2.12b for 2009): broad-scale assessment (using the 'manta-tow' technique; locations shown in Figure 2.25a for 2003 and 2.25b for 2009) and finer-scale assessment of specific reef and benthic habitats (Figures 2.26a and 2.27a for 2003; Figures 2.26b and 2.27b for 2009).

The broad-scale assessment was conducted by 'manta-tow', the main objective being to describe the distribution pattern of invertebrates (rareness/commonness, patchiness) at large scale and, importantly, to identify target areas for further, fine-scale assessment. Then, fine-scale assessment was conducted in target areas to specifically describe the status of resource in those areas of naturally higher abundance and/or most suitable habitat. In 2003, an estimated 28,867 m² area was assessed, while in 2009 the area assessed was twice as large at an estimated 57,674 m². The fishing ground referred to in this study as Dromuna belongs to the *qoliqoli* of Kaba, which is openly accessed by several villages in the area.

Table 2.12a: Number of stations and replicate measures completed at Dromuna in 2003

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	6	38 (1) transects
Reef-benthos transects (RBt)	3	18 transects
Soft-benthos transects (SBt)	7	42 transects
Soft-benthos infaunal quadrats (SBq)	4	32 (2) quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches	0 RFs 0 RFs_w	0 search period 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	0	0 search period

RFs = reef-front search; RFs_w = reef-front search by walking. (1) Transects were 350 m in length; (2) SBq stations are made of eight groups of four quadrats of 0.25 m x 0.25 m in size completed over a 40 m transect length (total surface assessed per station = 2 m²).

Table 2.12b: Number of stations and replicate measures completed at Dromuna in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	8	48 (1) transects
Reef-benthos transects (RBt)	12	72 transects
Soft-benthos transects (SBt)	5	30 transects
Soft-benthos infaunal quadrats (SBq)	4	32 (2) quadrat groups
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	2	12 search periods
Reef-front searches	3 RFs 0 RFs_w	18 search periods 0 search period
Sea cucumber night searches (Ns)	3	27 search periods
Sea cucumber day searches (Ds)	2	12 search periods

RFs = reef-front search; RFs_w = reef-front search by walking. (1) Transects were 350 m in length; (2) SBq stations are made of eight groups of four quadrats of 0.25 m x 0.25 m in size completed over a 40 m transect length (total surface assessed per station = 2 m²).

Figure 2.25a: Broad-scale survey stations for invertebrates in Dromuna in 2003.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 2.25b: Broad-scale survey stations for invertebrates in Dromuna in 2009.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 2.26a: Fine-scale reef-benthos transect stations and soft-benthos transect stations for invertebrates in Dromuna in 2003.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

Figure 2.26b: Fine-scale reef-benthos transect survey stations and soft-benthos transect stations for invertebrates in Dromuna in 2009.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

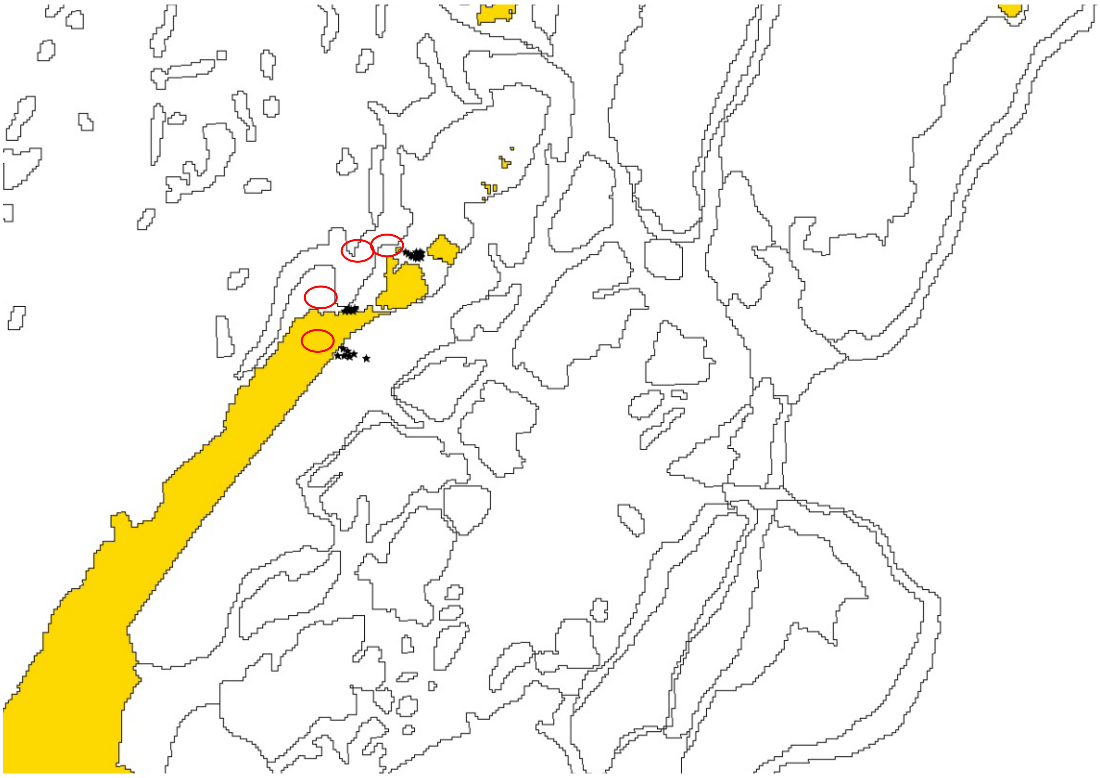

Figure 2.27a: Fine-scale survey stations for invertebrates in Dromuna in 2003.
Black stars: soft-benthos infaunal quadrat stations (SBq).
The red circles mark the two northerly sites in a channel distant from the main settlement, site 3 is found in front of the village, while site 4 was to the east of Dromuna.

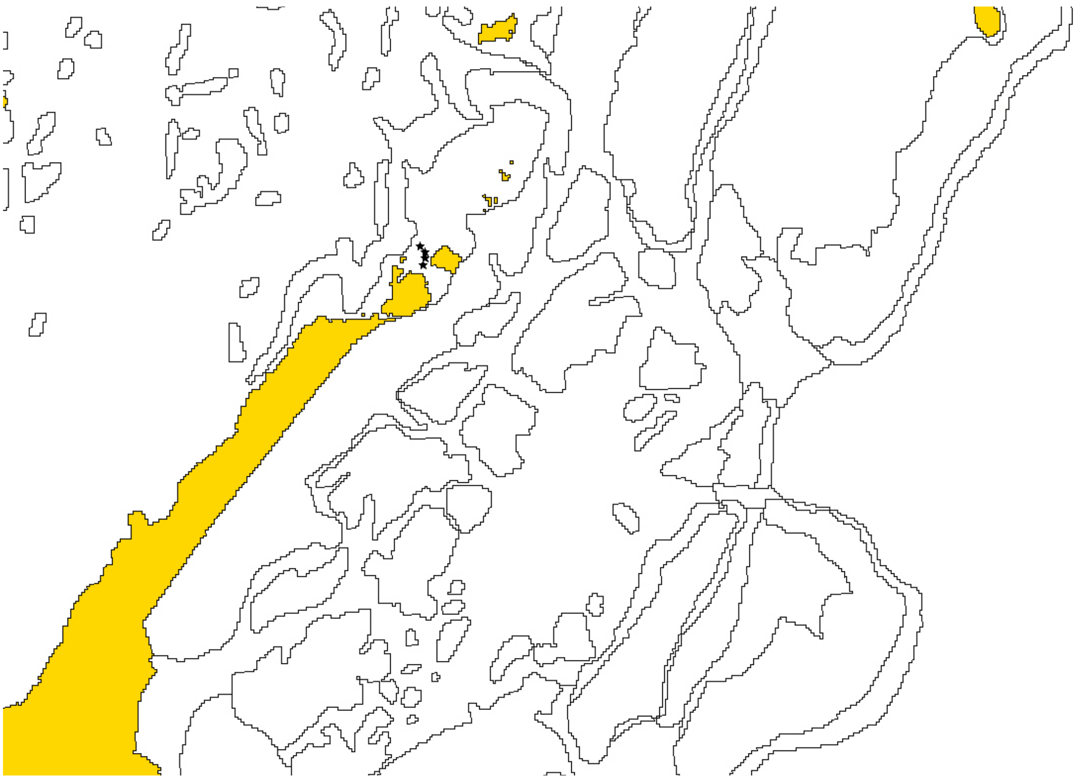

Figure 2.27b: Fine-scale survey stations for invertebrates in Dromuna in 2009.
Black stars: soft-benthos infaunal quadrat stations (SBq).

In 2003, fifty-eight species or species groupings (groups of species within a genus) were recorded in the Dromuna invertebrate surveys. Among these were 14 bivalves, 15 gastropods, 18 sea cucumbers, 4 starfish and 5 urchins (Appendix 4.1.1a).

In 2009, forty-one species or species groupings (groups of species within a genus) were recorded in the Dromuna invertebrate surveys. Among these were 5 bivalves, 13 gastropods, 18 sea cucumbers, 3 starfish and 1 urchin (Appendix 4.1.1b). Information on key families and species is detailed below.

2.4.1 2003–2009 stock status trends – giant clams: Dromuna

The lagoon reefs at Dromuna provided extensive habitat for giant clams (total area of reef 36.2 km², 30.8 km² inside the lagoon study area), and at a far greater scale than was available at Muaivuso (the other PROCFish site on Viti Levu). The reef comprised mainly shallow, intermediate patch and barrier reef, with little coastal fringing reef. There was noticeable land influence (high nutrient levels), with high algae and epiphyte cover, and siltation of reef surfaces. Most intermediate reef comprised predominantly rubble and mixed benthos, and the best areas of live coral were restricted to the edges of deeper-water channels. The coverage of brown algae *Sargassum* spp. was moderate to high, covering significant parts of the shallow-reef benthos. There was dynamic water flow across the barrier reef (especially through the passes to the east, southeast and south of Dromuna) and a large area of reef outside the lagoon (5.4 km² of exposed reef front and slope). Again, this was more extensive than in the other study area on Viti Levu.

Two species of clams were recorded at Dromuna both in 2003 and 2009, the elongate clam *Tridacna maxima* and the fluted clam *T. squamosa*. Broad-scale sampling provided an overview of giant clam distribution and, in these surveys, *T. maxima* had the widest occurrence (found in 5/6 broad-scale stations and 11/38 transects in 2003 and 4/8 stations and 5/48 transects in 2009) followed by *T. squamosa* (3/6 stations and 4/38 transects in 2003 and 2/8 stations and 2/48 transects in 2009, see Figures 2.28a and 2.28b).

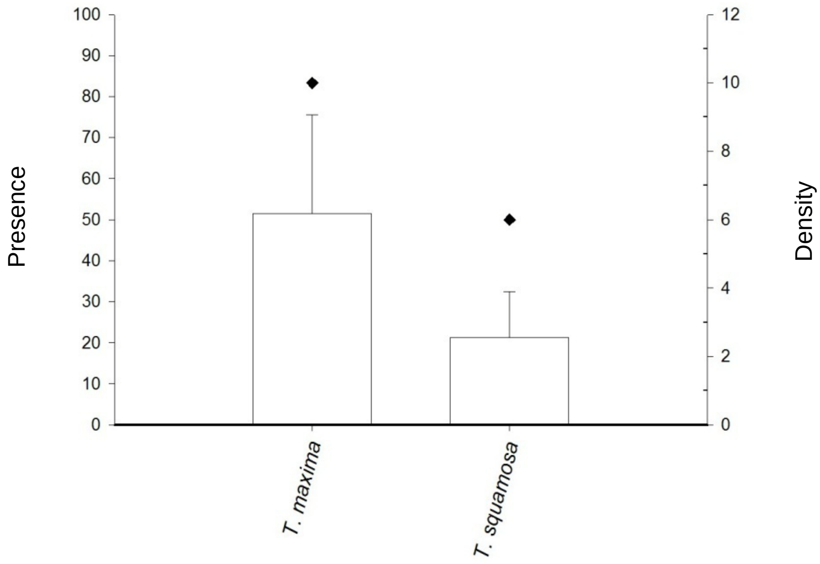

Figure 2.28a: Presence and mean density of giant clam species at Dromuna based on broad-scale survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

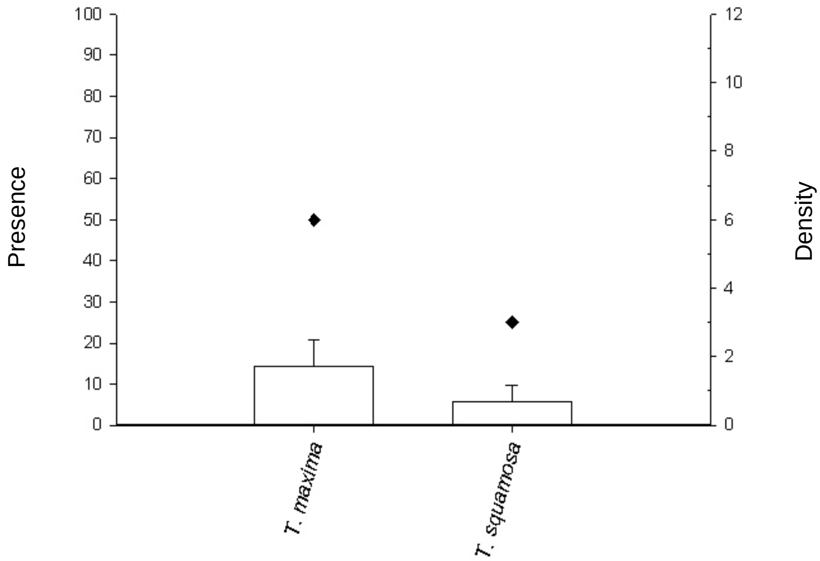

Figure 2.28b: Presence and mean density of giant clam species at Dromuna based on broad-scale survey in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Finer-scale surveys targeted specific areas of clam habitat (Figures 2.29a and 2.29b).

In 2003, during these reef-benthos assessments (RBt), *T. maxima* were present in 66% of survey stations (Figure 2.29a). The elongate clam was recorded in sparse distribution (clams were noted in only 22% of replicates from RBt stations) and at a low mean density of 55.6 /ha ±36.7. No fluted clams were recorded, but this is not surprising considering the low density at which they were recorded at broad scale and the limited number of RBt stations made.

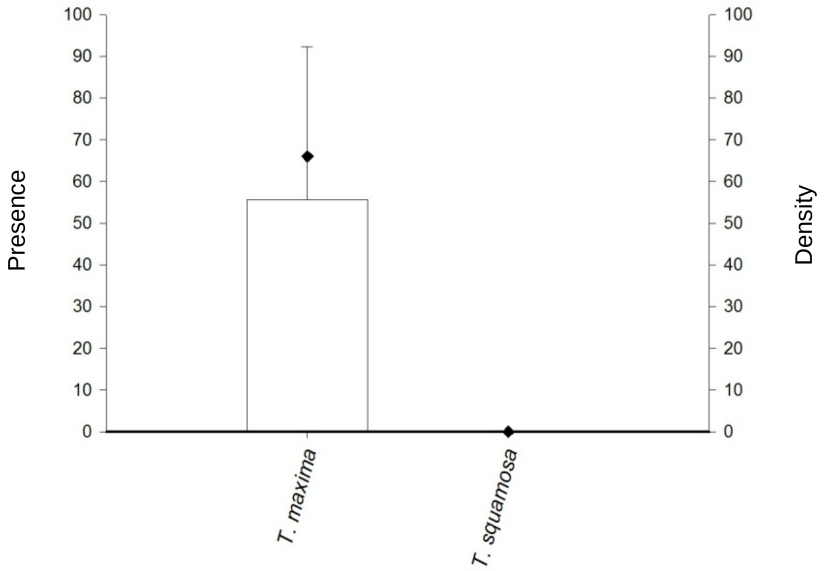

Figure 2.29a: Presence and mean density of giant clam species at Dromuna based on fine-scale reef-benthos transect survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

In 2009, *T. maxima* were present in 58% of survey stations and 11% of the replicates (Figure 2.29b). They were at a low mean density of 27.8 /ha ±7.8. Fluted clams were recorded twice, making them present at 17% of survey stations and at only 3% of the replicates. They were at a critically low mean density of 6.9 /ha ±4.7.

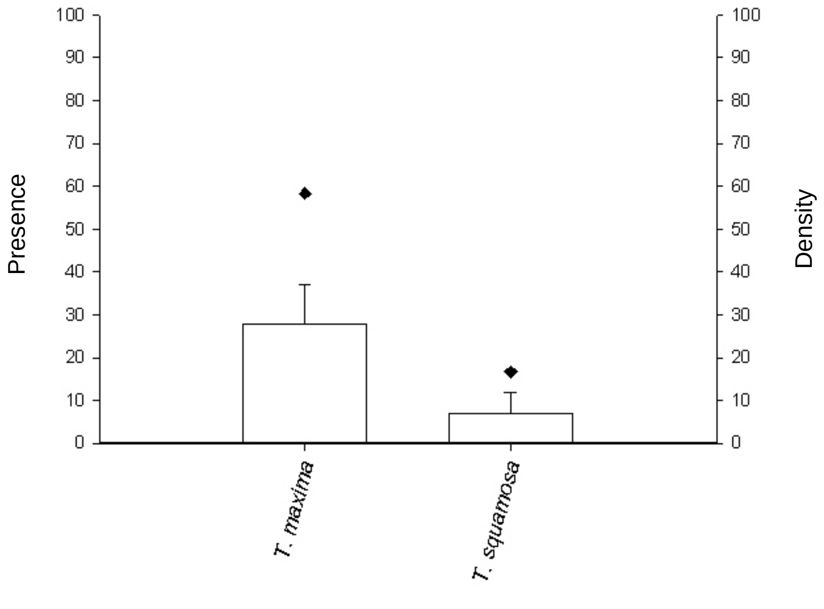

Figure 2.29b: Presence and mean density of giant clam species at Dromuna based on fine-scale reef-benthos transect survey in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

In 2003, a total of twenty *T. maxima* (mean length 17.6 cm ±1.4) and seven *T. squamosa* (mean length 26.2 cm ±3.0) were recorded during reef and broad-scale assessments (Figure 2.30a).

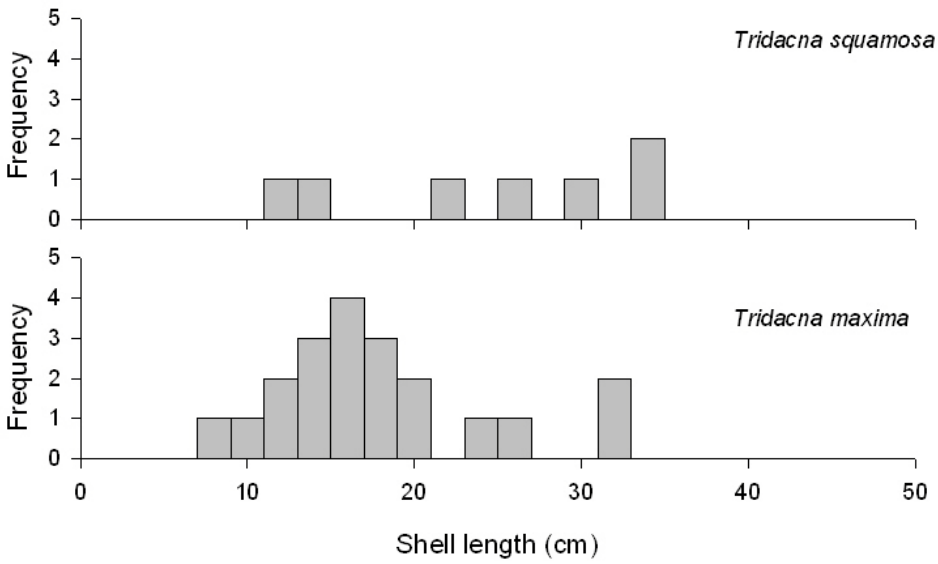

Figure 2.30a: Size frequency histograms of giant clams (*Tridacna squamosa* and *Tridacna maxima*) shell length (cm) for Dromuna in 2003.

In 2009, a total of seventeen *T. maxima* (mean length 18.6 cm ±2.9) and seven *T. squamosa* (mean length of 26.8 cm ±5.5) were recorded during reef and broad-scale assessments (Figure 2.30b). A large proportion of the giant clams was noted during the broad-scale assessment, which does not allow measurement (manta-tow). The number of measurements is low and does not provide robust information.

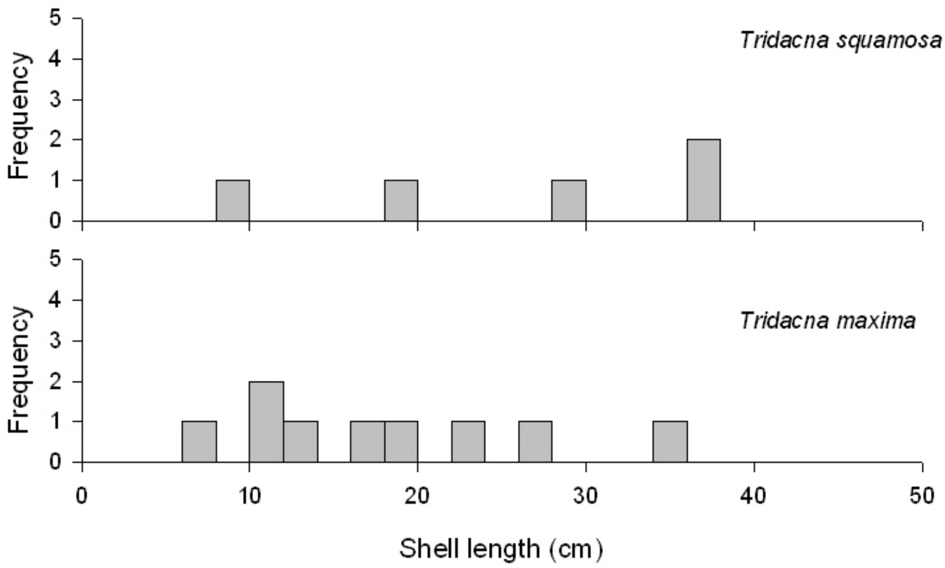

Figure 2.30b: Size frequency histograms of giant clams (*Tridacna squamosa* and *Tridacna maxima*) shell length (cm) for Dromuna in 2009.

In 2003, although clams were scarce, a full range of possible lengths of *T. maxima* was recorded in survey. The mean size of *T. maxima* (17.6 cm) represents a clam over six years old, and the presence of small and large individuals showed that stocks were still receiving recruitment despite their low abundance. The faster growing *T. squamosa* (which grows to an asymptotic length L_∞ of approximately 40 cm) had a large mean size (average 26.2 cm, also approximately 6–7 years old), and smaller specimens were also present (Figure 2.30a).

In 2009, giant clams of both species were scarcer than in 2003, but average sizes and the size ranges remained similar to those observed in 2003. Recruitment still occured but in very low numbers (Figure 2.30b).

2.4.2 2003–2009 stock status trends – mother-of-pearl species (MOP): Dromuna

The barrier reef, back-reef and patch reefs in the lagoon at Dromuna provide a significant suitable habitat for the commercial topshell *Trochus niloticus* (The barrier reef had an outer lineal distance of ~23.2 km.). The exposed reef was subject to large swells at certain times of year and had little in the way of offshore shoals to hold large densities of commercial topshells. However, rubble on the back- and intermediate reefs was linked to the barrier and presented extensive areas of suitable nursery ground for juvenile settlement and growth. In general, water movement was strong in the outer lagoon areas and there was no shortage of grazing for these herbivores in this land-influenced system.

In 2003, *T. niloticus* were recorded in both broad-scale and reef-benthos transect stations at low density (Table 2.13a). The green topshell *Tectus pyramis* (of low commercial value and with similar distribution and life history characteristics to trochus) was also recorded in these assessments. The presence and density of these species were low for the pearl oyster *Pinctada margaritifera* and *T. niloticus*, and moderate for *T. pyramis* although, as stated, the habitat was excellent for grazing gastropods in Dromuna and the assessments were not as comprehensive as one would have liked (56 B-S and RBt replicates, but no mother-of-pearl stations or reef-front searches). Targeted MOP surveys would have provided a more complete assessment of the status of trochus aggregations on the barrier reef at Dromuna.

In 2009, a more complete assessment was realised, including MOPs and RFs stations. The densities observed had declined since 2003 and were well below the level at which a stock is considered healthy. The threshold adopted by the invertebrate PROCFish team before considering stock fishable for *T. niloticus* is 500–600 specimens/ha. Those levels are observed in several well managed fisheries in the Pacific. In Dromuna, all assessment types revealed very low density levels.

Table 2.13a: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Dromuna in 2003
Based on various assessment techniques; mean density measured in numbers per ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Pinctada margaritifera				
B-S	6.0	1.9	5/6 = 83	9/38 = 24
RBt	0	0	0/3 = 0	0/18 = 0
Tectus pyramis				
B-S	1.5	0.7	2/6 = 33	4/38 = 11
RBt	208	208	1/3 = 33	4/18 = 22
Trochus niloticus				
B-S	0.8	0.5	2/6 = 33	2/38 = 5
RBt	41.7	41.7	1/3 = 33	3/18 = 17

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

Table 2.13b: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Dromuna in 2009
Based on various assessment techniques; mean density measured in numbers per ha (±SE).

	Density	SE	% of stations with species	% of transects or search periods with species
Pinctada margaritifera				
B-S	1.4	0.7	4/8 = 50	4/48 = 8
RBt	3.5	3.5	1/12 = 8	1/72 = 1
RFs	0		0/3 = 0	0/18 = 0
MOPs	0		0/2 = 0	0/12 = 0
Tectus pyramis				
B-S	0		0/8 = 0	0/48 = 0
RBt	24.3	18.1	2/12 = 17	5/72 = 7
RFs	3.5	2.0	2/3 = 67	3/18 = 17
MOPs	9.4	9.4	½ = 50	2/12 = 17
Trochus niloticus				
B-S	0		0/8 = 0	0/48 = 0
RBt	13.9	9.4	2/12 = 17	3/72 = 4
RFs	0		0/3 = 0	0/18 = 0
MOPs	12.5	6.2	2/2 = 100	3/12 = 25

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

In the 2003 survey, the mean size (basal width) of trochus *T. niloticus* was 8.6 cm ±1.5 (n = 5). The mean size for the green topshell *T. pyramis* was smaller at 5.6 cm ±0.2 (n = 18). Three of the trochus found in RBt assessments ranged in size from 5.5–7.1 cm basal width, which represents trochus of approximately 2–3 years old.

In the 2009 survey, the mean size of trochus was 9.6 cm ±0.4 (n = 13). The mean size for green topshell was 6.6 cm ±0.2 (n = 12). One juvenile of 5–6 cm basal length was recorded, showing that recruitment had occurred in the recent past (Figure 2.31).

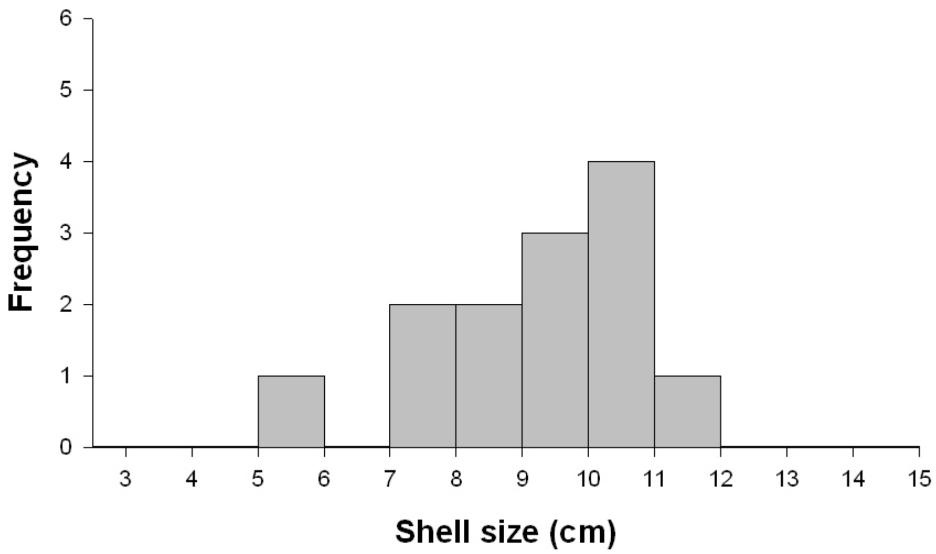

Figure 2.31: Size frequency histogram of *Trochus niloticus* shell length (cm) for Dromuna in 2009.

Pinctada margaritifera, a normally cryptic and sparsely distributed pearl oyster species, was recorded in 2003 at five of the six broad-scale stations (24% of transects). The mean size of blacklip pearl oysters recorded in 2003 was 14.6 cm ±0.6 (n = 15). Taking into account the cryptic nature of *P. margaritifera* and its general low density in the open reef systems characteristic of Melanesia, these results describe a medium-to-high presence of *P. margaritifera*.

In the 2009 survey, a single blacklip pearl oyster was measured at 11.0 cm and only five specimens were recorded. Today, the density observed is low compared to densities observed at other sites in the Pacific.

2.4.3 2003–2009 stock status trends – infaunal species and groups: Dromuna

Dromuna and other lagoon systems in Fiji Islands support notable stocks of *Anadara* spp. (arc shells), known locally as *kaikoso*. *Kaikoso* refers to several species of *Anadara*. *Kaikoso* inhabit shellfish beds that are actively targeted by fishers. Juvenile *Anadara* settle among seagrass roots, in crevices and on coral boulders and other suitable hard surfaces. *Anadara* spp. are fast growing, reaching full size in the fourth year (L_∞ = 8.4 cm), although they are usually fished in the 4–6 cm length range.

Concentrations of in-ground resources (shell beds) were reportedly fished at Dromuna, and assessments were made at four areas close to the main settlement (24 soft-benthos quadrat stations in 2003; see Figure 2.27a). Soft-benthos areas found within the lagoon were generally sandy with some rubble and coral outcrops. Seagrass was common at all infaunal sampling sites, and the pseudo passage north of Dromuna was particularly muddy compared to the other sampling areas closer to the village.

Kaikoso distribution was skewed towards the two northerly sites; 82% of quadrat groups held *kaikoso* at the two northerly areas, compared to 8% of quadrat groups at the two locations nearer the village (See Methods.). The overall mean station density for *kaikoso* was 9.9 /m² ±2.8, although arc shells at the two northerly sampling areas had a higher mean station density (19.3 /m² ±4.0) than the sites closer to the village (0.5 /m² ±0.1). Shell collection from sites in the north (creel survey) yielded between 170 and 290 shells per hour, at an average size and weight of 4.8 cm ±0.1 and 34.1 g ±1.5. The largest arc shell was 6.5 cm (88 g).

Mean shell length for all stations was 4.6 cm ±0.6 (size range 2.1–8.3 cm; see Figures 2.32 and 2.33), with some of the largest shells found east of the village (Figures 2.27a and 2.33).

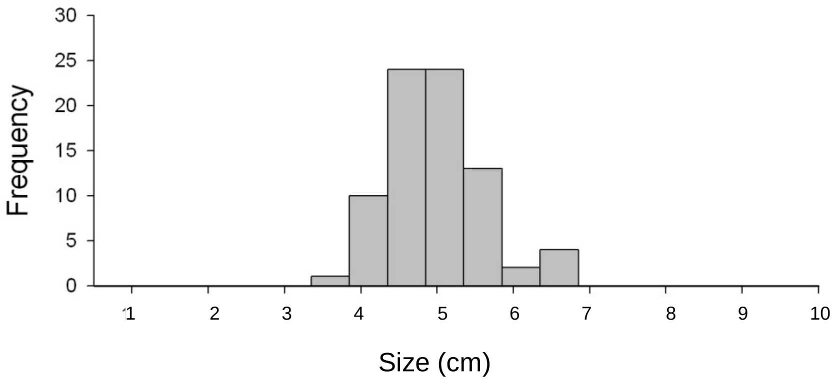

Figure 2.32: Size frequency histogram of arc shell length (cm) from catches sampled at Dromuna in 2003 (n = 78).

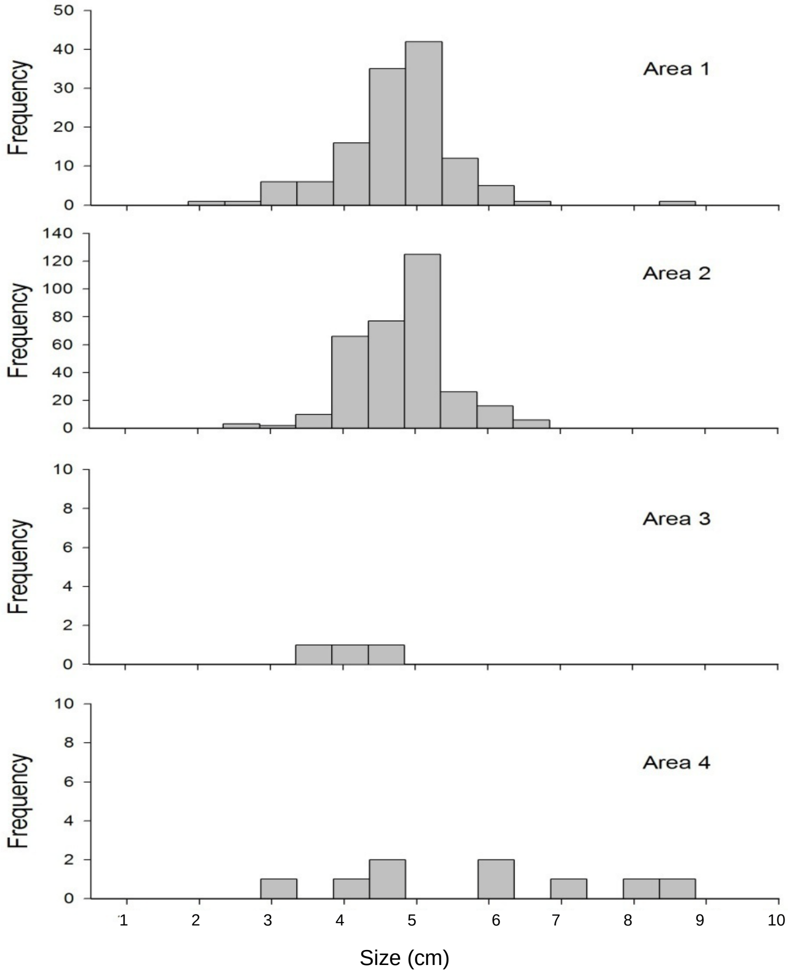

Figure 2.33: Size frequency histograms of arc shell length (cm) from the four areas sampled at Dromuna in 2003.
Sites one and two are found to the north, site three adjacent to the village, and site four east of the village.

As is often the case with sites receiving good settlement of infaunal bivalves (sites 1 and 2), the large number of shells has the potential to restrict growth due to competition among individuals for food and space. This effect may be operating here at the stations with the highest density of *Anadara* spp. Despite the average shell size being smaller at the higher-density locations (sites 1 and 2), 27–32% of all shells sampled were still ≥5 cm in length.

In addition to arc shells, other important bivalve resources recorded at low density were venus shells (*Gafrarium tumidum*), mussels (*Modiolus* spp.), hardshell clams (*Periglypta puerpera*), prow pitar (*Pitar proha*) and the palate tellin (*Tellina palatum*). *Strombus gibberulus gibbosus*, the humped conch (*golea* or *gera*), was also noted.

In 2009, assessment coverage was not as extensive as in 2003 (Figures 2.27b and 2.34), with only four stations covered compared to 24 in 2003. Nevertheless, stations were surveyed in the same area as in 2003, and areas 1 and 2 were the stations with the highest density. The density levels for *Anadara* spp. were much lower than in 2003. High fishing pressure may be one of the explanations of the observed decline, but the assessment revealed as well a lot of recently dead *Anadara* spp. still in place in the sand. The periostracum of the shell was still intact and specimens of all sizes were present, which suggests a recent peak of mortality hitting the population. We have no understanding of the origin of this mortality; we can only suggest a pollution or disease event. The station close to the passage had only dead shells, while the other ones further away had more live specimens.

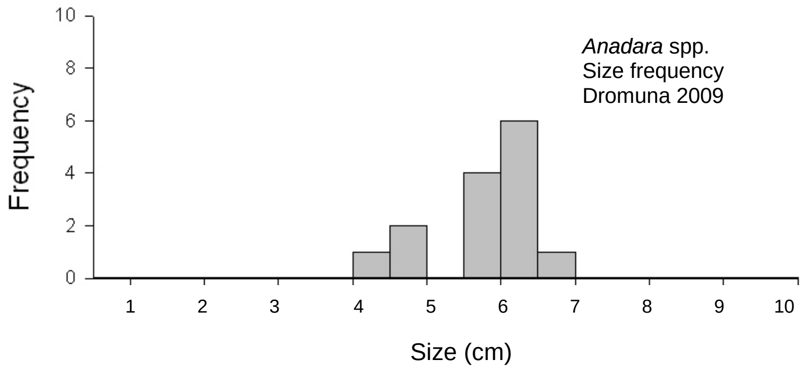

Figure 2.34: Size frequency histogram of arc shell length (cm) from the four areas sampled at Dromuna in 2009.

2.4.4 2003–2009 stock status trends – other gastropods and bivalves: Dromuna

In both the 2003 and 2009 surveys, two spider conch species were recorded: *Lambis lambis* (*yaga* or *ega*) and the larger of the conch species *L. truncata*.

Both species were recorded on broad-scale stations at similar densities in 2003 and 2009, but *L. lambis* was absent from the more dedicated technique SBt in 2009, while at moderately high density in 2003 (Appendices 4.1.1 to 4.1.6). *L. truncata* were also noted at low density in 2003 and at very low density in 2009.

Strawberry conch shells, *Strombus luhuanus*, were found at low density in 2003 (recorded in 21% of broad-scale transects) and at very low density in 2009 (recorded in 4% of broad-scale transects).

Turbo spp. (*la*), which are commonly collected along exposed reef fronts in the Pacific, were uncommon in both the 2003 and 2009 surveys.

Other resource species targeted by fishers (e.g. *Cerithium*, *Conus*, *Cypraea*, *Dolabella*, *Littoraria*, *Latirolagena*, *Polinices*, *Strombus* and *Vasum*) were recorded during independent survey (See lists in Appendices 4.1.1 to 4.1.6 for 2003 and Appendices 4.1.1 to 4.1.10 for 2009).

Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina*, *Hyotissa*, *Pinna*, *Spondylus* and *Trachycardium*, are also in Appendices 4.1.1 to 4.1.6 for 2003 and Appendices 4.1.1 to 4.1.10 for 2009.

In 2003, creel surveys were conducted at Dromuna. These included a catch survey from sea cucumber fishers coming to sell their wet produce to a marine products trader following one night's worth of collection (4 February 2003, at least 19 fishers), and a second catch from six fishers who had been gleaning on soft benthos with some patches of reef (6 February 2003). Both these catches are listed in Appendix 4.1.8 for 2003.

No creel survey was done in 2009.

2.4.5 2003–2009 stock status trends –lobsters and crabs: Dromuna

There was no dedicated night reef-front assessment of lobsters (See Methods.), and no lobsters were recorded at Dromuna either in 2003 or 2009. In the 2009 mission, a female fisher was seen with a catch of five pieces of rock lobster (*Panulirus versicolor*) ready to be taken to the Nausori market to be sold at FJD 17–18 /kg. No size measurement could be made but the catch include a juvenile (undersized), two medium (either under or legal size) and one good sized lobster. Toberua Island Resort no longer buys lobsters from the village in an attempt to discourage further harvesting.

Mud crabs, *Scylla serrata*, would be found in the mangroves fringing the shoreline; however, a snapshot independent survey would not supply a reliable indication of crab abundance and was not conducted in this survey period. The fishery for mud crabs is active in Dromuna; one fisher in 2009 collected 5–6 animals weekly for sale at Nausori market at FJD 12 /kg. One dead mud crab was observed caught in a gillnet that was set overnight on seagrass near the mangrove.

2.4.6 2003–2009 stock status trends – sea cucumbers[6]: Dromuna

Dromuna sits on a headland (or spit) which reaches east from the Viti Levu mainland into a shallow lagoon system. The lagoon is extensive and complex (the study area almost 100 km²), and is largely land-influenced, as the large Navuloa river discharges from the northerly base of the headland. The lagoon itself is mostly sheltered (The inshore areas support mangroves.) and supports a maze of mixed hard- (reticulated reef) and soft-benthos patches, with deeper-water channels linking the inshore system to the more oceanic-influenced and exposed barrier reef. Close to the mainland, water flow is limited, although in the relatively exposed east, water flow through the two main passes in the barrier ensures there is greater mixing of lagoon and oceanic water. The barrier reef was subject to a high degree of wave action and the outer-reef slope fell off relatively steeply into deep water.

Most areas within the lagoon are very suitable for commercial deposit feeders such as sea cucumbers (Sea cucumbers eat organic matter in the upper few mm of bottom substrates.). Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Tables 2.14a, 2.14b; Appendices 4.1.2 to 4.1.6 for 2003 and Appendices 4.1.2 to 4.1.10 for 2009; also see Methods).

In the 2003 survey, seventeen species of commercial sea cucumbers and one indicator species were recorded during in-water assessments (Table 2.14a).

In 2009, seventeen species of commercial sea cucumber and one indicator species were also recorded during in-water assessments (Table 2.14b). In 2003, *Actinopyga echinites*, *Holothuria leucospilota* and the high-value species *H. nobilis* were reported, but were not recorded in the 2009 survey. In 2009, *A. mauritiana*, *H. fuscopunctata* and *Thelenota anax* were reported, but they were not recorded in 2003. The new species reported can be explained by the fact that dedicated assessment techniques in specific habitats were used in

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

the 2009 survey that were not used in 2003; RFs and MOPs stations were surveyed in the breakers and on the outer slope where *A. mauritiana* lives, and Ds stations were completed at depth, where *T. anax* is usually recorded. The last newly reported species, *H. fuscopunctata* was reported only as one specimen in one RBt station. In 2009, 12 of these stations were surveyed as compared to only three in 2003; therefore it is likely that the single specimen could have been missed in 2003.

In 2003, sea cucumber species associated with reef, the medium-value leopardfish (*Bohadschia argus*) and the low-value flowerfish (*B. graeffei*), were not rare (recorded in 37% and 16% of broad-scale transects) but occurred at relatively low density. The high-value black teatfish (*Holothuria nobilis*), which is found on both inshore and back-reefs and at a range of depths, was present but rare (in 3% of broad-scale transects). This species, which is easily targeted by fishers, was recorded at low density (<1 /ha), which is the lowest density recorded during the PROCFish programme.

In 2009, the leopardfish (*B. argus*) was rare (in 6% of broad-scale transects) and at critically low density, while the flowerfish (*B. graeffei*) was uncommon (in 12.5% of broad-scale transects) and at low density. *H. nobilis* was not recorded, which means that this high-valued species is under great threat.

In 2003, the fast growing medium- / high-value greenfish (*Stichopus chloronotus*) was recorded in 33% of RBt stations at a very low density.

In 2009, *S. chloronotus* was recorded in 25% of RBt stations but at a very low density compared to the density recorded in 2003.

In 2003, the medium / high-value surf redfish (*Actinopyga mauritiana*), a species living on more exposed reef, was not recorded in survey as its typical habitat was not assessed.

In 2009, *A. mauritiana* was recorded sparsely distributed and at low densities.

More protected areas and embayments (soft benthos with small patches of reef) were common in the lagoon and adjacent to Dromuna village.

In 2003, the curryfish (*Stichopus hermanni*) was relatively common and at reasonable density on soft benthos, but not common overall at Dromuna. The brown sandfish (*Bohadschia vitiensis*) was also relatively common (near Toberua Island), as were the lower-value lollyfish (*Holothuria atra*) and pinkfish (*H. edulis*). Interestingly, deep-water redfish (*Actinopyga echinites*) a medium- / high-value species that is generally sparsely distributed across sites in the Pacific, was relatively common on soft benthos at Dromuna (in 43% of SBt stations). This species was also common at Muaivuso, the other PROCFish site on Viti Levu.

In 2009, *S. hermanni* was uncommon and found at low density on soft-benthos stations. Brown sandfish was also uncommon and at low density. Lollyfish and pinkfish were recorded commonly, but at low densities. Deep-water redfish was not recorded at all.

In 2003, the nocturnal species, the higher-value blackfish *Actinopyga miliaris* (*dri*) was common on soft benthos (in 71% of stations, 37% of transects) and found at high density (mean of 267 /ha on SBt stations). At a single station on the rich muds and seagrass near shell beds (at the pseudo passage north of the settlement) the mean density for *A. miliaris* was

1167 /ha. The blackfish at this site were small and not found hidden among limestone structures, but buried in the sediment (Figure 2.35).

In 2009, this species was relatively rare and was not found during daytime on the soft benthos as it was in 2003 but at night time, and at moderate density.

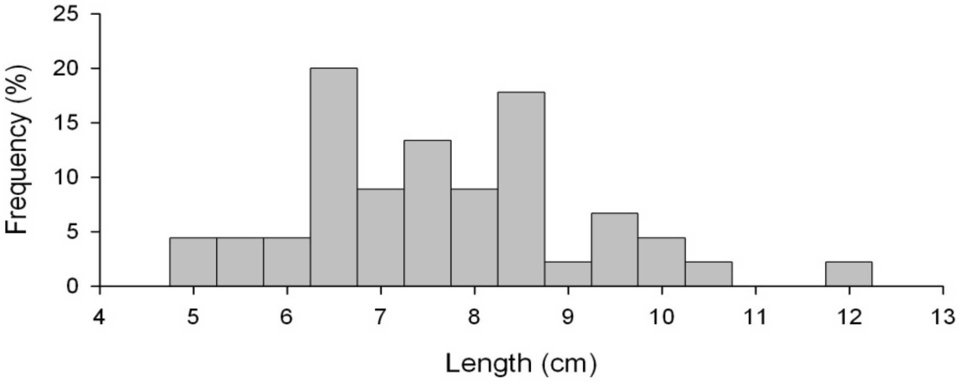

Figure 2.35: Size frequency histogram of blackfish *Actinopyga miliaris* (*dri*) from soft-benthos assessment stations in Dromuna, in 2003.

In 2003, false sandfish (*Bohadschia similis*), which are often found at the same sites as the higher-value sandfish, were relatively abundant at Dromuna on soft benthos (mean of 303.6 /ha at SBt stations). Although the high-value sandfish (*H. scabra*) cannot legally be exported from Fiji Islands, it was targeted by artisanal fishers and sold to marine products agents. Nevertheless, the species was still noted at reasonably high density at suitable soft-benthos habitats that were surveyed at Dromuna (mean density 291.7 /ha ±163.2). Sandfish are valued in Fiji Islands as a local food source and are especially vulnerable to overfishing as their range is usually limited to small areas in protected, shallow-water areas, which are easily targeted by fishers.

In 2009, the false sandfish was recorded only once and the high-value sandfish, even though still under the protection of the commercial export ban, had become rare, with only three specimens recorded during the survey, at the low density of 25.0 /ha ±25.0. Density for this species can reach several thousand specimens per hectare in the best habitats. We estimate that the minimum threshold to consider a stock at good density level is 1000–1200 species/ha.

In 2003, fishers were actively targeting sea cucumbers during our visit to Dromuna, (especially blackfish *A. miliaris*, sandfish *H. scabra* and brown sandfish *B. vitiensis*). We recorded the sale of 4202 individuals, predominantly *dri* or blackfish, for which Fiji Islands is well known (Figure 2.36). Fishing was conducted at night with torches, and produce was brought to the shore wet, where a local marine products buyer bought the catch. Creel records were collected during our time at this site (See Appendix 4.1.8 for 2003.). At the sale area we also noted that there was a relatively high level of discarding, whether of species that had not been transported well (dry in sacks), or of species from the *Stichopus* family, whose body walls had started to break down after removal from the water. Individual species of this family require careful handling and prompt processing after collection.

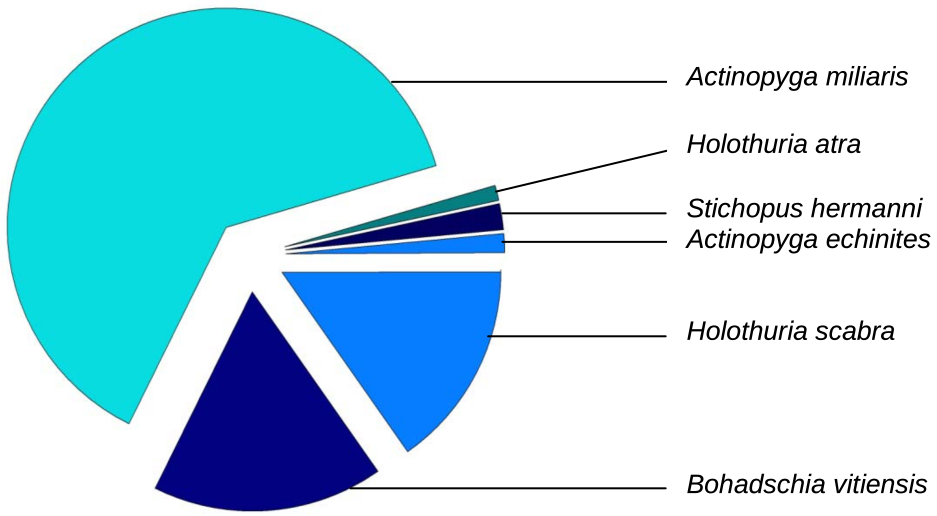

Figure 2.36: Species of sea cucumbers sold to the marine products trader (as a percentage of total number) at Dromuna from night fishing on the 4 February 2003.

In 2009, fishers were still fishing at night. The PROCFish team met females who were going to sell their previous night's catch; bêche-de-mer were 'first cooked', i.e. boiled once but not yet gutted. Products included *A. miliaris*, *S. hermanni* and *B. vitiensis*; the latter two species were sold as 'first cooked', while the former was sold fresh or alive. Blackfish is a high-value species in Fiji Islands and can be traded fresh, alive or dried. In Dromuna, larger specimens of blackfish are sold at a higher price (FJD 5.00 /kg) than smaller ones, which are sold at FJD 4.00 /kg. Tigerfish (*B. argus*) was sold fresh to the processor, who buys the product at FJD 3.00 per piece. All sea cucumber products are sold to a processor trader based in Nakelo Landing. Unfortunately, time did not allow a creel survey to be conducted and there are no data available to compare with the 2003 data.

In 2003, no SCUBA deep dives, or sea cucumber day searches (25–35 m depth) that would have enabled a preliminary assessment of deep-water stocks such as the high-value white teatfish (*Holothuria fuscogilva*), prickly redfish (*Thelenota ananas*) and lower-value amberfish
(*T. anax*) were completed at Dromuna. However, both white teatfish (*H. fuscogilva*) and prickly redfish (*T. ananas*) were recorded in shallow water using other survey techniques.

In 2009, two deep dives were completed. These revealed *H. fuscogilva* and *T. anax*; the latter species was not reported in 2003. Both *H. fuscogilva* and *T. anax* were recorded at very low densities. According to the local fishers, *H. fuscogilva* was collected in significant numbers in the past using SCUBA and hookah in the lagoon and passage area.

2.4.7 2003–2009 stock status trends – other echinoderms: Dromuna

In 2003, no edible slate urchins (*Heterocentrotus mammillatus*) were found at Dromuna; however, collector urchins (*Tripneustes gratilla*) were present (n = 10). *T. gratilla* were present across the lagoon (in 66% of RBt stations) and on one soft-benthos station near the village, but were not common. Mean densities reached a maximum of 291 /ha on RBt stations. No collector urchins were seen in the gleaners' catches. The smaller, inedible *Mespilia globulus* was recorded at relatively high density on soft benthos (mean density as high as 6042 /ha). It is not documented whether this species competes with *T. gratilla* for food or benthos, which could impact the potential for collector urchin numbers.

Echinothrix spp. (mainly *E. diadema*) and *E. mathaei* were found at moderate-to-high density in RBt stations (792–1833 /ha). The blue starfish (*Linckia laevigata*) was common (in 63% of B-S transects and 66% of RBt stations) and at moderately high densities (mean of 361.1 /ha ±182.2 on reef-benthos stations). Only ten coralivore (coral eating) starfish were recorded at Dromuna; eight cushion stars (*Culcita novaeguineae*) and two crown-of-thorns starfish (*Acanthaster planci*, COTS). Neither of these starfish were at high density (Appendices 4.1.1 to 4.1.6 for 2003).

In 2009, only one slate urchin was recorded on the surf zone. The absence of this species from 2003 records is due to the lack of assessment of the surf zone, which was the typical habitat of the slate urchin in 2003. In contrast, the collector urchin, commonly recorded in 2003, was not recorded in 2009, confirming that all species used for subsistence were rare. The smaller, inedible *Mespilia globulus* was recorded at relatively high density in soft infaunal quadrats. In other assessments, the species was not recorded due to its non-commercial value and the difficulty of detecting them (They cover themselves with debris and hide in seagrass and algae, making it virtually impossible to record accurately.). Species such as *Echinometra mathaei* and *Echinothrix diadema* were present, but the actual recordings are not accurate enough to make a decent comparison with the 2003 records.

The blue starfish (*Linckia laevigata*) was the most common invertebrate species recorded during the 2009 survey, with 351 specimens. It was present in 71% of B-S transects and 75% of RBt stations and at relatively high densities (mean of 555.6 /ha ±203.6 on RBt stations). Thirty-two coralivore (coral eating) starfish were recorded at Dromuna; seven cushion stars (*Culcita novaeguineae*) and 25 crown-of-thorns starfish (*Acanthaster planci*, COTS). COTS were locally recorded at relatively high density in broad-scale transects. Monitoring the crown-of-thorns starfish is important as it has the potential to be very destructive to coral cover if densities become high; one starfish can devour as much as 2–6 m^2 of coral each year. These starfish begin to eat coral at about six months of age (1 cm) and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several COTS per square metre and they can kill most of the living coral in an area of reef, reducing coral cover from the usual 25–40% of the reef surface to less than 1%, which can take up to a decade to recover (Appendices 4.1.1 to 4.1.10 for 2009).

On the Great Barrier Reef of Australia, the following system is used for defining COTS outbreaks:

- *Incipient outbreak* - The density at which coral damage is likely. Occurs when there are 0.22 adults per 2-minute ‘manta-tow’; or >30 adults and subadults per hectare, where subadults are 15–25 cm diameter (2 years old) and adults are >26 cm (>3 years old), using SCUBA diving counts (N.B. starfish may be mature at 2 years or 20 cm diameter, but for the definition of an outbreak >26 cm is used.).
- *Active outbreak* - COTS densities are >1.0 adults per 2-minute ‘manta-tow’, and adults are >15 cm diameter; or >30 adult-only starfish per ha if SCUBA diving.

2.4.8 Algae, seaweed and live coral

The growth of the brown algae (*Sargassum* spp.), as in the other Fiji Island sites, was greater than normal and covered potential shallow-reef benthos. The mean algal coverage in the shallow lagoon areas was 10–20% in all the assessment types. This could be normal in these locations due to the nutrient enrichment received from terrestrial discharges. Concentrated algal cover can potentially impact larval settlement, which can affect the recruitment of invertebrates. Live-coral growth inside the lagoon and back-reef was low (<20%) but relatively more healthy outside the barrier reef, with >30% coverage.

Table 2.14a: Sea cucumber species records for Dromuna in 2003

Species	Common name	Commercial value [5]	B-S transects n = 38			RBt stations n = 3			SBt stations n = 5			SBq stations n = 24		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H							35.7	83.3	43			
Actinopyga lecanora	Stonefish	M/H	0.8	28.6	3									
Actinopyga mauritiana	Surf redfish	M/H												
Actinopyga miliaris	Blackfish	M/H							267	373.8	71			
Bohadschia argus	Leopardfish	M	7.5	20.4	37	41.7	125	33						
Bohadschia graeffei	Flowerfish	L	2.6	16.7	16				6	41.7	14			
Bohadschia similis	False sandfish	L							303.6	708.3	43			
Bohadschia vitiensis	Brown sandfish	L	28.2	119	24				53.6	93.8	57			
Holothuria atra	Lollyfish	L	22.6	35.7	63				83.3	145.8	57			
Holothuria coluber	Snakefish	L												
Holothuria edulis	Pinkfish	L	4.5	21.4	21	27.8	41.7	66						
Holothuria fuscogilva [4]	White teatfish	H	0.4	14.3	3									
Holothuria fuscopunctata	Elephant trunkfish	M												
Holothuria leucospilota	Black fringed	L	0.4	14.3	3									
Holothuria nobilis [4]	Black teatfish	H	0.8	28.6	3	13.9	41.7	33						
Holothuria scabra	Sandfish	H							291.7	510.4	57	200 [6]	5000 [6]	4
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	1.9	17.9	11	13.9	41.7	33						
Stichopus hermanni	Curryfish	H/M	0.4	14.3	3				488.1	854.2	57			
Stichopus horrens	Peanutfish	H/M							28.9	67.5	43			
Stichopus vastus	Brown curryfish	M/H												
Synapta spp.	-	-	1.1	21.4	3				2148	3008	71			
Thelenota ananas	Prickly redfish	H	0.8	14.3	5									
Thelenota anax	Amberfish	M												

[1] D = mean density (numbers/ha); [2] DwP = mean density (numbers/ha) for transects or stations where the species was present; [3] PP = percentage presence (units where the species was found); [4] the scientific name of the black teatfish has recently changed from *Holothuria* (*Microthele*) *nobilis* to *H. whitmaei* and the white teatfish (*H. fuscogilva*) may have also changed name before this report is published. [5] L = low value; M = medium value; H= high value; H/M is higher in value than M/H; [6] the density is taken from a measure appropriate for infaunal bivalves, which is not representative for sea cucumbers; B-S transects= broad-scale transects; RBt = reef-benthos transect; SBt = soft-benthos transect; SBq = soft-benthos infaunal quadrats.

Table 2.14b: Sea cucumber species records for Dromuna in 2009

Species	Common name	Commercial value [5]	B-S transects n = 48			Other stations RBt = 12; SBt = 5			Other stations RFs = 3; MOPs = 2; SBq = 4			Other stations Ds = 2; Ns = 3		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H												
Actinopyga lecanora	Stonefish	M/H										5.1	7.6	67 Ns
Actinopyga mauritiana	Surf redfish	M/H				3.5	41.7	8 RBt				2.5	7.6	33 Ns
Actinopyga miliaris	Blackfish	M/H	0.3	16.7	2							73.6	110.4	67 Ns
Bohadschia argus	Leopardfish	M	1.0	16.7	6	24.3 8.3	145.8 41.7	17 RBt 20 SBt				8.8	2.0	23 Ds
Bohadschia graeffei	Flowerfish	L	2.4	19.4	12.5	3.5	41.7	8 RBt	15.6	15.6	100 MOPs			
Bohadschia similis	False sandfish	L							0.1	0.5	25 SBq			
Bohadschia vitiensis	Brown sandfish	L	8.0	27.4	29	3.5	41.7	8 RBt				12.7	19.0	67 Ns
Holothuria atra	Lollyfish	L	33.0	68.8	48	66.0	113.1	58 RBt						
Holothuria coluber	Snakefish	L												
Holothuria edulis	Pinkfish	L	5.9	35.4	17	59.0	236.1	25 RBt				5.1 2.2	15.2 2.0	33 Ns 23 Ds
Holothuria fuscogilva [4]	White teatfish	H	0.3	16.7	2							2.2	2	91 Ds
Holothuria fuscopunctata	Elephant trunkfish	M				3.5	41.7	8 RBt						
Holothuria leucospilota	Black fringed	L												
Holothuria nobilis [4]	Black teatfish	H												
Holothuria scabra	Sandfish	H				25.0	125.0	20 SBt						
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	3.1	50.0	6	13.9	55.6	25 RBt	3.1 2.3	6.2 3.5	50 MOPs 66 RFs			
Stichopus hermanni	Curryfish	H/M	2.8	44.4	6	50.0	250.0	20 SBt				2.5	7.6	33 Ns
Stichopus horrens	Peanutfish	M/L										2.5	7.6	33 Ns
Stichopus vastus	Brown curryfish	H/M												
Synapta spp.	-	-	1	25	4.2	25	62.5	40 SBt						
Thelenota ananas	Prickly redfish	H	1.0	25.0	4.2									
Thelenota anax	Amberfish	M										1.1	2.0	45 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; RBt = reef-benthos transect; SBt = soft-benthos transect; RFs = reef-front search; MOPs = mother-of-pearl search; SBq = soft-benthos infaunal quadrats; Ds = day search; Ns = night search.

2.4.8 Discussion and conclusions: invertebrate resources in Dromuna

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

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

- A wide range of reef environments suitable for giant clams was present in the intermediate and outer reaches of the lagoon system at Dromuna.

- The number of clam species recorded at Dromuna was low in 2003 and critically low in 2009. The elongate clam (*Tridacna maxima*) and fluted clam (*T. squamosa*) were the only two species noted. The true giant clam *T. gigas* and the horse-hoof or bear's paw clam *Hippopus hippopus* are considered extinct in Fiji Islands.

- Clam distribution and abundance showed significant depletion from what would be considered a healthy state. Noting the extensive reef area in the lagoon and the good exchange of lagoon and oceanic water, the distribution of clams was sparse, and abundance in the most suitable areas low. This result may have been partially due to the nature of the reef environment (sandy with high levels of algae, and the potential for episodic periods of heavy runoff from land sources), but fishing has undoubtedly played a major role in this depletion.

- At this low density, strong management of giant clam stocks is needed to enable sufficient recruitment to maintain the current status. For clam abundance to increase and for stocks to rebuild to a more 'healthy' level, there needs to be greater protection of the remaining stocks and some years of favourable conditions for breeding and settlement.

- When clam density falls below threshold levels across the reefs in the lagoon, this results in fewer successful fertilisation events (Sperm and eggs fertilise in the water column after release by male and female clams.). As clams have a complex development, which means that only the larger (older) individuals become female (protandry), the regular harvest of larger *T. maxima* and *T. squamosa* clams also leads to a shortage in egg supply.

- The habitat at Dromuna is especially suitable for the horse-hoof or bear's paw clam *Hippopus hippopus*. If there was to be re-introduction of this species, Dromuna could be considered as a potential release site, as the broken (patchy) bottom, sandy reef areas found inshore at Dromuna are well suited to this free-standing species.

Data on the distribution, density and length recordings of MOP species revealed the following:

- The reefs at Dromuna offered a range of hard-benthos intermediate and barrier-reef structures that would support commercial quantities of the topshell *Trochus niloticus*.

- From the limited data available on trochus distribution and abundance in 2003, we suggest that stock in Dromuna was present but sparsely distributed and at low density. In 2009, wider assessment confirmed the low density level. The level observed seems even to have declined since 2003.

- The smaller shell sizes for the trochus found in reef-benthos transects both in 2003 and 2009 supports the assumption that local recruitment was still occurring, despite the low density of trochus recorded in the lagoon.

- More trochus would have been noted if this location had not been impacted by fishing. From the preliminary surveys conducted, it would seem the fishery for trochus at Dromuna is depleted.

- Other mother-of-pearl stocks, such as the blacklip pearl oyster *Pinctada margaritifera* and green topshell *Tectus pyramis* (of low commercial value), were recorded in survey at medium density in 2003 but at low density in 2009.

- From the sample of live specimens collected in 2009, the average size of arc shells (*Anadara* spp.) was 5.9 cm ±0.2, which is a strong increase since 2003. This higher average size might be explained by the fact that larger specimens would have been more resistant than juveniles due to the unexplained peak of mortality.

- In 2003, shell beds to the north of Dromuna held moderately large numbers of arc shells *Anadara* spp. (*kaikoso*) at a range of size classes. Density and size range measures of arc shells from these areas describes a resource with good recruitment that is moderately impacted by fishing. Closer to Dromuna the benthos held fewer *Anadara* spp. In 2009, shell beds to the north of Dromuna held low numbers of *Anadara* spp., probably partially due to fishing pressure and to an unexplained mortality event.

Other species of bivalve and gastropod infaunal resources were present at low density.

Data on the habitat, distribution and density of sea cucumbers suggest the following:

- Lagoon habitat suitable for sea cucumbers was extensive at Dromuna.

- The majority of commercial sea cucumbers are deposit feeders that consume particles in the bottom sediments. The protected, land-influenced lagoon at Dromuna was suitable for a large range of species.

- The high total of 21 species of sea cucumbers recorded at this site (adding species numbers from the 2003 and 2009 surveys) reflects the diversity of environments present in Dromuna, including a predominantly land-influenced lagoon system.

- In the 2003 survey, the presence and density of sea cucumbers were considered relatively healthy for some medium- and low-value species. Careful monitoring of curryfish (*Stichopus hermanni*), brown sandfish (*Bohadschia vitiensis*) and blackfish (*Actinopyga miliaris*) at Dromuna could supply periodic but regular harvests with controlled fishing.

- In the 2003 survey, the presence and density of some medium/high- to high-value species, such as greenfish (*Stichopus chloronotus*), surf redfish (*Actinopyga mauritiana*), black teatfish (*Holothuria nobilis*) and sandfish (*H. scabra*) were more of a concern, and these species were considered impacted by fishing.

- During the 2003 surveys, sea cucumbers were subject to fishing pressure (night and day). One night harvest saw the removal of 4202 individuals, predominantly *dri* or blackfish, although other medium- and high-value species were sold. Current levels of commercial collection were too high at that time for sustainable management of these stocks.

- In 2009, all species of low/medium-to-high-value species were sparsely distributed and at low to critically low density.

- In 2009, despite the already weak level of density observed in 2003, the sea cucumber fishery was still active and night fishing continued to be practised. The export ban on sandfish is not efficient, as authorisation for local consumption seems to have a strong effect on stock depletion.

- Sea cucumber stocks at Dromuna as well as at the three other Fiji Island sites are at a critically low level. Densities of all species of interest are among the weakest observed across all the sites assessed in the Pacific.

2.5 Overall recommendations for Dromuna

- There is an urgent need to manage the finfish and invertebrate resources at Dromuna, with community-based management the best approach and the most likely to succeed.

- Rigorous awareness programmes need to be developed and implemented to educate people and communities on the need for management to sustain resources on a long-term basis.

- The community is advised to allocate certain areas of the coastal reef and associated mangrove areas as management or reserve sites.

- A monitoring system needs to be set in place as part of management arrangements to follow any further changes in finfish and invertebrate resource status.

- Strong management of giant clam stocks is needed to enable sufficient recruitment to maintain the current status.

- If a marine reserve is established, larger clams should be collected and placed in the reserve for protection to allow them to spawn and regenerate stocks over time.

- If the horse-hoof or bear's paw clam *Hippopus hippopus* is to be re-introduced, Dromuna should be considered as a potential release site, as the broken (patchy) bottom sandy reef areas found inshore at Dromuna are well suited to this free-standing species.

- A total ban on fishing the trochus stocks is required for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered. This ban should be enforced at the village level, as well as at the provincial and national levels.

- Reintroduction of trochus to the Dromuna outer-reef front is highly recommended, especially if the total ban is imposed.

- The subsistence use of trochus shell for food or handicrafts should be banned in the village.

- The management of sea cucumbers needs to be strengthened, and a total national ban implemented for at least 10 years (with no exceptions) and enforced to allow all of the commercial species to recover.

- Harvesting of juvenile lobsters and egg-bearing female lobsters was observed in 2009. We recommend that regulations on harvestable size limitations and on the harvest of egg-bearing lobsters or crustaceans in general be urgently developed and adopted.

3. PROFILE AND RESULTS FOR MUAIVUSO

3.1 Site characteristics

Muaivuso is a small, traditional community located close to Fiji Islands' capital, Suva on the island of Viti Levu (Figure 3.1). Muaivuso is a coastal fishing village where people have relatively good access to alternative income sources, including employment in the close-by urban areas. Public transport is easily accessible from the village. Fishers from the community sell their finfish catch to middlemen, shopkeepers, restaurants and at the two major markets, Lami and Suva. Invertebrates are caught and sold at the Suva markets at weekends, but some commercial species, including lobsters, are caught for restaurants or, in the case of bêche-de-mer, sold directly to Suva-based exporters. Most of the available reef was too shallow to cross at low tide. Water flow across the barrier and across the shallow lagoon was dynamic, originating from the east. The outer reef was exposed and the slope shelved steeply. Muaivuso is a study site for USP students and is often referred to as being well or over-studied, considering the smallness of the area. A community marine protected area (MPA) was set up over 60% of the reef from the middle of the reef flat up to the reef edge.

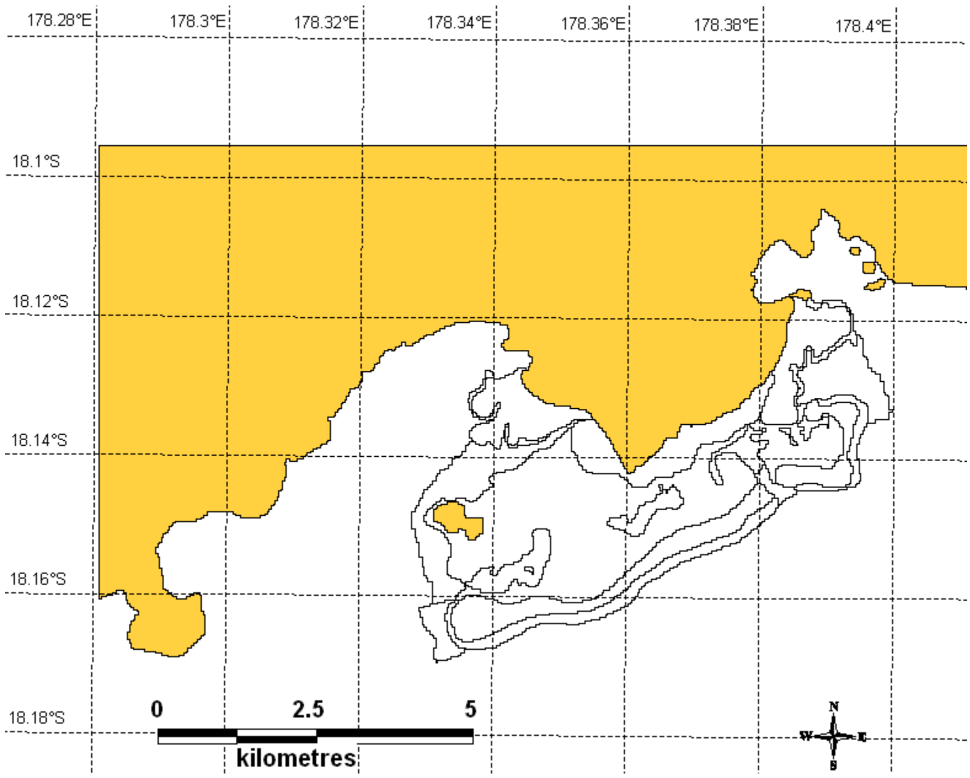

Figure 3.1: Map of Muaivuso.

3.2 Socioeconomic surveys: Muaivuso

Socioeconomic fieldwork was carried out in Muaivuso, located about 30 minutes by road west of Lami town and the capital city Suva, from 18 to 22 June 2007.

The Muaivuso community has a resident population of 241 and 42 households. A total of 15 households, which is 36% of the total households in the Muaivuso community, were surveyed, with all (100%) of these households being engaged in some form of fishing activities. In addition, a total of 24 finfish fishers (12 males and 12 females) and 17 invertebrate fishers (5 males and 12 females) were interviewed. The average household size was small with 5 people on average, suggesting that the village was subject to major urban migration.

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 consumed was also conducted.

People from Muaivuso have access to various habitats for fishing and these include: mangrove areas and associated soft-benthos, intertidal flats, a lagoon area associated with coastal reefs, and an outer reef. Muaivuso is located in a densely populated rural area and close to the country's capital Suva; hence its fishing grounds are subject to external fishers.

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

Our results (Figure 3.2) suggest that both fisheries and salaries are the main income sources for the people of Muaivuso. While fisheries and salaries each supply 40% of all households with first income, fisheries also provide secondary income for another 33%, salaries much less (7%). Agriculture does not play an important role for income; however, secondary income may be obtained from agricultural produce in 13% of all households in the community. Handicrafts are also not very developed, with 7% of all households earning first, and another 20% secondary income from mat weaving, done by females. Pigs are popularly reared, with 60% of all households having on average two or more pigs, while chickens are usually not accounted for but run freely around the village. Distributing fish and seafood produce on a non-monetary basis is still an important practice and 40% of all households reported consuming finfish they are given.

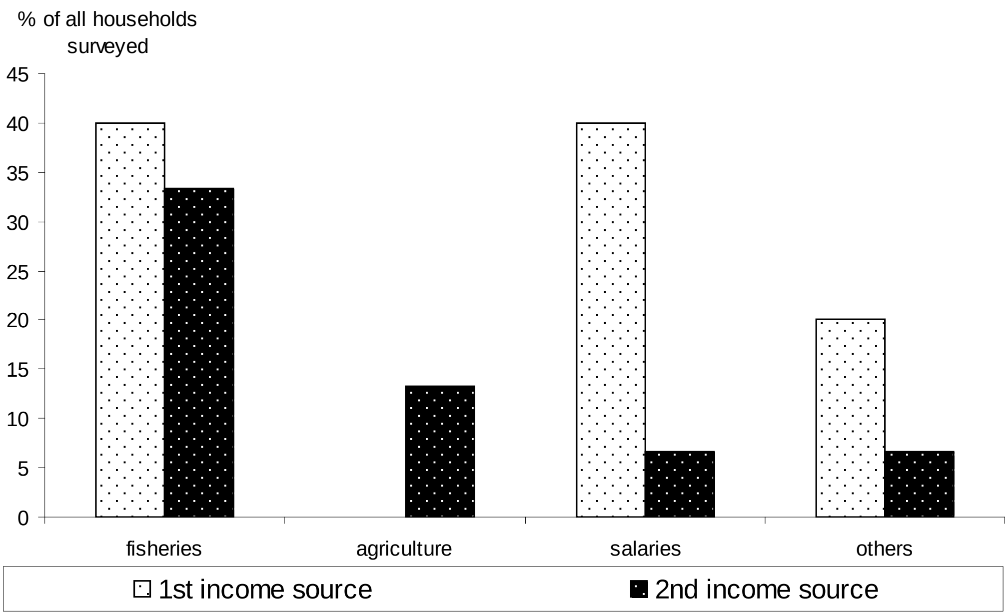

Figure 3.2: Ranked sources of income (%) in Muaivuso.
Total number of households = 15 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small business.

Our results (Table 3.1) show that annual household expenditures are low, with an average of USD 1243. People are self-sufficient in agricultural and marine produce, and income from salaries and fisheries provides the purchasing power to buy goods that are not readily available, or to cover costs for infrastructure, such as electricity, school fees and transport.

Only a very low percentage (13%) of all households benefit from remittances; however, these are large at USD 2545 /household/year, about double the average household expenditure.

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

	Site (n = 15 HH)	**Average across sites (n = 66 HH)**
Demography		
HH involved in reef fisheries (%)	100.0	98.5
Number of fishers per HH	2.33 (±0.21)	2.47 (±0.11)
Male finfish fishers per HH (%)	20.0	12.9
Female finfish fishers per HH (%)	0.0	0.6
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	2.9	9.8
Male finfish and invertebrate fishers per HH (%)	31.4	41.7
Female finfish and invertebrate fishers per HH (%)	45.7	35.0
Income		
HH with fisheries as 1st income (%)	40.0	69.7
HH with fisheries as 2nd income (%)	33.3	24.2
HH with agriculture as 1st income (%)	0.0	4.5
HH with agriculture as 2nd income (%)	13.3	15.2
HH with salary as 1st income (%)	40.0	13.6
HH with salary as 2nd income (%)	6.7	3.0
HH with other source as 1st income (%)	20.0	12.1
HH with other source as 2nd income (%)	6.7	19.7
Expenditure (USD/year/HH)	1243.20 (±113.97)	1163.72 (±64.04)
Remittance (USD/year/HH) (1)	2544.74 (±1006.06)	737.10 (±219.95)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	67.90 (±8.42)	74.00 (±2.96)
Frequency fresh fish consumed (times/week)	2.73 (±0.12)	3.20 (±0.07)
Quantity fresh invertebrate consumed (kg/capita/year)	10.23 (±2.72)	9.68 (±2.96)
Frequency fresh invertebrate consumed (times/week)	1.73 (±0.21)	2.11 (±0.13)
Quantity canned fish consumed (kg/capita/year)	3.04 (±0.88)	2.37 (±0.33)
Frequency canned fish consumed (times/week)	0.58 (±0.13)	0.47 (±0.05)
HH eat fresh fish (%)	100.0	98.8
HH eat invertebrates (%)	100.0	98.8
HH eat canned fish (%)	93.3	98.8
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	40.0	6.7
HH eat fresh fish they are given (%)	40.0	6.7
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 (%)	6.7	6.7

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

Survey results indicate an average of two fishers per household and, when extrapolated, the total number of fishers in Muaivuso amounts to 98, including 50 males and 48 females. Among these are 20 exclusive finfish fishers (males only), 3 exclusive invertebrate fishers (females only), and 76 fishers who fish for both finfish and invertebrates (31 males, 45 females). About 40% of all households own a boat, and all boats are fitted with an outboard engine.

Consumption of fresh fish is high at almost 68 kg/person/year. Although this is below the average across all the four study sites in Fiji Islands, it is nevertheless about double the regional average of ~35 kg/person/year (Figure 3.3). By comparison, consumption of invertebrates (edible meat weight only) (Figure 3.4) is lower, at ~10 kg/person/year. Canned fish (Table 3.1) is not commonly eaten and adds only ~3 kg/person to the annual protein supply from seafood. The consumption pattern of seafood found in Muaivuso highlights the fact that people also have access to agricultural produce but limited access to commercially available food items.

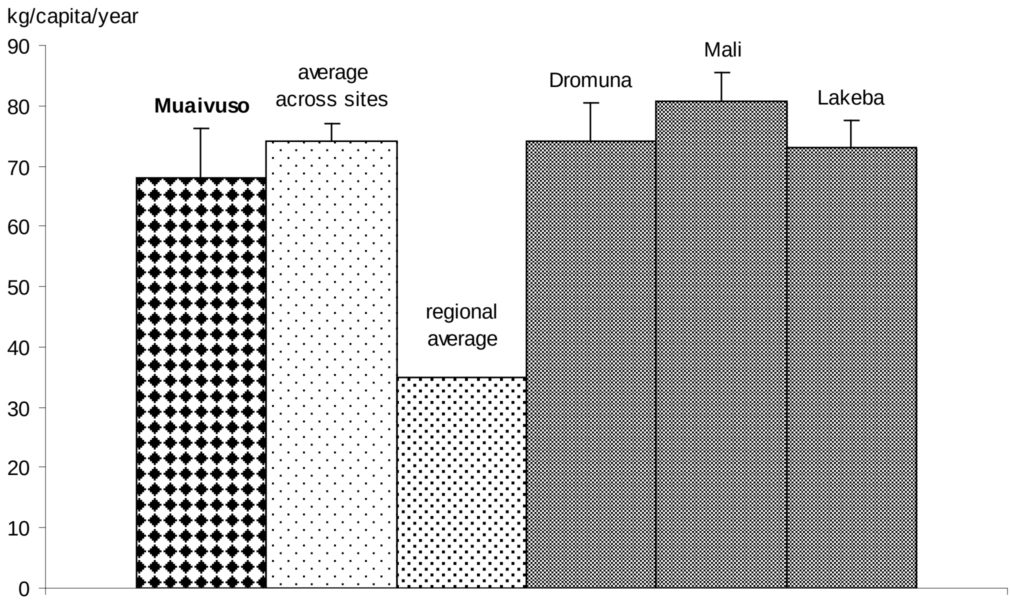

Figure 3.3: Per capita consumption (kg/year) of fresh fish in Muaivuso (n = 15) compared to the regional average (FAO 2008) and the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

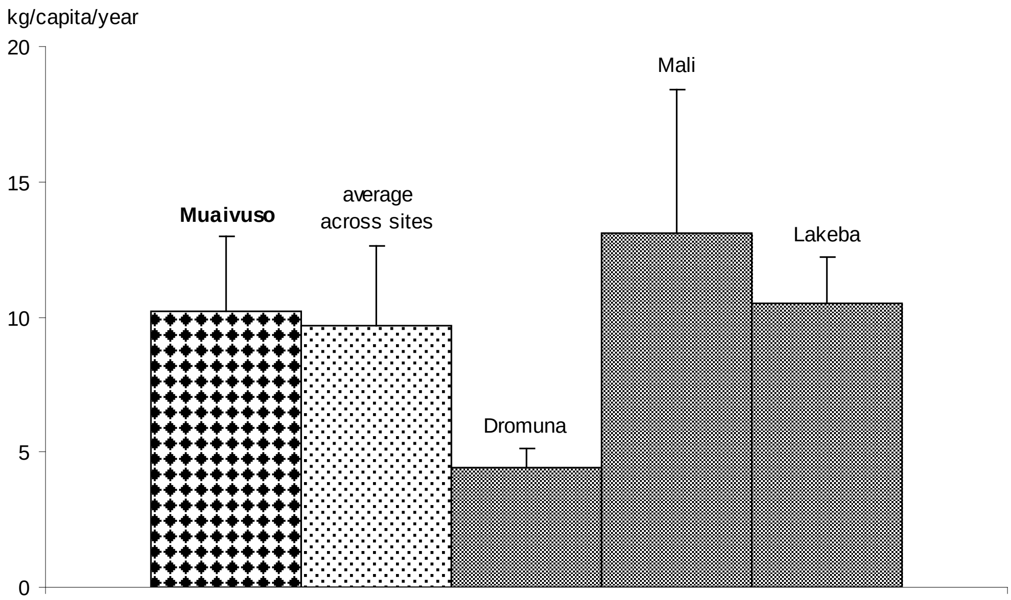

Figure 3.4: Per capita consumption (kg/year) of invertebrates (meat only) in Muaivuso (n = 15) compared to the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Comparing the results obtained for Muaivuso to the average figures across all four study sites surveyed in Fiji Islands, people of the Muaivuso community eat fresh fish and invertebrates slightly less often than average, but canned fish slightly more often. The consumption of fresh fish is lower than average, that of invertebrates and perhaps canned fish average. Muaivuso people conform to the average across all study sites in terms of the proportion of fish and invertebrates caught that they consume, but the proportion of finfish that they buy or may be given on a non-monetary basis is much higher than elsewhere. Compared to the Fiji Island situation overall, however, the proportion of catch that is reported as exchanged on a non-commercial basis is low. This may be explained by the fact that, in the sites studied, almost every household in the village has a member who goes fishing regularly. Nowadays, high cost is associated with most fishing trips, which pushes people to sell more of their catch to cover fuel costs. As in the other sites studied, sharing or giving catches would be more evident during traditional or religious functions, when people would fish specifically for such occasions and may give away large portions of their catches for community functions.

Salaries and fisheries play the most important role in generating income, with fisheries being less important than in all the other sites studied in Fiji Islands. The household expenditure level in Muaivuso is about average, i.e., generally low. The percentage of households receiving remittances is low, but the annual average amount of remittances received is extremely high. By comparison, boat ownership is slightly lower than elsewhere; however, all boats reported in any of the Fiji Island sites are motorised.

3.2.2 Fishing strategies and gear: Muaivuso

Degree of specialisation in fishing

Fishing is done by both gender groups; however, traditional roles are evident from the information shown in Figure 3.5. Males are much more engaged in exclusive finfish fisheries.

However, it is worth mentioning that the greatest share of males and females considered here fish for both finfish and invertebrates. Selling was mostly conducted individually, although some male and female fishers also fished together. However, catches were usually individually sold, with fishers in a group taking turns at taking the products to the market to be sold. Invertebrates were sold on a regular basis to the Suva market, with female fishers selling at weekends and sometimes on weekdays.

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

Targeted stocks/habitat

Considering their limited purchasing power, it is not surprising that Muaivuso finfish fishers mainly target the easily accessible habitats, namely the sheltered coastal reef and the lagoon, which are usually combined in one fishing trip. The lagoon and outer reef combined or the outer reef alone is fished by male fishers only, but not by as many and not as frequently as the more easily accessible habitats (Table 3.2). The commercial bêche-de-mer fishery and diving for commercial species of local interest are the most targeted fisheries by males. Females in Muaivuso target mainly the combined seagrass and reeftop habitats, but also the intertidal and reeftop areas, as they also engage in bêche-de-mer collection.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	75.0	100.0
	Lagoon & outer reef	25.0	0.0
	Outer reef	16.7	0.0
Invertebrates	Reeftop & other	20.0	0.0
	Reeftop & trochus & other	20.0	0.0
	Intertidal & reeftop	0.0	33.3
	Seagrass	0.0	8.3
	Seagrass & mangrove	20.0	25.0
	Seagrass & reeftop	0.0	58.3
	Bêche-de-mer	40.0	25.0
	Other	40.0	8.3

'Other' refers to trochus and lobster fisheries.
Finfish fisher interviews, males: n = 12; females: n = 12. Invertebrate fisher interviews, males: n = 5; 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 Muaivuso on their fishing grounds (Tables 3.2 and 3.3).

Our survey sample suggests that fishers from Muaivuso have a choice among sheltered coastal reef, lagoon and outer-reef fishing. Although fishing is one of the most important sources of cash income, fishers mostly target habitats that provide species for home consumption and local sale rather than focusing on the major commercial species, bêche-de-mer, only. This gives reason to believe that bêche-de-mer and other commercial species such as trochus and lobsters are no longer in great supply in the Muaivuso fishing ground (Figure 3.6).

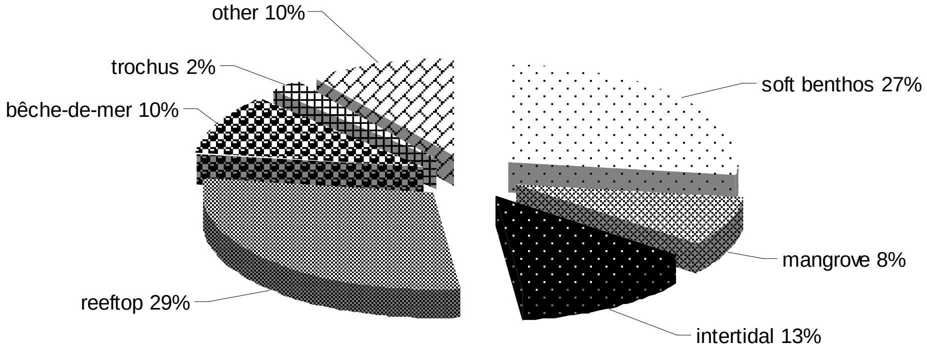

Figure 3.6: Proportion (%) of fishers targeting the seven primary invertebrate habitats found in Muaivuso.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to trochus and lobster fisheries.

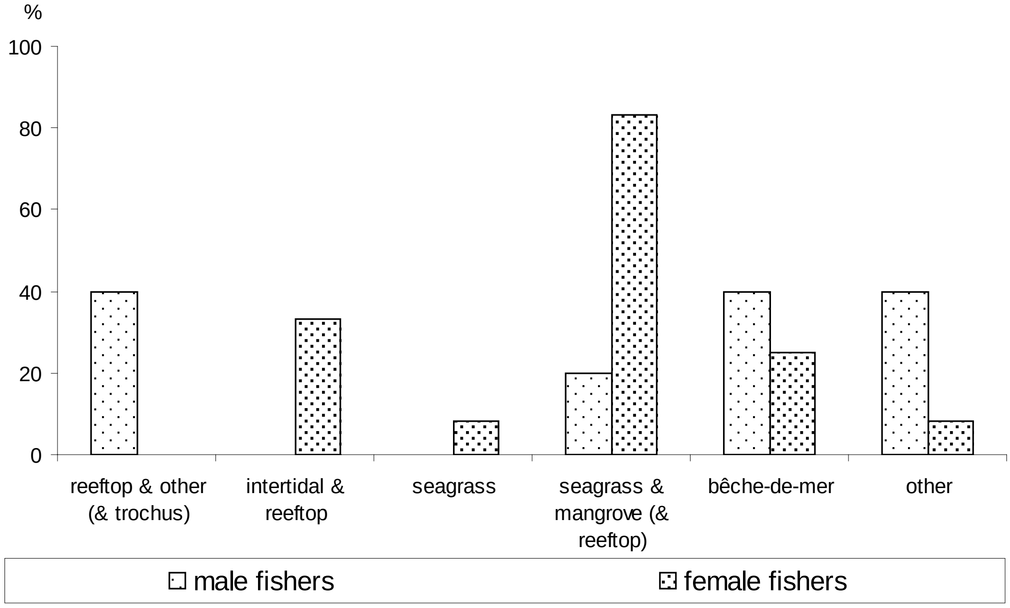

Figure 3.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Muaivuso.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 5 for males, n = 12 for females; 'other' refers to trochus and lobster fisheries.

Analysis of gender participation shows that females dominate the gleaning fisheries (intertidal and reeftop, seagrass, mangrove and reeftop), while males are mainly engaged in diving on reefs for trochus, lobsters, clams, etc. Both gender groups are engaged in bêche-de-mer collection, although there are more male fishers in this fishery (Figure 3.7).

Gear

Figure 3.8 shows that Muaivuso fishers use mainly gillnets and handlines in the habitats nearer to shore, while handlines are more common if the lagoon and outer reef or the outer reef alone are targeted. Spear diving is not popular among Muaivuso fishers, but gillnetting may be accompanied by handheld spearing.

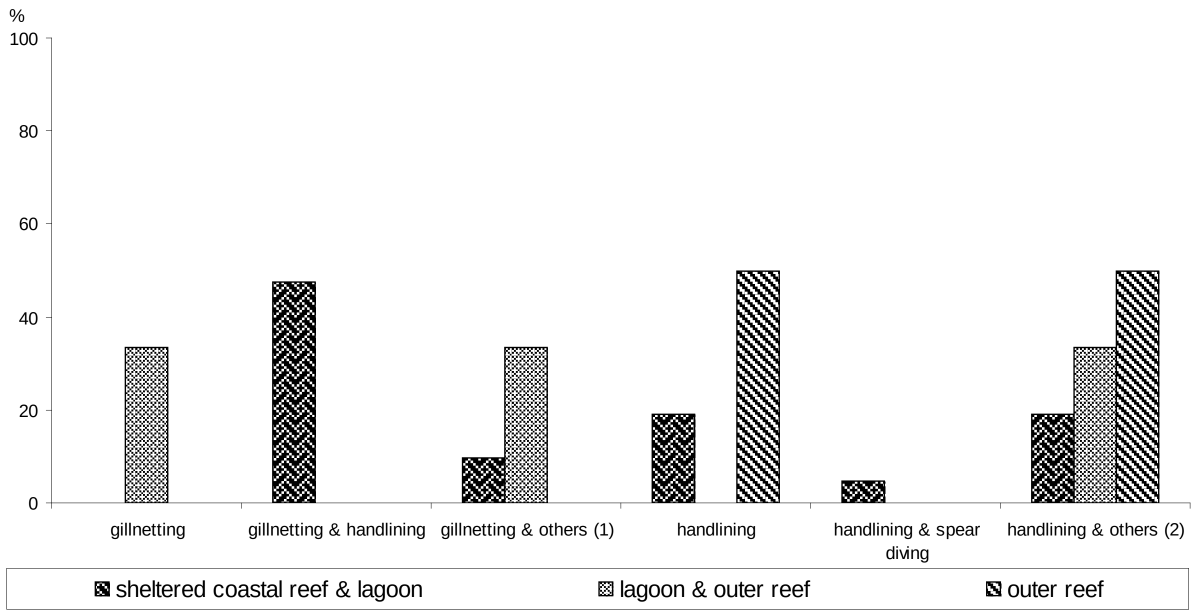

Figure 3.8: Fishing methods commonly used in different habitat types in Muaivuso.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.
(1) Handlining, spear diving & handheld spearing; (2) spear diving & handheld spearing.

Frequency and duration of fishing trips

Table 3.3 shows that finfish fishers go out to any of the habitats about twice per week. This is consistent for both gender groups. However, as mentioned earlier, females do not fish the outer reef. Popular invertebrate trips are undertaken twice per week and trips for less popular fisheries once a week. The average duration of a finfish fishing trip is about 3–5 hours for males, with longer trips to the outer reef, and about three hours for females targeting the sheltered coastal reef and lagoon habitats only. A typical invertebrate collection trip takes three hours for both male and female fishers. Bêche-de-mer collection requires on average 3–4 hours.

Most finfish fishers go out according to tidal conditions, i.e. during the day or night, while female fishers prefer fishing during the day. All fishing activities are performed throughout the year. Ice is not always used on finfish fishing trips, but is more regularly used when the outer reef is targeted.

Fishing in the sheltered coastal reef and lagoon areas does not necessarily require boat transport; however, with increasing distance from shore, boat transport becomes more important and is essential for fishing the outer reef. Gleaning for invertebrates is mostly done by walking, but commercial diving for trochus, clams, and other species, as well as bêche-de-mer collection, is done using motorised boat transport. Invertebrates can be collected at day or night time, and this applies to mangroves, bêche-de-mer, soft-benthos and reeftop habitats.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.61 (±0.33)	2.17 (±0.17)	3.78 (±0.32)	2.96 (±0.23)
	Lagoon & outer reef	1.67 (±0.17)	0	3.67 (±0.33)	0
	Outer reef	1.50 (±0.50)	0	5.50 (±0.50)	0
	Reeftop & other	0.50 (n/a)	0	3.00 (n/a)	0
Invertebrates	Reeftop & trochus & other	0.92 (n/a)	0	4.00 (n/a)	0
	Intertidal & reeftop	0	1.63 (±0.24)	0	3.00 (±0.00)
	Soft benthos	0	1.00 (n/a)	0	2.00 (n/a)
	Soft benthos & mangrove	1.00 (n/a)	1.33 (±0.33)	3.00 (n/a)	3.00 (±0.00)
	Soft benthos & reeftop	0	2.07 (±0.07)	0	3.36 (±0.24)
	Bêche-de-mer	2.00 (±0.00)	2.00 (±0.00)	4.00 (±0.00)	3.33 (±0.33)
	Other	0.75 (±0.25)	1.00 (n/a)	3.50 (±0.50)	3.00 (n/a)

Figures in brackets denote standard error; n/a = standard error not calculated; ‘other’ refers to trochus and lobster fisheries.
Finfish fisher interviews, males: n = 12; females: n = 12. Invertebrate fisher interviews, males: n = 5; females: n = 12.

3.2.3 Catch composition and volume – finfish: Muaivuso

The catches reported from the sheltered coastal reef and lagoon in Muaivuso are dominated by a few families. Lethrinidae alone represents >25% of the total annual reported catch. Lutjanidae, Mugilidae and Serranidae account for another 16%, 8% and >10% respectively. Catches reported for the combined fishing of the lagoon and outer reef do not vary much in composition. Again, Lethrinidae constitutes most (>57%) of the reported catch by weight, and Gerreidae, Hemiramphidae, Lutjanidae, Scaridae, Mullidae and Leiognathidae make up the balance. Lethrinidae still dominates the catch even when the outer reef is exclusively targeted. Overall, the reported catch composition for the Muaivuso fishery is not very diverse and suggests that the resource is depleted.

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

Figure 3.9 highlights findings from the socioeconomic survey that were reported earlier, i.e. that most of the finfish catch is sold rather than consumed by the community. The dominance of male fishers by impact and production is not that pronounced, but they still represent 61% of the total annual impact. Most impact is on the habitats closest to shore, i.e. the combination of sheltered coastal reef and lagoon; there is relatively little impact on the outer reef.

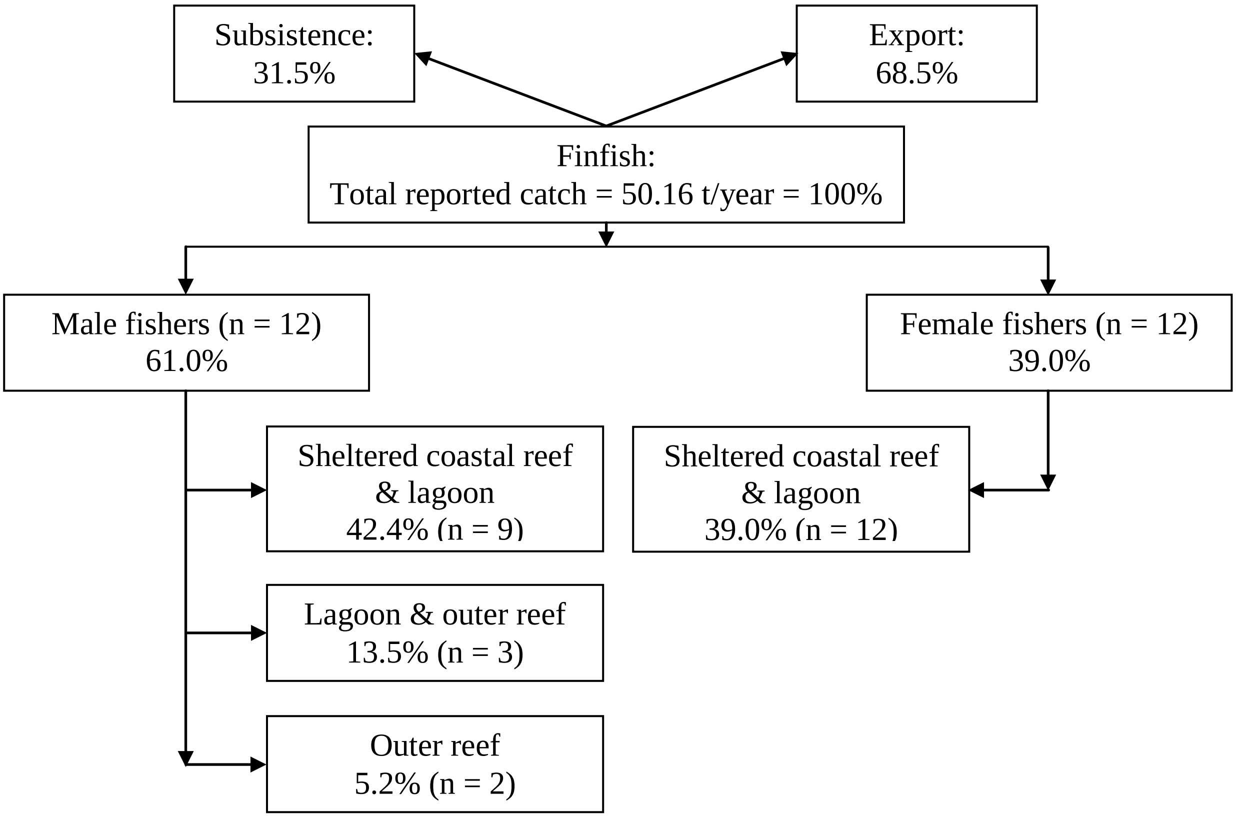

Figure 3.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Muaivuso.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

The distribution of annual catch weight between the more easily accessible sheltered coastal reef and lagoon and the more distant outer reef and passages is a consequence of the number of fishers rather than the annual catch rates. As shown in Figure 3.10, the average annual catch per male fisher is similar for sheltered coastal reef and lagoon fishing and for lagoon and outer-reef fishing. The lowest annual catch rates are reported from fishers targeting the outer reef alone. On average, annual catch rates are about 600 kg/fisher/year; female fishers catch on average less, i.e. ~450 kg/fisher/year.

Productivity rates are similar between genders (Figure 3.11) but the CPUEs calculated for fishers targeting the combined lagoon and outer-reef habitats are the highest. Generally, CPUEs are low at 1.5–2.4 kg/hour fishing trip. Again, and very interestingly, the lowest CPUEs exist at the outer reef, only ~1 kg/hour fishing trip. These figures also suggest resource depletion.

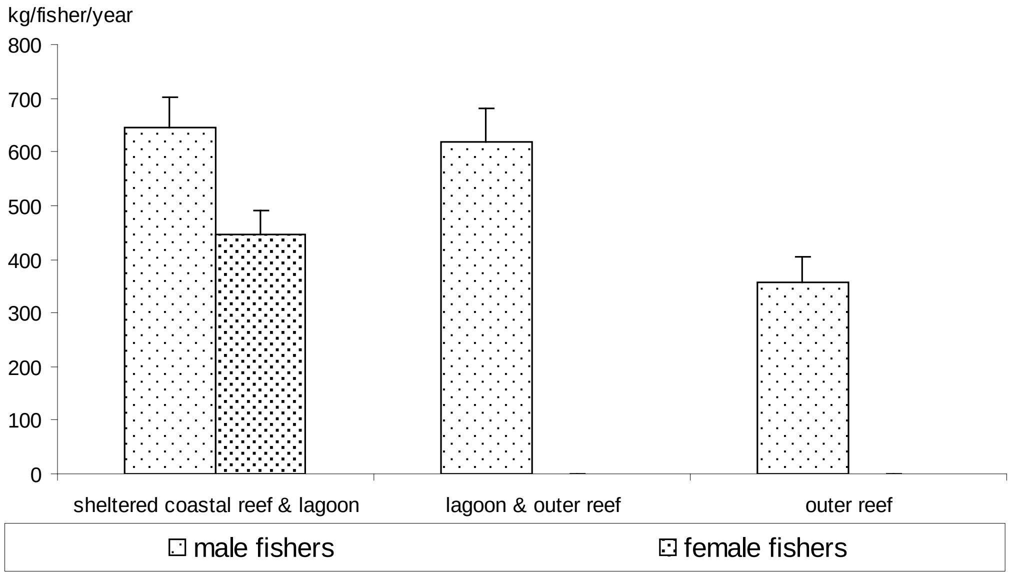

Figure 3.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Muaivuso (based on reported catch only).

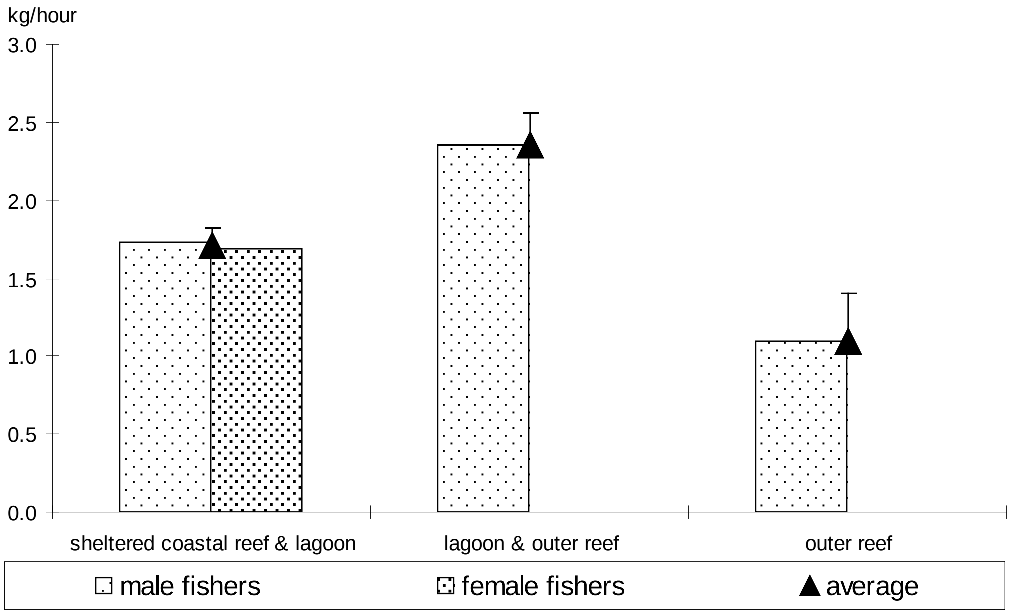

Figure 3.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Muaivuso.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Figure 3.12 highlights findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing is conducted both for income and for sale. The combined fishing of the sheltered coastal reef and lagoon is performed more for subsistence purposes, while fishers targeting the lagoon and the outer reef in one fishing trip mainly pursue commercial interests. Muaivuso is a community that is dependent upon fishing and still retains a strong, traditional, fishing background that requires people to use their knowledge of the species, habitats, winds, moons and tides to guide their daily fishing activities. The market economy has a lot of influence on fishing participation, fishing patterns and target species. Both male and female fishers target the more lucrative species for marketing 2–3 days per week on average.

Fishing participation is higher on Thursday and Fridays when fishers prepare for the Saturday market.

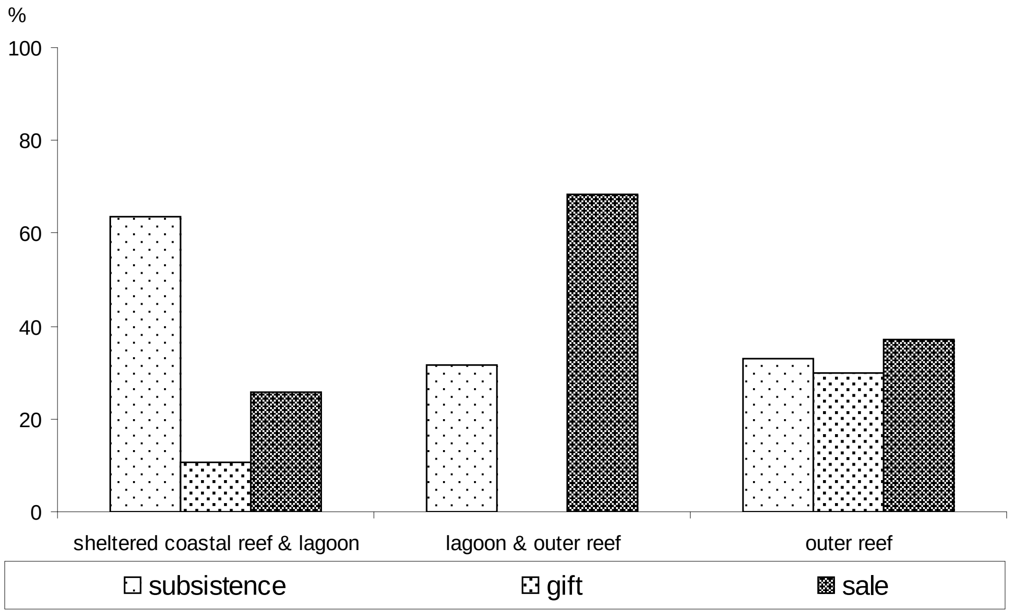

Figure 3.12: The use of finfish catches for subsistence, gift and sale, by habitat in Muaivuso. Proportions are expressed in % of the total number of trips per habitat.

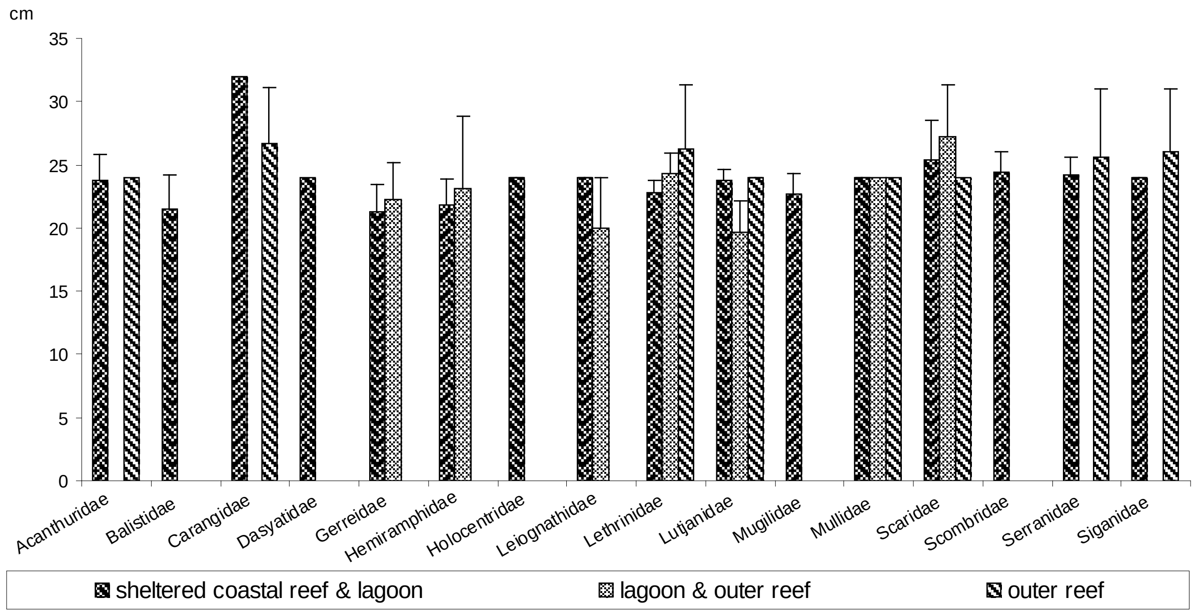

Figure 3.13: Average sizes (cm fork length) of fish caught by family and habitat in Muaivuso. Bars represent standard error (+SE).

Analysis of the overall finfish fishing productivity per habitat suggests a major difference between fishing the combined sheltered coastal reef and lagoon, and the lagoon and outer-reef habitats. Because CPUEs are lowest when the outer reef is targeted alone, these differences may reflect the change in fishing gear and strategy for the more commercially oriented fishers (lagoon and outer reef). These observations are further supported by the reported average fish lengths. In fact, the expected trend that sizes increase with distance from shore is not confirmed by the data shown in Figure 3.13. While most average sizes of families caught across the different habitats and combinations are similar, only Lethrinidae sizes increase with distance from shore. Lutjanidae caught in the lagoon and outer reef are smaller on average than those caught in the sheltered coastal reef and lagoon combined (Figure 3.13).

The parameters selected to assess the current fishing pressure on Muaivuso reef and lagoon resources are shown in Table 3.4. Due to the available reef surface and total fishing ground, population density is moderate, and fisher density and catch rates per unit areas of reef and fishing ground are low. However, if we consider the total annual catch rate from Muaivuso fishers, the total fishing pressure on reef and fishing ground areas increases substantially to 2.5–3 t/km² of reef and total fishing ground respectively. In addition, one must take into account the fact that the fishing ground is heavily targeted by fishers from surrounding communities, as well as by external fishers as far away as the Suva area. Catch composition, CPUEs and average reported fish sizes, as discussed above, suggest that fishing impact is already visible.

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

Parameters	Habitat				
	Sheltered coastal reef & lagoon	Lagoon & outer reef	Outer reef	Total reef area	Total fishing ground
Fishing ground area (km^2)	4.1	14.1	1.8	16.1	20.0
Density of fishers (number of fishers/km^2 fishing ground) (1)	18.9	0.8	3.8	5.9	4.7
Population density (people/km^2) (2)				14.9	12.0
Average annual finfish catch (kg/fisher/year) (3)	531.99 (±40.15)	617.18 (±64.96)	355.39 (±49.79)		
Total fishing pressure of subsistence catches (t/km^2)				0.6	0.5
Total number of fishers	77	11	7	95	95

Figures in brackets denote standard error; (1) total number of fishers is extrapolated from household surveys; (2) total population = 241; total number of fishers = 95; total subsistence demand = 9.44 t/year; (3) catch figures are based on recorded data from survey respondents only.

3.2.4 Catch composition and volume – invertebrates: Muaivuso

Analysis of reported catches from invertebrate fishers by wet weight suggests that the bêche-de-mer species *Holothuria* spp. and *Bohadschia* spp. account for most of the total annual catch volume. However, sampling does not allow exact annual production rates to be calculated. Therefore, Figure 3.14b only displays the reported catch composition by species. Annual catches for traditional species that are mainly targeted for home consumption (Figure 3.14a) and, to some extent, for local sale are mainly determined by sea urchins (*Tripneustes gratilla*), octopus and 14 other species that are insignificant in terms of their proportion of the total annual catch.

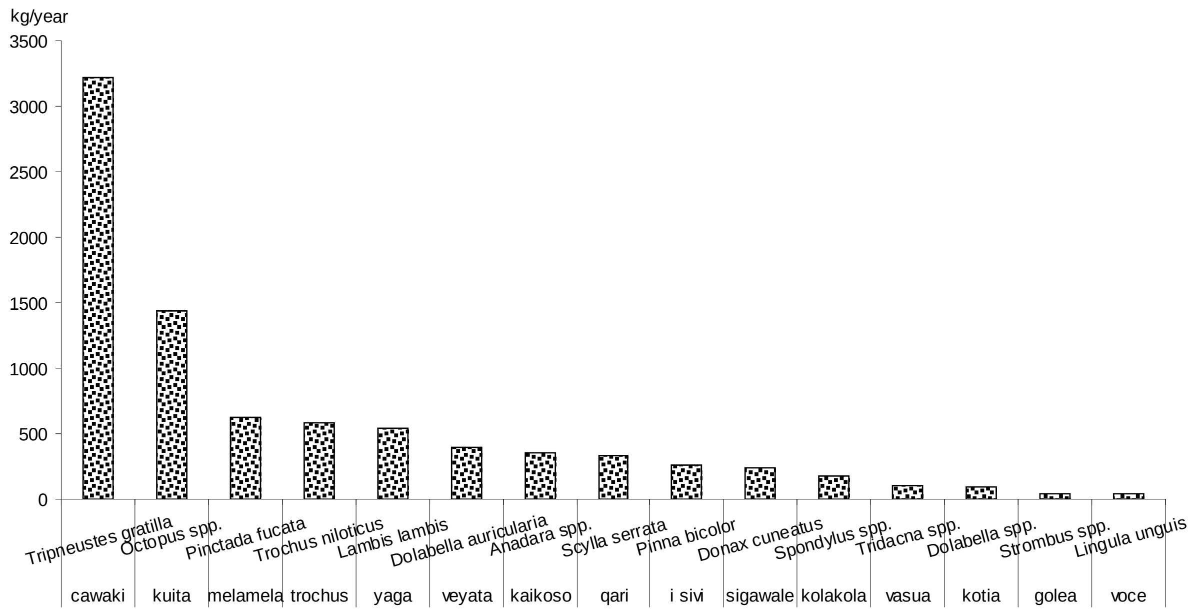

Figure 3.14a: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Muaivuso.

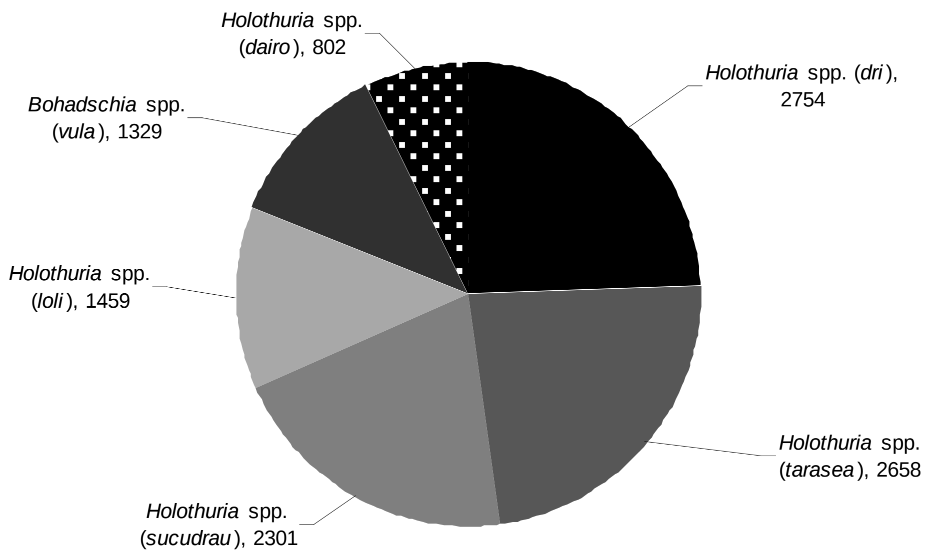

Figure 3.14b: Catch composition of the bêche-de-mer fishery in Muaivuso.

Figure 3.15 emphasises that Muaivuso fishers have access to a wide range of habitats and that these are often combined in one fishing trip. The number of target species identified by vernacular name, however, is not as varied as one would expect. Among the traditional fisheries, the combination of soft benthos and ‘others’, i.e. diving for reef-associated or submerged species, is represented by the highest number of vernacular names. There are at least eight different species of bêche-de-mer identified by distinct vernacular names; however, these represent only *Holothuria* spp. and, in one case, *Bohadschia* spp.

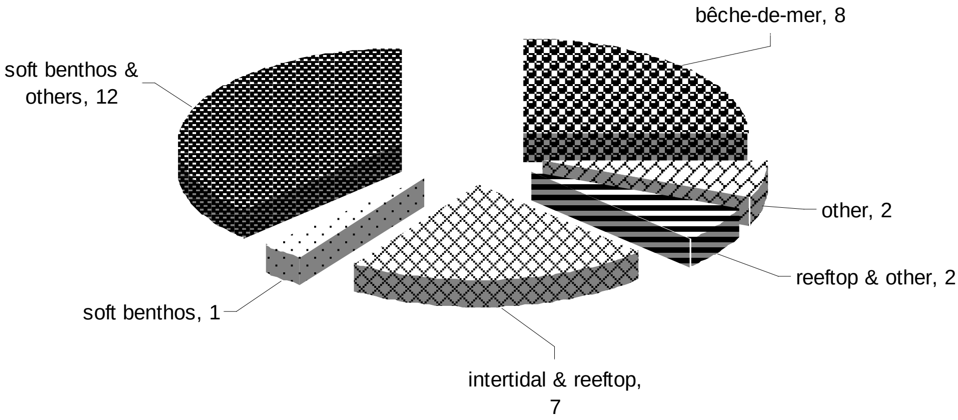

Figure 3.15: Number of vernacular names recorded for each invertebrate fishery in Muaivuso.

Analysis of the average annual catch per fisher by gender and fishery (Figure 3.16) reveals the substantial difference between the commercial bêche-de-mer and all other fisheries. Impact by gender group is highest for female fishers for bêche-de-mer, as females are also mainly responsible for the collection of all the catch from the intertidal and reeftop fishery, and the soft-benthos and reeftop fishery. Male fishers mainly dive for reef-associated species and target trochus, clams and octopus. Because the sample data does not allow quantification of the bêche-de-mer fishery, caution is advised in comparing this fishery to the other fisheries.

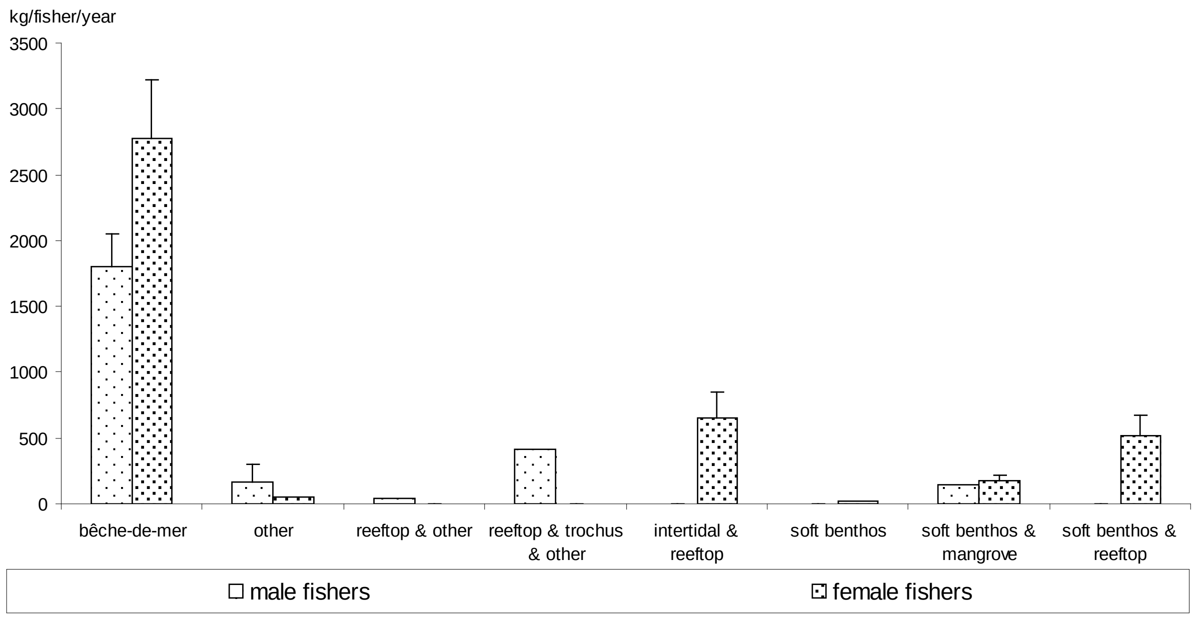

Figure 3.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Muaivuso.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 5 for males, n = 12 for females).

The fact that the Muaivuso community is highly dependent on marine resources for income also shows in Figure 3.17, which reveals the simple fact that most invertebrates are caught for sale, notably bêche-de-mer and, to a lesser extent, lobsters and 'others' for the local markets at Lami and Suva. If we assume that half of the catches reported for both sale and home consumption are sold, the proportion of the total invertebrate catch that is sold is about 77%.

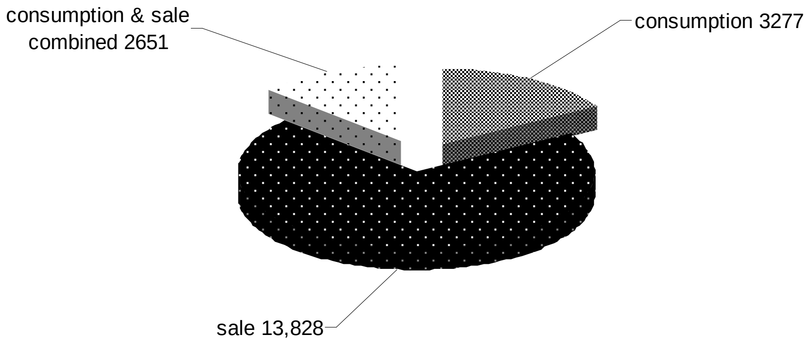

Figure 3.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Muaivuso.

As mentioned earlier, male and female fishers from Muaivuso are heavily involved in invertebrate fishing, but female fishers account for the highest impact, i.e. 77% (wet weight) (Figure 3.18). Most of the Muaivuso male invertebrate fishers target bêche-de-mer, as do female fishers. Female fishers also substantially target the intertidal and reeftop habitats, and the soft benthos and reeftop habitats.

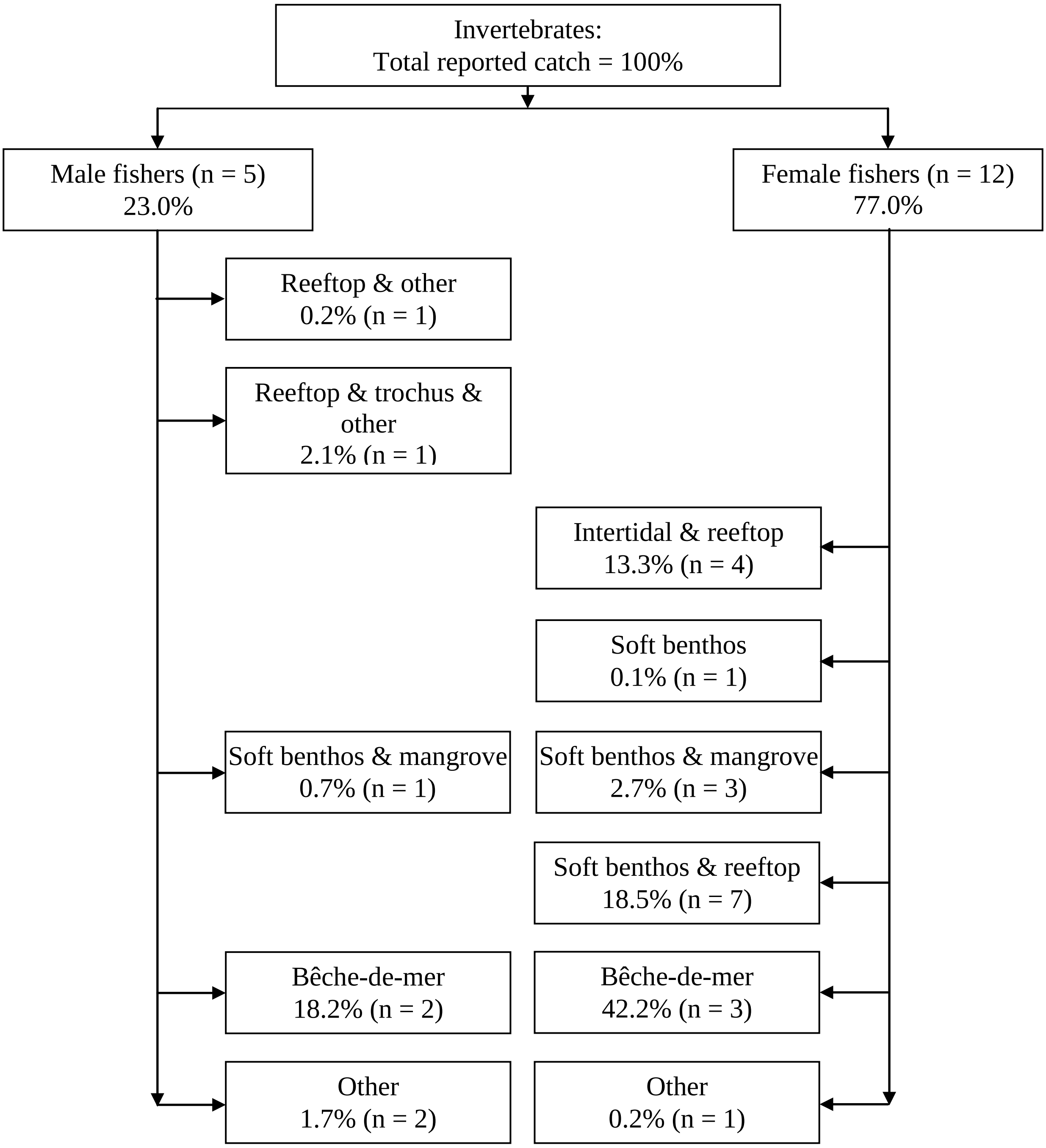

Figure 3.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Muaivuso.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery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

Taking into account the total area of sheltered coastal reef surface for any reeftop invertebrate fishery, the fisher-density parameters calculated are moderate. Also, the average annual catch rate for most fisheries is low. The bêche-de-mer fishery data are not reported here, as our sampling does not permit accurate quantitative calculations (Table 3.5). Although the parameters calculated to assess current fishing pressure suggest that there is not much adverse effect from the current level of fishing activity, this picture may be misleading. The Muaivuso fishing ground area is accessed by many fishers from the neighbouring villages, as well as by external fishers as far away as Suva. The bêche-de-mer fishery has a long record in

Fiji Islands, it is an open fishery, and resources are widely exhausted due to fishing over the past decades. The argument that suggests that the resources are depleted may be supported by the relatively few vernacular names reported for traditional as well as commercial fisheries, by a community that is highly dependent on marine resources for both food and income, and that traditionally has a food preference for many invertebrate species.

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

Parameters	Fishery / Habitat				
	Reeftop & other	Soft benthos	Soft benthos & mangrove	Bêche-de-mer	Other
Fishing ground area (km^2)	4.1	n/a	n/a	n/a	n/a
Number of fishers (per fishery) (1)	56	4	18	24	16
Density of fishers (number of fishers/km^2 fishing ground)	14	n/a	n/a	n/a	n/a
Average annual invertebrate catch (kg/fisher/year) (2)	43.97–657.40 (±191.18)	18.24 (n/a)	170.17 (±28.80)	n/a	127.75 (±86.02)

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

3.2.5 Fisheries management: Muaivuso

Fisheries are an integral part of the traditional lifestyle in Fiji Islands with resource management mechanisms built into the community lifestyle. Specific actions, such as the setting aside of *tabu* areas upon the death of a chief or in anticipation of a major traditional obligation, form a part of the traditional management techniques used. The development and exploitation of fish stocks are subject to the Fisheries Act (Cap 158), the Marine Species Act (Cap 158A) and subsidiary legislation. The Fisheries Act addresses fishing within traditional customary fishing areas. The policy on catching fish within customary fishing rights areas dictates that no commercial fishing activities may be undertaken unless by consent of the traditional owners and this policy is also covered in existing policies and regulations. There also exist customary management strategies in the various communities in Fiji Islands. These villages are under district, provincial, and *vanua* settings, and ownership of the fishing rights is usually on a larger scale than for the land, with ownership resting with the *tikina* (district), province or *vanua*. This is usually under the 14 provinces and 189 *tikina*. The ability to give consent to fish within a *qoliqoli* rests with the *vanua*, *tikina* or *yavusa* (traditional groupings of villages), depending on the ownership status of that particular *qoliqoli*. The ownership right of the marine resources belongs to the State as stipulated under the Fisheries Act. Policing of coastal fisheries is shared between the government and Traditional Fishing Rights Owners (TFROs) who, in most cases, lack the capacity to carry out their work. In recent years there have been changes to these with work done by FLMMA and the NGOs at the community level, targeting the strengthening of the role of fisheries wardens and others involved in community management.

Muaivuso has been the target of community-based management initiatives in the last few years, supported by USP and FLMMA. This work included training community representatives. University students also use the site for biological and geographical studies. A major challenge to any management work that maybe undertaken in the village is the nature of the customary marine tenure (CMT), which is under the larger grouping of the *vanua* (which encompasses several districts). This means that the paramount chief of the area has higher authority than the collective consensus of the people. In addition to these complexities in ownership and access rights arising from relationships established through marriage, the overlapping fishing areas and the challenge of outsiders poaching in the area have further complicated existing management initiatives. It is hoped that the PROCFish work in Muaivuso will add to existing baseline information for the site and will help in determining how to expand the management initiatives currently in place. Muaivuso has a protected area that is mainly respected by local fishers.

In general, there were sufficient management initiatives in place in Muaivuso, but there was a need to strengthen alternative opportunities for earning income other than fisheries. Closing off certain fishing areas for years means closing off opportunities for involvement in the sale of fisheries products for some portions of the communities. There need to be more alternatives offered to the people; consideration could be given to maximising agricultural products and moving into farming the more lucrative commodities.

3.2.6 Discussion and conclusions: socioeconomics in Muaivuso

Muaivuso is a small, traditional community located close to Fiji Islands' capital, Suva. Due to the available public transport and the short distance to markets, people in the community have several options available for earning income, particularly salary-based income in the greater urban Suva area. Arable land allows for crop production, both for home consumption and, to a smaller extent, for sale. Fisheries, notably finfish and bêche-de-mer collection, are the main income sources for 40% of all households, and salaries provide another 40% with first income. Fisheries, agricultural produce, and mat weaving (by females) complement income. The fishing grounds and fishing rights under customary ownership and rights are large. However, the fishing grounds are shared with neighbouring villages and illegally fished by outsiders from the wider urban Suva area.

In summary:

- Muaivuso has the highest income dependency on salaries and fisheries, and fisheries still play an important role as a second income source, or as a fallback position.

- Muaivuso still has a high food dependency on finfish particularly, and is far less dependent on invertebrates or canned fish; however, cash income allows some of the marine food items to be substituted by imported goods.

- Household expenditure level is relatively low, and only 13% of all households receive remittances. However, these are substantial in amount.

- Finfish and invertebrate fishers target many habitats and often combine two or more in one fishing trip.

- Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further away from shore, while females are more involved in handlining and gillnetting in the nearshore habitats and in collecting invertebrates. Both gender groups participate most in the commercial bêche-de-mer fishery.

- The highest fishing impact is imposed on the sheltered coastal reef and lagoon habitats, and much less on the outer reef and passages.

- While annual catch rates do not substantially vary per habitat (with the exception of the outer reef) CPUEs are significantly higher for fishers combining the lagoon and outer reef. The lowest annual production and CPUEs were reported for the outer-reef fisheries.

- Average reported fish lengths are small to moderate. While, for most fish families caught, these lengths do not change across the habitats fished, the expected increase in size with distance from shore only applies to Lethrinidae. The average reported fish lengths of Lutjanidae decreased from the sheltered coastal reef and lagoon to the lagoon and outer-reef habitats.

- Bêche-de-mer is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including sea urchins and octopus, are important for both home consumption and small-scale, local commercial sale.

- Fishing pressure parameters for both finfish and invertebrates suggest that current fishing pressure is moderate. However, these figures are misleading given that the fishing grounds are shared with neighbouring communities, and given the illegal but high impact imposed by external fishers from the wider urban Suva area.

When the current fishing levels of the community are coupled with the impact imposed by fishers from outside who share the fishing area and by those who fish illegally, current fishing pressure is assumed to be high. It can also be assumed that the current fishing pressure level has occurred for the past decade if not longer. Muaivuso is one of the major suppliers of seafood to the Suva market, with females selling finfish and invertebrates at weekends. Easy road access to the urban centres has allowed for increased commercialisation of resources, which prompted the management work undertaken in the village by the USP and FLMMA partners. The exploitation of bêche-de-mer species is a popular activity, possibly due to the availability of buyers in Suva. Male and female fishers sell to the buyers, who are also the exporters; thus the prices fetched for the various species sold are good.

Fisheries management mechanisms in Muaivuso are already in place. However, whether these are sufficient to ensure the long-term sustainability of resource use is questionable. Fishing pressure is high and is likely to remain high. Impact from external fishers on the Muaivuso fishing grounds cannot be excluded. Thus, fisheries management needs to include development of alternative, land-based activities to generate income. This could be done by providing training in land-based commodity production as the community has access to arable land, which is only partially used. Strengthening existing marketing networks and finding ways to minimise costs and people's time in selling products could be investigated to make fisheries production more efficient and to avoid any increase of catch to cover marketing and transport costs. Adding value to the products currently exploited should also be considered and this could indirectly result in the slowing down of the increased harvest rates of marine resources.

3.3 Finfish resource surveys: Muaivuso

Finfish resources and associated habitats were assessed in Muaivuso between 23 and 26 April 2003 (Figure 3.19), from a total of 18 transects (12 back-reef and 6 outer-reef transects; see Figure 3.19 and Appendix 3.2.1 for transect locations and coordinates respectively). The wide barrier reef is not far from the coast and a large back-reef is constructed to the inside. However, no real intermediate reefs were encountered and coastal reefs were only found in very shallow and murky water. Therefore, only two reef types were sampled at this site.

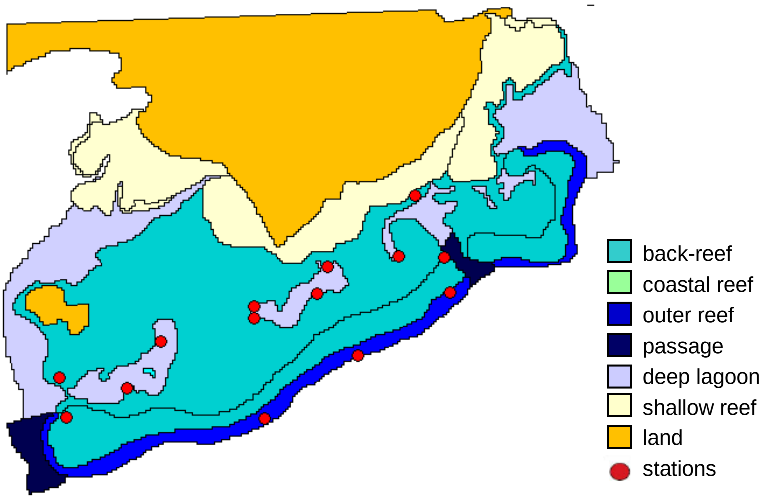

Figure 3.19: Habitat types and transect locations for finfish assessment in Muaivuso.

3.3.1 Finfish assessment results: Muaivuso

A total of 20 families, 46 genera, 140 species and 5589 fish were recorded in the 18 transects (See Appendix 3.2.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 39 genera, 132 species and 5350 individuals.

Finfish resources differed greatly between the two reef environments found in Muaivuso (Table 3.6). The back-reef contained lower density, size, size ratio, biomass and biodiversity than the outer reefs.

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

Parameters	Habitat		
	Back-reef (1)	**Outer reef** (1)	**All reefs** (2)
Number of transects	12	6	18
Total habitat area (km^2)	10.2	1.4	11.6
Depth (m)	3 (0–7) (3)	10 (5–15) (3)	5 (0–15) (3)
Soft bottom (% cover)	24 ±6	0 ±0	21
Rubble & boulders (% cover)	29 ±5	3 ±1	26
Hard bottom (% cover)	23 ±3	61 ±6	27
Live coral (% cover)	23 ±0	32 ±1	24
Soft coral (% cover)	12 ±0	6 ±0	1
Biodiversity (species/transect)	36 ±3	49 ±4	40 ±3
Density (fish/m^2)	0.5 ±0.1	0.6 ±0.1	0.5
Size (cm FL) (4)	16 ±0	19 ±1	17
Size ratio (%)	53 ±2	62 ±2	54
Biomass (g/m^2)	56.7 ±13.1	116.3 ±18.1	63.6

(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.

Back-reef environment: Muaivuso

The back-reef environment of Muaivuso was dominated by two herbivorous families: Scaridae and Acanthuridae and, to a much lesser extent, by carnivores Lutjanidae, Lethrinidae, Mullidae and Nemipteridae for both density and biomass (Figure 3.20). These six families were represented by 59 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scolopsis bilineata*, *Lutjanus fulviflamma*, *Scarus psittacus* and *L. fulvus* (Table 3.7). This reef environment presented a very diverse habitat with hard bottom, live coral, soft bottom and rubble in very similar percentages of cover (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 back-reef environment of Muaivuso

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05 ±0.01	5.5 ±1.6
	Scarus psittacus	Palenose parrotfish	0.05 ±0.01	3.1 ±1.1
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.04 ±0.02	6.0 ±2.4
Nemipteridae	*Scolopsis bilineata*	Bridled monocle bream	0.02 ±0.01	3.8 ±1.4
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.02 ±0.02	3.3 ±3.2
	Lutjanus fulvus	Flametail snapper	0.01 ±0.01	2.2 ±1.6

The density, biomass, size and size ratio as well as the biodiversity of finfish in the back-reefs of Muaivuso were lower than in the outer reefs. The trophic structure was only slightly dominated by carnivores, mainly represented by Labridae, Lethrinidae, Mullidae and Nemipteridae. Piscivorous Serranidae were practically absent. The substrate was composed of a good and equal proportion of both soft and hard substrate with a good cover of live coral, which explains the diverse composition of fish families. However, for some families sizes were below the maximum recorded values: Labridae, Lethrinidae, Mullidae and Scaridae displayed very low size ratios, indicating an impact from fishing on these targeted families.

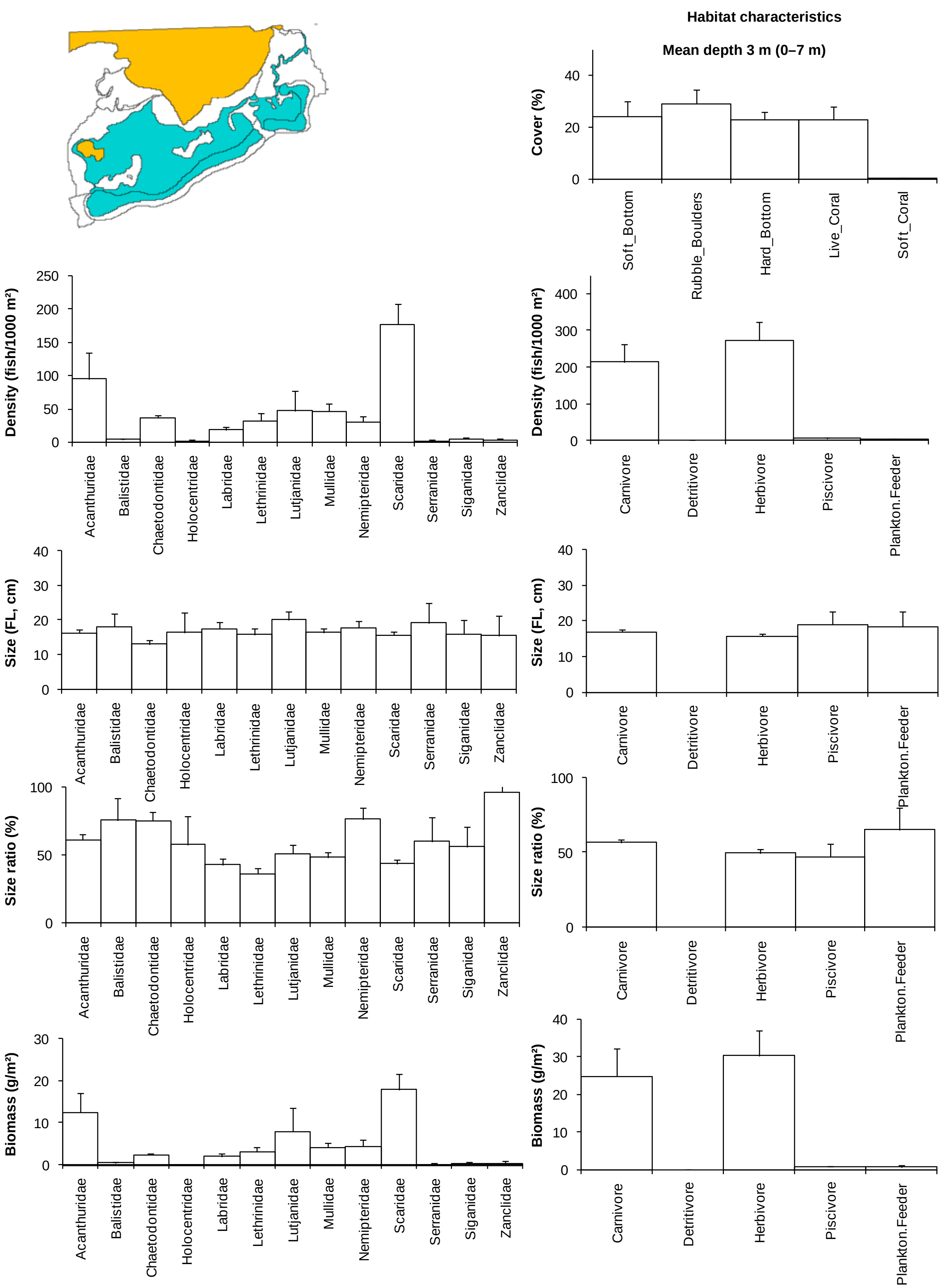

Figure 3.20: Profile of finfish resources in the back-reef environment of Muaivuso.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Muaivuso

The outer-reef environment of Muaivuso was dominated by two herbivorous families Acanthuridae and Scaridae and, to a much lower extent, by carnivorous Chaetodontidae (only for density) and Lutjanidae (Figure 3.21). The three commercial families were represented by 46 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus niger*, *Acanthurus xanthopterus*, *S. schlegeli*, *S. altipinnis* and *Lutjanus fulvus* (Table 3.8). This reef environment presented a high dominance of hard bottom and a high cover of live coral (32%, Table 3.6, Figure 3.21).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.12 ±0.02	20.8 ±4.8
	Acanthurus xanthopterus	Yellowfin surgeonfish	0.01 ±0.01	5.4 ±2.7
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.06 ±0.02	9.4 ±2.4
	Scarus altipinnis	Filamentfinned parrotfish	0.01 ±0.01	4.1 ±3.2
	Scarus niger	Black parrotfish	0.01 ±0.01	6.3 ±2.4
	Scarus schlegeli	Schlegel's parrotfish	0.02 ±0.01	4.5 ±1.3
Lutjanidae	*Lutjanus fulvus*	Flametail snapper	0.01 ±0.01	2.4 ±2.4

The density, biomass, size, size ratio and biodiversity of finfish in the outer reefs of Muaivuso were higher than in the back-reefs. However, biomass was lower than at Lakeba and Mali, although higher than at Dromuna outer reefs. The trophic structure in the Muaivuso outer reef was clearly dominated by herbivorous fish, represented primarily by Acanthuridae (largely dominated by the small species *Ctenochaetus striatus*) and Scaridae. Carnivores were represented mainly by Lutjanidae only, probably due to the particular composition of the substrate, i.e. mostly hard bottom and corals, with no cover of soft bottom, which would favour Lethrinidae and Mullidae species. Small values of size ratio were recorded for Kyphosidae, Labridae and Lethrinidae.

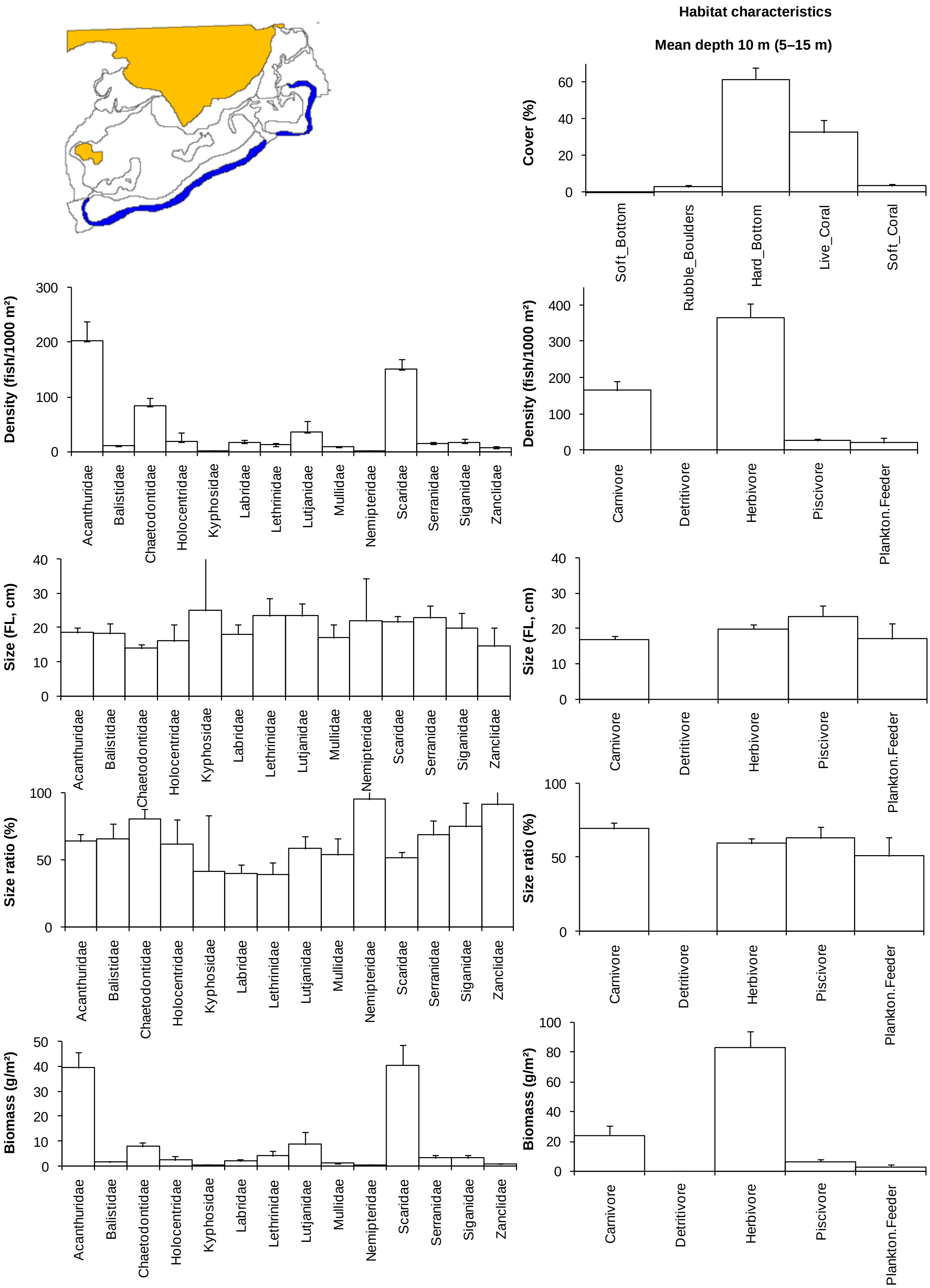

Figure 3.21: Profile of finfish resources in the outer-reef environment of Muaivuso.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Muaivuso

Overall, the fish assemblage of Muaivuso was dominated by herbivorous Scaridae and Acanthuridae and, to a much smaller extent, by carnivorous Lutjanidae, Mullidae and Lethrinidae (Figure 3.22). These five families were represented by a total of 69 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus psittacus*, *Lutjanus fulviflamma*, *Monotaxis grandoculis*, *L. fulvus* and *S. rivulatus* (Table 3.9). The average substrate was similarly composed of hard bottom (24%), rubble (26%) and soft bottom (21%), with a good cover of live coral (24%). The overall fish assemblage and substrate composition in Muaivuso shared characteristics of primarily back-reefs (88% of total habitat) and only to a smaller extent of outer reefs (12% of total habitat).

Table 3.9: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Muaivuso (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.05	7.8
	Chlorurus sordidus	Daisy parrotfish	0.05	5.9
Scaridae	*Scarus psittacus*	Common parrotfish	0.05	2.8
	Scarus rivulatus	Rivulated parrotfish	0.01	1.7
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.02	1.8
Lutjanidae	*Lutjanus fulviflamma*	Longspot snapper	0.02	3.2
	Lutjanus fulvus	Flametail snapper	0.01	2.2

Overall, Muaivuso appeared to support an average-to-low finfish resource, with similar density, size and size ratio to values at Lakeba and Dromuna. However, comparisons among all sites are not entirely reliable due to the fact that Muaivuso includes only back- and outer reefs. The more detailed assessment at the trophic and family level revealed a slight dominance of herbivores over carnivores, mainly due to the high presence of Scaridae and Acanthuridae. This trend could not be fully explained by the composition of the overall habitat, since this was composed of a complex proportion of hard and soft bottom, offering niches to different families. Kyphosidae, Labridae, Lethrinidae, Mullidae and Scaridae displayed size ratios much lower than the maximum known for these families, indicating a selective impact from fishing.

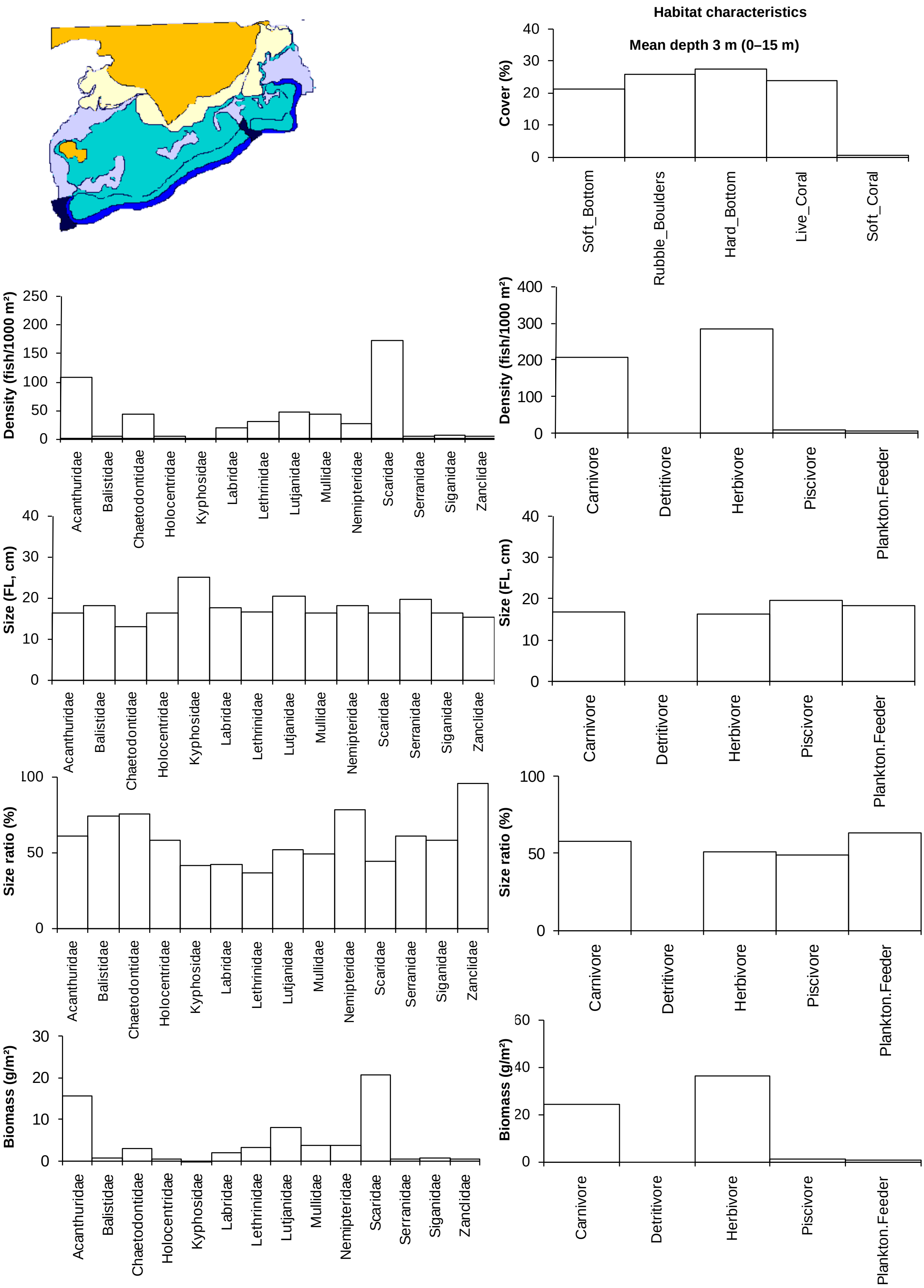

Figure 3.22: Profile of finfish resources in the combined reef habitats of Muaivuso (weighted average).
FL = fork length.

3.3.2 Discussion and conclusions: finfish resources in Muaivuso

The assessment indicated that the status of finfish resources in Muaivuso was average to low, with density, average fish size and biodiversity comparable to values at Dromuna and Lakeba but much lower than at Mali. The site is, however, limited in reef habitats (only back- and outer reefs are present), and this creates a natural disadvantage in terms of production and richness of resources. There was a slight dominance of herbivores over carnivores, mainly due to the large presence of Scaridae and Acanthuridae. Carnivores displayed very small sizes. The overall habitat was composed of a complex proportion of hard and soft bottom, offering niches to different families. Therefore, the scarcity or lack of carnivores and especially piscivores is to be related to fishing impact. Muaivuso is the most urbanised of the four villages, the closest to the capital Suva, and with the highest population density. People do not rely heavily on fishing for income generation but the fishing ground is very limited. Therefore, the resources still have to withstand a high fishing stress.

- The dominance of Acanthuridae and Scaridae could not be simply explained by the type of environment, which was very diverse and composed of hard and soft bottom, favouring different families. However, the outer reefs, where carnivores (Lutjanidae) were recorded in higher abundance, were composed primarily of hard bottom.

- Kyphosidae, Labridae, Lethrinidae, Mullidae and Scaridae displayed size ratios much lower than the maximum values known for these families, indicating a selective impact from fishing.

- The scarcity of piscivores, especially Serranidae, is most probably to be attributed to fishing impact.

3.4 Invertebrate resource surveys: Muaivuso

The diversity and abundance of invertebrate species at Muaivuso were independently determined using a range of survey techniques (Tables 3.10.a, b and c), broad-scale assessment (using the ‘manta-tow’ technique; locations shown in Figures 3.23a and b) and finer-scale assessment of specific reef and benthic habitats (Figures 3.24a and b).

The 2003 survey covered both the *qoliqoli* of Muaivuso (The whole area covering four villages is known traditionally as ‘Navakavu’.) and Tongalevu on the west, including the island of Namuka. The Navakavu Marine Protected Area (MPA) was established in 2001 with the help of USP, and the community is a member of the Fiji Locally Managed Marine Area (FLMMA) network. In 2009, the survey was conducted only inside the Muaivuso area with particular attention focused on the Navakavu MPA. Survey coverage thus shifted slightly east to include part of the community reef that was not covered in 2003.

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

Table 3.10a: Number of stations and replicate measures completed at Muaivuso in 2003

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	4	26 [(1)] transects
Reef-benthos transects (RBt)	3	18 transects
Soft-benthos transects (SBt)	7	43 transects
Soft-benthos infaunal quadrats (SBq)	18	144 [(2)] quadrat groups
Mother-of-pearl transects (MOPt)	4	24 [(3)] transects
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches	0 RFs 0 RFs_w	0 search period 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	0	0 search period

RFs = reef-front search; RFs_w = reef-front search by walking.
[(1)] Transects were 350–450 in length; [(2)] SBq stations are made of eight groups of four quadrats of 0.25 m x 0.25 m in size completed over a 40 m transect length (total surface assessed per station = 2 m²); [(3)] transects completed with help of Mr Semisi Meo, University of the South Pacific.

Table 3.10b: Number of stations and replicate measures completed in the open-access reef at Muaivuso in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	2	8 [(1)] transects
Reef-benthos transects (RBt)	3	18 transects
Soft-benthos transects (SBt)	9	54 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	0 RFs 0 RFs_w	0 search period 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	0	0 search period

RFs = reef-front search; RFs_w = reef-front search by walking.
[(1)] Transects were 300 m in length.

Table 3.10c: Number of stations and replicate measures completed inside the MPA at Muaivuso in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	3	16 [(1)] transects
Reef-benthos transects (RBt)	7	42 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches	0 RFs 0 RFs_w	0 search period 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	1	6 search periods

RFs = reef-front search; RFs_w = reef-front search by walking.
[(1)] Transects were 300 m in length.

The total estimated surface covered by the assessment was 24,578 m² in 2003 and 23,376 m² in 2009 (8900 m² in the open-access area and 14,476 m² in the MPA).

Figure 3.23a: Broad-scale survey stations for invertebrates in Muaivuso in 2003.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

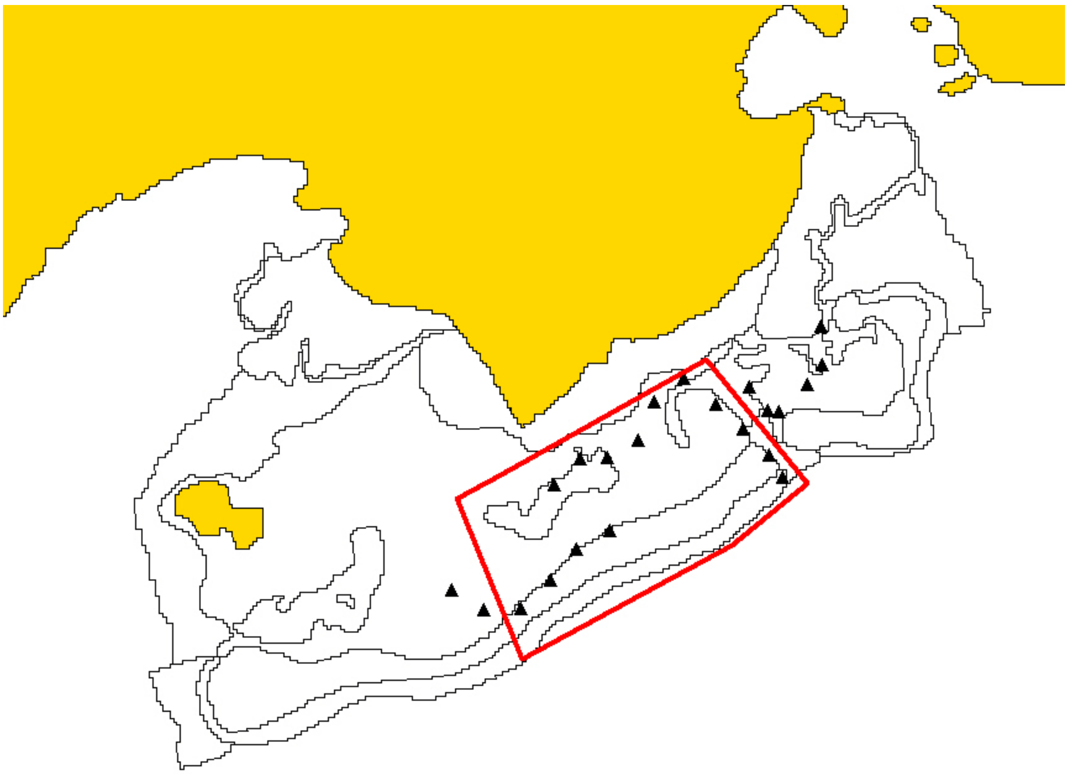

Figure 3.23b: Broad-scale survey stations for invertebrates in Muaivuso in 2009.
Data from broad-scale surveys conducted using 'manta-tow' board; MPA delineation is in red;
black triangles: transect start waypoints.

Figure 3.24a: Fine-scale reef-benthos transect survey stations and soft-benthos transect stations for invertebrates in Muaivuso in 2003.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

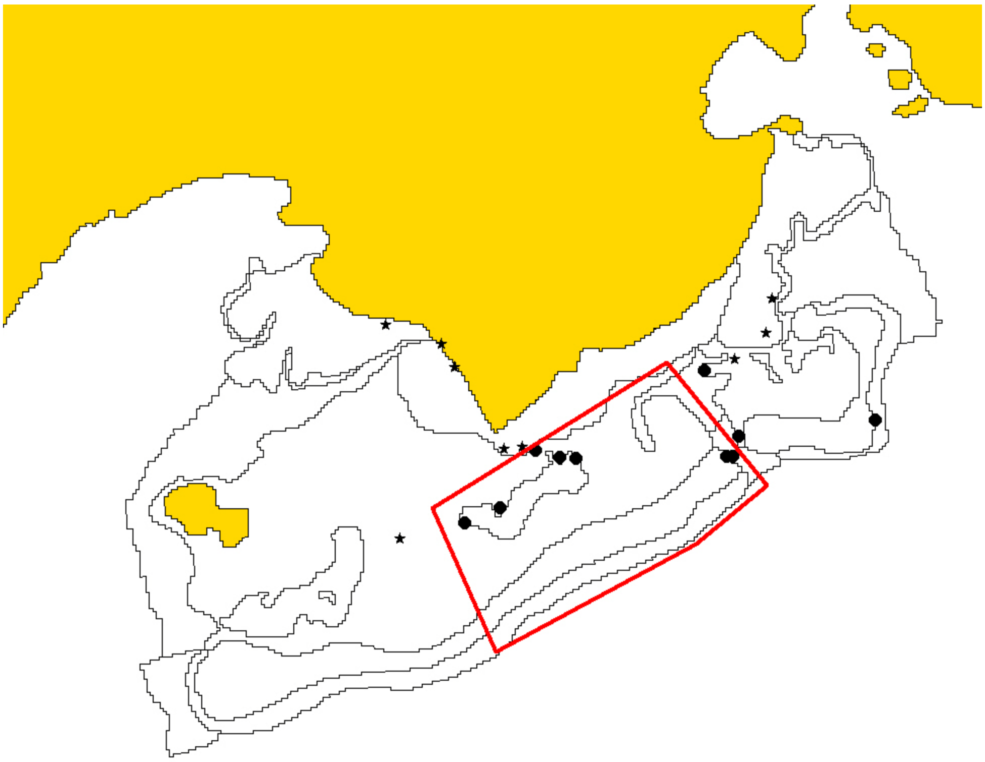

Figure 3.24b: Fine-scale reef-benthos transect survey stations and soft-benthos transect stations for invertebrates in Muaivuso in 2009.
MPA delineation is in red.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

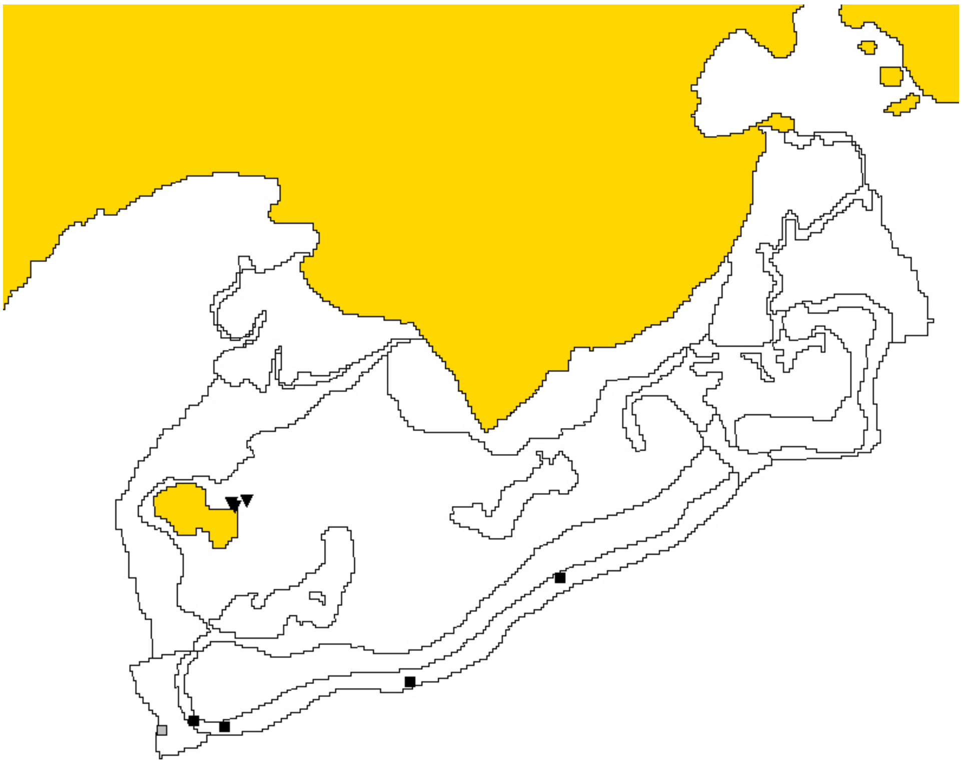

Figure 3.25a: Fine-scale survey stations for invertebrates in Muaivuso in 2003.
Grey squares: mother-of-pearl search stations (MOPs);
black squares: mother-of-pearl transect stations (MOPt)
black stars: soft-benthos infaunal quadrats (SBq).

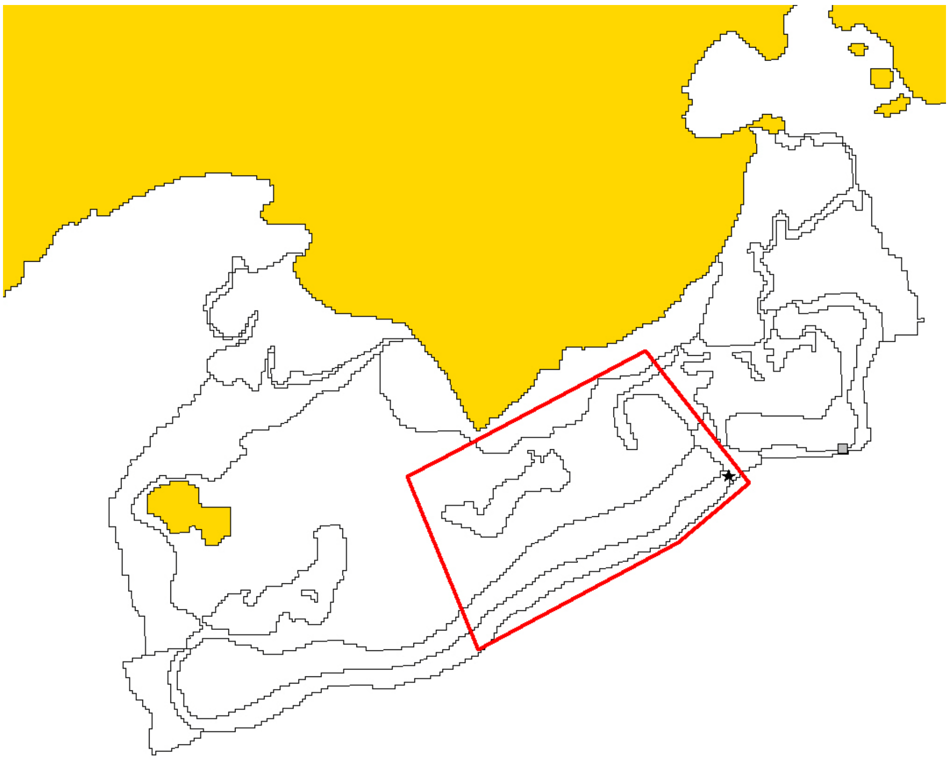

Figure 3.25b: Fine-scale survey stations for invertebrates in Muaivuso in 2009.
MPA delineation is in red.
Grey squares: mother-of-pearl search stations (MOPs);
black stars: sea cucumber day search (Ds).

In 2003, fifty-four species or species groupings (groups of species within a genus) were recorded in the Muaivuso invertebrate surveys. Among these were 9 bivalves, 19 gastropods, 21 sea cucumbers, 4 starfish and 6 urchins (Appendix 4.2.1 for 2003).

In 2009, thirty-nine species or species groupings (groups of species within a genus) were recorded in the Muaivuso invertebrate surveys (including MPA and open-access reefs). Among these were 5 bivalves, 9 gastropods, 1 crustacean, 13 sea cucumbers, 4 starfish and 6 urchins (Appendices 4.2.1 and 4.2.2 for 2009). Information on key families and species is detailed below.

3.4.1 2003–2009 stock status trends – giant clams: Muaivuso

Habitat that is suitable for giant clams was limited within the lagoon because, apart from some pooling sections, most of the sheltered areas were generally very shallow, sandy and without extensive fringing or intermediate reef. Most of the available reef was patch reef in shallow water (<2 m depth), and this was restricted to the edges of deeper-water pools, along channels in the barrier, and on some places at the back-reef (<1 km² in total area). There was dynamic water flow across the barrier reef (especially through the passes to the east and west of Muaivuso), and across the shallow lagoon, originating from the east. Outside the lagoon, the more exposed reef front and slope did not represent an extensive area (<0.5 km², lineal distance 7 km) and in most areas the reef slope shelved relatively steeply, without extensive offshore shoaling.

Although difficult to complete due to the sandy nature and shallow depth of the lagoon, broad-scale sampling provided an overview of giant clam distribution around Muaivuso.

In the 2003 survey, the elongate clam *Tridacna maxima* was not recorded, and only a single fluted clam *T. squamosa* was noted (mean density of 0.6 /ha ±0.6). This equates to one clam per 8.8 km of broad-scale searches (total benthos area recorded with broad scale: 16,600 m²). This result highlighted the sandy nature of the environment, but also the low number of clams present in the lagoon. This result was further supported by creel survey information (fishery dependent); no clams were fished in over 25 hours of fishing by 10 fishers.

Finer-scale surveys targeting clam habitat for a closer inspection were conducted using reef-benthos assessments on the barrier reef, and on small patches of reef found within soft-benthos areas (RBt and SBt; see Appendices 4.2.3 and 4.2.4 for 2003). No giant clams were recorded during these assessments on the inside of the barrier reef; however, a single *T. squamosa* clam was recorded in transects over soft benthos (mean station density of 2.8 /ha ±2.8).

A total of five *T. maxima* clams were noted in mother-of-pearl assessments conducted on the outer sectors of the barrier reef (reef front and passage), where the large swell limited access to gleaning fishers. *T. maxima* in these MOPt stations had a mean density of 20.8 /ha ±20.8 (See Appendix 4.2.7 for 2003.).

The two *T. squamosa* clams from broad-scale and soft-benthos stations were 22 cm and 19.1 cm respectively. *T. maxima* clams were not measured.

In 2009, in broad-scale survey, no elongate giant clams were recorded in the MPA and only one was recorded in the open-access reef area (mean density of 4.2 /ha ±4.2). No fluted giant clams were recorded. This illustrates the scarcity of giant clams at this site (one clam for 12,678 m² surveyed).

As in 2003, finer-scale surveys targeting clam habitat were conducted using reef-benthos assessments on the barrier reef, patch reefs surrounding the pool of the lagoon, and on small patches of reef found within soft-benthos areas (RBt and SBt; see Appendices 4.2.3 and 4.2.4 for 2009.). Only one station was surveyed on the shoal outside the barrier reef, which usually holds some specimens at depth.

At RBt stations inside the MPA, seven *T. maxima* clams were recorded at a mean density of 41.7 /ha ±12.9, while only one *T. squamosa* clam was noted at a mean density of 6.0 /ha ±6.0. On the open-access reef area, no giant clams were recorded at all on RBt, but one *T. maxima* clam was recorded on a SBt station.

The *T. maxima* clams' average size in the MPA (6 measurements) was 17.3 cm ±2.8 and the single specimen of *T. squamosa* was 20.0 cm (See Appendix 4.2.11 for 2009.).

In the open-access reef area, only one specimen of *T. maxima* was measured at 11.0 cm (See Appendix 4.2.10 for 2009.).

3.4.2 2003–2009 stock status trends – mother-of-pearl species (MOP): Muaivuso

The Muaivuso barrier reef has a limited area of fore-reef and back-reef habitat for the commercial topshell *Trochus niloticus* (an outer lineal distance approximately 7 km), and suitable reef habitat within the lagoon is negligible. The reefs within the lagoon lack many of the elements required for juvenile trochus habitat (rubble and hard bottom), although water movement is strong and the limited amount of rubble back-reef that is available (for juvenile settlement and growth) is linked to the barrier reef. The exposed reef is subject to large swells and there are few areas of shallow-water reef offshore (shoals) to hold commercial topshells.

However, in 2003, *T. niloticus* was recorded within the lagoon (SBt stations), on windward reef slopes (MOPt), and in the catches of fishers gleaning the barrier reeftop (Table 3.11a). On the outer-reef slope, the highest density per station was 167 trochus/ha. This equates to five trochus per station, although the greatest number of trochus per 80 m² transect was three individuals.

In 2009, *T. niloticus* was recorded within the lagoon and on the sides of the passages in B-S, RBt and SBt stations but not on the outer shoal (Only one station was surveyed due to lack of time). Distributions were scarce and densities were of the same order of magnitude at RBt stations, inside the MPA (65.5 /ha ±58.8) and outside the MPA (41.7 /ha ±24.1). Part of the reason for these low records was because the reefs at Namuka passage, where trochus were recorded in 2003, were not assessed in 2009 (Tables 3.11b and c).

In 2003, the mean size (basal width) of trochus *T. niloticus* was 9.9 cm ±1.2 (n = 7) from survey, and 4.1 cm ±0.1 from fishers on the reeftop (n = 4). Data on trochus distribution and shell size suggest that stocks in Muaivuso are still spawning and recruiting despite the heavy fishing pressure (Table 3.11a).

In 2009, the mean size of trochus was 5.4 cm ±1.2 (n = 4) on open-access reefs and 10.2 cm ±0.6 inside the MPA (n = 12). Several small specimens recorded in 2009 show that there is still active recruitment despite the low densities observed and the ongoing fishing activity. The important difference in average size of trochus observed between the MPA and the open-access reefs indicates that the MPA is successful in protecting the trochus (Tables 3.11b and c).

The green topshell *Tectus pyramis* (of low commercial value), a species closely related to trochus, with similar distribution and life history characteristics, was also recorded in assessments made in the lagoon and on the barrier-reef slope.

In 2003, the presence and density of *T. pyramis* was moderate, possibly reflecting the less-than-ideal habitat conditions for grazing gastropods in Muaivuso, although *T. pyramis* was also targeted by fishers (found in catches during creel surveys), and may also be considered to be under significant fishing pressure. The average size of *T. pyramis* was 5.0 cm ±0.3 (n = 7). Similarly to trochus, *T. pyramis* was also recorded at small, recruit sizes (Table 3.11a).

In 2009, the presence and density of *T. pyramis* were lower than in 2003, both inside and outside the MPA. The average size in the open-access reefs was slightly smaller (5.8 cm ±0.2, n = 5) than in the MPA (6.3 cm ±0.4, n = 6), again showing that the MPA may play a role in protecting species (Tables 3.11b and c)

Pinctada margaritifera, a normally cryptic and sparsely distributed pearl oyster species, was recorded in 2003 in two broad-scale stations (8% of transects). *P. margaritifera* was also recorded on reef-benthos stations (Table 3.11a) but was not noted in creel surveys from fishers gleaning the reeftop. The mean size of blacklip pearl oysters recorded in this study was 9.1 cm ±2.5 (n = 3). Taking into account the cryptic nature of *P. margaritifera* and its general low density in open-reef systems characteristic of Melanesia, these results describe a low-to-medium occurrence of *P. margaritifera*.

In 2009, *P. margaritifera* was recorded only once in a broad-scale station, showing again the rarity of the species in this site. No measurement was recorded (Tables 3.11b and c).

In summary, the reefs at Muaivuso provide limited habitat for mother-of-pearl stocks such as trochus. Some potential habitat can be found on the sides of the Nukusaga passage and the side of the main Suva passage, but the reef here is polluted with silt from the harbour. Trochus densities in 2009 were everywhere lower than in 2003. Nevertheless, the MPA seems to be active in preserving spawning populations. As in the other Fiji Island sites surveyed, the trochus resource in Muaivuso is in danger of local extinction. Urgent management attention should be taken. Closure of the whole fishery is the best way forward to allow the resource to replenish itself.

Table 3.11a: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Muaivuso in 2003
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	1.2	0.7	2/4 = 50	2/26 = 8
RBt	27.8	27.8	1/3 = 33	1/18 = 6
SBt	0	0	0/15 = 0	0/91 = 0
MOPt	0	0	0/4 =0	0/24 = 0
Tectus pyramis				
B-S	0	0	0/4 = 0	0/26 = 0
RBt	97.2	77.3	2/3 = 67	4/18 = 22
SBt	0	0	0/15 = 0	0/91 = 0
MOPt	145.8	64.2	4/4 =100	12/24 = 50
Trochus niloticus				
B-S	0	0	0/4 = 0	0/26 = 0
RBt	0	0	0/3 = 0	0/18 = 0
SBt	8.3	6.0	2/15 = 13	3/91 = 3
MOPt	67.7	35.5	3/4 =75	9/24 = 38

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

Table 3.11b: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* at open-access reefs in Muaivuso in 2009
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	2.1	2.1	1/2 = 50	1/8 = 12.5
RBt	0	0	0/3 = 0	0/18 = 0
SBt	0	0	0/9 = 0	0/54 = 0
MOPs	0	0	0/1 =0	0/6 = 0
Tectus pyramis				
B-S	0	0	0/2 = 0	0/8 = 0
RBt	55.6	55.6	2/3 = 67	1/18 = 6
SBt	0	0	0/9 = 0	0/54 = 0
MOPs	6.2		1/1 =0	1/6 = 0
Trochus niloticus				
B-S	0	0	0/2 = 0	0/8 = 0
RBt	41.7	24.1	2/3 = 67	3/18 = 17
SBt	4.6	4.6	1/9 = 11	1/54 = 2
MOPs	0	0	0/1 =0	0/6 = 0

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

Table 3.11c: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* inside the MPA at Muaivuso in 2009
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	0	0	0/3 = 0	0/14 = 0
RBt	0	0	0/7 = 0	0/42 = 0
Tectus pyramis				
B-S	0	0	0/3 = 0	0/14 = 0
RBt	35.7	24.8	2/7 = 28	4/42 = 10
Trochus niloticus				
B-S	1.2	1.2	1/3 = 33	1/14 = 7
RBt	65.5	58.8	2/7 = 28	6/42 = 14

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

3.4.3 2003–2009 stock status trends – infaunal species and groups: Muaivuso

The soft-benthos areas found within the Muaivuso lagoon were generally sandy with some rubble and coral outcrops. Seagrass and muddy areas were found close to the mangroves west of Muaivuso settlement but no concentrations of in-ground resources (shell beds) were located.

In the 2003 survey, arc shells *Anadara* spp. (*kaikoso*) were found at low density across the lagoon but no *Anadara* were noted in creel surveys conducted in Muaivuso. Fine-scale infaunal stations (quadrat surveys) were completed, mainly to estimate the density of *Strombus* (*gibberulus*) *gibbosus*, the humped conch (*golea* or *gera*), which was reportedly collected by fishers. In these surveys *gera* was noted at all the three stations sampled (16 out of 18 quadrat groups) at a mean density of 11.8 /m² ±2.8. The mean live shell length was 3.3 cm ±0.02 (n = 89). A single *Anadara* sp. of 4.4 cm was found in these surveys. *Anadara* spp. were also recorded in soft-benthos transects at a mean density of 22.2 /ha ±11.4. This latter record is probably an underestimate, as SBt surveys do not target infaunal species.

In 2009, no arc shells were recorded during the survey. Again, the limited time to assess the site did not allow any dedicated survey for infaunal species to be conducted.

3.4.4 2003–2009 stock status trends – other gastropods and bivalves: Muaivuso

In 2003, *yaga* (or *ega*) the smaller spider conch (both *Lambis lambis* and *Lambis crocata*) were recorded in broad-scale and soft-benthos stations and within creel surveys at moderate density (mean for SBt was 71.8 ±35.6 /ha; see Appendix 4.2.4 for 2003). None of the larger Seba's spider conch *L. truncata* were noted, and the smaller strawberry conch *Strombus luhuanus* was only present at a single reef-benthos station (No high-density patches were located.).

In 2009, *L. lambis* were recorded outside the MPA, but these may include *L. crocata* specimens as the locally trained team was not sufficiently experienced to detect the difference between these two very similar species. *L. lambis* was recorded at a low density (mean for SBt was 18.5 ±10.1 /ha; see Appendix 4.2.7 for 2009.). The larger spider conch *L. truncata* was recorded on one occasion inside the MPA. The strawberry conch *S. luhuanus* recorded was only anecdotal, and was not present in sufficient quantity to be considered as a subsistence resource.

In 2003, turban shells (*Turbo* spp.), which are commonly collected along exposed reef fronts in the Pacific, were not common in surveys, although the swell was high and access to the reef front was limited during the study. Fishers interviewed on the reeftop while looking for octopus were collecting reasonable numbers of *la*, noted as *Turbo crassus* (although they may have been large specimens of *T. argyrostomus*; see Appendix 4.2.3 for 2003). The smaller turban species found at more protected, inshore locations, *T. chrysostomus*, was moderately common at Muaivuso.

In 2009, no turban shells were recorded. This does not necessarily mean that the species was not present (as it is often found on the top of the barrier reef, which was not assessed in 2009), but it does reflect the widespread level of depletion of most subsistence food species.

Other resource species targeted by fishers (e.g. *Cerithium*, *Conus*, *Cypraea*, *Dolabella*, *Littoraria* and *Strombus* spp.) were recorded during independent surveys. Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Chama*, *Fragum*, *Hyotissa*, *Modiolus*, *Pinna*, and *Spondylus*, are also in the appendices (See Appendices 4.2.2 to 4.2.7 for 2003 and Appendices 4.2.2 to 4.2.10 for 2009.). One crown-of-thorns predator shell, a large *Charonia tritonis* (triton shell), was recorded outside the station at the Nukusaga passage to the east in very shallow water.

In 2003, creel surveys were conducted at Muaivuso of catches by 10 different fishers over two days (Appendix 4.2.10 for 2003).

No creel survey assessment was realised in 2009.

3.4.5 2003–2009 stock status trends – lobsters and crabs: Muaivuso

There was no dedicated night reef-front assessment of lobsters (See Methods.), and no lobsters were recorded during other assessments at Muaivuso. The mud crab, *Scylla serrata*, would be found in the mangroves fringing the shoreline; however, a snapshot independent survey would not supply a reliable indication of crab abundance and was not conducted either during the 2003 or the 2009 surveys.

3.4.6 2003–2009 stock status trends – sea cucumbers[7]: Muaivuso

Muaivuso is part of Vitu Levu and, therefore, on a large land mass that slopes down to a restricted shallow lagoon. There are at least eight small river outflows into the lagoon, where mixed hard and soft benthos, reef margins and fringing mangroves provide suitable habitat for a number of sea cucumber species. These commercial deposit feeders generally eat organic matter in the upper few mm of bottom substrates and are common in protected, shallow-water lagoonal environments bordering high islands. The shallow lagoon at Muaivuso has dynamic water flow, but is relatively exposed (too shallow), except in the

[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.

deeper pools and adjacent to the main mangrove stands in the west. At the barrier, most reefs are subject to a high degree of wave action and the reef slope falls off steeply into deep water.

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Tables 3.12a, b and c; Appendices 4.2.2 to 4.2.7 for 2003 and Appendices 4.2.2 to 4.2.10 for 2009; also see Methods).

Despite the generally shallow habitat, 19 species of commercial sea cucumber and one indicator species were recorded during in-water assessments in 2003 (Table 3.12a).

In 2009, nine commercial species plus one indicator species were recorded in the open-access reef area and nine commercial species were recorded inside the MPA. The total number of species recorded for both the open-access reef area and the MPA is 12 commercial species plus one indicator species.

In 2003, sea cucumber species associated with reef, the low-value flowerfish (*Bohadschia graeffei*) and medium-value leopardfish (*B. argus*), were common (recorded in 42–56% of broad-scale transects). Higher-value species such as greenfish (*Stichopus chloronotus*) and black teatfish (*Holothuria nobilis*) were present but less common (in 4–12% of broad-scale transects) and the density of all these species was not high. Despite their medium density, black teatfish records were relatively unusual at Muaivuso. Four of the five records from the survey were for juvenile *H. nobilis* (three of 11 cm and one of 14.5 cm). Juvenile black teatfish are normally very hard to find and this suggests the site might be unusually suited to this species. This suggestion arose as local fishers interviewed at the site (with a catch of black teatfish) reported that they regularly harvested 1–6 pieces of this species per gleaning trip (on foot but using a mask). This species is generally found at low density on back-reefs.

In 2009, leopardfish (*B. argus*) was recorded in 50% of broad-scale transects inside the MPA but only at 12% on the open-access reefs. Greenfish were recorded in both areas but more commonly inside the MPA than in the open-access reefs (respectively 29 and 12.5% of broad-scale transects). The medium-/high-value species *Stichopus hermanni* was recorded inside the MPA but was absent from the open-access reefs during broad-scale surveys. Neither flowerfish nor black teatfish were recorded in broad-scale surveys, but both were recorded in fine-scale surveys in both areas. The high-value *H. nobilis* was recorded at relatively good density in RBt stations inside the MPA, but at a relatively lower density than during the 2003 survey.

The exposed oceanic nature of the site suited surf redfish, *Actinopyga mauritiana*.

In 2003, *A. mauritiana* was relatively rare, found only at one RBt station and not recorded on the outer slope.

In 2009, *A. mauritiana* was absent from the survey. However, this is understandable as only one station in its preferred habitat was surveyed, while several stations were surveyed in 2003, although only one specimen was noted.

More protected soft-benthos areas with patches of reef were common in the pools in front of Muaivuso settlement and to the west where seagrass and mangrove stands predominate.

In 2003, elephant trunkfish (*Holothuria fuscopunctata*) and brown sandfish (*Bohadschia vitiensis*) were recorded, as were lower-value lollyfish (*H. atra*), pinkfish (*H. edulis*) and snakefish (*H. coluber*). The higher-value *dri* (*Actinopyga miliaris*) was not found at high density but was present at Muaivuso.

Interestingly, deep-water redfish (*Actinopyga echinites*) was the exception at Muaivuso as it was common across the site, and small individuals of this species were found in very high-density aggregations on the sandy back-reef (over 1 m² at the two reef-benthos stations, where they were recorded). Deep-water redfish, which is a relatively cryptic sea cucumber often found in shallow water, is not easily seen in broad-scale surveys. The average length of the deep-water redfish was 7.8 cm ±0.1 (n = 270, range 4.1–20 cm).

Lastly, in the *tabu* area close to the mangroves, false sandfish (*Bohadschia similis*) and sandfish (*Holothuria scabra*) were common. The high-value sandfish (not exported from Fiji Islands) was present in all four stations situated close to the mangroves at a mean station density range of 125–1042 individuals/ha. The mean length of sandfish in this area was 19.4 cm ±0.8, whereas stations closer to the Muaivuso settlement held fewer (41–250 individuals/ha) and smaller sandfish (18.8 cm ±0.6; see Figure 3.26). Stations that contained *H. scabra* records in 2003 were located to the west, i.e. outside the Muaivuso boundary.

In 2009, the composition list of species recorded in this environment changed; no *H. fuscopunctata*, *A. miliaris* or *A. echinites* were recorded but a specimen of the high-value *H. scabra versicolor* was noted (After a recent change in taxonomic name, this species is called *Holothuria lessonii* but, to keep consistency across all PROCFish reports, the former name is retained.). It is very surprising that these three species were not recorded, as they were common to abundant in 2003. *A. echinites* was especially abundant and recorded at high densities over a large reef area and *A. miliaris* was recorded throughout a number of SBt and RBt stations at moderate densities. We do not have any explanation for this dramatic shift. The species may still be present but the simple fact that none were recorded already indicates that they are no longer at a fishable level. If any statistics on bêche-de-mer sold from this place were available, they may give some indication on whether or not fishing activity is responsible for this decline in numbers.

Sandfish (*H. scabra*) and golden sandfish (*H. versicolor*) were both recorded only once on the open-access reefs and none were recorded in the MPA.

Lollyfish (*H. atra*), greenfish (*S. chloronotus*) and pinkfish (*H. edulis*) were the most abundant species recorded at Muaivuso in the 2009 survey. Densities for these species were significantly higher in the MPA (565.5, 440.5 and 148.8 individuals/ha respectively) than on the open-access reefs (27.8, 55.6 and 83.3 individuals/ha respectively).

In summary, the sea cucumber stocks of Muaivuso have dramatically declined to a critically low level between 2003 and 2009. *Actinopyga echinites* and the high-value *A. miliaris* and *H. fuscopunctata* were present in moderate-to-good densities in 2003 but were absent in the 2009 surveys. The three species may still be present but at such a low level that they can be considered commercially extinct. The high-value *H. scabra* (*dairo*) and *H. scabra versicolor* (golden sandfish) were recorded in the 2009 survey but at dangerously low populations. These two species are on the verge of extinction from the area. A similar result for these two species was found also in Dromuna and Lakeba in Vanua Levu. On a positive note, the densities of *H. atra, H. edulis, S. chloronotus, B. argus, S. hermanni* and *H. nobilis* were higher inside the MPA than in the open-access reefs. The MPA has been effective in protecting sea cucumber stocks against overexploitation; however, the stocks are still far below a profitable, fishable level for fishing to be considered.

Management considerations for sea cucumbers

A national ban on the sea cucumber fishery is recommended to assist the conservation effort in Muaivuso. No discretionary exemptions should be given for exploitation except for research purposes. This ban should be enforced for all species at the village, provincial and national levels. Once stocks have rebuilt to significant levels, the fishery can recommence at more reasonable rates of harvest to be determined by a national fishery plan. A national sea cucumber fishery management plan is required.

The Muaivuso community is aware of the need to conserve its resources, and the establishment of the MPA is testament to their concern. If the resources outside the MPA are not showing signs of real improvement then there is a need for concrete action at the national level.

Fishing of sea cucumbers in Muaivuso is not profitable at the moment. All sea cucumber fishing should be closed to conserve the remaining stocks for breeding purposes. The reef in Muaivuso is small as compared to the three other sites studied in Fiji Islands but there is potential for some species of sea cucumber.

The export ban on commercial export species such as *Holothuria scabra* (*dairo*) should also include subsistence and semi-commercial use. *H. scabra* is exempt from the 1988 ban on export; however, its continued exploitation by the subsistence and semi-commercial fishery has had a devastating impact on the resource.

The absence of *dri* (*Actinopyga miliaris)* and *A. echinites* in Muaivuso (also in Mali, Lakeba) should raise concerns for these high-value and easily accessible species. The species could possibly be extinct from these areas.

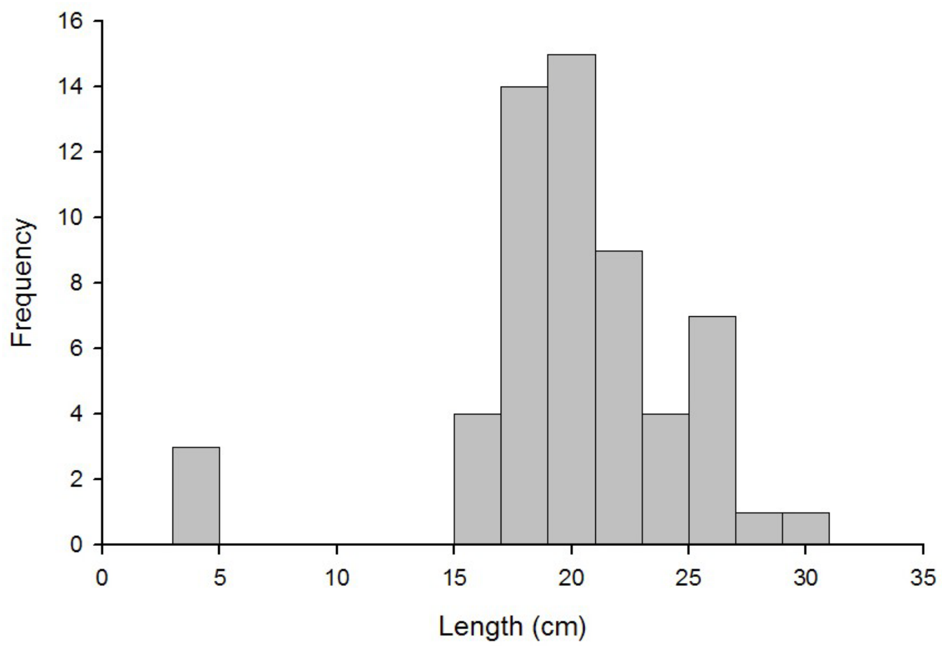

Figure 3.26: Size frequency histogram of sandfish (*Holothuria scabra*) from soft-benthos assessment stations at Muaivuso in 2003.

Deep dives on SCUBA during sea cucumber day searches (25–35 m in depth) would provide a preliminary assessment of deep-water stocks such as the high-value white teatfish (*H. fuscogilva*), prickly redfish (*Thelenota ananas*) and the lower-value amberfish (*T. anax*), but these were not completed at Muaivuso in 2003. However, both prickly redfish (*T. ananas*) and amberfish (*T. anax*) were noted in survey.

In 2009, one deep dive was conducted at 12–23 m deep. It recorded the presence of *T. anax*, *H. nobilis* and *H. edulis*. *T. anax* was recorded at a good density of 17.6 specimens/ha; the other two species were recorded only once.

3.4.7 2003–2009 stock status trends – other echinoderms: Muaivuso

In 2003, no edible slate urchins (*Heterocentrotus mammillatus*) were found at Muaivuso; however, collector urchins (*Tripneustes gratilla*) were plentiful and supported a regular artisanal fishery. *T. gratilla* were present across the lagoon but were most plentiful on the back-reefs. Mean densities reached a maximum of 33,750 /ha or 3.4 /m² in one station (The overall average for all RBt stations was 14,263.9 /ha ±9752.1). In the lagoon, the mean density for soft-benthos stations was lower (677.8 /ha ±235.1), with 2792 /ha recorded at the soft-benthos station with the greatest density. A creel survey of gleaners' catches of collector urchins was also conducted. In general, collectors harvested 1–7 flour bags of urchins per trip (approximately 150 sea urchins per 50 kg flour bag; see Appendix 4.2.10). The average test diameter of these urchins was 7.5 cm ±0.1 (See Figure 3.27.).

The density of *T. gratilla* or *cawake*, the main edible sea urchin collected at Muaivuso, declined between 2003 and 2009. Muaivuso is the main supplier of *cawake* to the Suva market.

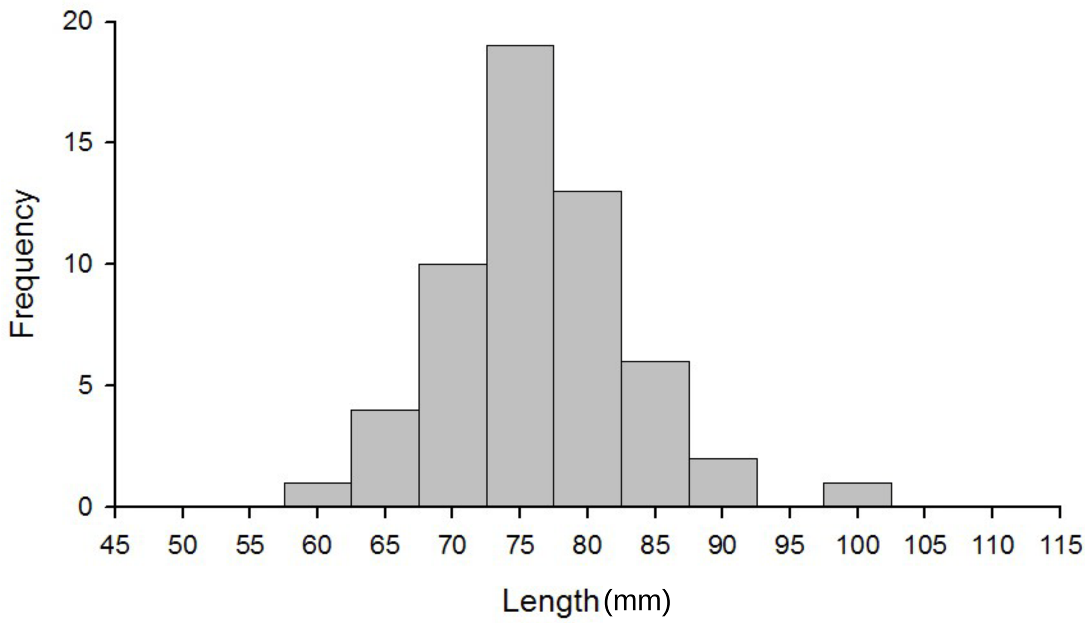

Figure 3.27: Size frequency histogram of collector urchin (*Tripneustes gratilla*) test diameter from artisanal catches at Muaivuso in 2003.

Toxopneustes pileolus was found irregularly, but the smaller *Mespilia globulus* was recorded at relatively high density in soft-benthos stations (mean density 5654.8 /ha ±3098.8). It is not documented whether this species competes with *T. gratilla* for food or benthos, which could impact the 'health' of the collector urchin artisanal fishery. At present *M. globulus* is isolated to the lagoon and not found on the reeftop, where most of the commercial fishing for *T. gratilla* takes place. There is also confusion among some fishers who believe that *M. globulus* specimens are juveniles of *T. gratilla*.

Echinometra mathaei was found at moderate-to-high density on limestone pieces in the soft benthos; *Echinothrix* spp. were also recorded but at lower density.

The blue starfish (*Linckia laevigata*) was very common (recorded in 81% of broad-scale transects, and in 73% and 100% of soft- and reef-benthos stations respectively) and at relatively high densities (mean of 916.7 /ha ±292.7 on reef-benthos stations). Three coralivore (coral eating) starfish were recorded at Muaivuso: the cushion star (*Culcita novaeguineae*) the 'Kenya' or 'dough-boy' star (*Choriaster granulatus*) and the crown-of-thorns starfish (*Acanthaster planci*, COTS). None of these starfish were at high density (Appendices 4.2.1 to 4.2.7).

In 2009, as in 2003, no edible slate urchins (*Heterocentrotus mammillatus*) were found. *Tripneustes gratilla* were still recorded at relatively good density compared to numbers at the other PROCFish sites. Nevertheless, the density observed varied a lot inside and outside the MPA. In the open-access reefs, the density observed in broad-scale transects was 12.5 /ha ±12.5, while inside the MPA it was 372.7 /ha ±372.7. Overall, 269 specimens were recorded in the MPA (total surface coverage of 14,476 m^2 in the MPA) compared to 60 recorded in the open-access reef (8900 m^2 in the open-access area). This indicates that the MPA is playing a significant role in preserving this species.

The dangerous *Toxopneustes pileolus* (whose sting can cause death) was common (a total of 23 specimens) and recorded at high density compared to that in other sites assessed across the Pacific.

The blue starfish (*Linckia laevigata*) was recorded at the highest densities observed at PROCFish sites, at 492.0 /ha ±177.4 inside the MPA and 338.1 /ha ±78.8 at the open-access reefs in broad-scale transects. The very favourable habitats, as well as the diminishing competition with other species, are factors that may explain these high densities.

The crown-of-thorns starfish (*Acanthaster planci*) was recorded in all habitats. In broad-scale transects, density was high (52.14 /ha ±35.0) in the open-access reefs and low (1.6 /ha ±1.6) in the MPA. This density is high enough to be defined as an 'active outbreak' situation.

On the Great Barrier Reef of Australia, the following system is used for defining COTS outbreaks:

- *Incipient outbreak* - The density at which coral damage is likely. Occurs when there are 0.22 adults per 2-minute 'manta-tow'; or >30 adults and subadults per hectare, where subadults are 15–25 cm diameter (2 years old) and adults are >26 cm (>3 years old), using SCUBA diving counts (N.B. starfish may be mature at 2 years or 20 cm diameter but, for the definition of an outbreak, >26 cm is used.).
- *Active outbreak* - COTS densities are >1.0 adults per 2-minute 'manta-tow', and adults are >15 cm diameter; or >30 adult-only starfish per ha if SCUBA diving.

Monitoring COTS is important as it has the potential to be very destructive to coral cover if densities become high. One starfish can devour as much as 2–6 m² of coral each year. These starfish begin to eat coral at about six months of age (when they are 1 cm in size) and grow over two years to about 25 cm in diameter. During a severe outbreak, there can be several COTS per square metre and they can kill most of the living coral in an area of reef, reducing coral cover from the usual 25–40% of the reef surface to less than 1%, which can take up to a decade to recover (Appendices 4.2.1 to 4.2.9 for 2009).

The population of COTS reached an active outbreak level in 2009 in contrast to a low level in 2003. This outbreak is responsible for the coral predation recorded at the Nukusanga passage (where this aggregation was recorded). A COTS removal campaign should be undertaken to control its numbers and damage. This can be organised by the fishery department in partnership with NGOs, diving clubs and the local community.

3.4.8 2003–2009 stock status trends – other molluscs: Muaivuso

No octopus were recorded in either the 2003 or the 2009 assessments; however, there were no dedicated assessments made of these rock-dwelling molluscs. Octopus was recorded in the 2003 fisher catch survey, but no fisher catch was assessed in 2009. According to Van Beukering *et al.* (2007) the people of Muaivuso noted an increase in octopus catch outside the MPA.

3.4.9 Algae, seaweed and live coral: Muaivuso

The growth of the brown algae (*Sargassum* spp.) as in other Fiji Island sites, seems to be greater than normal, covering potential shallow-reef benthos. The mean algal coverage in the shallow lagoon areas was 10–20% in broad-scale stations. This could be normal in this location due to the nutrient enrichment received from terrestrial discharges. Concentrated algal cover can potentially impact larval settlement and, therefore, recruitment of invertebrates. Live-coral growth inside the lagoon and back-reef was low (<20%) but relatively more healthy outside the barrier reef, with >30% coverage.

Marine protected area (MPA)

The establishment of the MPA in Muaivuso was a good initiative and is showing positive results. Densities of most species inside the MPA were higher than on the open-access reefs. However, critical invertebrate habitats, such as those for *Holothuria scabra*, are not protected. Extension of the MPA area inward to include an area of mangrove-associated habitat is recommended.

Environmental issues

A crown-of-thorns (*Acanthaster planci*) cleaning campaign is recommended to control the current outbreak. Muaivuso has limited live-coral cover, which can be wiped out quickly in a short period of time if this coral-eating starfish is not controlled.

The growth of the brown algae (*Sargassum* spp.) was high on Muaivuso reef flat as in other Fiji Island sites and could be a problem for Muaivuso. Its growth has increased in recent years (Van Beukering *et al.* 2007). Increased growth of *Sargassum* spp. is caused by increased nutrient loading in the marine environment (Mosley and Aalsberg 2003, Tamata 2007). Dense *Sargassum* beds can negatively impact invertebrate species by taking over the habitat and preventing the growth of other algae that act as food for invertebrate grazers. Studies are needed to assess the impact of *Sargassum* on invertebrates resources.

A solid-waste clean-up campaign is also recommended. Littered plastics, glass bottles, metals and fishing nets are continuously deposited on Muaivuso reef in shallow waters. These can be easily removed.

Siltation of the eastern reef of Muaivuso (on the western side of Suva harbour) is affecting potential invertebrate habitat in the area. However, this is beyond the control of the Muaivuso community.

Table 3.12a: Sea cucumber species records for Muaivuso in 2003

Species	Common name	Commercial value [5]	B-S transects n = 26			Reef-benthos stations n = 3			Other stations SBt = 15			Other stations MOPs = 1; MOPt = 4		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H	0.6	16.7	4	7917	11875	66	65.5	89.3	73			
Actinopyga lecanora	Stonefish	M/H												
Actinopyga mauritiana	Surf redfish	M/H				13.9	41.7	33						
Actinopyga miliaris	Blackfish	M/H				69.4	104.2	66	82.2	154.0	53			
Bohadschia argus	Leopardfish	M	15.0	26.0	56	13.9	41.7	33	11.1	55.6	20	5.2	20.8	25 MOPt
Bohadschia graeffei	Flowerfish	L	25.6	60.6	42	139.0	139.0	100				51.2	69.0	75 MOPt
Bohadschia similis	False sandfish	L				139.0	416.7	33	683.3	1025.0	67			
Bohadschia vitiensis	Brown sandfish	L	5.5	28.6	19				71.8	97.9	73			
Holothuria atra	Lollyfish	L	12.1	34.9	35	278.0	278.0	100	30.6	76.4	40			
Holothuria coluber	Snakefish	L	15.9	51.7	31				38.9	145.8	27			
Holothuria edulis	Pinkfish	L	24.5	48.9	50				8.3	62.5	13			
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M	4.9	25.7	19									
Holothuria leucospilota	-	L				333	500	66	2.8	41.7	7			
Holothuria nobilis [4]	Black teatfish	H	0.5	14.3	4	27.8	83.3	33	5.6	41.7	13			
Holothuria scabra	Sandfish	H							160.3	267.2	60			
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	4.8	41.7	12	236	236	100	2.8	41.7	7			
Stichopus hermanni	Curryfish	H/M							19.4	58.3	33			
Stichopus horrens	Peanutfish	M/L				27.8	83.3	33						
Synapta spp.	-	-				1208.0	1813.0	66	1500.0	1608.0	93			
Thelenota ananas	Prickly redfish	H	2.8	18.5	15	Seen outside transect								
Thelenota anax	Amberfish	M	2.9	19.0	15									

[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; MOPs = mother-of-pearl search; MOPt = mother-of-pearl transect.

Table 3.12b: Sea cucumber species records for Muaivuso in the open-access reefs in 2009

Species	Common name	Commercial value [5]	B-S transects n = 8			Reef-benthos stations n = 3			Other stations SBt = 9		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H									
Actinopyga lecanora	Stonefish	M/H									
Actinopyga mauritiana	Surf redfish	M/H									
Actinopyga miliaris	Blackfish	M/H									
Bohadschia argus	Leopardfish	M	2.1	16.7	12.5	13.9	41.7	33			
Bohadschia graeffei	Flowerfish	L				277.8	416.7	67	4.6	41.7	11
Bohadschia similis	False sandfish	L									
Bohadschia vitiensis	Brown sandfish	L	15.6	62.5	25				4.6	41.7	11
Holothuria atra	Lollyfish	L	58.3	93.3	62.5	27.8	41.7	67	60.2	90.3	67
Holothuria coluber	Snakefish	L									
Holothuria edulis	Pinkfish	L				83.3	125.0	67			
Holothuria fuscogilva [4]	White teatfish	H									
Holothuria fuscopunctata	Elephant trunkfish	M									
Holothuria leucospilota	-	L									
Holothuria nobilis [4]	Black teatfish	H							4.6	41.7	11
Holothuria scabra	Sandfish	H							4.6	41.7	11
Holothuria scabra versicolor	Golden sandfish	H							4.6	41.7	11
Stichopus chloronotus	Greenfish	H/M	11.5	91.7	12.5	55.6	166.7	33	4.6	41.7	11
Stichopus hermanni	Curryfish	H/M									
Stichopus horrens	Peanutfish	M/L									
Stichopus vastus	Brown curryfish	H/M									
Synapta spp.	-	-							268.5	402.8	67
Thelenota ananas	Prickly redfish	H									
Thelenota anax	Amberfish	M									

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

Table 3.12c: Sea cucumber species records for Muaivuso in the MPA in 2009

Species	Common name	Commercial value [5]	B-S transects n = 14			Reef-benthos stations n = 7			Other stations Ds = 6		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H									
Actinopyga lecanora	Stonefish	M/H									
Actinopyga mauritiana	Surf redfish	M/H									
Actinopyga miliaris	Blackfish	M/H									
Bohadschia argus	Leopardfish	M	8.7	17.4	50	23.8	83.3	29			
Bohadschia graeffei	Flowerfish	L				71.4	100	71			
Bohadschia similis	False sandfish	L									
Bohadschia vitiensis	Brown sandfish	L									
Holothuria atra	Lollyfish	L	528.9	617.1	86	565.5	659.7	86			
Holothuria coluber	Snakefish	L				17.9	125.0	14			
Holothuria edulis	Pinkfish	L	13.8	38.7	36	148.8	208.3	71	2.2	13.2	17
Holothuria fuscogilva [4]	White teatfish	H									
Holothuria fuscopunctata	Elephant trunkfish	M									
Holothuria leucospilota	-	L									
Holothuria nobilis [4]	Black teatfish	H				11.9	83.3	14	2.2	13.2	17
Holothuria scabra	Sandfish	H									
Holothuria scabra versicolor	Golden sandfish	H									
Stichopus chloronotus	Greenfish	H/M	17.0	59.6	29	440.5	513.9	86			
Stichopus hermanni	Curryfish	H/M	2.4	16.7	14						
Stichopus horrens	Peanutfish	M/L									
Stichopus vastus	Brown curryfish	H/M									
Synapta spp.	-	-	2.4	33.3	7						
Thelenota ananas	Prickly redfish	H									
Thelenota anax	Amberfish	M							17.6	26.5	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; Ds = day search.

3.4.8 Discussion and conclusions: invertebrate resources in Muaivuso

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

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

- The shallowness of the lagoon and the lack of extensive protected areas of hard benthos at Muaivuso limited the area of suitable habitat for giant clams.

- Despite the lack of extensive habitat, two species of clam were noted but clams were still uncommon at Muaivuso both in the 2003 and 2009 surveys. The true giant clam, *Tridacna gigas*, is not found in Fiji Islands, and there is some uncertainty as to whether it was lost through overfishing or was never present. The bear's paw clam (*Hippopus hippopus*) is only known from the fossil record in Fiji Islands. However, the inshore lagoon areas at Muaivuso provide habitat especially suitable for the re-introduction of this species. The density of giant clams recorded at Muaivuso represents a very low abundance and suggests that giant clams have undoubtedly been affected by fishing.

- The largely open-reef environment makes an already fragile, slow-growing stock such as the giant clam stock even more susceptible to overfishing. Recruitment to local reefs following broadcast spawning will need to rely on stock that is under surrogate protection within the wave zone outside the barrier reef, and incoming larvae from remote sources. Tridacnidae clams tend to have a limited larval life (less than eight days), which limits their dispersal; they need to be at relatively high density for the broadcast spawners to achieve good rates of external fertilisation when eggs and sperm are released into the water column during periods of reproduction.

- The MPA in place at Muaivuso seems to have provided efficient protection to giant clams as density is higher inside than outside the MPA. Although the density is still critically low, the area outside the MPA will benefit from the future population increase inside the MPA.

- At the low density levels observed for both *T. maxima* and *T. squamosa,* it is very difficult to detect any changes in density between 2003 and 2009.

Data on the distribution, density and length recordings of MOP species reveal the following:

- Reefs at Muaivuso provide suitable habitat for the commercial topshell, *Trochus niloticus*, but conditions are somewhat limited due to the small scale of the area, its exposure, the sandy nature of the lagoon and reefs, and the lack of shoaling on the outer reef.

- Other mother-of-pearl stocks, such as the blacklip pearl oyster, *Pinctada margaritifera,* and the green topshell, *Tectus pyramis* (of low commercial value), were recorded in survey and are considered to be at low-to-medium density.

In summary, the environment, and the distribution and density recordings for sea cucumbers give a mixed picture of stock health.

- Habitat for sea cucumbers in Muaivuso was limited in scale and subject to daily fishing pressure. Although exposed, the shallow lagoon held a range of habitats, from inshore seagrass areas, to mid-lagoon pools and oceanic back-reef habitat. Generally, the lagoon was well-flushed with water from the east.

- Sea cucumber stocks in Muaivuso were varied, but the density of individual species groups suggested stocks were generally depleted in 2003 and totally overfished in 2009.

- In 2003, exceptions were the high-density aggregations of deep-water redfish (*Actinopyga echinites*) on the back-reef and the promising settlement of the higher-value black teatfish (*Holothuria nobilis*). However, in the 2009 survey, not a single specimen was recorded.

- The preliminary survey in 2003 suggested that the occurrence and density of sea cucumbers were too low for general commercial collection at that time, although deep-water redfish (*Actinopyga echinites*) was at sufficient abundance for controlled fishing.

- The 2009 survey revealed a much weaker level of bêche-de-mer resources, most of the stocks being at a critical level of depletion.

- One specimen each of *H. scabra* and *H. scabra versicolor* indicated that both species were present in the area but at dangerously low levels. Both specimens were found in the open-access area and could be collected at anytime.

- The current level of fishing activity is likely to lead to the local extinction of several species in the near future. It is recommended that a moratorium be declared for the bêche-de-mer fishery until the stocks are fully recovered. It is also recommended that a MPA or MPA network be designed in order to protect the broodstock once the moratorium ends.

- The 2009 results noted increases in the abundance and density of *H. atra*, *H. edulis*, *S. chloronotus*, *B. argus*, *S. hermanni* and *H. nobilis* within the MPA, which indicates the positive impact of the MPA in protecting resources against overexploitation.

3.5 Overall recommendations for Muaivuso

- Other giant clam species be introduced.

- The community-based management and monitoring in place in Muaivuso be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.

- The community continue to support the marine protected area (MPA) and expand the area covered if possible.

- The community consider the development of land-based activities for income generation given the current fishing pressure and poor state of the resources.

- A ban be placed on fishing for giant clams to conserve the remaining populations.

- Some larger clams be collected and placed in the MPA to boost the stocks and allow them to spawn and regenerate over time.

- If the horse-hoof or bear's paw clam *Hippopus hippopus* is to be re-introduced, Muaivuso be considered as a potential release site, as the broken (patchy) bottom sandy reef areas found in the area are well suited to this free-standing species.

- The trochus stocks be protected for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- The management of sea cucumbers be strengthened, and a total ban implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

- A clean-up campaign be implemented to control the current outbreak of the crown-of-thorns starfish (*Acanthaster planci*).

4. PROFILE AND RESULTS FOR MALI

4.1 Site characteristics

Mali is a traditional community located on a small island off Labasa on Vanua Levu (Figure 4.1). Half of the Vuata reef in front of the island was set aside as an MPA some years ago by the community with the support of Macuata Province and the Fiji Locally Managed Marine Area (FLMMA) group. Voro voro passage was added recently into the MPA area as a fish-spawning aggregation site, with plans to declare the passage a national marine reserve. This allowed for sampling stations to be located inside and outside the MPA. The second village surveyed, Nakawaqa, was selected for its coverage under the 1999 World Bank study “voices from the village”.

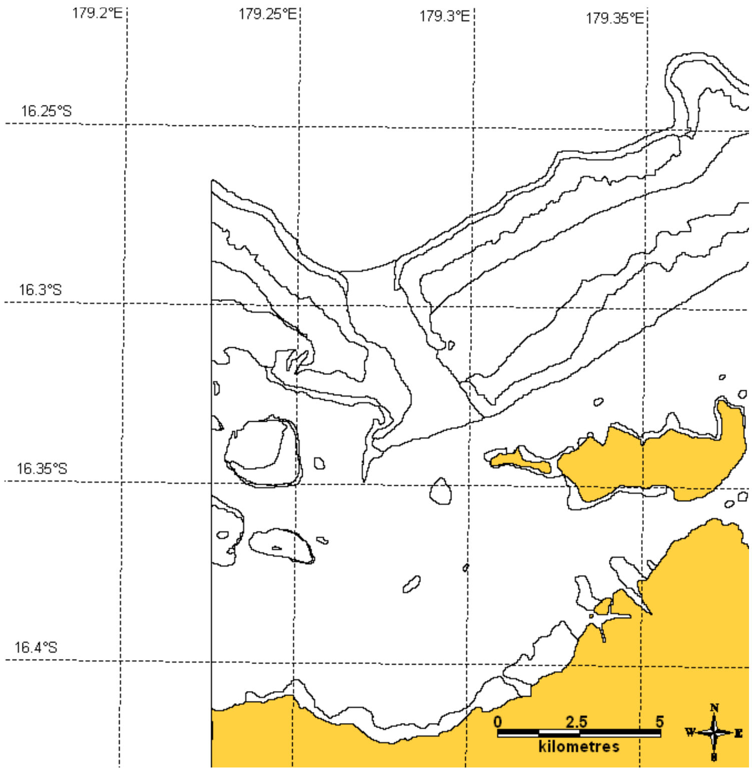

Figure 4.1: Map of Mali.

4.2 Socioeconomic surveys: Mali

Socioeconomic fieldwork was carried out in Mali village on the small island of Mali, located about 30 minutes by boat from Labasa, the main city on Vanua Levu, from 28 June to 3 July 2007. Because Mali is in close proximity to Labasa, people have access to distribution outlets and the main market. Mali is one of the main suppliers of seafood to the Labasa market, restaurants, shops and middle sellers in the main urban centre, thus the fishing dynamics are influenced by market factors. At the end of a fishing trip, male fishers often take their catch directly to the market, to other outlets, or to pre-arranged buyers. The fact that fishers have a choice of buyers for their products, including buyers from the urban centre, allows them to negotiate prices for their produce to some extent. Some buyers act as middlemen, who transfer some of the catch to the Suva market.

The Mali community has a resident population of 290 and 40 households. A total of 16 households, which is 40% of the total households in the Mali community, were surveyed, with almost all (94%) of these households being engaged in some form of fishing activities. In addition, a total of 22 finfish fishers (13 males and 9 females) and 25 invertebrate fishers (12 males and 13 females) were interviewed. The household size is medium to large with seven people on average, suggesting that the village still enjoys a predominantly rural and isolated lifestyle.

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 consumed was also conducted.

People from Mali have access to various habitats for fishing and these include mangrove areas and associated mud and sand flats, a lagoon area associated with coastal reefs, and an outer reef with passages. During the survey, the Mali fishing areas were under a five-year management plan, which declared most of the coastal reef areas as a ‘no fishing zone’. As a result, most fishing concentrated on the main lagoon areas around the *tabu* zones and at the outer reef.

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

Our results (Figure 4.2) suggest that fisheries are the main income source for the people of Mali. In fact, all households earn money from fishing in one form or the other. Most, i.e. 88%, earn first income from fisheries, while the remaining 12% earn complementary, secondary income from the sector. There are very few salary-based incomes on the island and agricultural production is marginal and hence does not offer any income opportunities. The need for additional income is suggested by the fact that 50% of all households earn secondary income from handicrafts made by females, i.e. mat weaving. Pigs are not popularly reared; only 19% of all households have perhaps one pig, while chickens are usually not accounted for but are numerous and run freely around the village. Distribution of fish and seafood produce on a non-monetary basis is still an important practice; 38% of all households reported consuming finfish that they are given.

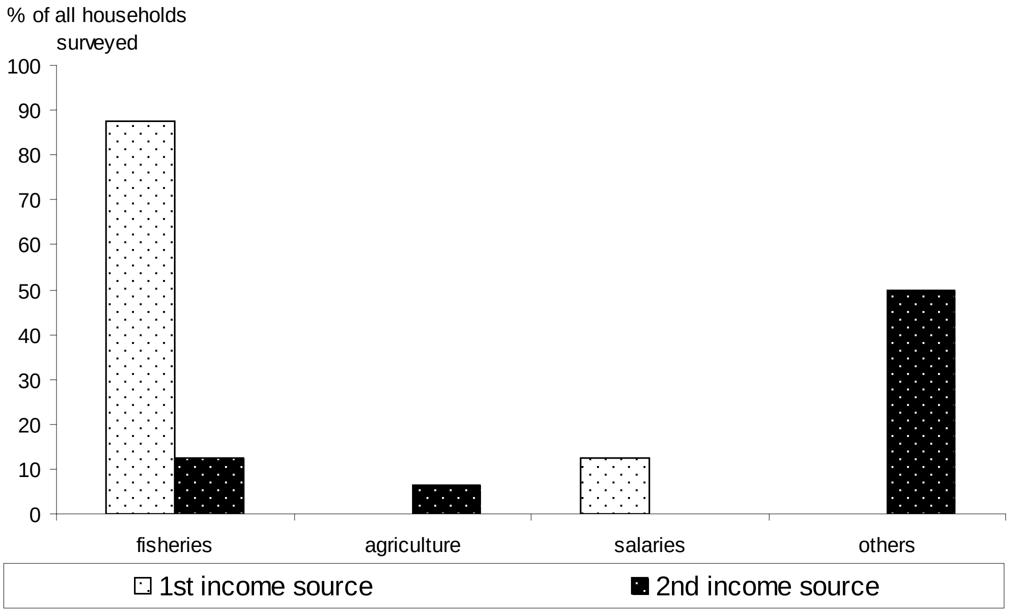

Figure 4.2: Ranked sources of income (%) in Mali.
Total number of households = 16 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible. 'Others' are mostly home-based small businesses.

Our results (Table 4.1) show that annual household expenditures are above the average found across all sites studied in Fiji Islands; however, they are generally low, on average USD 1330. People are self-sufficient regarding marine produce, and income from fisheries provides the purchasing power to buy agricultural and imported goods to complement fishery produce.

Remittances play almost no role on Mali, with only 6% of households receiving money sent from elsewhere. The average amount received by those few households is relatively low, i.e. USD 767 /household/year or about half of the annual basic household expenditure.

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

Survey coverage	Site (n = 16 HH)	Average across sites (n = 66 HH)
Demography		
HH involved in reef fisheries (%)	93.8	98.5
Number of fishers per HH	2.44 (±0.24)	2.47 (±0.11)
Male finfish fishers per HH (%)	10.3	12.9
Female finfish fishers per HH (%)	2.6	0.6
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	10.3	9.8
Male finfish and invertebrate fishers per HH (%)	46.2	41.7
Female finfish and invertebrate fishers per HH (%)	30.8	35.0
Income		
HH with fisheries as 1st income (%)	87.5	69.7
HH with fisheries as 2nd income (%)	12.5	24.2
HH with agriculture as 1st income (%)	0.0	4.5
HH with agriculture as 2nd income (%)	6.3	15.2
HH with salary as 1st income (%)	12.5	13.6
HH with salary as 2nd income (%)	0.0	3.0
HH with other source as 1st income (%)	0.0	12.1
HH with other source as 2nd income (%)	50.0	19.7
Expenditure (USD/year/HH)	1330.08 (±111.11)	1163.72 (±64.04)
Remittance (USD/year/HH) (1)	769.34 (n/a)	737.10 (±219.95)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	80.73 (±4.78)	74.00 (±2.96)
Frequency fresh fish consumed (times/week)	3.63 (±0.11)	3.20 (±0.07)
Quantity fresh invertebrate consumed (kg/capita/year)	13.09 (±5.33)	9.68 (±2.96)
Frequency fresh invertebrate consumed (times/week)	2.14 (±0.25)	2.11 (±0.13)
Quantity canned fish consumed (kg/capita/year)	1.77 (±0.45)	2.37 (±0.33)
Frequency canned fish consumed (times/week)	0.46 (±0.11)	0.47 (±0.05)
HH eat fresh fish (%)	100.0	98.8
HH eat invertebrates (%)	100.0	98.8
HH eat canned fish (%)	81.3	98.8
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	0.0	6.7
HH eat fresh fish they are given (%)	37.5	6.7
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 (%)	31.3	6.7

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

Survey results indicate an average of 2–3 fishers per household and, when extrapolated, the total number of fishers in Mali amounts to 98, including 55 males and 43 females. Among these are 13 exclusive finfish fishers (10 males, 3 females), 10 exclusive invertebrate fishers (females only) and 75 fishers who fish for both finfish and invertebrates (45 males, 30 females). More than half (56%) of all households own a boat, and all boats are fitted with an outboard engine.

Consumption of fresh fish is high at almost 81 kg/person/year, and above the average across all four study sites in Fiji Islands, and more than double the regional average of ~35 kg/person/year (Figure 4.3). By comparison, consumption of invertebrates (edible meat weight only) (Figure 4.4) is lower but still important at ~13 kg/person/year. Canned fish (Table 4.1) is not commonly eaten and adds only ~2 kg/person to the annual protein supply from seafood. The consumption pattern of seafood found in Mali highlights the fact that people have little if any access to agricultural produce and also limited purchasing power to acquire commercially available food items.

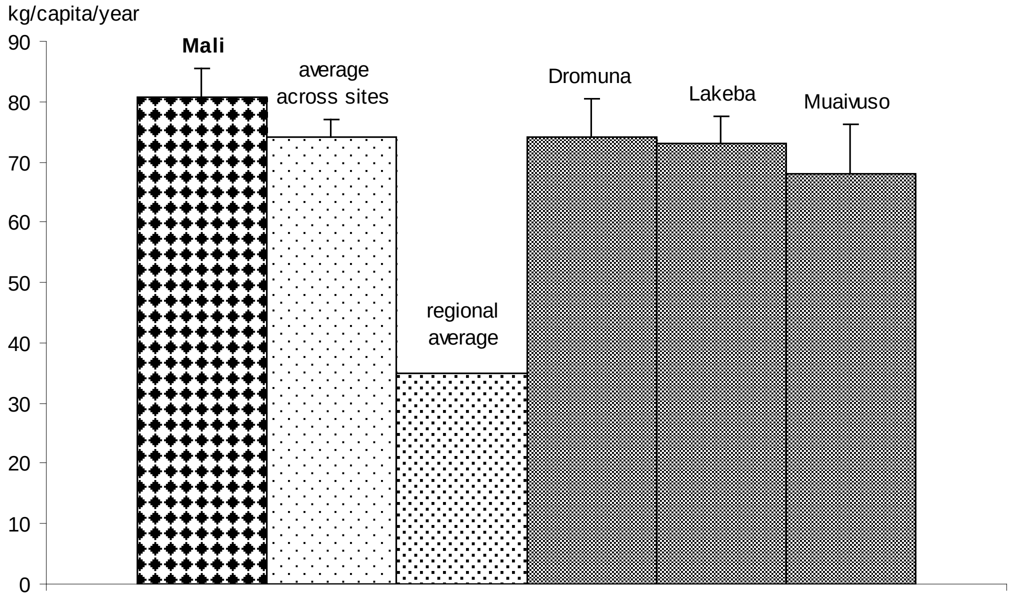

Figure 4.3: Per capita consumption (kg/year) of fresh fish in Mali (n = 16) compared to the regional average (FAO 2008) and the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

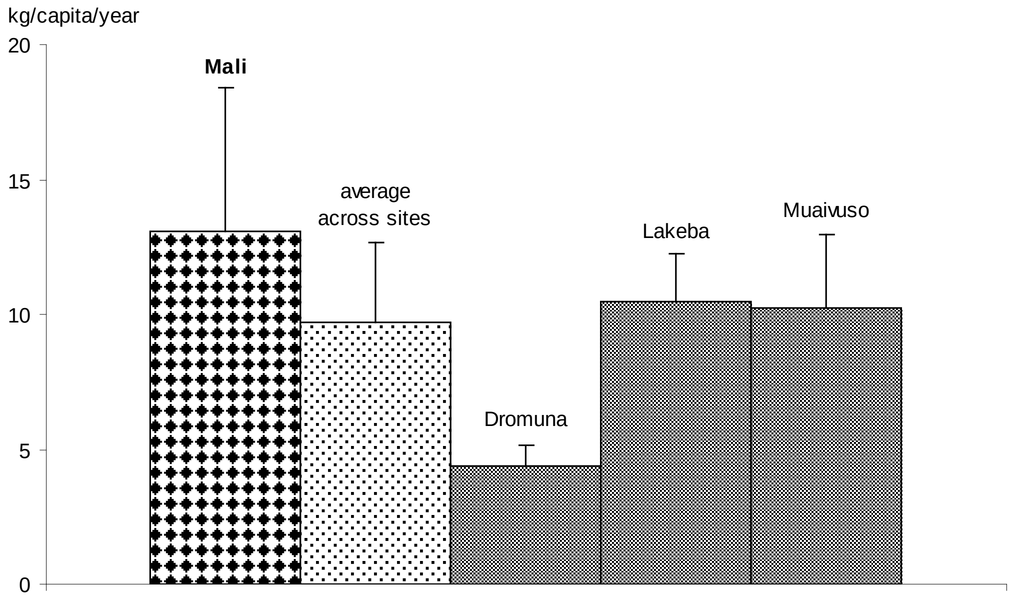

Figure 4.4: Per capita consumption (kg/year) of invertebrates (meat only) in Mali (n = 16) compared to the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Comparing results obtained for Mali to the average figures across all four study sites surveyed in Fiji Islands, people of the Mali community eat fresh fish slightly more often and invertebrates and canned fish about as often as average. The per capita consumption of fresh fish and invertebrates is well above the average across all sites studied in Fiji Islands, but the consumption of canned fish is slightly below average. Mali people conform to the average across all study sites in terms of the proportion of fish and invertebrates caught that they consume, but the proportion of finfish that buy or are given on a non-monetary basis is much higher than elsewhere. As in the other sites studied, sharing or giving catches would be more evident during traditional or religious functions when people would fish specifically for such occasions or give away large portions of their catches for community functions.

Fisheries provide almost the only income source, with handicrafts made by females representing the most important complementary activity that generates cash income. The household expenditure level in Mali is slightly above average, which may be explained by the small agricultural production capacity. However, the overall household expenditure level in the Fiji Island study sites is generally low. The percentage of households receiving remittances is very low, and the annual average amount of remittances received is small. By comparison, boat ownership is higher than observed elsewhere, which may be due to the island situation of the community; as reported elsewhere, all boats are motorised.

4.2.2 Fishing strategies and gear: Mali

Degree of specialisation in fishing

Fishing is done by both gender groups; however, traditional roles are evident from the information shown in Figure 4.5. Males are much more engaged in exclusive finfish fisheries. There was also a trend of fishing in family units, with females fishing the outer reef together with their husbands. Female fishers, however, are the only exclusive invertebrate collectors. However, it is worth mentioning that the greatest share of males and females considered here fish for both finfish and invertebrates. Selling was mostly conducted individually. Invertebrates, such as lobsters and trochus, were collected and sold exclusively by males, while smaller, coastal invertebrates collected for sale were mostly caught and sold by females.

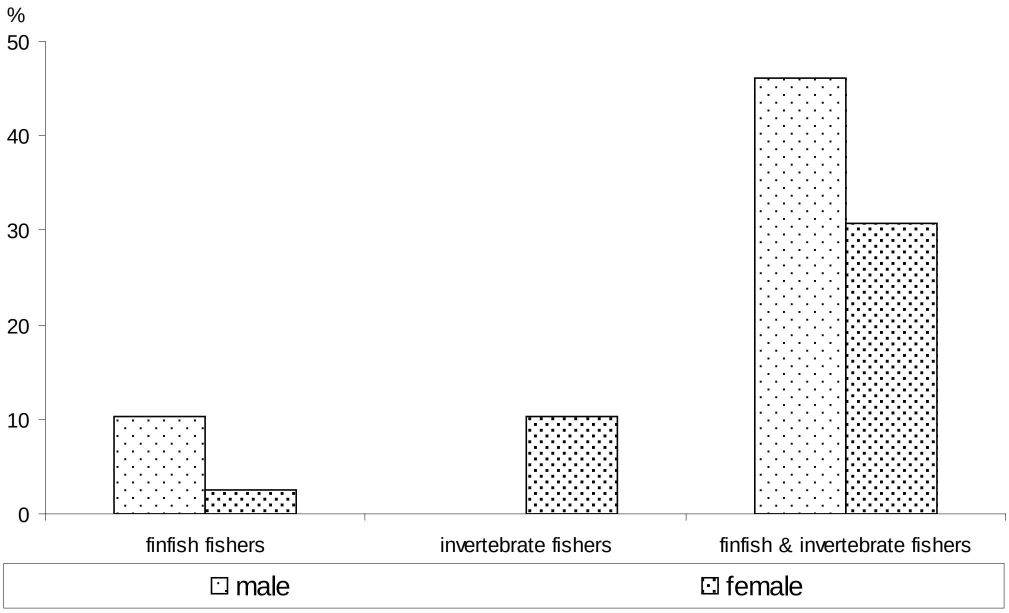

Figure 4.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Mali.
All fishers = 100%.

Targeted stocks/habitat

Considering the ongoing management plan and the 'no-fishing' zone restrictions, it is not surprising that Mali finfish fishers mainly target the permitted habitats, namely the lagoon, and the outer reef with passages. Both habitats are usually combined in one fishing trip. Fishing the outer reef alone or in combination with the passages is not performed by females from Mali (Table 4.2). Female fishers target a wide range of the more available and accessible habitats for invertebrates, and most fishing is done by combining several of the habitats in one trip. Male fishers from Mali, on the other hand, focus on collecting species that require free-diving, i.e. bêche-de-mer, lobster, trochus and 'others' (mainly giant clams and octopus). Female fishers are not engaged in free-diving in offshore areas but they do participate to some extent (23%) in collecting the lucrative bêche-de-mer.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	46.2	44.4
	Lagoon	0.0	22.2
	Lagoon & outer reef	61.5	33.3
	Outer reef	7.7	0.0
	Outer reef & passage	30.8	0.0
Invertebrates	Reeftop & trochus & other	16.7	0.0
	Intertidal & reeftop	0.0	23.1
	Intertidal & reeftop & other	0.0	7.7
	Seagrass & mangrove	0.0	30.8
	Seagrass & mangrove & reeftop	0.0	7.7
	Seagrass & mangrove & intertidal & reeftop	0.0	7.7
	Seagrass & reeftop	0.0	23.1
	Seagrass & reeftop & other	0.0	7.7
	Seagrass & intertidal & reeftop	0.0	23.1
	Mangrove	8.3	0.0
	Bêche-de-mer	66.7	23.1
	Lobster	33.3	0.0
	Trochus	8.3	0.0
	Trochus & other	33.3	0.0
	Other	33.3	0.0

'Other' refers to octopus fishery.
Finfish fisher interviews, males: n = 13; females: n = 9. Invertebrate fisher interviews, males: n = 12; 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 Mali on their fishing grounds (Tables 4.2 and 4.3).

Our survey sample confirms that fishers from Mali have a wide choice of habitats and this is represented in the diverse fishing strategies adopted by female fishers for the collection of invertebrates (Figure 4.6). These are either used for home consumption or sold at the local markets. Most focus is on reeftop and soft-benthos gleaning rather than intertidal and mangrove collection, and these activities are dominated by females (Figure 4.7). Male fishers concentrate more on the commercial species, mainly bêche-de-mer, trochus, lobster, clams and octopus (Figures 4.6 and 4.7).

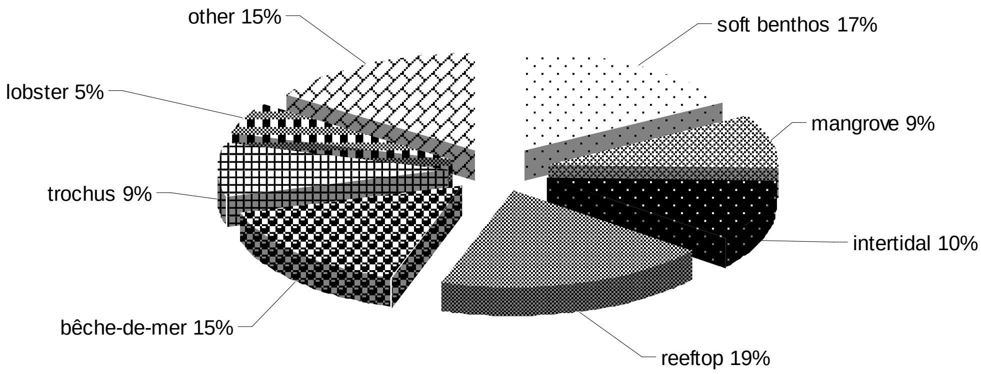

Figure 4.6: Proportion (%) of fishers targeting the eight primary invertebrate habitats found in Mali.
Data based on individual fisher surveys; data for combined fisheries are disaggregated. 'Other' refers to octopus fishery.

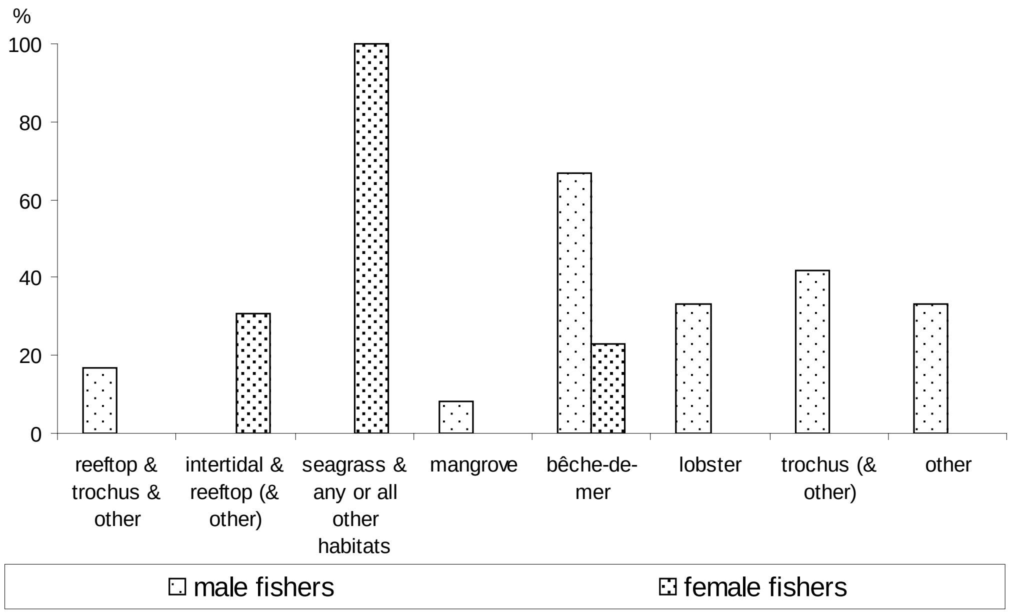

Figure 4.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Mali.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 12 for males, n = 13 for females; 'other' refers to octopus fishery.

Gear

Figure 4.8 shows that Mali fishers use mainly gillnets and handlines in the habitats nearer to shore, while handlines are more important if the lagoon is targeted. When the outer reef or the combined outer reef and passage are fished, handlines in combination with spear diving, occasional trolling, and other techniques are the most commonly used. Female fishers mainly use handlines in the lagoon area, and sometimes gillnetting.

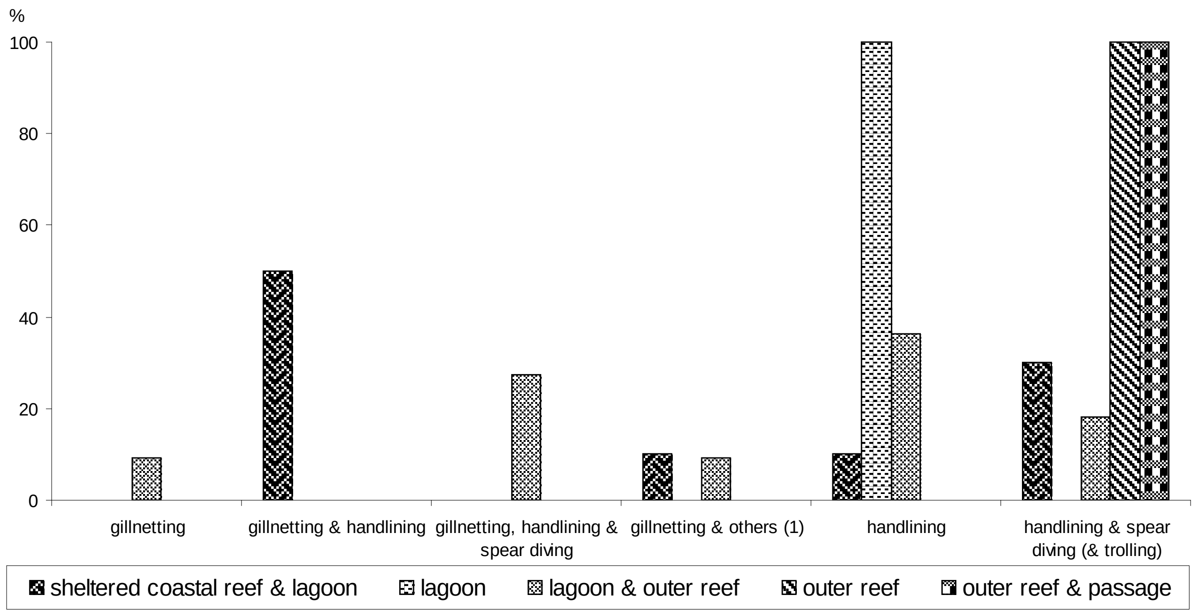

Figure 4.8: Fishing methods commonly used in different habitat types in Mali.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.
(1) Handlining, spear diving and handheld spearing.

Frequency and duration of fishing trips

The frequency at which finfish fishers visit any of the habitats is around twice per week. This is consistent for both gender groups. However, as mentioned earlier, females do not fish the outer reef and passages. In the case of male fishers, trips for popular invertebrates are undertaken twice per week and trips for less popular resources once a week. Female fishers usually go out twice per week to collect invertebrates. The average duration of a finfish fishing trip is about 3–6 hours for males, with longer trips when the outer reef and passages are included. Trips made by females targeting the lagoon and the permitted sheltered coastal reef habitats last about three hours, but five hours and more if the lagoon is combined with the outer reef. A typical invertebrate collection trip takes 2–3 hours for female fishers, and 4–5 hours for males free-diving for invertebrates. The latter is explained by the fact that most of these activities take place at the outer reef and passages, which involves a longer travelling time by boat.

Most finfish fishers go out according to the tidal conditions, i.e. during the day or night, while female fishers prefer fishing during the day. All fishing activities are performed throughout the year. Ice is often used on finfish fishing trips, more regularly when the fishing grounds targeted are further off shore and the fishing trip is longer.

Most fishing requires motorised boat transport, and this is true for all the invertebrate dive fisheries. Gleaning for invertebrates is mostly done by walking. Invertebrates can be collected either at day or night time, and this applies to resources in the mangroves, bêche-de-mer, soft-benthos and reeftop habitats as well as commercial species that male fishers dive for. Generally there is a preference for daytime gleaning, although diving for lobsters is specifically done at night.

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

Resource	Stock	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	1.58 (±0.33)	2.00 (±0.00)	3.50 (±0.56)	3.13 (±0.31)
	Lagoon	0	2.50 (±0.50)	0	3.00 (±0.00)
	Lagoon & outer reef	1.88 (±0.08)	1.83 (±0.17)	6.50 (±0.60)	5.33 (±1.45)
	Outer reef	1.00 (n/a)	0	5.00 (n/a)	0
	Outer reef & passage	1.25 (±0.25)	0	5.50 (±0.29)	0
Invertebrates	Reeftop & trochus & other	1.00 (±0.00)	0	3.50 (±0.50)	0
	Intertidal & reeftop	0	1.33 (±0.33)	0	3.33 (±0.33)
	Intertidal & reeftop & other	0	2.00 (n/a)	0	5.00 (n/a)
	Soft benthos & mangrove	0	1.37 (±0.38)	0	3.50 (±0.29)
	Soft benthos & mangrove & reeftop	0	2.50 (n/a)	0	2.00 (n/a)
	Soft benthos & mangrove & intertidal & reeftop	0	2.00 (n/a)	0	3.00 (n/a)
	Soft benthos & reeftop	0	2.00 (±0.00)	0	3.00 (±0.58)
	Soft benthos & reeftop & other	0	2.00 (n/a)	0	3.00 (n/a)
	Soft benthos & intertidal & reeftop	0	2.50 (±0.29)	0	4.00 (±0.00)
	Mangrove	1.00 (n/a)	0	2.00 (n/a)	0
	Bêche-de-mer	2.05 (±0.63)	0.49 (±0.26)	5.00 (±0.33)	4.67 (±0.67)
	Lobster	1.10 (±0.64)	0	4.75 (±0.63)	0
	Trochus	0.23 (n/a)	0	6.00 (n/a)	0
	Trochus & other	1.10 (±0.31)	0	4.25 (±0.48)	0
	Other	1.00 (±0.00)	0	3.25 (±0.25)	0

Figures in brackets denote standard error; n/a = standard error not calculated; 'other' refers to octopus fishery.
Finfish fisher interviews, males: n = 13; females: n = 9. Invertebrate fisher interviews, males: n = 12; females: n = 13.

4.2.3 Catch composition and volume – finfish: Mali

The catches reported from the combined sheltered coastal reef and lagoon in Mali are dominated by a few families. Lethrinidae alone represent ~30% of the total annual reported catch. Acanthuridae, Serranidae and Haemulidae account for another 12%, 11% and 10% respectively. Catches reported for lagoon fishing, which is predominantly a females' domain, mainly include Lethrinidae (>55%), Serranidae, Chanidae and Mugilidae. The catches from the combined fishing of the lagoon and outer reef do not vary much in composition. Again, Lethrinidae constitute most of the reported catch with >35% by weight, complemented by Carangidae, Serranidae, Acanthuridae and others. The dominance of Lethrinidae is visible in catches from the outer reef and the outer-reef and passage combined. Overall, the reported catch composition for Mali is not as diverse as one would expect and gives reason to assume resource depletion.

Detailed information on catch composition by species, species groups and habitats is reported in Appendix 2.3.1.

Figure 4.9 highlights findings from the socioeconomic survey that were reported earlier, i.e. that finfish is not only a major food source but also a major income source for the Mali community. About half of the catch (48%) is consumed and the other part (52%) is sold. The dominance of male fishers by impact and production is not that pronounced, but they still represent 61% of the total annual impact. Most impact is on the habitats that are not restricted, i.e. the combination of lagoon and outer reef, and the outer reef and passages. Relatively little impact is imposed on the lagoon combined with the permitted sheltered coastal reef areas.

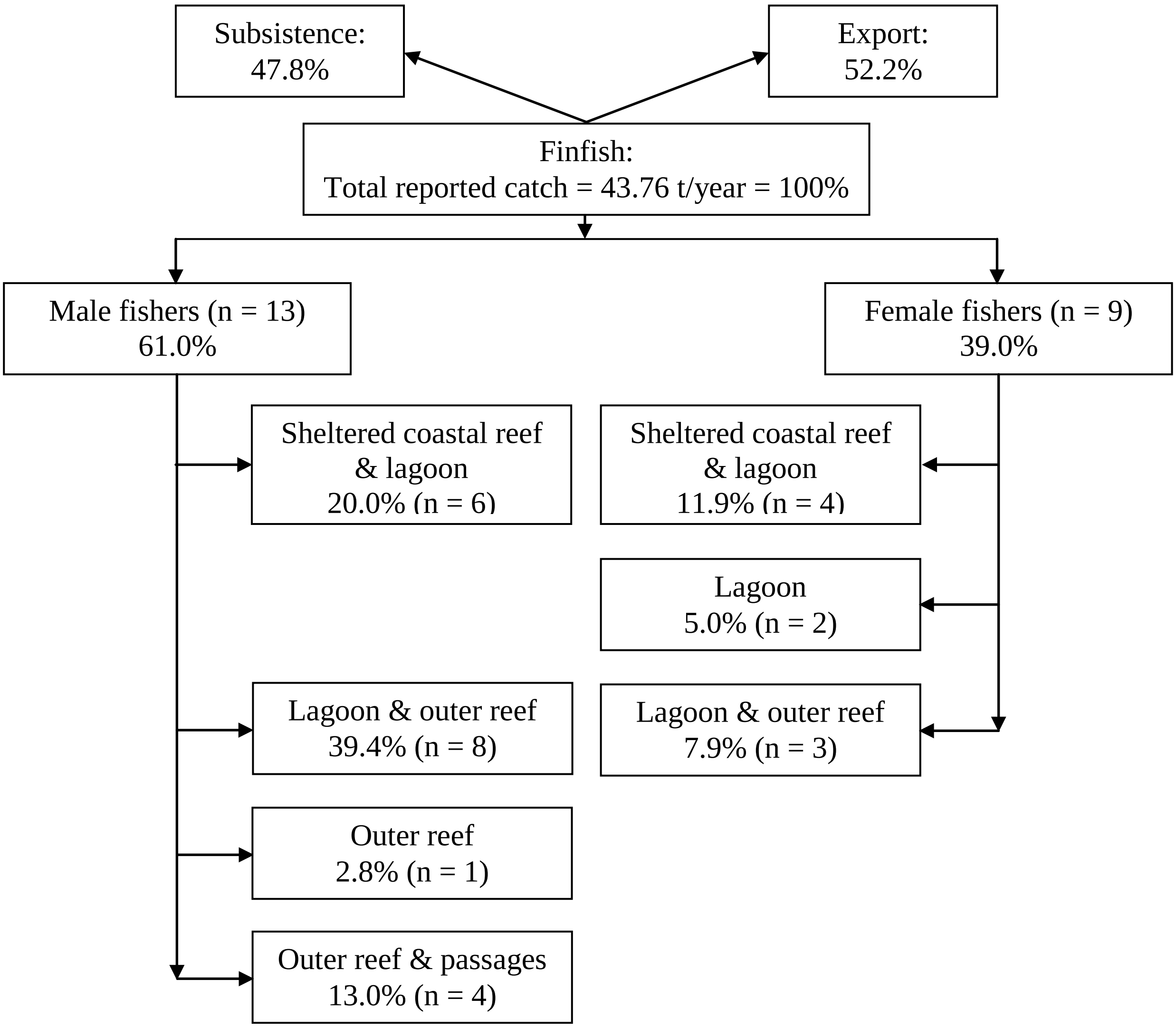

Figure 4.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mali.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and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

The distribution of annual catch weight is a consequence of the 'no fishing' zones and the number of fishers rather than the annual catch rates. As shown in Figure 4.10, the average annual catch per male fisher is similar in almost all the habitats fished, with the exception of the combined lagoon and outer-reef fishing by male fishers. This provides an average catch rate of 700 kg/fisher/year as compared to the range of 400–450 kg/fisher/year for any of the other habitats or combinations fished. With the exception of the fishing of the lagoon and outer reef combined, annual catch rates are comparable for both gender groups for habitats that are targeted by both.

Productivity rates vary between one and two kg/hour fished and are generally low. On average, CPUEs calculated for female fishers are lower than those for male fishers. The highest CPUE is gained by male fishers targeting the lagoon combined with the permitted sheltered coastal reef habitats, followed by outer-reef and passage fishing (Figure 4.11). The low CPUEs also suggest resource depletion.

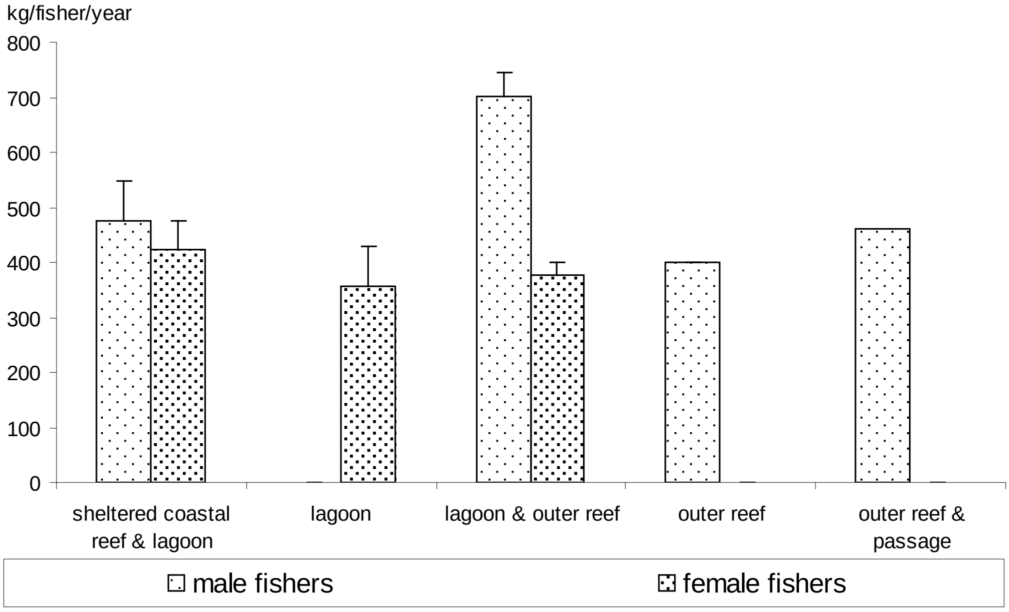

Figure 4.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Mali (based on reported catch only).

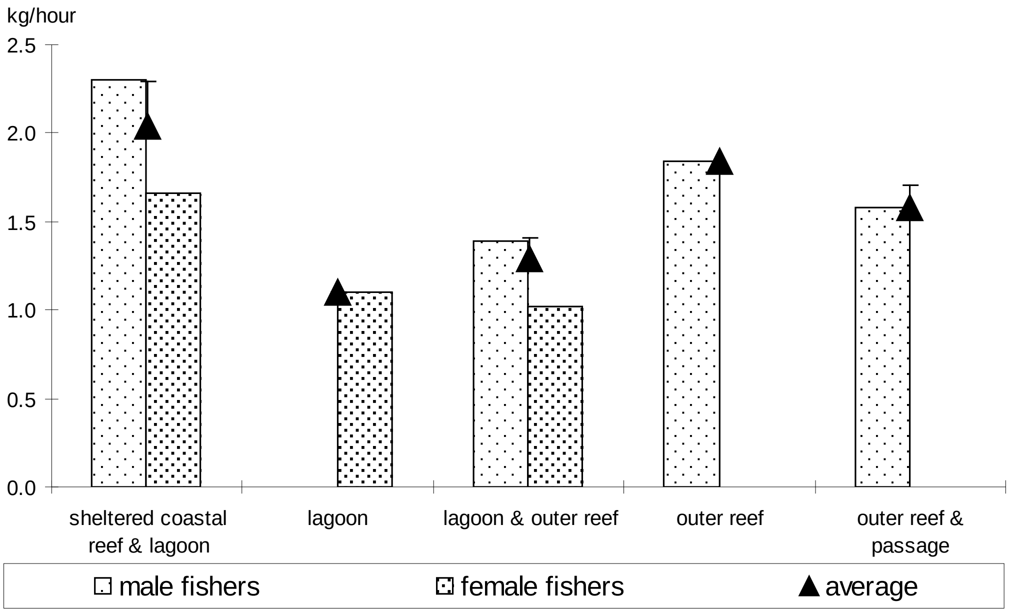

Figure 4.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat in Mali.
Effort includes time spent in transporting, fishing and landing catch. Bars represent standard error (+SE).

Figure 4.12 highlights findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing is performed for both subsistence and sale. The combined fishing of the permitted sheltered coastal reef areas and lagoon is conducted more for subsistence purposes, while fishers targeting the lagoon with the outer reef, and the outer reef and passages mainly pursue commercial interests. The Mali community is dependent upon fishing, and retains a strong traditional fishing background, which requires people to use their knowledge of the species, habitats, winds, moons and tides to guide their daily fishing activities. The market economy has considerable influence on fishing participation, fishing patterns and species targeted by both male and female fishers.

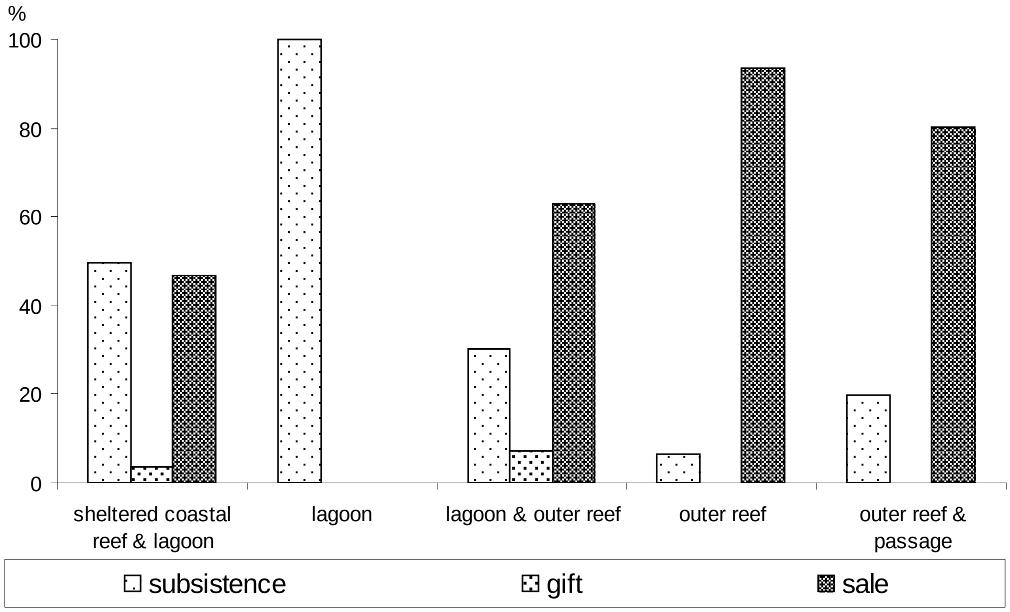

Figure 4.12: The use of finfish catches for subsistence, gift and sale, by habitat in Mali.
Proportions are expressed in % of the total number of trips per habitat.

Analysis of the overall finfish fishing productivity per habitat suggests a major difference between fishing the combined sheltered coastal reef and lagoon, and the lagoon and outer reef. CPUEs were lowest for fishing the lagoon and the combined fishing of the lagoon and outer reef. Data suggest that previous and, perhaps, current fishing pressure had and continues to have detrimental effects on the resource status. This observation is further supported by the average fish lengths reported. In fact, the expected trend that sizes increase with distance from shore is not confirmed by the data shown in Figure 4.13. While most average sizes of families caught across the different habitats and combinations are similar, only the sizes of Lethrinidae follow this trend clearly (Figure 4.13). Overall, reported fish sizes are moderate to large, 25–30 cm on average. People reported that sizes had increased in the previous two years, following the implementation of the fishing ban on coastal reef areas.

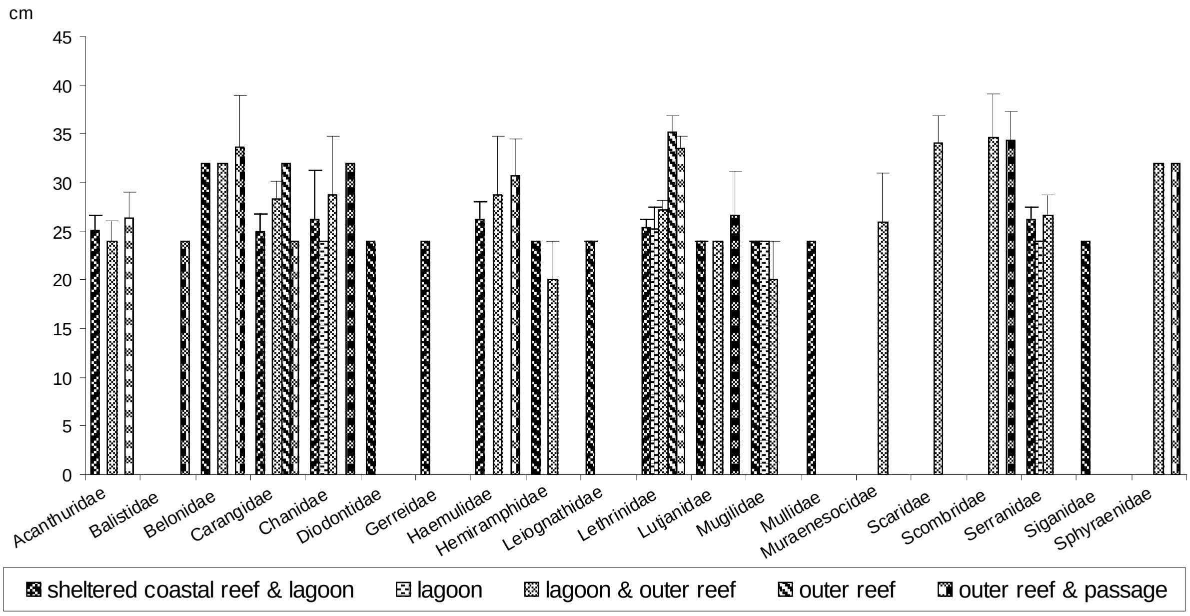

Figure 4.13: Average sizes (cm fork length) of fish caught by family and habitat in Mali.
Bars represent standard error (+SE).

The parameters selected to assess current fishing pressure on Mali's reef and lagoon resources are shown in Table 4.4. Due to the large available reef surface and total fishing ground, population density, fisher density and catch rates are all low. This picture does not change if we consider the total annual catch rate from Mali fishers. However, one must take into account that the fishing ground is also subject to impact from fishers from the greater Labasa area. Catch composition, CPUEs and average reported fish lengths, as discussed above, suggest that fishing impact is already visible.

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

Parameters	Habitat						
	Sheltered coastal reef & lagoon	Lagoon	Lagoon & outer reef	Outer reef	Outer reef & passage	Total reef area	Total fishing ground
Fishing ground area (km^2)	9.6	213.8	213.8	15.1	n/a	92.6	238.5
Density of fishers (number of fishers/km^2 fishing ground) (1)	3.2	0.0	0.2	0.2	n/a	0.9	0.4
Population density (people/km^2) (2)						3.1	1.2
Average annual finfish catch (kg/fisher/year) (3)	454.19 (±47.16)	357.68 (±71.54)	612.60 (±55.79)	400.66 (n/a)	461.31 (±83.39)		
Total fishing pressure of subsistence catches (t/km^2)						0.1	0.0
Total number of fishers	31	7	34	3	12	87	87

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers is extrapolated from household surveys; (2) total population = 290; total number of fishers = 87; total subsistence demand = 11.86 t/year; (3) catch figures are based on recorded data from survey respondents only.

4.2.4 Catch composition and volume – invertebrates: Mali

The catches reported by invertebrate fishers suggest that the bêche-de-mer species *Holothuria* spp. and *Bohadschia* spp., account for most of the total annual catch volume by wet weight. However, sampling does not allow the exact annual production rates to be calculated. Therefore, Figure 4.14b only displays the reported catch composition by species. Annual catches for traditional species that are mainly targeted for home consumption (Figure 4.14a) and, to some extent, for local sale are mainly determined by *Scylla serrata*, giant clams and lobsters. Trochus, *Cardisoma*, octopus, *Anadara* and *Conus* spp. play a minor role by comparison. In addition, there are many other invertebrate species collected, mostly for home consumption, but these are marginal by wet weight.

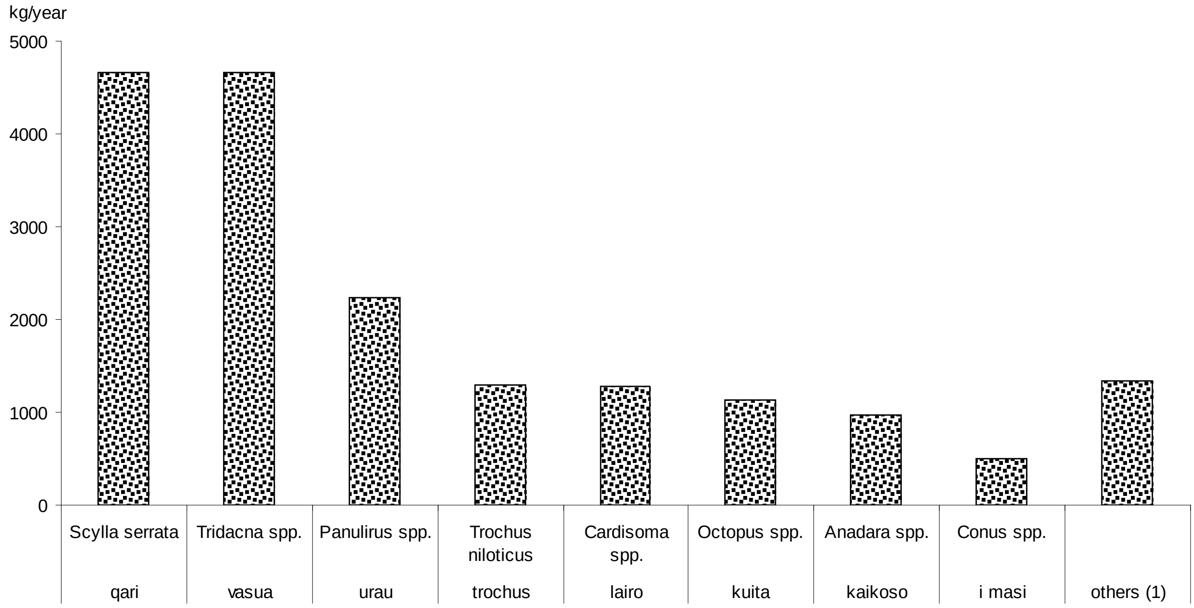

Figure 4.14a: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Mali.
(1) 'Others' include *kuita* (*Octopus* spp.), *vasua* (*Tridacna* spp.), *qaqa* (*Gafrarium tumidum*), *golea* (*Strombus gibberulus*), *tadruku* (*Acanthopleura gemmata*), *bosucu* (*Turbo* spp.), *senikavere* (*Dolabella* spp.), *nama* and *lumi* (seaweeds).

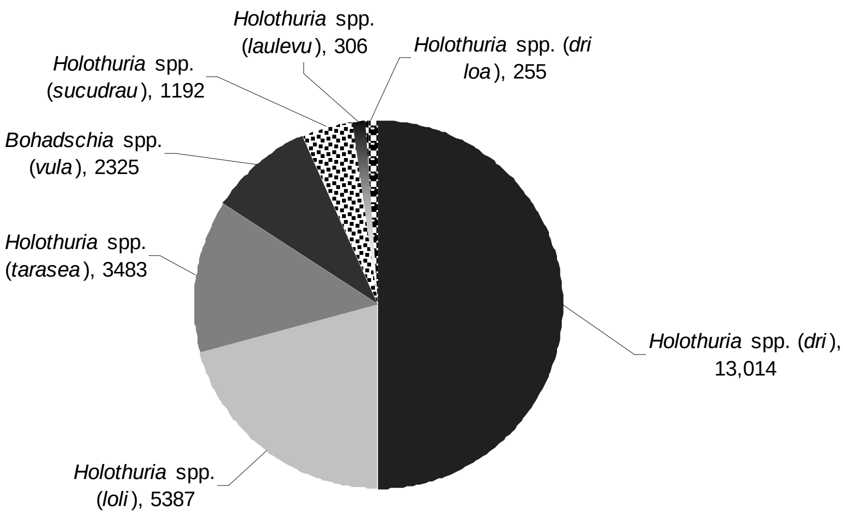

Figure 4.14b: Catch composition of the bêche-de-mer fishery in Mali.

Figure 4.15 emphasises that Mali fishers have access to a wide range of habitats and that these are often combined in one fishing trip. The number of target species identified by vernacular name, however, is not as varied as one would expect. Among the traditional fisheries, the resources collected from the soft benthos and intertidal flats in combination with any of the other permitted and easily accessible habitats are represented by the highest number of vernacular names. There are at least eight different species of bêche-de-mer identified by distinct vernacular names; however, these represent *Holothuria* spp. and, in one case, *Bohadschia* spp. only.

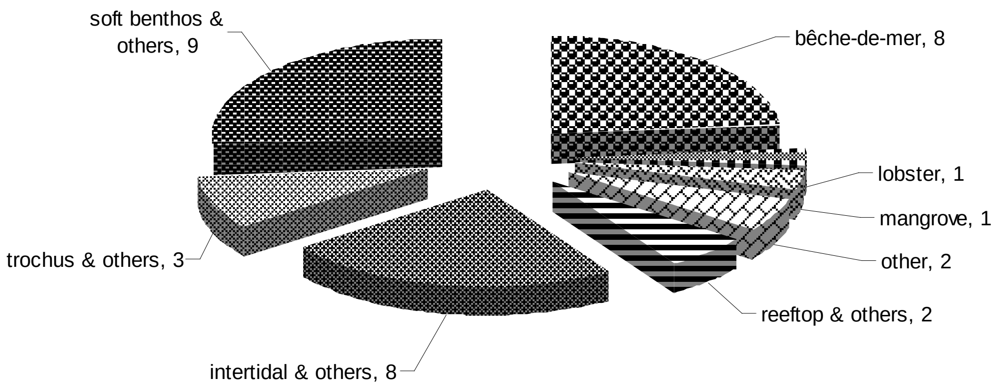

Figure 4.15: Number of vernacular names recorded for each invertebrate fishery in Mali.
'Other' refers to octopus fishery.

Analysis of the average annual catch per fisher by gender and fishery (Figure 4.16) reveals a substantial difference between the commercial bêche-de-mer and all other fisheries. Impact by gender group is highest for female fishers for the combined gleaning of the soft benthos and intertidal flats, in combination with all kinds of easily accessible habitats. Males' main target species by annual production are bêche-de-mer. Because the sample data does not allow the quantification of the bêche-de-mer fishery, caution is advised in comparing this fishery with the other fisheries.

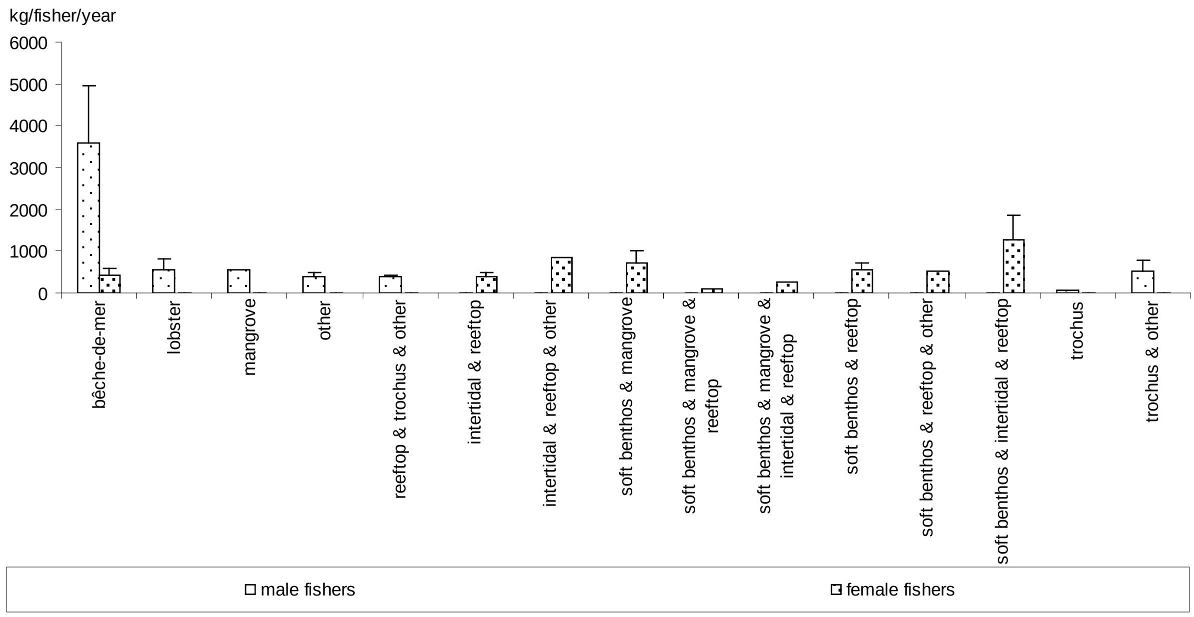

Figure 4.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Mali.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 12 for males, n = 13 for females). 'Other' refers to octopus fishery.

The fact that the Mali community is highly dependent on marine resources for income also shows in Figure 4.17, which shows the simple fact that most invertebrates are caught for sale at the local markets at Labasa, notably bêche-de-mer and, to a lesser extent, lobsters, clams and others. If we assume that half of the catches reported for both sale and home consumption are sold, the commercial proportion of the total invertebrate catch is about 79%.

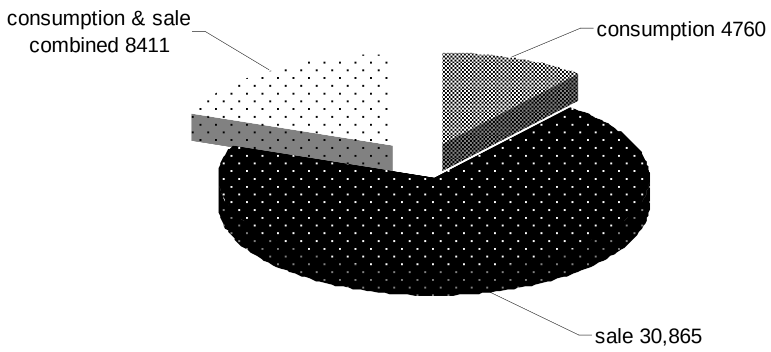

Figure 4.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Mali.

As mentioned earlier, both male and female fishers from Mali fully participate in invertebrate fisheries, but male fishers account for the highest impact, i.e. 74% (wet weight) (Figure 4.18). Most male invertebrate fishers target bêche-de-mer. However, female fishers target a wide range of habitats, mostly in combination, and the highest impact by wet weight is imposed on the soft benthos combined with the mangroves or any other easily accessible habitat. By comparison, female fishers do not substantially contribute to the bêche-de-mer collection, mainly because bêche-de-mer are collected from the more distant areas and involve free-diving.

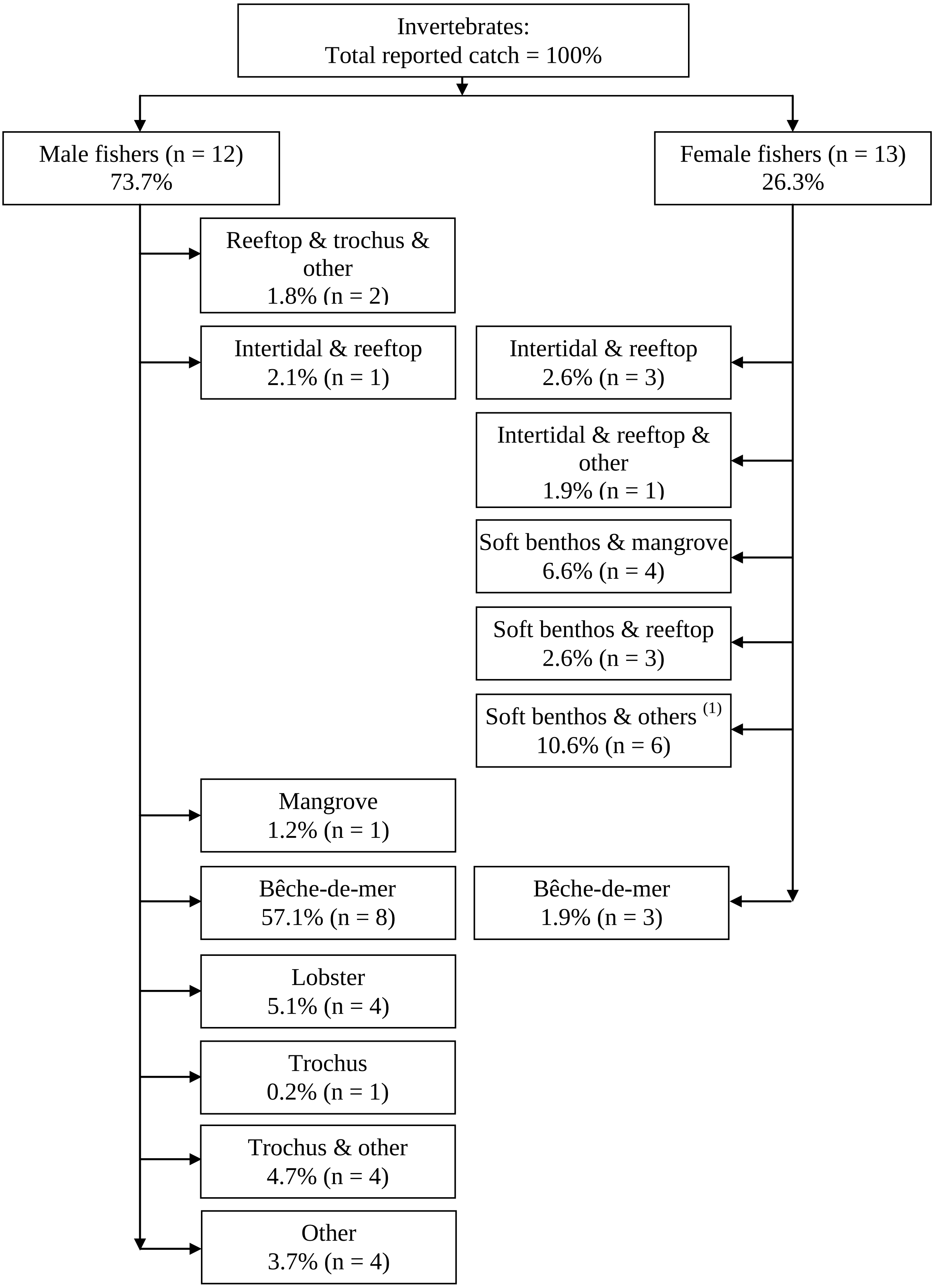

Figure 4.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Mali.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. (1) 'Others' include one or more of mangrove, reeftops, intertidal and other. 'Other' refers to giant clam and octopus fisheries.

Taking into account the total sheltered coastal reef surface areas for any reeftop invertebrate fishery, the fisher-density parameters calculated are low. Also, the average annual catch rate for most fisheries is low. Bêche-de-mer fishery data are not reported here, as our sampling does not permit accurate quantitative calculations (Table 4.5). Although the parameters calculated to assess current fishing pressure do not suggest much adverse effect from the current level of fishing activities, this picture may be misleading. The Mali fishing ground area has been heavily fished over the past decades and may also be accessed by many fishers from the greater Labasa area. The bêche-de-mer fishery has a long record in Fiji Islands, it is an open fishery, and the resources are widely exhausted due to fishing over the past decades. The argument that suggests the resources are depleted may be supported by the relatively few vernacular names reported for the traditional as well as the commercial fisheries, by a community that is highly dependent on marine resources for both food and income, and that traditionally has a food preference for many invertebrate species.

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

Parameters	Fishery / Habitat							
	Reeftop, trochus & other	Intertidal & reeftop (& other)	Soft benthos & others (3)	Mangrove	Bêche-de-mer	Lobster	Trochus (& other)	Other
Fishing ground area (km^2)	9.6							
Number of fishers (per fishery) (1)	7	12	40	4	39	15	19	15
Density of fishers (number of fishers/km^2 fishing ground)	0.8							
Average annual invertebrate catch (kg/fisher/year) (2)	390.86 (±43.4)	386.22 (±102.2) –846.9 (n/a)	106.94 (n/a) –1265.91 (±600.0)	547.2 (n/a)	n/a	560.6 (±256.0)	80.0 (n/a) –512.9 (±279.6)	405.0 (±93.4)

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; (1) total number of fishers is extrapolated from household surveys; (2) catch figures are based on recorded data from survey respondents only; (3) 'others' may include one or more of mangrove, reeftop, intertidal and other; 'other' refers to giant clam and octopus fisheries.

4.2.5 Management issues: Mali

A description of the fisheries legislation, etc. relevant to managing the fisheries in Fiji Islands is given in section 2.2.5 above.

The community of Mali is included in the larger communal grouping of a district under the province of Macuata. These administrative and traditional groupings of villages mean that fisheries management and development are sometimes organised or implemented along district or provincial lines rather than as single communities. For Fiji Islands the larger area management interventions work well in some places given the ownership status under the customary marine tenure. Unlike land ownership in Fiji Islands, the ownership of and jurisdiction over fisheries rights falls usually under the wider collection of village groupings called the district. This wider ownership results in several villages having access and ownership rights over overlapping areas and, sometimes, over wider areas outside the immediate village fishing ground.

Although the *tabu* areas are generally perceived to be successful, some concern was expressed by females and other respondents on the *tabu* being implemented. For some fishers, the *tabu* have restricted fishing activities and income-earning opportunities and the limited access to motorised boats restricts fishing in distant areas or at the outer reef.

Management initiatives in place in Mali during the study were part of a strategy implemented at a provincial level, with specific activities and strategies implemented at the community level. Communities were also responsible for choosing sites and establishing ‘no-take’ zones, as well as for the monitoring and enforcement work in the reserves. The current management includes a ban on all coastal reef areas for five years, the ban on the use of SCUBA for diving, and various other specific, village-based regulations. Problems the community face are mostly related to the monitoring of their management initiative. For Mali the main threat faced is from poachers, especially fishers from the main island coming in to fish at night, with the local people lacking the necessary boats or gear to check their fishing area. The management strategy, which was strongly supported by the chiefs in the area, had been successful in its implementation, with most villages and communities in the Macuata province declaring most coastal reef areas close to their villages as ‘no-fishing zones’, or reserves. The management strategy in place meant that people could not access the areas they had previously fished. Therefore, certain finfish and invertebrate species, such as bêche-de-mer, although believed to be plentiful, could not be fully exploited.

Because of the province-wide *tabu*, implementation has been successful, and evidence of the success of the ban on fishing noticed by community members. This management initiative involves co-management among the communities, international NGOs such as WWF, local NGOs, FLAMMA and the Fisheries Department.

4.2.6 Discussion and conclusions: socioeconomics in Mali

Mali is a small, traditional community located on a small island off Labasa on Vanua Levu. Due to the short distance by boat, people in the community have good access to markets to sell their fisheries produce, almost the sole means of generating income, and one of the most important food sources. In addition, females generate complementary income by making handicrafts (mat weaving). There are almost no opportunities to earn salaries on the island, or for agricultural production. Fishing grounds and fishing rights under customary ownership and rights are large; however, resources are poached by fishers from the greater Labasa area.

In summary:

- The Mali community depends mostly on fisheries; no other sectors play any role in providing first income. Handicrafts are the only important source of second income.

- Mali has a high food dependency particularly on finfish, but also on invertebrates, which is explained by the very limited agricultural capacity on the island.

- The household expenditure level is relatively low, and remittances are only received by 6% of all households, and in very low amounts.

- Finfish and invertebrate fishers target many habitats, and often combine two or more in one fishing trip. Due to the restricted fishing zones, most impact is on the lagoon, outer-reef and passage habitats, much less on the partly restricted sheltered coastal reef.

- Both male and female fishers participate in finfish fishing and invertebrate collection; however, there is a gender separation. Male fishers are the most important finfish fishers, also targeting habitats further from shore, while females are more involved in handlining and gillnetting the nearshore habitats, mainly the lagoon and permitted sheltered coastal reef areas. Female fishers are heavily engaged in traditional invertebrate collection, but male fishers who free-dive for invertebrates account for the highest impact by wet weight.

- While annual catch rates do not vary substantially per habitat (with the exception of the combined lagoon and outer reef), CPUEs are higher for the sheltered coastal reef and lagoon combined, and the outer-reef and passages combined than for the combined lagoon and outer reef.

- Average reported fish sizes are moderate to large. While, for most families, these lengths do not change among habitats fished, the expected increase in fish size with distance from shore only applies to Lethrinidae.

- Bêche-de-mer is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including *Scylla serrata*, giant clams and lobsters, are important both for home consumption and small-scale, local commercial sale.

- Fishing pressure parameters for both finfish and invertebrates suggest that the current fishing pressure is low; however, these figures are misleading given the fact that poaching by fishers from the greater Labasa area is common.

The high dependency on fisheries for food and income will continue for the Mali community due to the lack of alternative opportunities for earning income, including agriculture and other employment, on the island. Because the data suggest that the resources around Mali are stressed and depleted, more management is needed, as already stated in the framework of the provincial fisheries management plan. Fishing strategies could be optimised if a steady marketing system was installed. Revenues could be increased by reducing fishing pressure in the case of the bêche-de-mer fishery if fishers learnt to process their catch rather than selling it raw as is currently practised. Boat transport could be made more effective to reduce fishing costs, and fisher groups could be formed. These measures should go hand in hand with the declaration of *tabu* areas, which makes fishers with no boat transport more dependent on fishers who do own boats, and disadvantages their access to fishing grounds. If large-scale protected areas are declared, consideration needs to be given on how this will affect female fishers as they will be forced to fish further offshore, thus depending on boat transport and spending much more time at sea than they are used to, or can afford. Also, any increase in boat transport demands an increase in catch to compensate for the higher costs incurred.

The fisheries management that has already been implemented in Mali is considered successful by the local community. There is, however, a need to increase the capacity of local people to protect their fishing grounds from poaching, which is substantial in the case of Mali. There is a further need for ongoing awareness work in the community given the current target species and financial dependence on fisheries. A wider approach may be to investigate the possibilities of creating alternatives to fisheries for generating income for the Mali community. This could include organising efficient transport to allow daily commuting to the mainland of Vanua Levu to gain employment.

4.3 Finfish resource surveys: Mali

All four types of reefs were present in Mali, allowing the normal PROCFish methodology to be followed. A total of 24 stations were sampled on 12–17 of June 2004 (6 coastal reefs, 6 intermediate reefs, 6 back-reefs and 6 outer reefs; Figure 4.19).

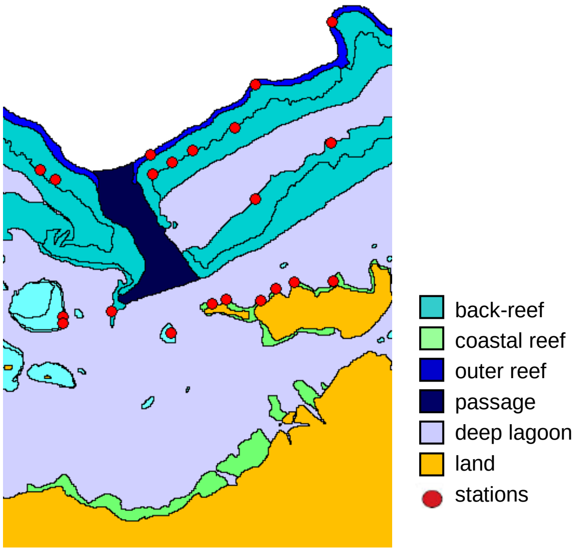

Figure 4.19: Habitat types and transect locations for finfish assessment in Mali.

4.3.1 Finfish assessment results: Mali

A total of 22 families, 58 genera, 173 species and 9510 fish were recorded in the 24 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 48 genera, 154 species and 8734 individuals.

Finfish resources varied greatly among the four reef environments found in Mali. Biomass increased from the coastal reefs (106 g/m²) to the outer reefs (237 g/m²); density was highest at the back-reefs (0.8 fish/m²) and size and size ratio were lowest at the back-reefs (18 cm FL and 61%) and highest at the outer reefs (22 cm FL and 65%, Table 4.6).

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

Parameters	Habitat				
	Sheltered coastal reef (1)	Intermediate reef (1)	Back-reef (1)	Outer reef (1)	All reefs (2)
Number of transects	6	3	9	6	24
Total habitat area (km^2)	9.6	8.1	59.8	5.3	82.8
Depth (m)	2 (1–4) (3)	4 (1–6) (3)	2 (1–6) (3)	6 (1–11) (3)	2 (1–11) (3)
Soft bottom (% cover)	18 ±3	13 ±6	17 ±3	1 ±0	13
Rubble & boulders (% cover)	18 ±4	29 ±6	30 ±3	15 ±12	28
Hard bottom (% cover)	47 ±4	29 ±14	43 ±4	63 ±11	48
Live coral (% cover)	13 ±3	27 ±7	9 ±2	14 ±5	10
Soft coral (% cover)	0 ±0	1 ±1	1 ±0	7 ±3	1
Biodiversity (species/transect)	34 ±5	54 ±7	41 ±3	39 ±8	40 ±3
Density (fish/m^2)	0.5 ±0.1	0.7 ±0.1	0.8 ±0.1	0.7 ±0.3	0.8
Size (cm FL) (4)	19 ±1	19 ±1	18 ±1	22 ±1	18
Size ratio (%)	63 ±3	64 ±3	61 ±2	65 ±3	61
Biomass (g/m^2)	106.2 ±27.2	154.8 ±2.0	133.3 ±17.2	236.7 ±129.8	143.2

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

Sheltered coastal reef environment: Mali

The sheltered coastal reef environment of Mali was highly dominated by two families, the herbivorous Acanthuridae and Scaridae (Figure 4.20), represented by 25 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus bleekeri*, *Acanthurus lineatus*, *Chlorurus sordidus*, *Scarus psittacus*, *A. blochii* and *S. rivulatus* (Table 4.7). This reef environment presented a high dominance of hard bottom (47%), a similar cover of soft bottom and rubble (18% each) and a low cover of live coral (13%) (Table 4.6).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.11 ±0.02	20.7 ±5.8
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.01	6.5 ±2.8
	Acanthurus lineatus	Lined surgeonfish	0.01 ±0.01	8.5 ±8.5
Scaridae	*Chlorurus bleekeri*	Bleeker's parrotfish	0.03 ±0.02	8.9 ±5.6
	Scarus rivulatus	Rivulated parrotfish	0.03 ±0.01	5.5 ±1.9
	Chlorurus sordidus	Daisy parrotfish	0.03 ±0.01	8.1 ±4.2
	Scarus psittacus	Common parrotfish	0.02 ±0.01	7.6 ±3.9

The density of finfish in the coastal reefs at Mali was the lowest among the four reef environments and similar to the Dromuna coastal-reef values but lower than those in the Lakeba coastal reefs. Biomass was also the lowest among all reefs at the site, but much higher than in the coastal reefs at Dromuna and comparable to the coastal reefs in Lakeba. Average size and size ratio of fish were similar to values in the intermediate reefs, higher than in the back-reefs but lower than in the outer reefs. Biodiversity was the lowest among all four reefs in Mali and the lowest among all coastal reefs in the country sites. Herbivores highly dominated the trophic structure, with two main families, Acanthuridae and Scaridae, dominating the fish community. Carnivores were almost absent, with Lethrinidae displaying the highest biomass. Average size ratios were low for Labridae and Lethrinidae, probably as a response to fishing. Lethrinidae were among the most frequently caught fish families.

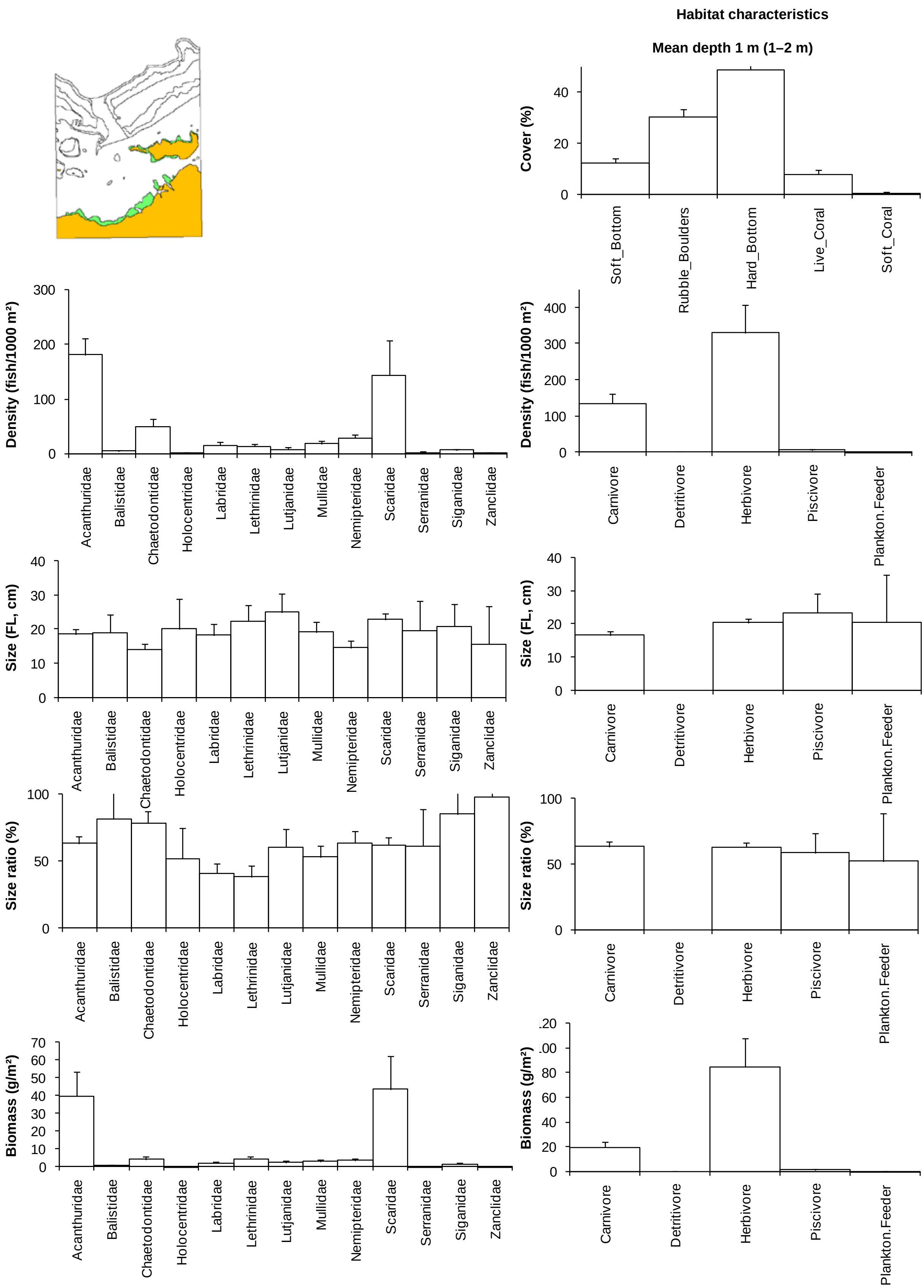

Figure 4.20: Profile of finfish resources in the sheltered coastal reef environment of Mali.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Mali

The intermediate-reef environment of Mali was dominated by two herbivorous families: Scaridae and Acanthuridae and, to a much lesser extent, by carnivorous Labridae, Mullidae, Lethrinidae and Nemipteridae for both density and biomass (Figure 4.21). Chaetodontidae was important only numerically. The six major families were represented by 52 species; particularly high abundance and biomass were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Scarus rivulatus*, *Monotaxis grandoculis*, *Scolopsis bilineata* and *Acanthurus blochii* (Table 4.8). This reef environment presented a very diverse habitat with hard bottom and rubble dominating (29% of total coverage each), a high cover of live coral (27%) and a relatively good cover of soft bottom (14%, 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 intermediate-reef environment of Mali

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.05 ±0.01	9.3 ±4.2
	Scarus rivulatus	Rivulated parrotfish	0.05 ±0.03	17.3 ±9.3
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.13 ±0.05	26.9 ±12.2
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.01	8.6 ±2.8
Nemipteridae	*Scolopsis bilineata*	Bridled monocle bream	0.03 ±0.02	5.3 ±3.4
Lethrinidae	*Monotaxis grandoculis*	Bigeye bream	0.03 ±0.02	11.0 ±6.3

The density of fish in the intermediate reefs of Mali was higher than in the coastal reefs, but lower than the back-reef value. Size and size ratio were similar to those in the coastal reefs but lower than in the outer reefs. Biomass was higher than at both the coastal and back-reefs, and still lower than at the outer reefs. Biodiversity was, however, the highest among all reefs and also of all the reefs studied in Fiji Islands. The trophic structure was only slightly dominated by herbivores, and carnivores had a diverse representation of families: Lethrinidae, Mullidae, Nemipteridae and Labridae. Piscivores, e.g. Serranidae, however, were practically absent. The substrate was composed of a good and equal proportion of both soft and hard substrate, with a good cover of live coral, which explains the healthy and diverse composition of families. However, for some families, sizes were below the maximum recorded values: Lutjanidae, Serranidae, and especially Lethrinidae (among the most frequently caught fish) displayed very low size ratios, probably indicating an impact from fishing on these special targets.

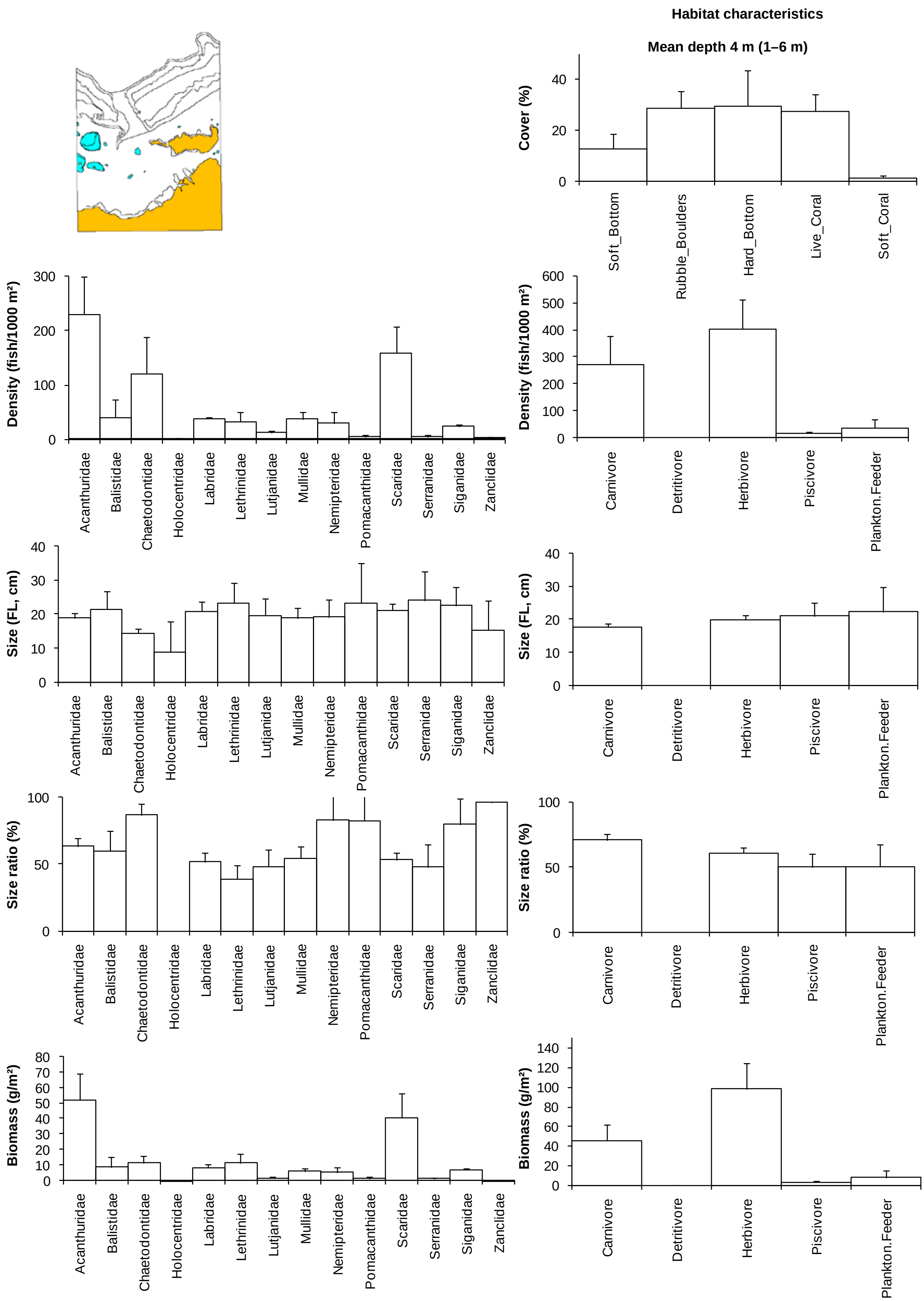

Figure 4.21: Profile of finfish resources in the intermediate-reef environment of Mali.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Mali

The back-reef environment at Mali was dominated by three herbivorous families, Acanthuridae, Scaridae and Siganidae (Figure 4.22). The three commercial families were represented by 40 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus blochii*, *Siganus spinus*, *Chlorurus sordidus*, *Scarus psittacus*, *A. triostegus*, *Siganus doliatus* and *S. ghobban* (Table 4.9). This reef environment presented a high dominance of hard bottom (43%) and rubble (30%), a relatively scarce cover of soft bottom (17%) and a low cover of live coral (9%, Table 4.6, Figure 4.22).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.11 ±0.03	16.0 ±2.9
	Acanthurus blochii	Ringtail surgeonfish	0.02 ±0.01	13.9 ±4.8
	Acanthurus triostegus	Convict tang	0.04 ±0.01	3.2 ±1.0
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.08 ±0.03	11.7 ±3.2
	Scarus psittacus	Common parrotfish	0.06 ±0.02	9.3 ±2.3
	Scarus ghobban	Bluebarred parrotfish	0.01 ±0.01	5.2 ±1.7
Siganidae	*Siganus spinus*	Little spinefoot	0.09 ±0.04	9.1 ±3.9
	Siganus doliatus	Barred spinefoot	0.02 ±0.01	3.5 ±1.9

The density of finfish in the back-reefs of Mali was the highest across the site. Size and size ratio were the lowest and biomass was only higher than the coastal-reef value. Biodiversity was second only to the intermediate-reef value. The finfish trophic structure in the back-reef at Mali was highly dominated by herbivorous fish, here well represented by the three major families of Acanthuridae, Scaridae and Siganidae. Carnivores were dominated by Nemipteridae but present also were Lethrinidae, Lutjanidae, Mullidae and Labridae. Piscivores of the Serranidae family were absent. Labridae and Lethrinidae displayed size ratios lower than 50% of their maximum values, suggesting an impact from fishing. In fact, Serranidae and Lethrinidae were among the most frequently caught fish.

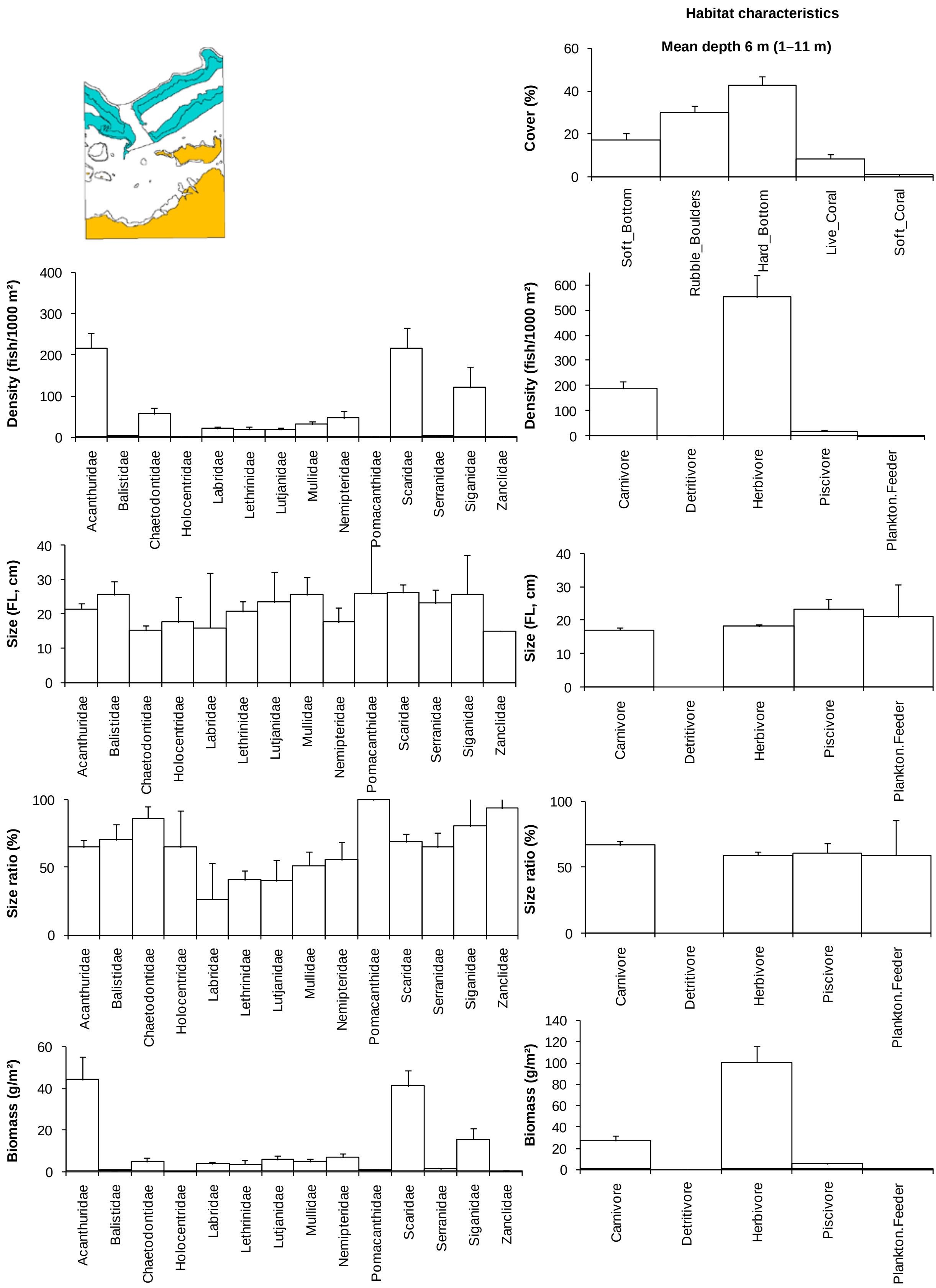

Figure 4.22: Profile of finfish resources in the back-reef environment of Mali.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Mali

The outer-reef environment of Mali was dominated by two herbivorous families, mainly Acanthuridae followed by Scaridae, and by a carnivorous family, Lutjanidae. Chaetodontidae were the fourth relevant family only in terms of density (Figure 4.23). The three main families were represented by 41 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Lutjanus gibbus*, *Chlorurus sordidus*, *Naso hexacanthus*, *N. lituratus*, *Acanthurus lineatus and Scarus niger* (Table 4.10). This reef environment presented a high dominance of hard bottom (63%) and a relatively good cover of live coral (14%, Table 4.6, Figure 4.23).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.19 ±0.03	38.7 ±3.4
	Acanthurus lineatus	Yellowfin surgeonfish	0.02 ±0.02	8.2 ±6.5
Scaridae	*Naso hexacanthus*	Sleek unicornfish	0.04 ±0.04	21.1 ±21.1
	Naso lituratus	Orangespine unicornfish	0.03 ±0.01	11.9 ±4.9
	Chlorurus sordidus	Daisy parrotfish	0.06 ±0.02	19.5 ±7.9
	Scarus niger	Black parrotfish	0.02 ±0.02	20.2 ±20.2
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.11 ±0.11	46.4 ±46.3

The density of finfish in the outer reef of Mali was the second-highest after the value at the back-reefs. Size, size ratio and biomass were the highest among the four reef habitats. Biodiversity was only the second-lowest, higher only than the coastal-reef value. The trophic structure in the outer reef was dominated by herbivorous fish, represented primarily by large-sized species of the Acanthuridae family (*Naso hexacanthus* and *N. lituratus*). Carnivores were represented mainly by Lutjanidae, probably due to the particular composition of the substrate, which was strongly dominated by hard bottom and corals, with very little cover of soft bottom, which would tend to favour Lethrinidae and Mullidae species. Small values of size ratio were recorded for Kyphosidae, Labridae and Lethrinidae. Lethrinidae were among the most frequently caught fish.

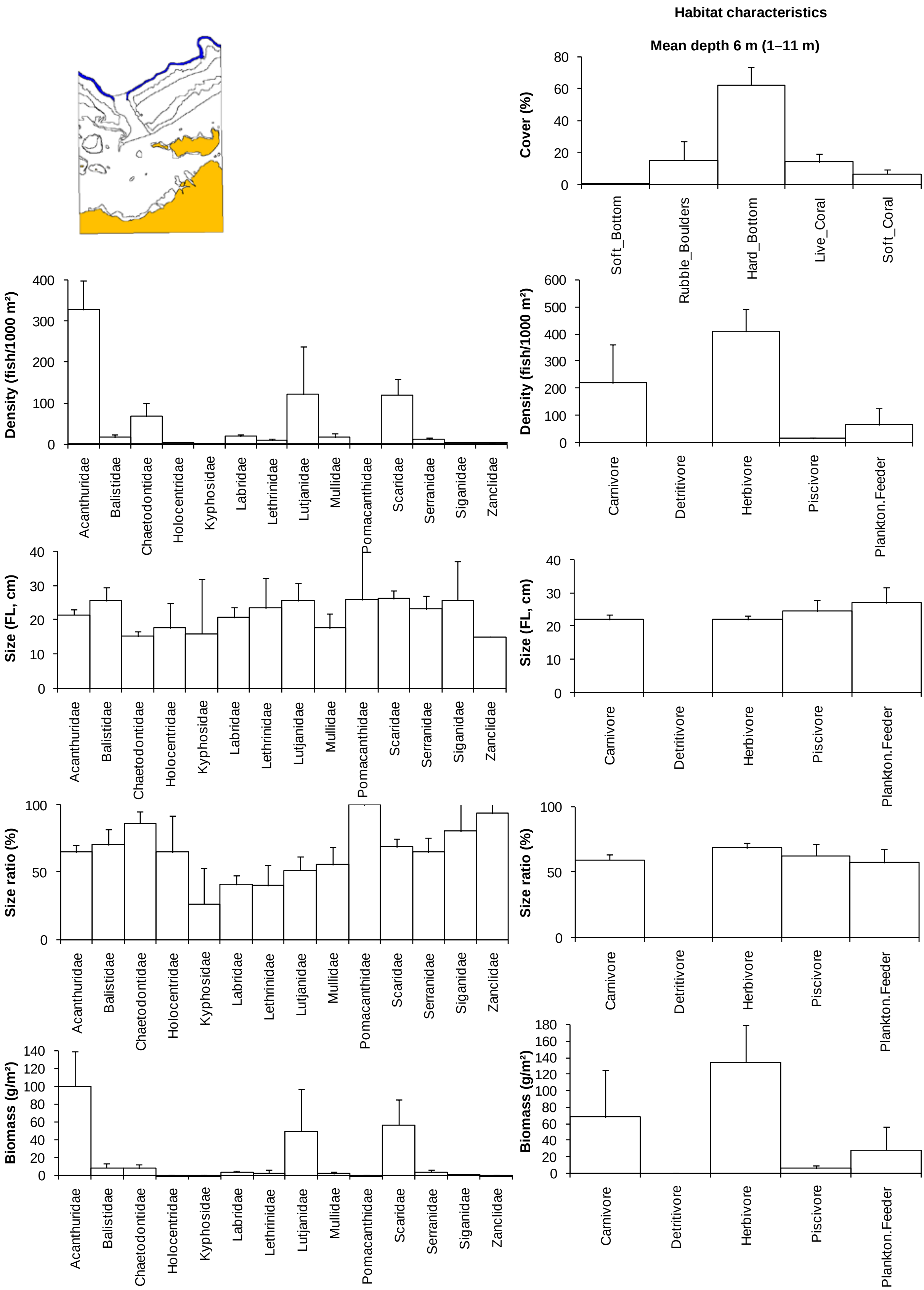

Figure 4.23: Profile of finfish resources in the outer-reef environment of Mali.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Mali

Overall, the fish assemblage at Mali was dominated by herbivorous Scaridae, Acanthuridae and Siganidae (Figure 4.24). These three families were represented by a total of 52 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Siganus spinus*, *Chlorurus sordidus*, *Scarus psittacus* and *Acanthurus blochii* (Table 4.11). The average substrate was composed mainly of hard bottom (48%), then by rubble (28%), soft bottom (13%) and a small cover of live coral (10%). The overall fish assemblage and substrate composition in Mali shared characteristics of primarily back-reefs (72% of total habitat), and only to a smaller extent coastal reefs (11%), intermediate reefs (10%) and finally outer reefs (6%).

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

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.12	17.0
	Acanthurus blochii	Ringtail surgeonfish	0.02	13.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.09	13.1
	Scarus psittacus	Common parrotfish	0.06	8.6
Siganidae	*Siganus spinus*	Little spinefoot	0.10	9.9

Overall, Mali appeared to support a rather healthy finfish resource, with much higher density, size, size ratio and biomass than at the other three sites. Biomass was comparable to the Muaivuso and Dromuna values. However, comparisons among all sites are not entirely reliable due to the fact that Muaivuso includes only back- and outer reefs. The more detailed assessment at the trophic and family level revealed a clear dominance of herbivores over carnivores, due to the high density of Scaridae, Acanthuridae and Siganidae. The habitat was composed mainly of hard bottom, offering little favourable habitat for carnivores of the Mullidae and Lethrinidae families. Kyphosidae, Labridae, Lethrinidae and Mullidae displayed size ratios much lower than the maximum known for these families, indicating a selective impact from fishing. In fact, Lethrinidae were among the most frequently caught fish throughout the four villages.

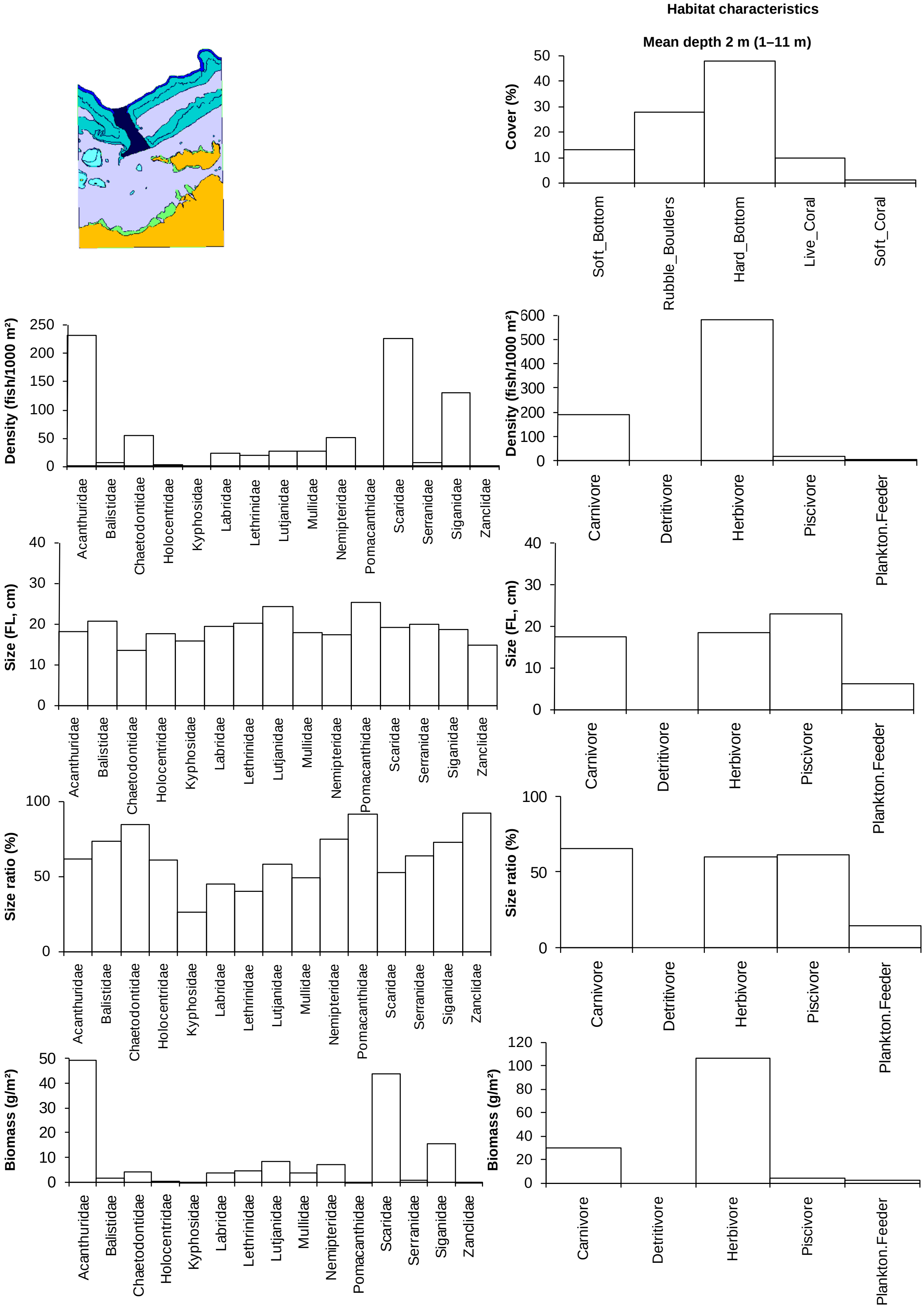

Figure 4.24: Profile of finfish resources in the combined reef habitats of Mali (weighted average).
FL = fork length.

4.3.2 Discussion and conclusions: finfish resources in Mali

The assessment indicated that the status of finfish resources in the Mali site was relatively healthy, with much higher density, size, size ratio and biomass compared to the values in the other three sites. Biodiversity was the same as the values at Muaivuso and Dromuna. The detailed assessment at the trophic and family level revealed a clear dominance of herbivores over carnivores. The average family composition was dominated, as was the case at Lakeba, by Scaridae, Acanthuridae and Siganidae. The habitat was composed mainly of hard bottom, offering little favourable habitat to carnivores of the Mullidae and Lethrinidae families. Kyphosidae, Labridae, Lethrinidae and Mullidae displayed size ratios much lower than the maximum known for these families, indicating a selective impact from fishing. Lethrinidae, together with Serranidae, often very rare, were among the most frequently caught fish throughout the four villages.

Mali, the village on the island of Mali, is one of the less urbanised of the four villages surveyed, displaying the lowest fishing pressure, due especially to the very large area of the available reefs and fishing ground and the low population density. Therefore, although this village is dependent on fishing for income generation and has a high fresh-fish consumption and high catches compared to the other villages, the fishing pressure on the resources is limited.

- The reefs of Mali were dominated by hard bottom and rubble with very small amounts of live coral and soft bottom. This could explain the low abundance of some carnivorous families.

- Overall, fish density, size and biomass were high.

- The dominance of herbivores was consistent in all the reef habitats. The coastal and intermediate reefs displayed a similar family composition, with Acanthuridae and Scaridae equally important and dominating. The back-reefs (representing the majority of all reefs) displayed also a large presence of Siganidae. In the outer reefs, Lutjanidae were also well represented.

- Size ratios were low for Kyphosidae, Labridae, Lethrinidae and Mullidae, most probably as a response from fishing.

4.4 Invertebrate resource surveys: Mali

The diversity and abundance of invertebrate species at Mali were independently determined using a range of survey techniques (Tables 4.12a for 2003, 4.12b and 4.12c for 2009), broad-scale assessment (using the ‘manta-tow’ technique; locations shown in Figures 4.25a for 2003 and 4.25b for 2009) and finer-scale assessment of specific reef and benthic habitats (Figures 4.26a and 4.27a for 2003; Figures 4.26b and 4.27b for 2009).

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

In 2003, the total survey coverage area was estimated at 81,893 m², while in 2009 it was estimated at 50,746 m² (42,586 m² at the open-access reefs and 8160 m² in the MPA). The 2003 survey extended west, outside the traditional boundary of Mali. The recent survey (2009) was concentrated on the Mali area alone. Mali is a member of the Fiji Locally Managed Marine Area (FLMMA) network, through the village MPA established around 2000. The 2009 survey focused on the MPA area for impact-assessment purposes.

Table 4.12a: Number of stations and replicate measures completed in Mali in 2003

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	15	90 [(1)] transects
Reef-benthos transects (RBt)	15	90 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	5	30 search periods
Reef-front searches	2 RFs 0 RFs_w	12 search periods 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	1	6 search periods

RFs = reef-front search; RFs_w = reef-front search by walking; [(1)] transects were 350 m in length.

Table 4.12b: Number of stations and replicate measures completed at the open-access reef in Mali in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	3	18 [(1)] transects
Reef-benthos transects (RBt)	11	66 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	4	24 search periods
Reef-front searches	4 RFs 0 RFs_w	27 search periods 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	2	12 search periods

RFs = reef-front search; RFs_w = reef-front search by walking; [(1)] transects were 300 m in length.

Table 4.12c: Number of stations and replicate measures completed in the MPA in Mali in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	2	12 [(1)] transects
Reef-benthos transects (RBt)	4	24 transects
Soft-benthos transects (SBt)	0	0 transect
Soft-benthos infaunal quadrats (SBq)	0	0 quadrat group
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	0	0 search period
Reef-front searches	0 RFs 0 RFs_w	0 search period 0 search period
Sea cucumber night searches (Ns)	0	0 search period
Sea cucumber day searches (Ds)	0	0 search period

RFs = reef-front search; RFs_w = reef-front search by walking; [(2)] transects were 300 m in length.

Figure 4.25a: Broad-scale survey stations for invertebrates in Mali in 2003.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.
Geomorphological contour lines outside the boundary were not available for mapping.

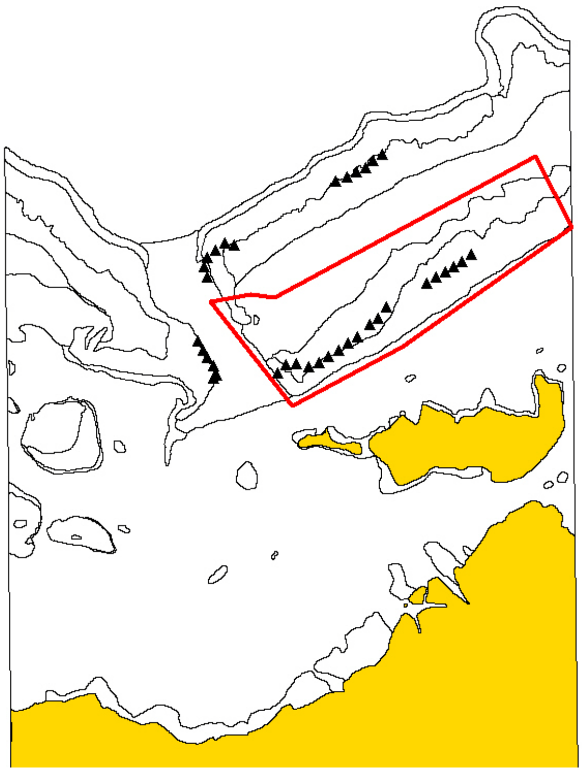

Figure 4.25b: Broad-scale survey stations for invertebrates in Mali in 2009.
Data from broad-scale surveys conducted using 'manta-tow' board; MPA boundary in red;
black triangles: transect start waypoints.

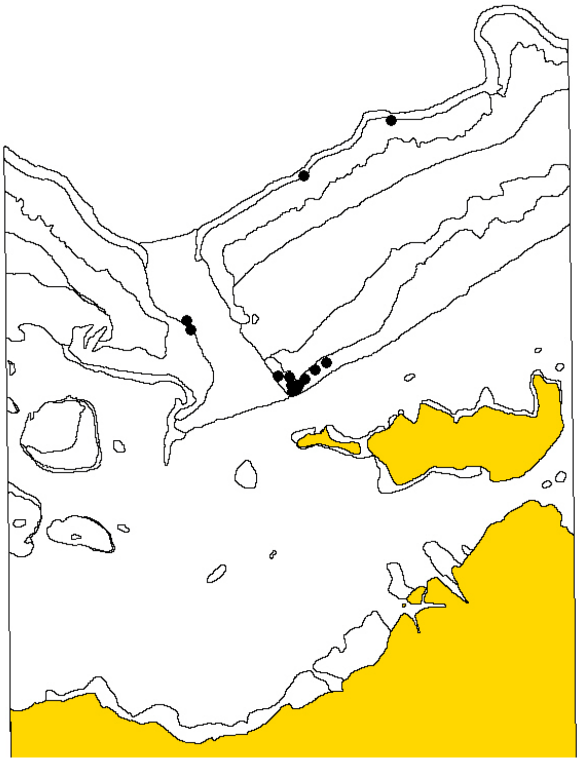

Figure 4.26a: Fine-scale reef-benthos transect survey stations for invertebrates in Mali in 2003.
Black circles: reef-benthos transect stations (RBt).

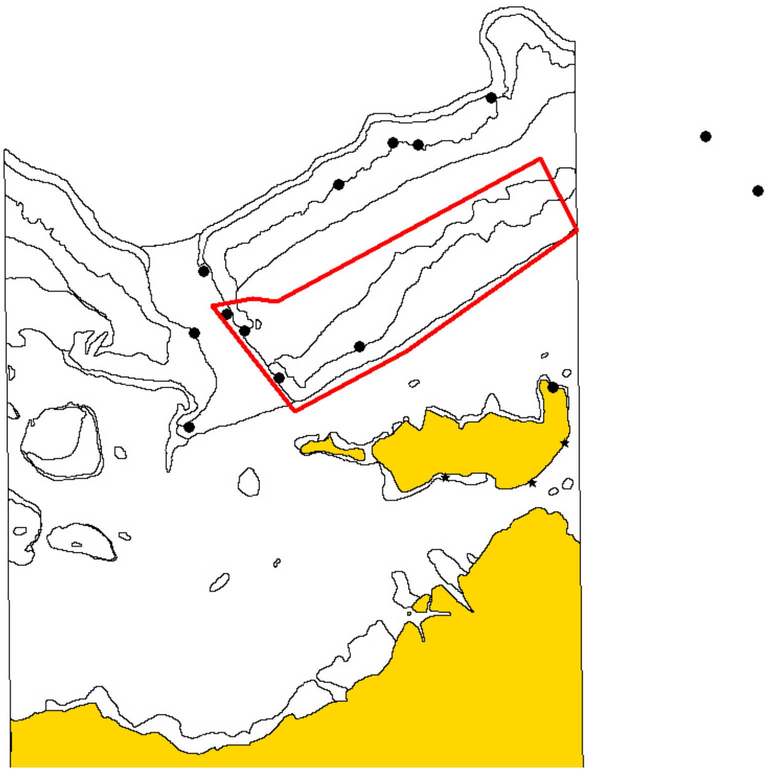

Figure 4.26b: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations for invertebrates in Mali in 2009.
MPA boundary in red;
black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

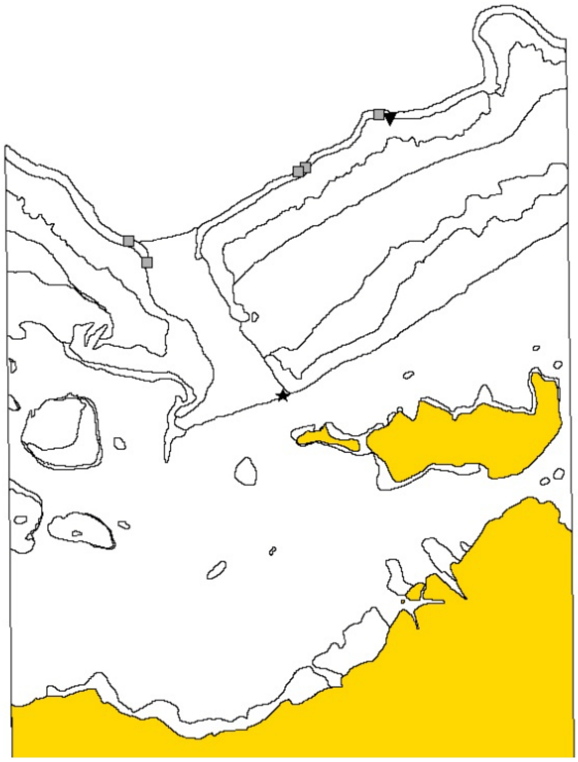

Figure 4.27a: Fine-scale survey stations for invertebrates in Mali in 2003.
Inverted black triangle: reef-front search station (RFs);
grey star: sea cucumber day search station (Ds);
grey squares: mother-of-pearl search stations (MOPs).

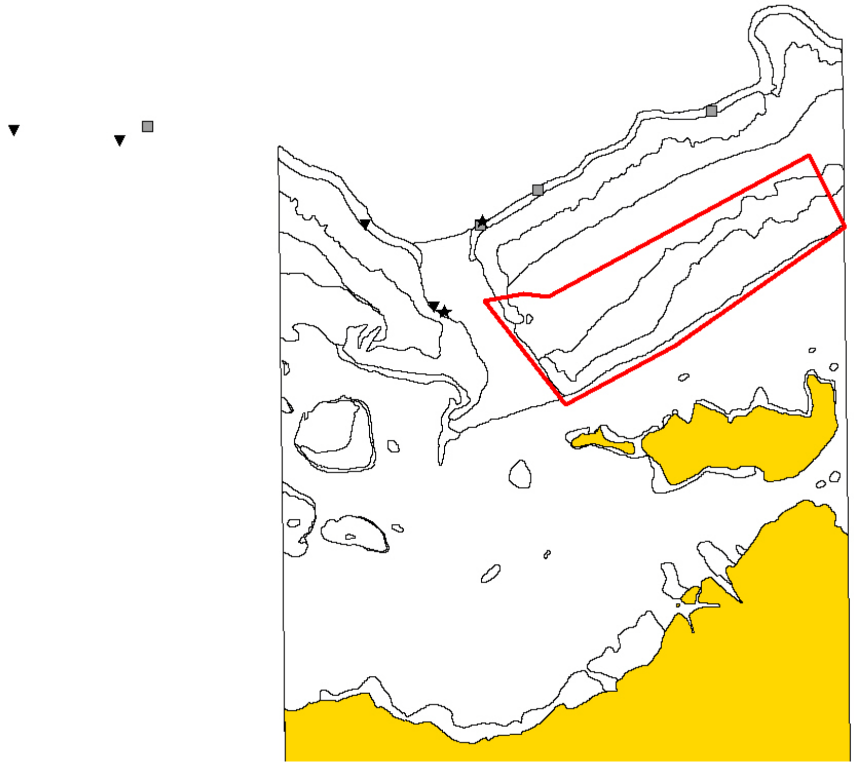

Figure 4.27b: Fine-scale survey stations for invertebrates in Mali in 2009.
MPA boundary in red;
Inverted black triangles: reef-front search stations (RFs);
grey stars: sea cucumber day search stations (Ds);
grey squares: mother-of-pearl search stations (MOPs).

In 2003, forty-five species or species groupings (groups of species within a genus) were recorded in the Mali invertebrate surveys. Among these were 1 crustacean, 7 bivalves, 14 gastropods, 14 sea cucumbers, 4 starfish and 3 urchins (Appendix 4.3.1 for 2003).

In 2009, forty-one species or species groupings were recorded. Among these were 1 crustacean, 8 bivalves, 15 gastropods, 11 sea cucumbers, 3 starfish and 2 urchins (Appendix 4.3.1 for 2009).

Information on key families and species is detailed below.

4.4.1 2003–2009 stock status trends – giant clams: Mali

Reef habitat suitable for giant clams is extensive within the large, complex lagoon at Mali (103 km^2 of shallow reef in a lagoon area of 299 km^2). Lagoon patch reefs that comprise rubble and hard limestone benthos extend from the shoreline to the back-reef of the barrier. The back-reef is composed mainly of sand and rubble, but a pseudo barrier (Vuata reef) in front of Mali island before the main barrier (Cakaulevu reef) holds large amounts of healthy coral and limestone substrate suitable for giant clams. There is dynamic water flow through most of the outer lagoon and across the barrier reef, especially through the main pass (Voro voro, NNW of Mali) and the minor passage just to the northeast. Outside the lagoon, the more exposed reef front and slope cover approximately 17.7 km^2 (lineal distance 38.4 km) and, in both 2003 and 2009, it was not heavily impacted by swell at the time of the survey.

Both the elongate clam, *Tridacna maxima*, and the fluted clam, *T. squamosa*, were noted in the 2003 and 2009 surveys. Broad-scale sampling provided an overview of giant clam distribution.

In 2003, both species of clam were recorded in 53% of stations monitored. *T. maxima* had the widest occurrence (recorded in 20 of 90 transects), whereas *T. squamosa* was only recorded in 12 transects (Figure 4.28a).

In 2009, *T. maxima* was recorded at 100% of stations and 27.8% of the replicates monitored at the open-access reefs, but at 50% of stations and 25% of replicates inside the MPA. However, this information is based on a small number of stations and is not directly comparable with the 2003 results. *T. squamosa* was recorded at 33.3% of stations and 5.6% of replicates at the open-access reefs and at 50% of stations and 8.3% of replicates inside the MPA (Figure 4.28b).

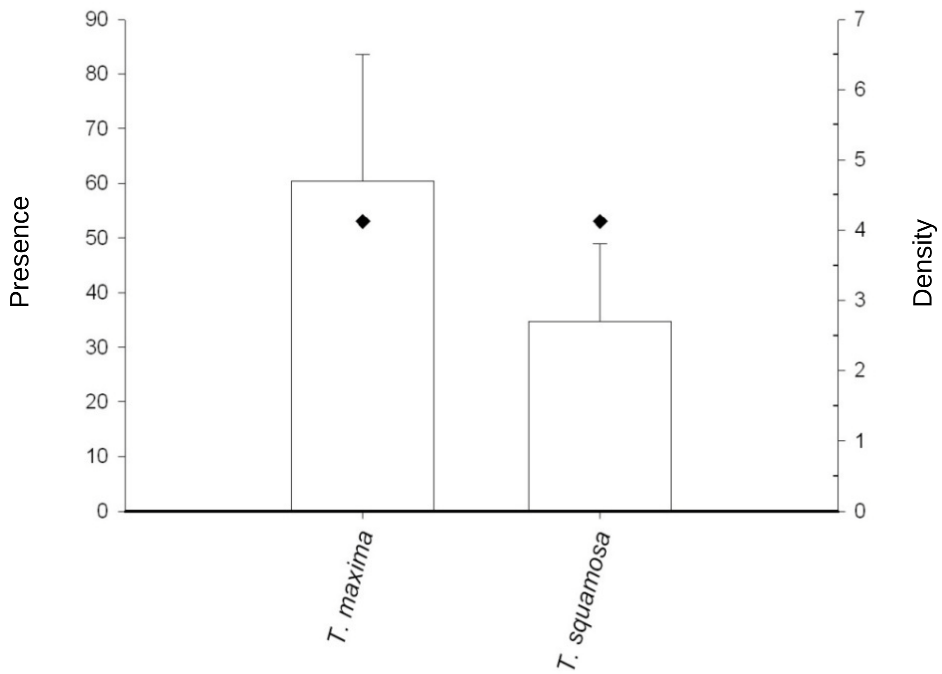

Figure 4.28a: Presence and mean density of giant clam species at Mali based on broad-scale survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

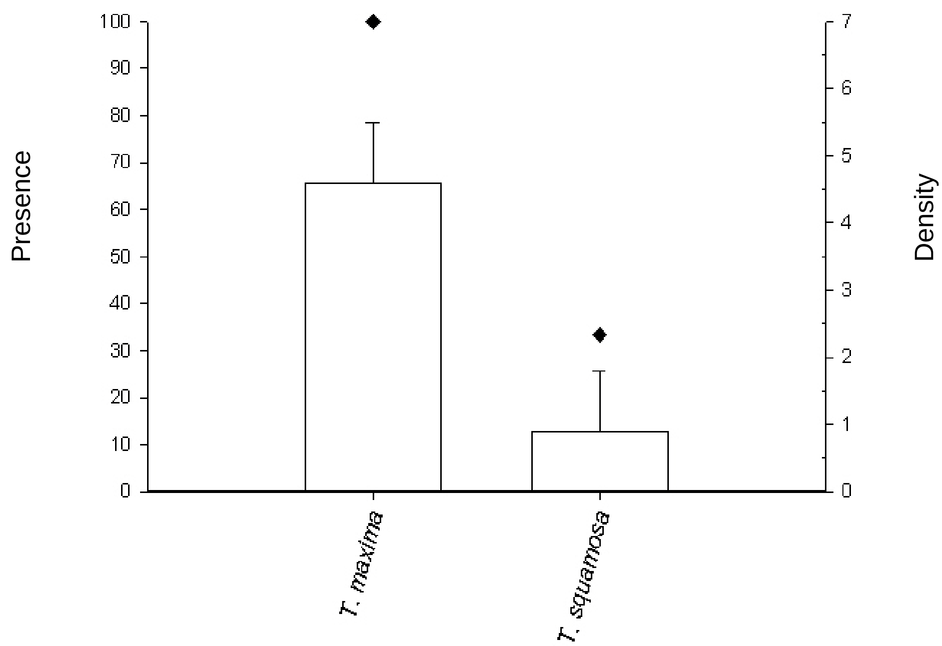

Figure 4.28b: Presence and mean density of giant clam species at Mali based on broad-scale survey at open-access reefs in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Finer-scale surveys targeted specific areas of clam habitat (Figures 4.29a for 2003, 4.29b and c for 2009).

In 2003, in reef-benthos assessments (RBt), *T. maxima* was present in 73% of survey stations, with a mean station density of 143.9 /ha ±40.3 at the 11 stations where this species was recorded. *T. squamosa* was also relatively common (recorded at 53% of stations) and had a mean density of 67.7 /ha ±15.6 (at the eight stations where they were noted; Figure 4.29a).

In 2009, *T. maxima* was present in 18.2% of survey stations at the open-access reefs, at a mean density of 83.3 /ha ±41.7 at the two stations where it was recorded. Inside the MPA, it was present at 25% of the stations at a mean density of 166.7 /ha at the single station where it was found. The fluted clam, *T. squamosa*, was also present at 18.2% of the stations on the open-access reefs at the same density (83.3 /ha ±41.7 at the two stations where it was recorded). Inside the MPA, it was recorded at 50% of the stations at the mean density of 104.2 /ha ±62.5 at the two stations where it was recorded (Figures 4.29b and c).

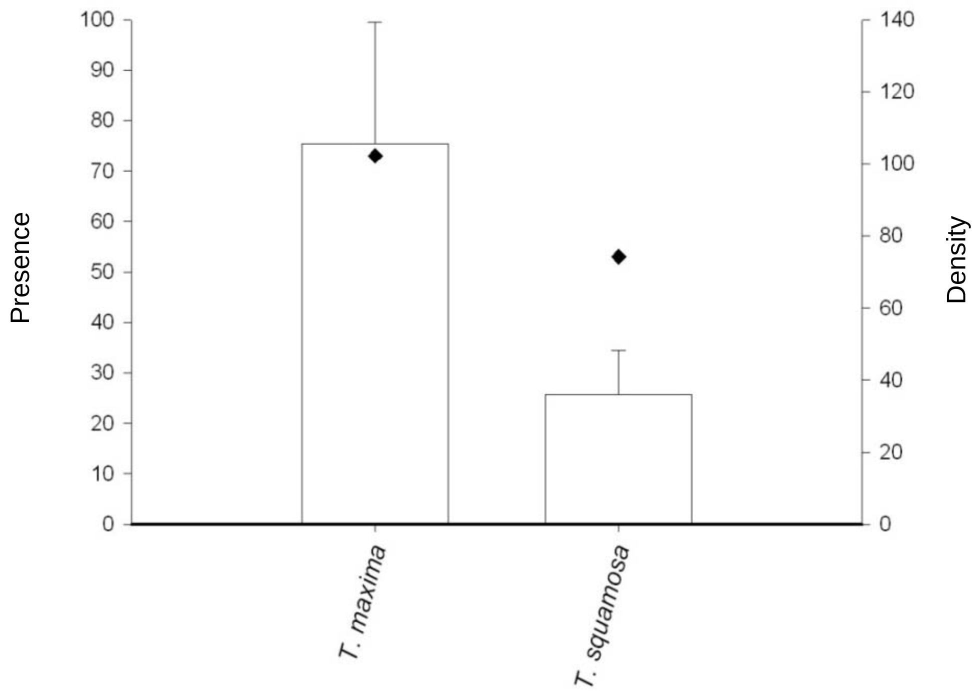

Figure 4.29a: Presence and mean density of giant clam species at Mali based on fine-scale reef-benthos transect survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

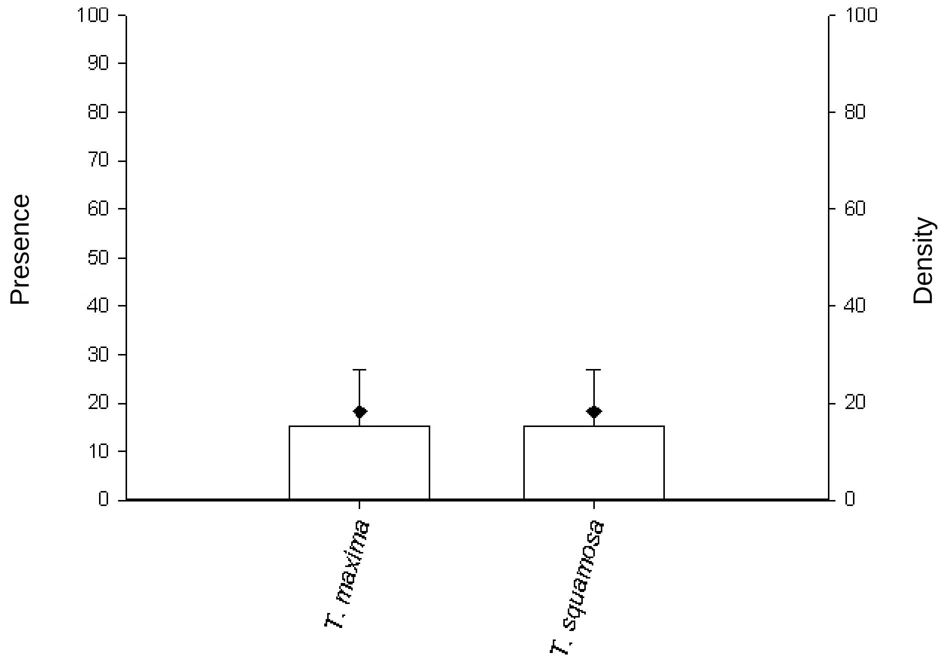

Figure 4.29b: Presence and mean density of giant clam species at Mali based on fine-scale reef-benthos transect survey, at open-access reefs in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

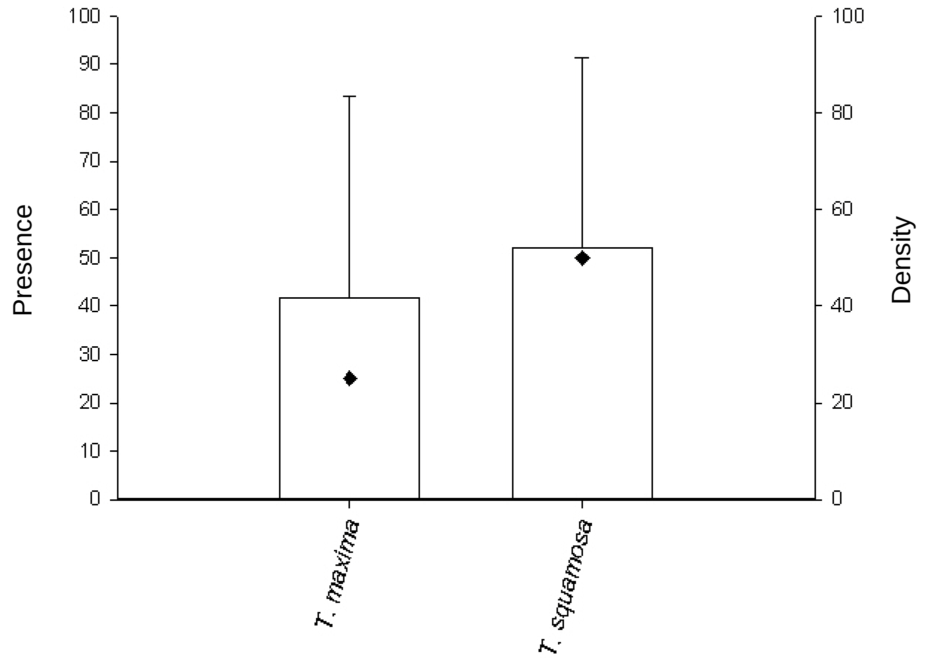

Figure 4.29c: Presence and mean density of giant clam species at Mali based on fine-scale reef-benthos transect survey, inside the MPA in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

In 2003, a total of 74 *T. maxima* clams (mean length of 13.7 cm ±0.6) and 31 *T. squamosa* clams (mean length of 20.8 cm ±1.8) were recorded during reef and broad-scale assessments (Figure 4.30a).

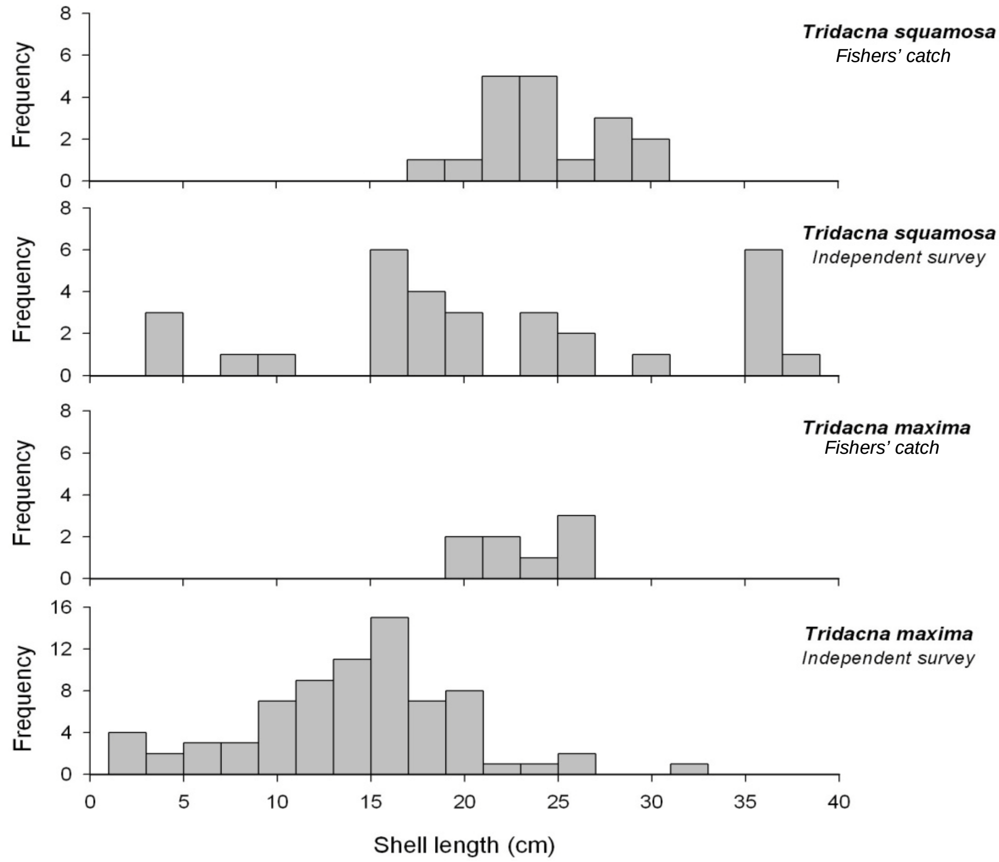

Figure 4.30a: Size frequency histograms of giant clam shell length (cm) from fishers' catches and from independent surveys at Mali in 2003.

As the length frequency graph (Figure 4.30a) shows, a complete range of possible clam lengths were recorded for both species in the 2003 survey, although the larger size classes did not dominate the length frequency profile. The mean-sized *T. maxima* (length of 13.7 cm) represents a clam of about six years old and the presence of small individuals showed that stocks were still receiving recruitment despite their generally low abundance. The faster growing *T. squamosa* (which grows to an asymptotic length L_∞ of approximately 40 cm) had a large mean size (average 26.2 cm, also representing a clam ~6–7 years old), but smaller specimens were also present (Figure 4.30a).

In 2009, no creel survey was made. The total number of giant clams recorded during the survey was 14 *T. maxima* (mean length 18.3 cm ±2.0) and six *T. squamosa* (mean length 20.5 cm ±1.8) at the open-access reefs, and eight *T. maxima* (mean length 8.0 cm) and seven *T. squamosa* (mean length 20.4 cm ±3.6) inside the MPA. Not all the specimens recorded were measured (See Appendices 4.3.10 to 4.3.11. and Figure 4.30b). From the small sample measured, we can observe that recruitment is active, with young, small specimens of both *T. maxima* and *T. squamosa* recorded. Large-sized specimens were also present, with a maximum size of 26.0 cm observed for *T. maxima* and 30.0 cm for *T. squamosa*.

Two giant clam species were recorded in Mali, *T. maxima* and *T. squamosa*. Generally, as in other Pacific Island sites studied, *T. maxima* is the most common species, while *T. squamosa* is the rarest. In Mali, the opposite occurs, there were more *T. squamosa* recorded than *T. maxima*. The status of the *T. maxima* stock declined to a low density level in 2009. On the other hand, the stock of *T. squamosa* remained relatively healthy inside the MPA, which shows the positive impact of the MPA in protecting the stock. Most of the *T. squamosa* recorded were inside the MPA. On the whole, the overall giant clam distribution was more limited in 2009 than in 2003, which illustrates the overall depletion trend. The reefs inside the MPA do not cover the most suitable habitat for *T. maxima*, which inhabits areas of relatively clean water, especially along the back-reef of the outer barrier, which in Mali remains open-access. The MPA area should be extended outward to the reef slope to cover suitable habitat for *T. maxima*. Active breeding of both giant clam species (Juveniles were recorded in 2009.) was still occurring in Mali, which is linked to the protection afforded by the MPA for spawning clams.

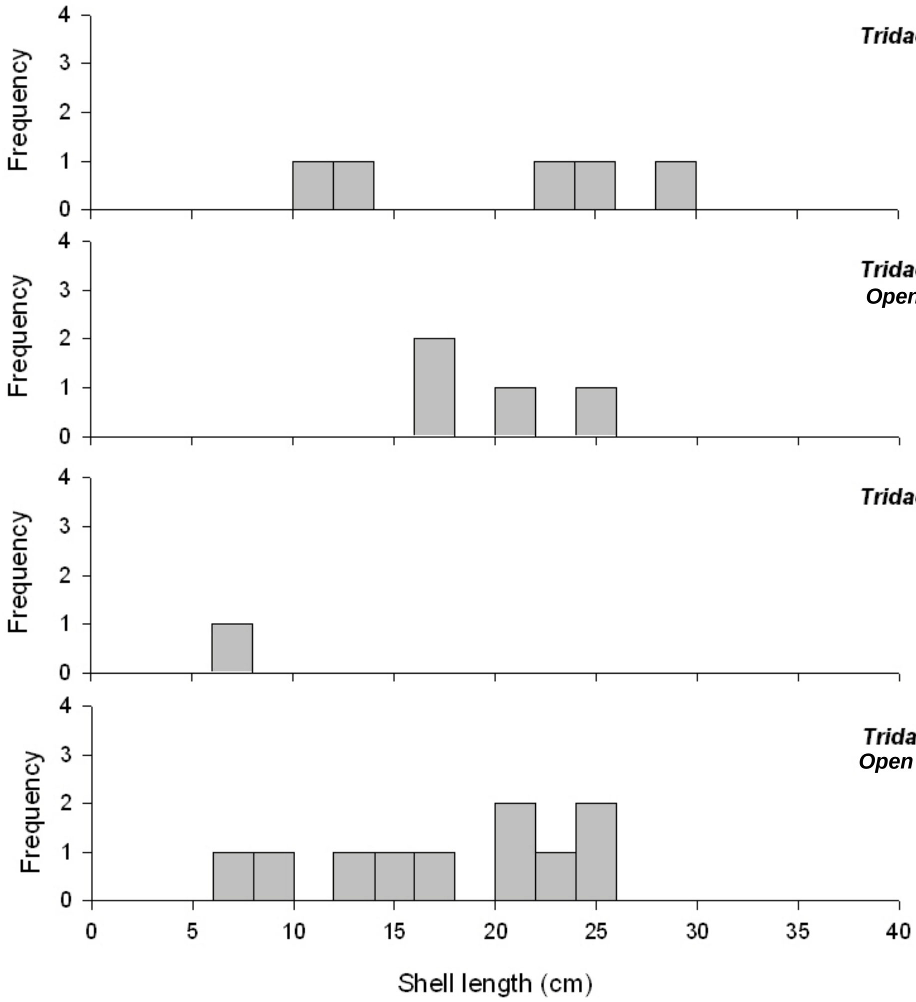

Figure 4.30b: Size frequency histograms of giant clam shell length (cm) from open-access reefs and MPA assessment stations at Mali in 2009.

4.4.2 2003–2009 stock status trends – mother-of-pearl species (MOP): Mali

Mali had extensive reef habitat for the commercial topshell, *Trochus niloticus* (an outer lineal distance of ~38.4 km). The reefs within the lagoon in Mali were complex and contained many of the elements required for juvenile settlement and growth and for adult trochus, such as rubble back-reef on the barrier and complex limestone structure subject to significant water movement. The exposed barrier reef was subject to swell, but somewhat isolated from the lagoonal reef (Intermediate structures tended to run along the lagoon.) and there were no extensive offshore shoals to hold large densities of adult topshells.

In 2003, *T. niloticus* were recorded within the lagoon on the pseudo barrier (Vuata reef) and on Cakaulevu reef, the main barrier (Table 4.13a). The highest-density stations were recorded in lagoon and barrier-reef shallows, with lower density noted on the outer-reef slope. The highest-density station recorded at Mali was 167 /ha for RBt and 22 /ha for MOPs. In well defined RBt surveys, this equates to four trochus per station.

In 2009, *T. niloticus* aggregations were mostly recorded on both sides of the channel and were sporadically found outside the barrier reef. The highest density was recorded on one RBt station at the east side of the channel at 292 /ha (Tables 4.13b and c). Overall, density was low, and far below the threshold of 500 specimens/ha considered for a healthy stock.

Table 4.13a: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Mali in 2003
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	1.2	0.5	6/15 = 40	7/90 = 8
RBt	13.9	5.2	5/15 = 33	5/90 = 6
MOPs	1.5	1.5	1/5 = 20	1/30 = 3
Tectus pyramis				
B-S	0.3	0.2	2/15 = 13	2/90 = 2
RBt	102.8	69.0	3/15 = 20	11/90 = 12
MOPs	1.5	1.5	1/5 = 20	1/30 = 3
Trochus niloticus				
B-S	0.6	0.5	1/15 = 7	2/90 = 2
RBt	25.0	14.0	3/15 = 20	6/90 = 7
MOPs	7.6	4.8	2/5 = 40	4/30 = 13

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

Table 4.13b: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* at open-access reefs in Mali in 2009
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	3.7	2.2	1/3 = 33	3/18 = 17
RBt	3.8	3.8	1/11 = 9	1/66 = 2
RFs	0	0	0/4 = 0	0/27 = 0
MOPs	0	0	0/4 = 0	0/24 = 0
Tectus pyramis				
B-S	9.3	3.1	2/3 = 66	7/18 = 39
RBt	45.5	19.0	5/11 = 45	8/66 = 12
RFs	3.2	2.2	2/4 = 50	4/27 = 15
MOPs	34.3	11.0	4/4 = 100	8/24 = 33
Trochus niloticus				
B-S	0.9	0.9	1/3 = 33	1/18 = 6
RBt	53.0	30.8	3/11 = 27	10/66 = 15
RFs	2.9	1.0	¾ = 75	4/27 = 15
MOPs	25.0	8.5	4/4 = 100	12/24 = 50

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

Table 4.13c: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* inside the MPA in Mali in 2009
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	4.2	2.2	2/2 = 100	3/12 = 25
RBt	20.8	20.8	1/4 = 25	2/24 = 8
Tectus pyramis				
B-S	0	0	0/2 = 0	0/12 = 0
RBt	135.4	121.9	2/4 = 50	5/24 = 21
Trochus niloticus				
B-S	0	0	0/2 = 0	0/12 = 0
RBt	41.7	29.5	2/4 = 50	2/24 = 8

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

In the 2003 survey, the mean size (basal width) of trochus (*T. niloticus*) was 9.4 cm ±0.6 (n = 18) and a full range of trochus sizes were represented (Figure 4.31a). Two shells were also noted by boatmen on snorkel from the southeastern side of Vuata reef when we accompanied fishers on a gleaning trip. These were 11 cm and 10 cm in size.

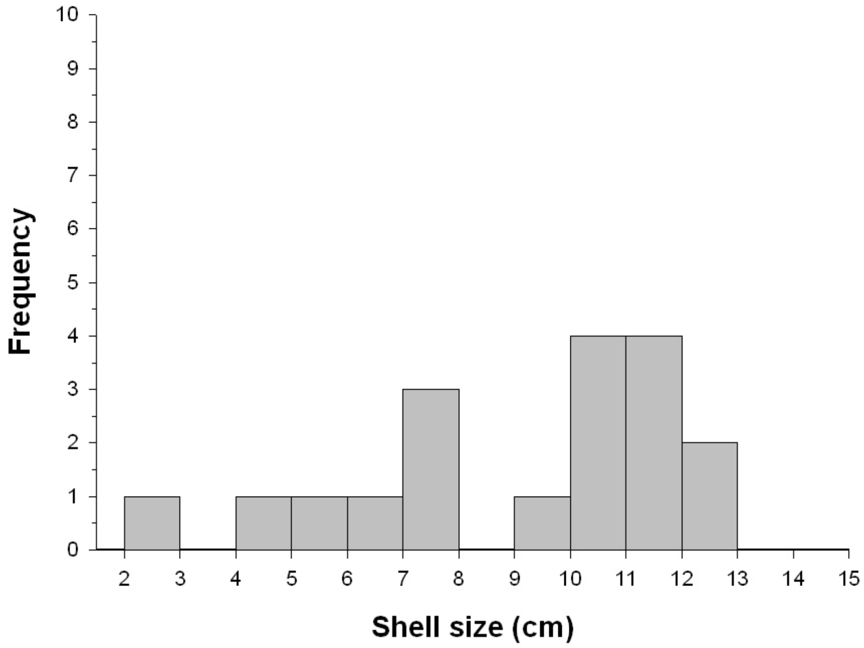

Figure 4.31a: Size frequency histogram of trochus shell base diameter (cm) for Mali in 2003.

In the 2009 survey, the mean size of trochus was 8.6 cm ±0.4 at the open-access reefs (31 measurements) and 7.1 cm ±1.3 inside the MPA (only four specimens recorded and measured). The cryptic, smaller size was absent from the survey, indicating a possible lack of recruitment during the previous year. Intermediate sizes (5–7 cm) were present, indicating that there had been active recruitment in 2006 and 2007 (See Figures 4.31b and c.).

In summary, there are more *Trochus niloticus* in the passage reefs than in the outer barrier reef slope. No change in density was detected between the two surveys, pointing to a possible breeding problem in the existing population. Recruitment may be happening but at a slow rate. Breeding difficulties are common in depleted stocks of broadcast spawners such as trochus when the few remaining spawners are too far apart for gamete fertilisation to be successful.

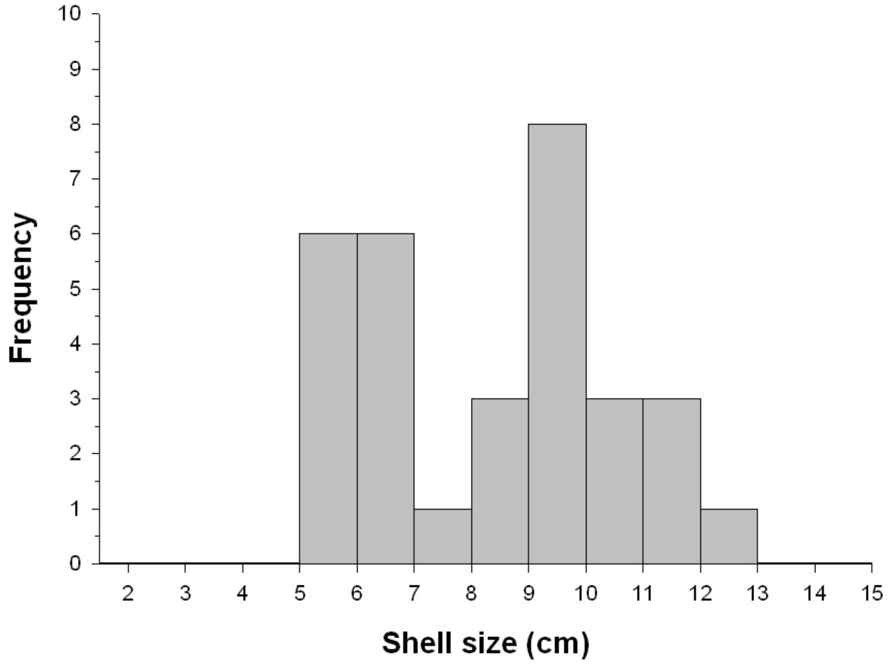

Figure 4.31b: Size frequency histogram of trochus shell base diameter (cm) at open-access reefs at Mali in 2009.

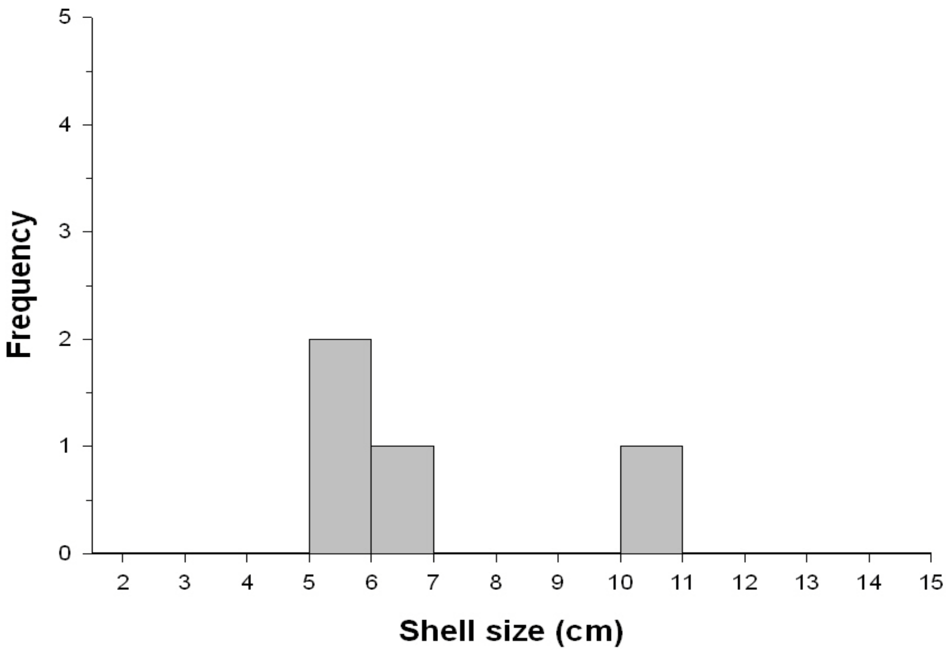

Figure 4.31c: Size frequency histogram of trochus shell base diameter (cm) inside the MPA at Mali in 2009.

The green topshell *Tectus pyramis* (of low commercial value), a species closely related to trochus, with similar distribution and life history characteristics, was also recorded in assessments made in the lagoon and barrier-reef slope.

In 2003, the presence and density of this species were moderate to high, but denoted that the environment was only moderately suitable for grazing gastropods similar to trochus. The green topshells had an average size of 5.9 cm ±0.1 (n = 30). No *T. pyramis* were seen in the limited catches recorded during creel surveys.

In 2009, the presence and density remained moderate to high. Average size was 6.0 cm ±0.2 at the open-access reefs (n = 12) and 5.3 cm ±0.2 inside the MPA (n = 5).

Pinctada margaritifera, the blacklip pearl oyster, is a normally cryptic and sparsely distributed species.

In 2003, *P. margaritifera* was recorded in six broad-scale stations (8% of transects). It was also recorded in reef-benthos stations and in creel surveys from fishers gleaning the reeftop (n = 3, mean size 15.1 cm). The mean size of blacklip pearl oysters recorded from independent survey was 14.4 cm ±8.2 (n = 11). Taking into account the cryptic nature of *P. margaritifera* and its general low density in open reef systems characteristic of Melanesia, these results describe a medium occurrence of *P. margaritifera*.

In 2009, the blacklip was recorded in 17% of broad-scale transects at the open-access reefs and in 25% of broad-scale transects inside the MPA. It was also recorded on RBt stations, both in the open-access reefs and inside the MPA, but at low densities. A single blacklip measurement was recorded at both the open-access reef and MPA; both measures were 15.0 cm.

In summary, the density level of *P. margaritifera* declined between 2003 and 2009.

4.4.3 2003–2009 stock status trends – infaunal species and groups: Mali

Being an island within the lagoon, Mali is fringed with hard-benthos substrates without mangroves (Mangroves are located on the shoreline of Vanua Levu, west of the Mali settlement.) or concentrations of in-ground resources (shell 'beds'). No arc shell, *Anadara* spp. (*kaikoso*) or Venus shell *Gafrarium* spp. areas were found and, therefore, no fine-scale infaunal stations (quadrat surveys) were completed.

4.4.4 2003–2009 stock status trends – other gastropods and bivalves: Mali

In 2003, *yaga* (or *ega*), the smaller spider conch (both *Lambis lambis* and *L. crocata*) was recorded in broad-scale and reef-benthos stations and within creel surveys at moderate density (Appendices 4.3.2 and 4.3.6 for 2003). A single large Seba's spider conch (*L. truncata*) was noted but no aggregations of the small strawberry conch (*Strombus luhuanus*) were recorded in survey.

In 2009, only one species of spider conch, y*aga* (*Lambis lambis*), was recorded sporadically at moderate density on B-S and RBt stations.

Strombus luhuanus was recorded locally at relatively high density at RBt stations (534.1 /ha ±421.4) but was recorded only at 2 of the 11 RBt stations.

Turban shells (*Turbo* spp.) are commonly collected along exposed reef fronts in the Pacific but in the 2003 survey they were not common. The density of *la*, *T. crassus* (which may have been large *T. argyrostomus*; see Appendix 4.3.3) was 72.2 ±47.2 (n = 26) on RBt stations. *T. crassus*, the larger of the two common turban shells, was recorded at a mean size of 5.7 cm ±0.2. The smaller, more inshore species, *T. chrysostomus* (average size of 3.5 cm ±0.3), was not commonly recorded.

In 2009, no turban shells were recorded during the survey, which may indicate rarefaction of this group, which is usually under strong gleaning pressure from the subsistence fishers.

Other resource species targeted by fishers (e.g. *Conus*, *Cypraea*, *Latirolagena*, *Thais* and *Vasum*) were recorded during independent survey (See lists in Appendices 4.3.1 to 4.3.7 for 2003 and Appendices 4.3.1 to 4.3.11 for 2009.). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina*, *Chama*, *Hyotissa* and *Spondylus* are also in these Appendices for 2003 and 2009.

In 2003, two creel surveys were conducted at Mali, including seven fishers (groups) on the 14 June 2003 gleaning on shallow reef, and three fishers walking the shoreline around Mali island on 17 June 2003 (Appendix 4.3.9 for 2003). A list of the species collected is given in Table 4.14.

Table 4.14: List of species noted in catches during creel surveys in Mali in 2003

Group	Species	Number
Bivalve	*Atrina vexillum*	12
Bivalve	*Pinctada margaritifera*	3
Bivalve	*Spondylus* spp.	1
Bivalve	*Tridacna maxima*	9
Bivalve	*Tridacna squamosa*	20
Bivalve	*Tridacna* spp.	47 (mostly *T. maxima*)
Polyplacophora (Chiton)	*Acanthopleura gemmata*	40
Cnidarian (Sea anemone)	*Heteractis* spp.	3
Crustacean (Crab)	*Eriphia sebana*	1
Crustacean (Crab)	*Scylla serrata*	1
Crustacean (Crab)	*Grapsus albolineatus*	1
Echinoderm (Urchin)	*Tripneustes gratilla*	1
Gastropod	*Chicoreus ramosus*	1
Gastropod	*Conus litteratus*	1
Gastropod	*Cypraea tigris*	7
Gastropod	*Lambis lambis*	19
Gastropod	*Trochus niloticus*	2
Gastropod	*Nerita albicilla*	290
Gastropod	*Nerita polita*	19
Gastropod	*Nerita plicata*	20
Gastropod	*Nerita undata*	80
Gastropod	*Littoraria scabra*	148
Gastropod	*Turbo cinereus*	184
Sea cucumber	*Actinopyga lecanora*	1
Sea cucumber	*Actinopyga miliaris*	1
Sea cucumber	*Holothuria nobilis*	1

One species that is eaten in the Pacific Islands but not often reported is the chiton, which is a Polyplacophora mollusc found attached to rocks. This species is difficult to measure in creel surveys as the individuals roll up once detached from the rocks, but weights were taken during this assessment (Figure 4.32).

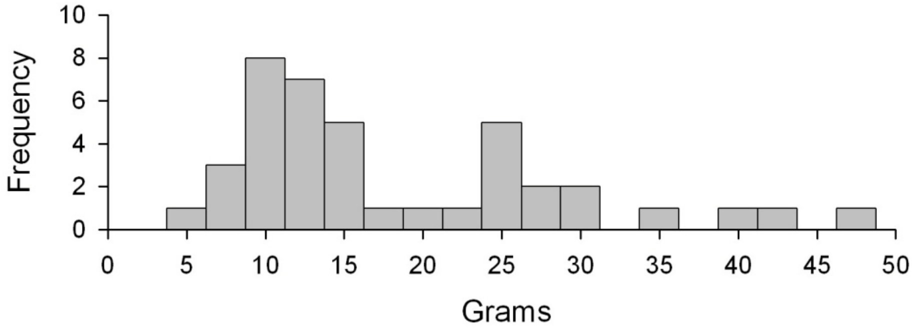

Figure 4.32: Weight frequency histogram of chiton, *Acanthopleura gemmata* (g) in Mali in 2003.

No creel survey was conducted in 2009.

4.4.5 2003–2009 stock status trends – lobsters and crabs: Mali

There was no dedicated night reef-front assessment of lobsters (See Methods.) but, in 2003, six lobsters were recorded in general B-S and MOP surveys, half of which were juveniles. Mud crabs (*Scylla serrata*) and a number of other shore crabs were present on Mali island; however, a snapshot independent survey would not supply a reliable indication of crab abundance and was not conducted in this survey period. No slipper lobsters (*Parribacus* spp.) or sand lobsters (*Lysiosquillina* spp.) were noted in survey.

In 2009, only one lobster (*Panulirus versicolor*) was recorded on the oceanic slope of the barrier reef. No other crustacean was recorded during the survey, which may indicate that the crustacean resources are depleted.

4.4.6 2003–2009 stock status trends – sea cucumbers[8]: Mali

Mali island and the small, neighbouring Voro voro island are high islands but of limited scale (~9.8 km² of land mass). Inshore waters near these islands are largely influenced by the main island of Vanua Levu (1–3.5 km away), which has at least six large river systems emptying into the lagoon and is bordered by extensive mangroves. Further offshore, the lagoon is more influenced by oceanic factors, and water movement around the main passage is significant.

The open lagoon has a full range of environments suitable for sea cucumbers, from restricted embayed areas of shallow lagoon to wave-impacted reef fronts outside the barrier. Reef margins and mixed, hard- and soft benthos, with small, shallow lagoons near the intermediate islands provide suitable habitat for these deposit feeders (Sea cucumbers eat organic matter in the upper few mm of bottom substrates.).

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

Species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (No night assessments were conducted either in 2003 or 2009.).

In 2003, despite the wide range of environments found in the vicinity of Mali, only 11 species of commercial sea cucumber and one indicator species were recorded during in-water assessments.

In 2009, the same number of 11 species of sea cucumber was recorded. Seven were recorded at the open-access reefs and seven were recorded inside the MPA. However, the open-access reefs were monitored using several techniques that were not used in the MPA, including reef-front searches and sea cucumber day searches. This latter technique assesses mostly deep-water species, such as *T. anax* and *T. ananas*, which were recorded at open-access reefs. Overall, considering only the techniques used both inside and outside the MPA, the diversity was found to be higher inside the MPA. This does not mean that the species were absent from the open-access reefs, but that their density was too low to ensure detection during the survey.

In 2003, common sea cucumber species associated with reef, such as the low-value flowerfish (*Bohadschia graeffei*) and the medium-value leopardfish (*B. argus*), were rare in survey (recorded in 4–7% of broad-scale transects). The high-value black teatfish (*Holothuria nobilis*), which is found on both inshore and back-reefs and at a range of depths, was present but rare (not recorded in broad-scale surveys and only a single individual noted in shallow-reef RBt stations). This species which is easily targeted by fishers, was recorded in catches from a creel survey of fishers who had been collecting invertebrates on Vuata reef. The medium/high-value and fast growing greenfish (*Stichopus chloronotus*) was more common, noted in both broad-scale and RBt stations relatively commonly (in 67% of RBt stations), although the average density did not exceed 50 /ha.

In 2009, no *Bohadschia* spp., only one *H. nobilis* (black teatfish) and only very few *Stichopus chloronotus* (n = 5) were recorded at the open-access reefs. Inside the MPA, *B. vitiensis* (brown sandfish) were recorded occasionally on RBt stations and one *B. graeffei* was recorded at a broad-scale station.

The mix of the exposed, oceanic nature of the barrier-reef section of the lagoon, and significant nutrient flows, suited the surf redfish, *Actinopyga mauritiana*. This species was noted in surveys but the average density was low. Unlike at the sites at Viti Levu, the deep-water redfish (*A. echinites*) was not found in any high-density aggregations on the sandy back-reef.

More protected areas of soft benthos, with patches of reef, were commonly noted in the pseudo-lagoons of small reef banks within the complex reef system south of the passage. These areas had shallows of seagrass, rubble covered in fleshy algae (*Sargassum*) and silty, limestone banks with coral fringing the channels. Reef habitat was quite ‘rich’ and very suitable for the species most characteristic of the sea cucumber industry in Fiji Islands, the *dri* or blackfish, *A. miliaris*.

Prior to the mission in 2003, we managed to source some data collected by an SPC survey group and Fiji Fisheries Division in Nov/Dec 1988, fifteen years earlier. In this earlier work, researchers focused their survey particularly on *dri loli* (blackfish, *Actinopyga miliaris*) in northern Vanua Levu (in Macuata and Bua). The survey comprised about one week of desk research and interviews with bêche-de-mer traders and exporters, two weeks of field survey work in Macuata and Bua, and one week during which the results were analysed and discussed and a report was prepared. Although the initial surveys included broad-scale and fine-scale work by the end of the survey, only spot searches and quadrats (100 m² and 1600 m²) were used, since the authors thought these more intense, smaller-scale surveys were more appropriate to assess *dri* than were broad-scale or longer line transects.

The 1988 survey recorded *dri* at a number of locations. In some cases, the population, (defined as 'Type 1') comprised non-cryptic, small individuals (typically less than 100 g live whole weight) and was recorded on shallow-reef flat at high density (up to 78,900 /ha, Type 1 population, Tables 4.15a and b). They also identified a second type (Type 2) of mainly large (500–1200 g live whole weight), well-hidden individuals at the seaward crest of lagoon island reefs, present at densities of 0–250 /ha.

Table 4.15a: Density and size range (weight) of two 'types' of *A. miliaris*, as described by 1988 survey in Mali

Population 'type'	Number /100 m²		Weight (g) /100 m²	
	Minimum	Maximum	Minimum	Maximum
1	241.0	789.0	18,100	49,550
2	0.5	2.3	252	1538

Table 4.15b: Catch rates for two 'types' of *A. miliaris*, as described by 1988 survey in Mali

Population 'type'	Number /man hour		Weight (g) /man hour	
	Minimum	Maximum	Minimum	Maximum
1	76.7	686.0	7000	50,300
2	0.3	20.3	19	12,613

Data from Preston *et al.* n.d.

In the 2003 SPC surveys, many of the locations that were sampled in the 1988 survey were re-searched for *A. miliaris*, but no aggregations of shallow, non-cryptic, small *dri* were recorded on shallow-reef flats, and the less cryptic, larger individuals were also absent. There was evidence that small numbers of the larger *dri* still existed (from a small number of droppings located), but these individuals would only emerge from holes and cracks in the limestone at night, and boat access was not available for night work at the sampling sites we wished to target south of the passage.

In 2009, not a single specimen of either 'type' of *A. miliaris* was recorded, denoting a stock fished to total depletion.

In 2003, small numbers of elephant trunkfish (*Holothuria fuscopunctata*) and brown sandfish (*Bohadschia vitiensis*) were recorded. Snakefish (*H. coluber*) were noted in 20% of reef-benthos stations, which gives an indication of the 'richness' of the system, as snakefish are mostly recorded in places with significant organic deposits and rich silts.

The lower-value lollyfish (*H. atra*) and pinkfish (*H. edulis*) were both very common (in 63% of broad-scale transects and 80% of RBt stations) and at moderate density.

In 2009, no *H. fuscopunctata* was recorded at all. Only a few *B. vitiensis* and *H. coluber* specimens were recorded inside the MPA and none outside. The low-value *H. atra* and *H. edulis* were present but not very common at open-access reefs (present in 33% and 22% of broad-scale transects respectively) but common inside the MPA (present in 100% and 78% of broad-scale transects respectively). At the open-access reefs, both species were recorded at low density on RBt stations (respectively 68.2 /ha ±24.0 and 30.3 /ha ±26.4). Inside the MPA, the densities were higher, although still low (respectively 312.5 /ha ±185.2 and 364.6 /ha ±255.4). One *H. nobilis* was recorded during RBt assessment, but none during the broad-scale survey, highlighting that this high-value species is still present but at critically low density.

Deep dives on SCUBA during sea cucumber day searches can obtain a preliminary assessment of deep-water stocks such as the high-value white teatfish (*H. fuscogilva*), prickly redfish (*T. ananas*) and the lower-value amberfish (*T. anax*).

In 2003, one deep survey station was completed and two white teatfish (*H. fuscogilva*) and two amberfish (*T. anax*) were noted.

In 2009, two stations were completed, but none of the most-prized *H. fuscogilva* were recorded. One specimen of *T. anax* and two specimens of *T. ananas* were recorded, while one specimen of the usually more shallow, highly-prized species *H. nobilis* was also recorded.

In summary, the species composition of commercial sea cucumbers remains the same in the two surveys at 11 species. This places Mali at the bottom of the four sites in terms of sea cucumber diversity. A small stock of *H. scabra* inhabits the mainland side of Mali island according to local fishers but there were none recorded in the 2009 assessment. In 1988, *A. miliaris* was abundant (Preston 1988), but it was not recorded in either the 2003 or the 2009 surveys, suggesting possible local extinction of the species. The sea cucumber resources of Mali were at a critically low level in both assessments. Slight improvement in density was recorded inside the MPA, which is positive; however, the stock level is still too poor for fishing. Two adult white teatfish individuals (*H. fusgogilva*) were found in the pseudo-lagoon between Vuata reef and the outer barrier (Cakaulevu) reef outside the MPA. These individuals were unprotected and could be fished at any time; these few specimens need maximum protection as breeding stock.

Vuata reef was silty, but perhaps this is its natural condition. Sea cucumbers are the cleaners of benthic substrates; they recycle organic matter and bioturbate sand and mud to maintain an ecological balance on the reef. Loss of sea cucumbers results in a potential build-up of detritus, creating conditions that can promote the development of non-palatable algal mats (blue–green algae) and anoxic (oxygen-poor) conditions, unsuitable for life.

Management considerations for sea cucumbers in Mali

A national ban on sea cucumber fishery is recommended to assist the conservation effort at the community level as in Mali. There should be no discretionary exemptions for exploitation except for research purposes. This ban should be enforced for all species at the village, provincial and national levels. At least 10 years are required to allow strong recovery of resources. Once stocks have rebuilt to a significant level, the fishery can recommence at more reasonable rates of harvest to be determined by a national fishery plan.

An education campaign has been conducted in Mali under the FLMMA umbrella. Communities are aware of the declining resources and have taken steps to institute an MPA.

If the resources are not showing sign of real improvement then there is a need for concrete action at the national level as stated above.

Fishing of sea cucumbers in Mali is not profitable at the moment. It should be stopped to conserve the remaining stocks for replenishment purposes. Mali possesses suitably extensive reef habitat that can potentially support increased stocks of sea cucumbers.

The ban on commercial export species such as *H. scabra* (*dairo*) should also include subsistence and semi-commercial use. *H. scabra* is exempt from the 1988 ban on export; however, continued exploitation by the subsistence and semi-commercial fisheries has had a devastating impact on the resource.

The absence of *dri* (*A. miliaris*) in Mali, Lakeba and Muaivuso is of concern for this high-value and easily accessible species. The species could possibly be considered commercially extinct from these areas.

<u>Marine protected area (MPA)</u>

The establishment of an MPA in Mali was a good initiative and is showing positive signs. Densities of most species inside the MPA are higher than on the open-access reefs. However, critical invertebrate habitats such as those for *H. fuscogilva*, *H. scabra* and *T. maxima* are not protected. Extension of the MPA area outward to include the barrier reef is recommended. The current MPA is too limited to include all the suitable habitats for the main species.

4.4.7 2003–2009 stock status trends – other echinoderms: Mali

In 2003, no edible slate urchins (*Heterocentrotus mammillatus*) or collector urchins (*Tripneustes gratilla*) were recorded during survey at Mali. One collector urchin was noted in the creel survey from gleaners of shallow-water reef. Both *Echinometra mathaei* and *Echinothrix diadema* were found at moderate-to-low densities in survey.

In 2009, only two species of sea urchin (*Echinometra mathaei* and *Echinothrix diadema*) were recorded, both in the surf zone at very low densities (respectively 3 and 1 specimens recorded only).

The edible urchin *T. gratilla* stock declined between 2003 and 2009, while the opposite is true for the non-edible species. Fishing pressure rather than any environmental impacts is the main culprit in the reduction of these food species.

In 2003, the blue starfish (*Linckia laevigata*) was very common (in 76% of broad-scale transects and 73% of reef-benthos stations) and at relatively high density (mean of 872.2 /ha ±158.8 on reef-benthos stations). A range of coralivore (coral eating) starfish was recorded at Mali: the cushion star (*Culcita novaeguineae*, n = 22), the Kenya, dough-boy star (*Choriaster granulatus*, n = 13) and the crown-of-thorns starfish (*Acanthaster planci*, COTS, n = 11). Although none of these starfish pose a threat to coral at their present densities, the majority of the COTS were recorded on the northerly edge of Vuata reef, facing the barrier reef. This area would be worth monitoring in the future as the level of colonisation in one of the six transects can be considered an ‘incipient outbreak’ as described by Australian scientists working on the Great Barrier Reef (GBR) (0.22 adults per 2-minute ‘manta-tow’; or >30 adults and subadults per ha). PROCFish broad-scale transects of 300 m x 2 m swathe take about 8 minutes to complete and, therefore, recordings of >1 COTS per transect would be sufficient to qualify for an 'incipient outbreak' classification (Three COTS were recorded on replicate two). Using the PROCFish method, >4 COTS per transect would be classed as an 'active outbreak' (On the GBR an 'active outbreak' is when >1.0 adult is recorded per 2 minutes of 'manta-tow', and where adults are >15cm diameter, or >30 adult only starfish per ha if SCUBA diving.) (See Appendices 4.3.1 to 4.3.7.).

In 2009, *Linckia laevigata* was the most-recorded invertebrate during the survey. Most of the lagoonal stations held good densities of this species. Two other species, the coralivore *Culcita novaeguineae* and *Acanthaster planci* were also recorded but at low densities (four specimens of each species recorded).

Table 4.16a: Sea cucumber species records for Mali in 2003

Species	Common name	Commercial value [5]	B-S transects n = 90			Reef-benthos stations n = 15			Other stations RFs = 2; MOPs = 5			Other stations Ds = 1		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H												
Actinopyga lecanora	Stonefish	M/H												
Actinopyga mauritiana	Surf redfish	M/H							8.3	16.7	50 RFs			
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M	1	15.1	7	8.3	41.7	20						
Bohadschia graeffei	Flowerfish	L	0.6	14.3	4				1.5	7.6	20 MOPs			
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L	1	14.3	7	5.6	41.7	13						
Holothuria atra	Lollyfish	L	54.6	86.1	63	444.4	555.6	80						
Holothuria coluber	Snakefish	L	1	28.6	3	19.4	97.2	20						
Holothuria edulis	Pinkfish	L	59.2	93.4	63	300	375	80						
Holothuria fuscogilva [4]	White teatfish	H										4.8	4.8	100
Holothuria fuscopunctata	Elephant trunkfish	M	0.8	25.4	3									
Holothuria leucospilota	Black-fringed fish	L												
Holothuria nobilis [4]	Black teatfish	H				2.8	41.7	7						
Holothuria scabra	Sandfish	H												
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	4.9	26.1	19	47.2	70.8	67						
Stichopus hermanni	Curryfish	H/M	1	14.3	7									
Stichopus horrens	Peanutfish	H/M												
Stichopus vastus	Brown curryfish	M/H												
Synapta spp.	-	-				11.1	41.7	27						
Thelenota ananas	Prickly redfish	H												
Thelenota anax	Amberfish	M										4.8	4.8	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; RFs = reef-front search; MOPs = mother-of-pearl search; Ds = day search.

Table 4.16b: Sea cucumber species records on open-access reefs for Mali in 2009

Species	Common name	Commercial value [5]	B-S transects n = 18			Reef-benthos stations n = 11			Other stations MOPs = 4			Other stations Ds = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H												
Actinopyga lecanora	Stonefish	M/H												
Actinopyga mauritiana	Surf redfish	M/H												
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M												
Bohadschia graeffei	Flowerfish	L												
Bohadschia similis	False sandfish	L												
Bohadschia vitiensis	Brown sandfish	L												
Holothuria atra	Lollyfish	L	13.0	38.9	33	68.2	125.0	55	1.6	6.2	25			
Holothuria cinerascens	-	L												
Holothuria coluber	Snakefish	L												
Holothuria edulis [4]	Pinkfish	L	3.7	16.7	22	30.3	166.7	18						
Holothuria fuscogilva	White teatfish	H				3.8	41.7	9						
Holothuria fuscopunctata [4]	Elephant trunkfish	M												
Holothuria leucospilota	-	L												
Holothuria nobilis	Black teatfish	H				3.8	41.7	9				1.1	2.2	50
Holothuria scabra	Sandfish	H												
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	0.9	16.7	6	15.2	166.7	9						
Stichopus hermanni	Curryfish	H/M												
Stichopus horrens	Peanutfish	M/L												
Stichopus vastus	Brown curryfish	H/M												
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H										2.2	4.4	50
Thelenota anax	Amberfish	M										1.1	1.1	50

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

Table 4.16c: Sea cucumber species records inside MPA for Mali in 2009

Species	Common name	Commercial value [5]	B-S transects n = 18			Reef-benthos stations n = 4		
			D [1]	DwP [2]	PP [3]	D	DwP	PP
Actinopyga echinites	Deep-water redfish	M/H						
Actinopyga lecanora	Stonefish	M/H						
Actinopyga mauritiana	Surf redfish	M/H						
Actinopyga miliaris	Blackfish	M/H						
Bohadschia argus	Leopardfish	M						
Bohadschia graeffei	Flowerfish	L	0.9	16.7	6			
Bohadschia similis	False sandfish	L						
Bohadschia vitiensis	Brown sandfish	L	0.9	16.7	6	125.0	250.0	50
Holothuria atra	Lollyfish	L	252.8	252.8	100	312.5	416.7	75
Holothuria cinerascens	-	L						
Holothuria coluber	Snakefish	L				72.9	291.7	25
Holothuria edulis [4]	Pinkfish	L	40.7	52.4	78	364.6	79.2	50
Holothuria fuscogilva	White teatfish	H						
Holothuria fuscopunctata [4]	Elephant trunkfish	M						
Holothuria leucospilota	-	L						
Holothuria nobilis	Black teatfish	H						
Holothuria scabra	Sandfish	H						
Holothuria scabra versicolor	Golden sandfish	H						
Stichopus chloronotus	Greenfish	H/M	12.0	36.1	33	10.4	41.7	25
Stichopus hermanni	Curryfish	H/M	0.9	16.7	6			
Stichopus horrens	Peanutfish	M/L						
Stichopus vastus	Brown curryfish	H/M						
Synapta spp.	-	-						
Thelenota ananas	Prickly redfish	H						
Thelenota anax	Amberfish	M						

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

4.4.8 Discussion and conclusions: invertebrate resources in Mali

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

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

- A wide range of reef environments suitable for giant clams was present in the coastal, intermediate and outer reaches of the lagoon system at Mali island, both in the 2003 and 2009 surveys. Having a double set of barriers (one pseudo-barrier) provided extensive and varied hard benthos at a range of exposure grades suitable for giant clams.

- Only two clam species were recorded at Mali both in 2003 and 2009: the elongate clam (*Tridacna maxima*) and the fluted clam (*T. squamosa*). The true giant clam (*T. gigas*) and the horse-hoof or bear's paw clam (*Hippopus hippopus*) are considered extinct in Fiji Islands, although there is some dispute as to whether the true giant clam was ever found in significant abundance in Fiji Islands, due to the lack of archaeological records.

- In the 2003 survey, giant clam distribution and abundance showed that the stocks were somewhat depleted from what might be considered a healthy state. Noting the extensive reef area in the lagoon and the good exchange of lagoon and oceanic water, the distribution of clams was relatively sparse, but the abundance in some of the more suitable areas was moderately high. In particular, the presence and abundance of *T. squamosa* was relatively good. In other countries in the Pacific, these larger clams are often the first to become depleted through fishing but, in Mali, the number and size range of fluted clams revealed that stocks were only moderately impacted by fishing.

- In the 2009 survey, *T. maxima* was sparsely distributed and quite depleted. The general densities observed were low to very low. The best station was recorded inside the MPA, with an average density of 167 /ha, which is low compared to the 500 /ha recorded in 2003. In contrast, the *T. squamosa* population seems to be at a healthy status, especially inside the MPA, where it locally reached the density of 167 /ha (This species is naturally recorded at much lower density than *T. maxima*.), but the distribution was sparser than in 2003.

- The 2003 observations considered the need to protect the giant clams stocks to avoid further decline. In 2009, these observations were confirmed, with a global decline recorded. Continued strong management of giant clam stocks, especially the protection of parts of the fishery, will help in maintaining present rates of recruitment and ensure the current status of clams is not allowed to degrade further. There needs to be protection of some of the remaining stocks to ensure successful fertilisation events (Sperm and eggs fertilise in the water column after release by male and female clams.). Clams have a complex development, which means that only the larger (older) individuals are female (protandry); the regular harvest of larger clams will lead to a shortage in egg supply.

- Juveniles of the two giant clam species were recorded in the MPA, which indicates active recruitment. The western end of the MPA closer to Voro voro passage is suitable for *T. squamosa*; numbers should start to increase the longer the protection is enforced.

In summary, the condition of the reefs, distribution, density and length recordings of MOP species revealed the following:

- The barrier reefs at Mali provided extensive suitable habitat for the commercial topshell, *Trochus niloticus*. This site could potentially support a large population and fishery for trochus. However, there were few trochus in the outer reefs of Mali, and no dead shells observed outside the reefs. Either this is due to intensive fishing in the past or trochus naturally inhabit only the inner reef area on the passage reefs and the reef crest areas.

- Data on trochus distribution, density and shell size suggested that the stocks in Mali were not abundant, perhaps heavily impacted by fishing prior to 2003. However, trochus were still spawning and recruiting, and small numbers of trochus were recorded across the intermediate reef, back-reef and the reef slope.

- There is no potential for commercial fishing of trochus at this time. In general, the stock at stations within the core areas of a fishery should be allowed to reach a minimum density of 500 /ha before commercial fishing can be considered. Trochus are broadcast spawners, which need to be in aggregations of high density to ensure spawning is successful. In addition, larger female shells (>11cm base width) have the potential for producing far greater numbers of eggs than those just a couple of cm smaller.

- Other mother-of-pearl stocks, such as the blacklip pearl oyster (*Pinctada margaritifera*) and the green topshell (*Tectus pyramis*, of low commercial value), were recorded in survey at moderate density.

In summary, the environment for sea cucumbers, their distribution, density and length recordings revealed the following:

- Habitat for sea cucumbers around Mali island was both extensive in scale and varied in structure and environment. The large lagoon system was predominantly protected and land-influenced (suitable for these deposit-feeding resources) but more exposed, oceanic areas were also found near the barrier reef and on the reef slope.

- The number of species of sea cucumbers recorded at Mali in 2003 and 2009 (n = 11), was low for a lagoonal site in Fiji Islands, especially since the site supported such a wide range of environments.

- In 2003, the abundance of sea cucumbers was found to be low, without exception. Even the low-value species noted were not at high density. The fact that *Actinopyga miliaris* had been at high density here in 1988, but in 2003 was absent from many of the areas that it previously inhabited, showed that the range of commercial species was becoming restricted, even though they were only locally depleted.

- In 2009, the abundance of sea cucumber species was found to be critically low for all species; most of the species were recorded at only one to few specimens. The MPA seems to have a positive impact, with densities not as low as on the open-access reefs.

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

- The preliminary 2003 survey suggested that the occurrence and density of sea cucumbers was too low for commercial collection at that time. The 2009 survey recorded stocks at a critically low level, and fishing should be halted for a period to allow stocks to rebuild. Mali presents a very a suitable site for a significant sea cucumber fishery and, once stocks have rebuilt to significant numbers of these important reef-cleaning resources, the fishery can recommence at more reasonable rates of harvest.

4.5 Overall recommendations for Mali

- The community-based management and monitoring in place in Mali be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.

- The community continue to support the marine protected area (MPA) and expand the area covered if possible, especially to cover the potential giant clam (*Tridacna maxima*) habitat on the back-reefs of the barrier reef.

- The Fisheries Department provide support to increase the capacity of local people to protect their fishing grounds from poaching, which is substantial in the case of Mali.

- An awareness programme be developed and implemented to educate people and communities on the need for management to sustain their resources on a long-term basis.

- Strong management of giant clam stocks be implemented to enable sufficient recruitment to maintain the current status.

- Introduction of other giant clam species be considered.

- Some larger clams be collected and placed in the MPA to boost the stocks and allow them to spawn and regenerate stocks over time.

- Trochus be re-introduced to the reefs of Mali to develop a stronger spawning stock. Suitable habitat is provided on the northwestern reef front between Mali and Kia islands.

- The trochus stocks be protected from fishing for at least five years (with no exceptions) so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- The management of sea cucumbers be strengthened, and a total ban on fishing implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

5. PROFILE AND RESULTS FOR LAKEBA

5.1 Site characteristics

Lakeba is a rural, coastal village located in the Macuata Province at the northernmost tip of the island of Vanua Levu at 16º 12' S latitude and 179º 44' E longitude (Figure 5.1). Lakeba is not far in distance from the island's main centre, Labasa; however, road conditions and transport are poor, making marketing and exchange with the urban centre difficult. Due to the transport problem the community is heavily dependent on buyers who come to the village, and these visits are not necessarily regular. The reef system is productive, with all the suitable habitats present (mangroves, seagrass beds, mudflats, lagoons, back-reefs and outer-reef slopes). The lagoon is extensive but mainly sandy, with scattered patches of dead coral. Water flow is dynamic through most of the outer lagoon and across the barrier reef. The more exposed reef front and slope are largely oceanic. A community-based MPA, established in 2003 through the help of FLMMA, was opened in 2007 to harvest sea cucumbers (mainly *Actinopyga miliaris*) to raise funds for the 2007 Methodist Church Conference. The MPA was re-established in January 2009.

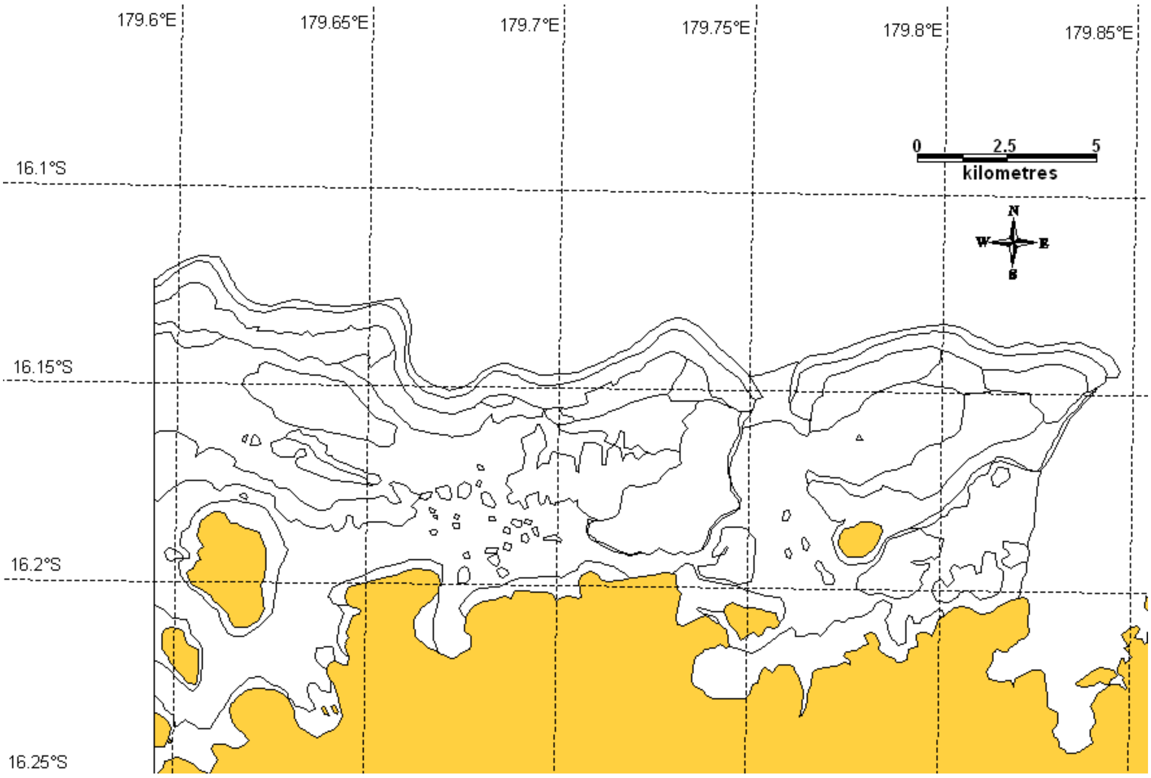

Figure 5.1: Map of Lakeba.

5.2 Socioeconomic surveys: Lakeba

Socioeconomic fieldwork was carried out in Lakeba village, on the island of Vanua Levu, Fiji Islands, from 3 to 7 July 2007.

The Lakeba community has a resident population of 141 and 25 households. A total of 20 households, which is 80% of total households in the Lakeba community were surveyed, with all (100%) of these households being engaged in some form of fishing activities. In addition, a total of 24 finfish fishers (16 males and 8 females) and 32 invertebrate fishers

(15 males and 17 females) were interviewed. The household size is small with 5 people on average, suggesting that the village is subject to urban migration due to educational or employment reasons.

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

Fishers from Lakeba have access to various habitats; these include mangrove areas and associated mud and intertidal flats, a lagoon area associated with coastal reefs, and an outer reef with passages. Because of the relative isolation of the village, poaching or sharing fishing grounds with neighbouring communities seldom occurs.

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

Our results (Figure 5.2) suggest that fisheries are the main income source for the people of Lakeba. In fact, all households earn money from fishing in one form or the other. Most, i.e. 65%, earn first income from fisheries, while the remaining 35% earn complementary, secondary income from the sector. Agricultural production due to the community's access to arable land determines first and second income for 10% of all households each. Handicrafts made by females supply one quarter of all households with first income. There are no salary-based incomes in the community. Pigs are reared by 30% of all households, but each has only one or two pigs. Chickens are usually not accounted for, but they are numerous and run freely around the village. Distribution of fish and seafood produce on a non-monetary basis is still an important practice; 20% of all households reported consuming finfish they are given.

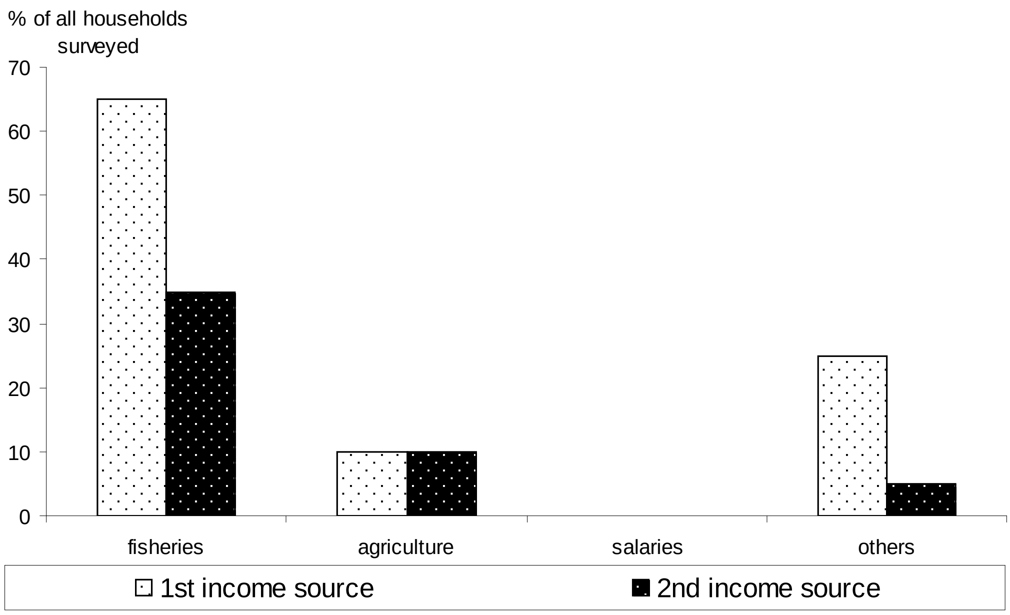

Figure 5.2: Ranked sources of income (%) in Lakeba.
Total number of households = 20 = 100%. Some households have more than one income source and those may be of equal importance; thus double quotations for 1st and 2nd incomes are possible.
'Others' are mostly home-based small businesses.

Our results (Table 5.1) show that annual household expenditures are significantly below the average found across all sites studied in Fiji Islands and, as everywhere, generally low, i.e. USD 861 /household/year. People are self-sufficient regarding marine and agricultural produce, and income from fisheries, agriculture and handicrafts provides a limited purchasing power to buy imported goods from the urban centre, which is difficult to reach.

Remittances play a role for the Lakeba community, with 42% of all households receiving money sent from elsewhere, which supports the suggestion that urban migration occurs in order to seek employment. However, the average amount received by those households is relatively low, i.e. USD 496 /household/year, or about half of the annual basic household expenditure.

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

Survey coverage	Site (n = 20 HH)	Average across sites (n = 66 HH)
Demography		
HH involved in reef fisheries (%)	100.0	98.5
Number of fishers per HH	2.45 (±0.21)	2.47 (±0.11)
Male finfish fishers per HH (%)	0.0	12.9
Female finfish fishers per HH (%)	0.0	0.6
Male invertebrate fishers per HH (%)	0.0	0.0
Female invertebrate fishers per HH (%)	6.1	9.8
Male finfish and invertebrate fishers per HH (%)	51.0	41.7
Female finfish and invertebrate fishers per HH (%)	42.9	35.0
Income		
HH with fisheries as 1st income (%)	65.0	69.7
HH with fisheries as 2nd income (%)	35.0	24.2
HH with agriculture as 1st income (%)	10.0	4.5
HH with agriculture as 2nd income (%)	10.0	15.2
HH with salary as 1st income (%)	0.0	13.6
HH with salary as 2nd income (%)	0.0	3.0
HH with other source as 1st income (%)	25.0	12.1
HH with other source as 2nd income (%)	5.0	19.7
Expenditure (USD/year/HH)	860.69 (±79.12)	1163.72 (±64.04)
Remittance (USD/year/HH) (1)	495.84 (±69.95)	737.10 (±219.95)
Consumption		
Quantity fresh fish consumed (kg/capita/year)	73.09 (±4.46)	74.00 (±2.96)
Frequency fresh fish consumed (times/week)	3.40 (±0.10)	3.20 (±0.07)
Quantity fresh invertebrate consumed (kg/capita/year)	10.49 (±1.74)	9.68 (±2.96)
Frequency fresh invertebrate consumed (times/week)	2.79 (±0.27)	2.11 (±0.13)
Quantity canned fish consumed (kg/capita/year)	1.92 (±0.50)	2.37 (±0.33)
Frequency canned fish consumed (times/week)	0.42 (±0.11)	0.47 (±0.05)
HH eat fresh fish (%)	100.0	98.8
HH eat invertebrates (%)	100.0	98.8
HH eat canned fish (%)	80.0	98.8
HH eat fresh fish they catch (%)	100.0	100.0
HH eat fresh fish they buy (%)	0.0	6.7
HH eat fresh fish they are given (%)	20.0	6.7
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 (%)	10.0	6.7

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

Survey results indicate an average of 2–3 fishers per household and, when extrapolated, the total number of fishers in Lakeba amounts to 61 (31 males, 30 females). Among these are no exclusive finfish fishers, 4 exclusive invertebrate fishers (females only), and 57 fishers who fish for both finfish and invertebrates (31 males, 26 females). More than half (60%) of all households own a boat, and all boats are fitted with an outboard engine.

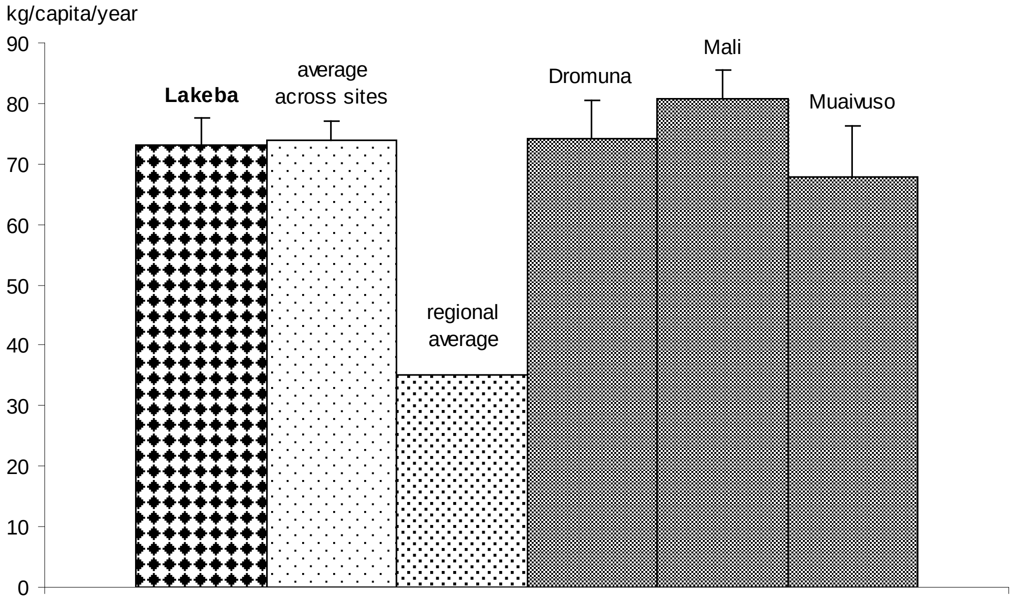

Figure 5.3: Per capita consumption (kg/year) of seafood in Lakeba (n = 20) compared to the regional average (FAO 2008), the average across sites and the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of fish. Bars represent standard error (+SE).

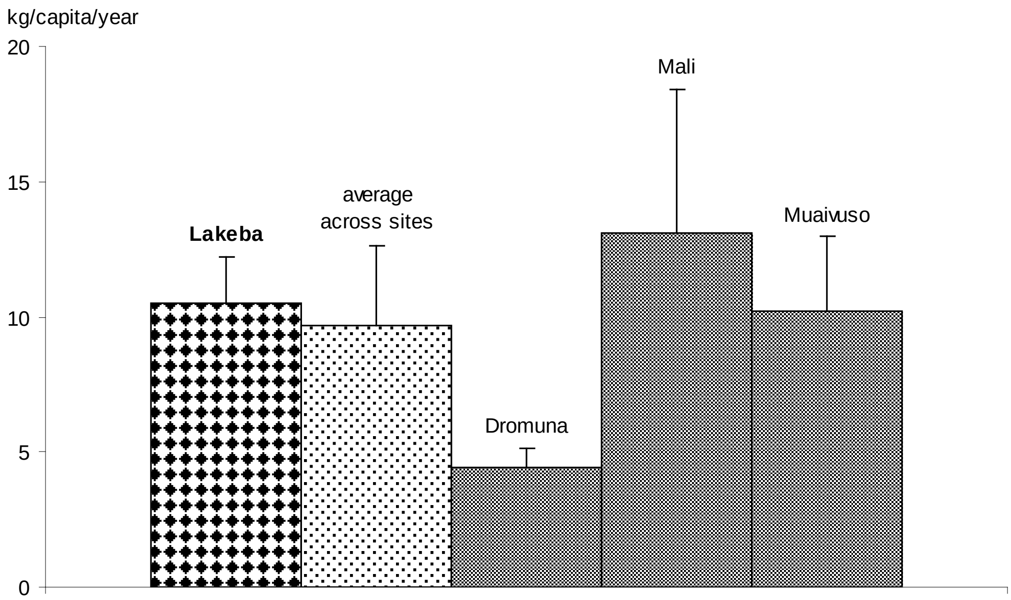

Figure 5.4: Per capita consumption (kg/year) of invertebrates (meat only) in Lakeba (n = 20) compared to the other three PROCFish/C sites in Fiji Islands.
Figures are averages from all households interviewed, and take into account age, gender and non-edible parts of invertebrates. Bars represent standard error (+SE).

Consumption of fresh fish is high (almost 73 kg/person/year), and about average across all the four study sites in Fiji Islands, but 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 lower but still important (~10.5 kg/person/year). Canned fish (Table 5.1) is not commonly eaten and adds only ~2 kg/person/year to the protein supply from seafood. The consumption pattern of seafood found in Lakeba highlights the fact that people have access to agricultural land and agricultural produce, and limited purchasing power to acquire commercially available food items.

Comparing the results obtained for Lakeba to the average figures across all the four study sites surveyed in Fiji Islands, people of the Lakeba community eat fresh fish, invertebrates and canned fish about as often as found on average. The consumption of fresh fish and canned fish is also about average, but more invertebrates are consumed than is found elsewhere. Lakeba people conform to the average across all study sites in terms of the proportion of fish and invertebrates caught that they consume, but the proportion of finfish that they buy or are given on a non-monetary basis is much higher than elsewhere. As in the other sites studied, sharing or giving from catches would be more evident during traditional or religious functions, when people would fish especially for these occasions or would give away large portions of their catches for community functions.

Fisheries, complemented by handicrafts and some agricultural production, play the most important income role, with handicrafts made by females earning a higher proportion of the average income than found on average across the other sites studied. The household expenditure level in Lakeba is extremely low, which may be explained by the isolated location, the high level of self-sufficiency in producing agricultural crops, and the good access to seafood. The percentage of households receiving remittances is much higher than elsewhere, but the annual average amount of remittances received is small. By comparison, boat ownership is the highest among all the sites studied; this may be the result of a former seaweed community project, which provided boats fitted with outboard engines.

5.2.2 Fishing strategies and gear: Lakeba

Degree of specialisation in fishing

Fishing is done by both gender groups, and traditional roles are not visible from the general figures shown in Figure 5.5. Both males and females are mostly engaged in fishing for both finfish and invertebrates.

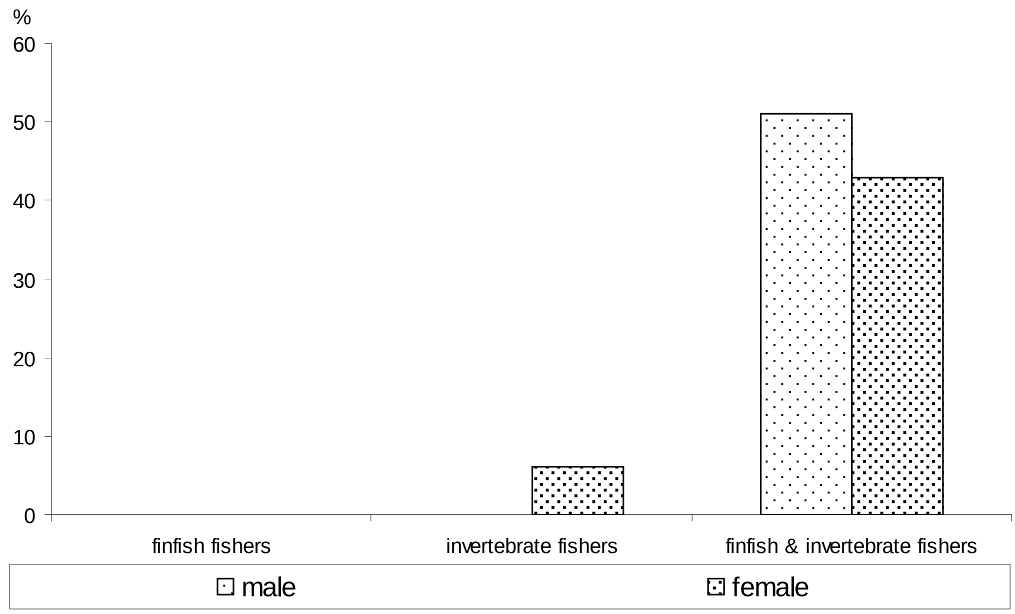

Figure 5.5: Proportion (%) of fishers who target finfish or invertebrates exclusively, and those who target both finfish and invertebrates in Lakeba.
All fishers = 100%.

Targeted stocks/habitat

Under a province-wide management strategy, some coastal reef areas had been declared 'no-fishing' zones for the previous five years. However, these restrictions did not seem to have had an impact on the fishing strategies of Lakeba people. Considering the low cash flow within the community, it is not surprising that Lakeba finfish fishers mainly target the most easily accessible habitats, i.e. the sheltered coastal reef and lagoon areas. However, often, the lagoon is also combined with visits to the outer reef in one fishing trip. Exclusive fishing of the outer reef is only done by male fishers, and not as often as fishing in the other habitats (Table 5.2). Female fishers target a wide range of accessible habitats for invertebrates, and most fishing is done by combining several of the habitats in one trip. Most focus is on the intertidal and reeftop habitats, seagrass, and mangrove areas. While male fishers from Lakeba also glean the seagrass, reeftop and possibly other habitats, they mostly engage in the collection of species that require free-diving, i.e. bêche-de-mer, lobsters, trochus and 'others' (mainly giant clams and octopus). Female fishers do not engage in free-diving in the offshore areas, but they do participate to some extent (~18%) in collecting the lucrative bêche-de-mer.

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

Resource	Fishery / Habitat	% of male fishers interviewed	% of female fishers interviewed
Finfish	Sheltered coastal reef & lagoon	56.3	75.0
	Lagoon & outer reef	43.8	25.0
	Outer reef	25.0	0.0
Invertebrates	Reeftop	0.0	5.9
	Reeftop & other	6.7	11.8
	Intertidal & reeftop	0.0	52.9
	Seagrass & mangrove	6.7	64.7
	Seagrass & reeftop & other	13.3	0.0
	Seagrass & intertidal & reeftop	0.0	23.5
	Mangrove	0.0	5.9
	Mangrove & reeftop	0.0	5.9
	Bêche-de-mer	73.3	17.6
	Bêche-de-mer & other	6.7	0.0
	Lobster	33.3	0.0
	Trochus	20.0	0.0
	Trochus & other	20.0	0.0
	Other	20.0	0.0

'Other' refers to the giant clam and octopus fisheries.
Finfish fisher interviews, males: n = 16; females: n = 8. Invertebrate fisher interviews, males: n = 15; females: n = 17.

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 Lakeba on their fishing grounds (Tables 5.2 and 5.3).

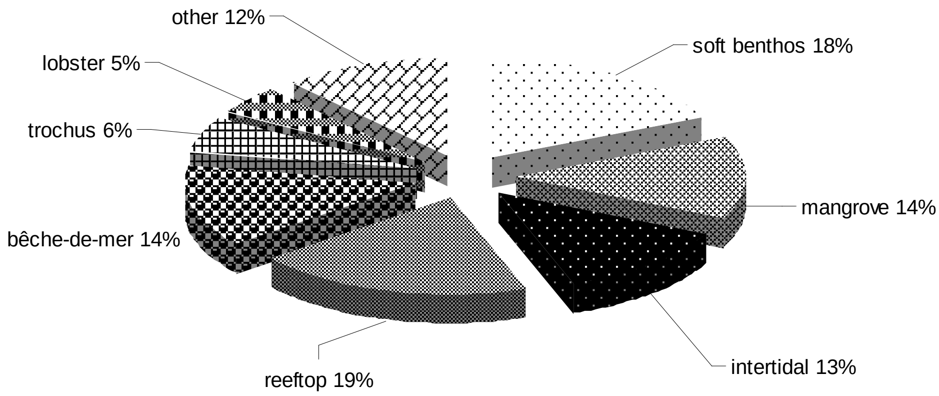

Figure 5.6: Proportion (%) of fishers targeting the primary invertebrate habitats found in Lakeba.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; 'other' refers to the giant clam and octopus fisheries.

Our survey sample confirms that fishers from Lakeba have a wide choice of habitats and this is reflected in the diverse fishing strategies adopted by female fishers for collecting invertebrates (Figure 5.6). These serve either home consumption or are also sold at the local markets if possible. Impact is distributed among reeftop, soft-benthos, intertidal and mangrove areas, activities that are dominated by females (Figure 5.7). Male fishers concentrate more on the commercial species, mainly bêche-de-mer, trochus, lobster, clams and octopus (Figures 5.6 and 5.7).

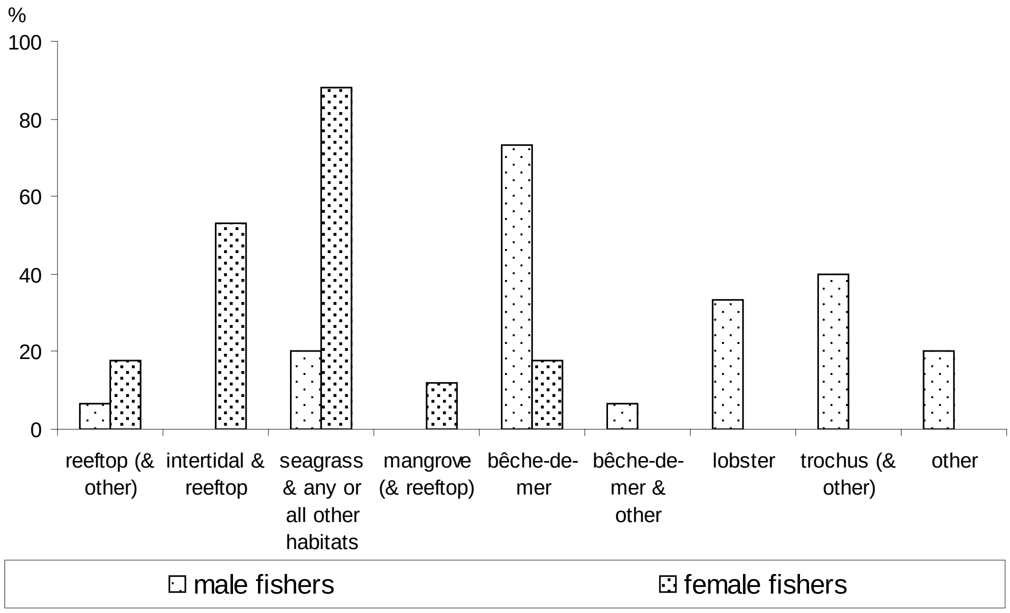

Figure 5.7: Proportion (%) of male and female fishers targeting various invertebrate habitats in Lakeba.
Data based on individual fisher surveys; data for combined fisheries are disaggregated; fishers commonly target more than one habitat; figures refer to the proportion of all fishers who target each habitat: n = 15 for males, n = 17 for females; 'other' refers to the giant clam and octopus fisheries.

Gear

Figure 5.8 shows that Lakeba fishers mainly use the low-investment-cost technique of handlining in all habitats targeted. However, they also use gillnetting in the habitats closer to shore, and spear diving is used in the combined fishing of the lagoon and outer-reef area. Gillnetting may be complemented by handheld spearing. Female fishers mainly use handlines, but they may also participate in gillnetting.

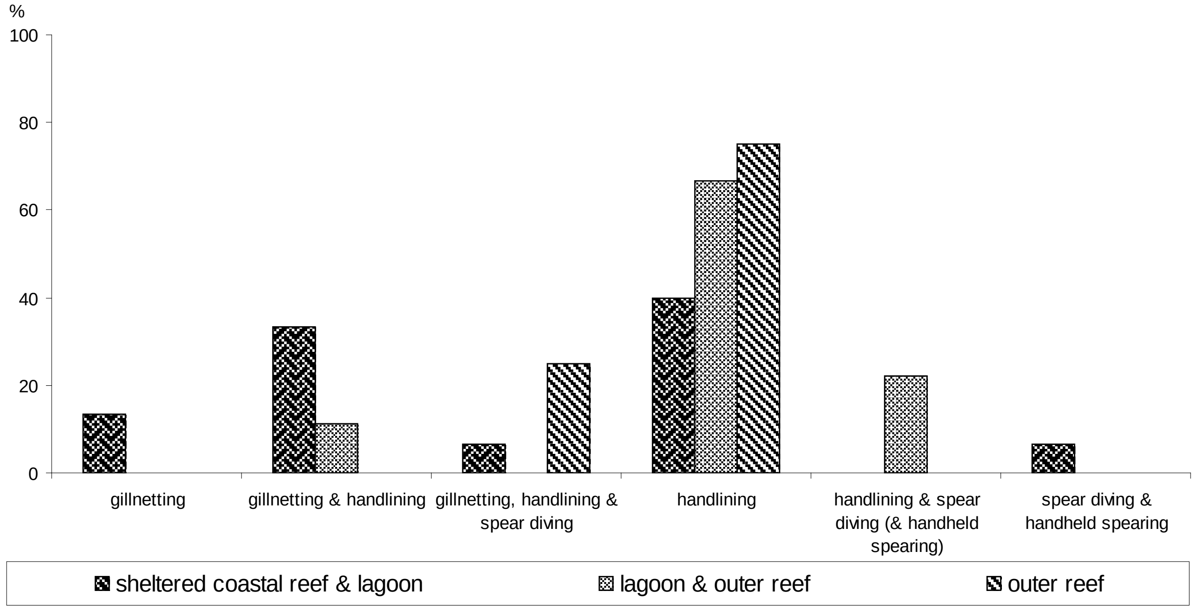

Figure 5.8: Fishing methods commonly used in different habitat types in Lakeba.
Proportions are expressed in % of total number of trips to each habitat. One fisher may use more than one technique per habitat and target more than one habitat in one trip.

Frequency and duration of fishing trips

The frequency at which finfish fishers visit any of the habitats is around twice per week for male fishers, and once or twice per week for female fishers. However, as mentioned earlier, females do not fish the outer reef, which is visited about 1.5 times per week by male fishers. In the case of male fishers, trips for popular invertebrates are undertaken once per week and trips for less popular invertebrates about twice per month. Female fishers usually go out twice or three times per week to collect invertebrates. The average duration of a finfish fishing trip is about 4 hours for both genders, and 7 hours if the outer reef is exclusively targeted by male fishers. A typical invertebrate collection trip takes 3 hours for female fishers, and 5 hours for the free-diving collection done by males. The longer trip is explained by the fact that most of these activities require longer transport times to reach the more distant fishing grounds.

Most finfish fishers go fishing according to tidal conditions, i.e. during the day or night, while some of the female fishers prefer fishing during the day. All fishing activities are performed throughout the year. Ice is often used on finfish fishing trips, the more regularly the further away are the fishing grounds targeted and the longer the fishing trip. This is made possible by the generator and ice-making facilities in the village's cooperative store.

Most fishing requires motorised boat transport, and this is true for all the invertebrate dive fisheries, particularly bêche-de-mer, trochus, giant clams and octopus. Gleaning for invertebrates is mostly done by walking; however, to reach some of the habitats, motorised boat transport may be used as well. Invertebrates are collected during daytime with the exception of lobsters, which are fished at night.

At the time of the survey, marketing structures determined the intensity of fishing activities. Fishing for finfish increased in intensity when a middle seller visited the community or when the village cooperative store bought fish to be sold to the Fisheries Department outlet. Harvesting of invertebrates increased every Wednesday, Thursday and Friday as females prepared products to be taken to the market on Saturdays. At the time of the study, sea cucumbers were mostly sold unprocessed to the buyers and fetched prices between FJD 10.00 and FJD 15.00 per kg.

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

Resource	Fishery / Habitat	Trip frequency (trips/week)		Trip duration (hours/trip)	
		Male fishers	Female fishers	Male fishers	Female fishers
Finfish	Sheltered coastal reef & lagoon	2.28 (±0.15)	1.83 (±0.17)	4.67 (±0.53)	3.33 (±0.33)
	Lagoon & outer reef	2.21 (±0.31)	1.00 (±0.00)	4.00 (±0.22)	5.00 (±0.00)
	Outer reef	1.50 (±0.29)	0	7.00 (±1.29)	0
Invertebrates	Reeftop	0	1.00 (n/a)	0	3.00 (n/a)
	Reeftop & other	1.00 (n/a)	2.00 (±0.00)	4.00 (n/a)	4.00 (±0.00)
	Intertidal & reeftop	0	1.67 (±0.17)	0	2.89 (±0.20)
	Soft benthos & mangrove	0.23 (n/a)	1.68 (±0.14)	4.00 (n/a)	3.09 (±0.21)
	Soft benthos & reeftop & other	1.00 (±0.00)	0	2.50 (±0.50)	0
	Soft benthos & intertidal & reeftop	0	3.00 (±0.41)	0	3.38 (±0.47)
	Mangrove	0	0.69 (n/a)	0	3.00 (n/a)
	Mangrove & reeftop	0	2.00 (n/a)	0	3.00 (n/a)
	Bêche-de-mer	0.99 (±0.20)	0.97 (±0.51)	5.27 (±0.36)	6.00 (±1.15)
	Bêche-de-mer & other	0.46 (n/a)	0	5.00 (n/a)	0
	Lobster	0.46 (±0.07)	0	6.00 (±0.63)	0
	Trochus	0.31 (±0.08)	0	4.67 (±1.33)	0
	Trochus & other	0.64 (±0.18)	0	5.33 (±0.33)	0
	Other	1.33 (±0.33)	0	3.00 (±0.58)	0

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 = 16; females: n = 8. Invertebrate fisher interviews, males: n = 15; females: n = 17.

5.2.3 Catch composition and volume – finfish: Lakeba

The catches reported from the combined sheltered coastal reef and lagoon in Lakeba are dominated by a few families. Lethrinidae accounts for 21.5%, Mugilidae for 17% and Acanthuridae for 9% of the total annual reported catch. There is a wide variety of species identified by vernacular names included in Lethrinidae, and also in the remaining catch composition. The catch compositions reported by fishers targeting the lagoon and outer reef in one fishing trip or exclusively the outer reef are less diverse. Lagoon and outer-reef catches are dominated by Lethrinidae, which accounts for almost 60% of the catch; Serranidae, Acanthuridae and Carangidae make up most of the remaining catch. For the outer reef, mainly Lethrinidae (>50%), Acanthuridae (~30%) and Serranidae (~15%) were reported.

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

Figure 5.9 highlights findings from the socioeconomic survey that were reported earlier, that finfish is not only a major food but also income source for Lakeba people. About 35% of the catch is consumed and the other 65% sold. The dominance of male fishers by impact and production is pronounced; they represent ~84% of the total annual impact. Most impact is on the combination of sheltered coastal reef and lagoon (~53%) and the combined lagoon and outer reef (~32%); relatively little is on the outer reef only (~15%).

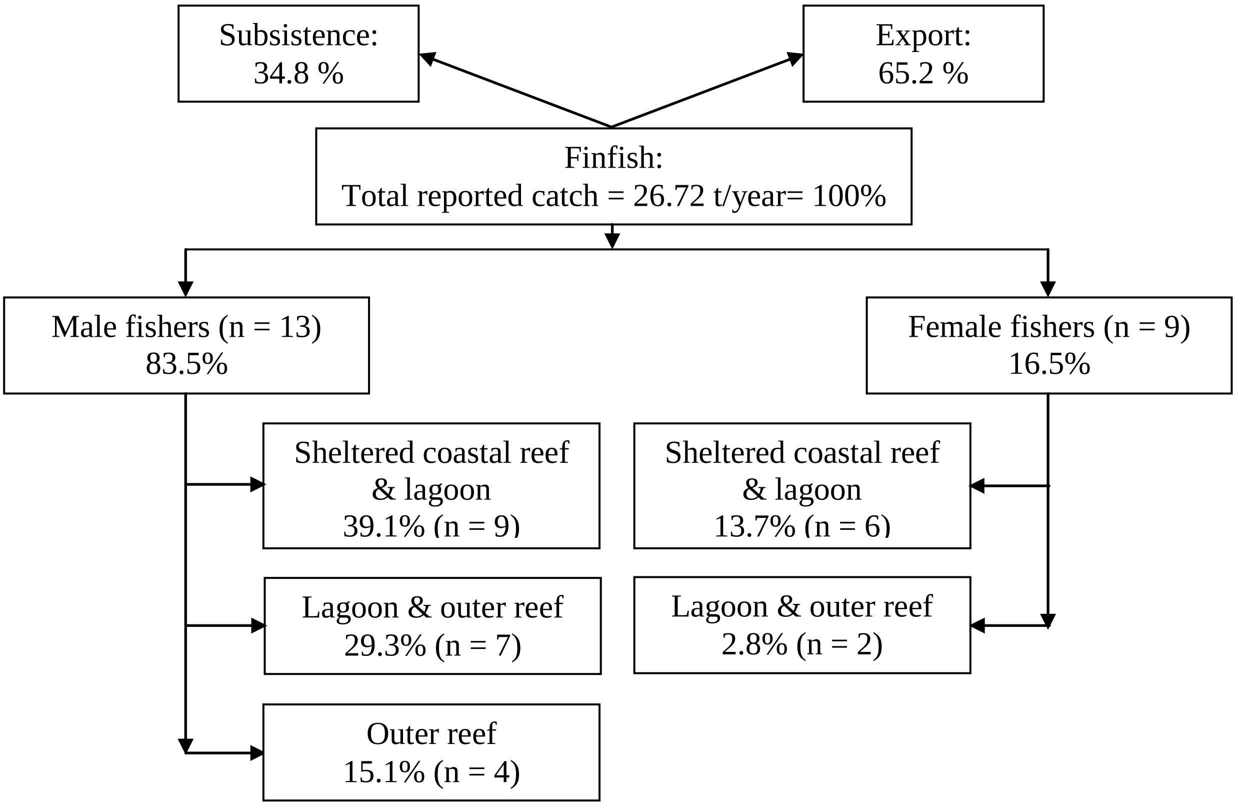

Figure 5.9: Total annual finfish catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Lakeba.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey.

The distribution of annual catch weight is a consequence of the number of fishers rather than the annual catch rates. As shown in Figure 5.10, the average annual catch per male fisher is comparative across all habitats targeted. Female fishers catch less, but most in the combined sheltered coastal reef and lagoon areas. On average, male fishers catch ~600 kg/year, female fishers ~200–300 kg/year.

Productivity rates vary between 1.2 and 1.6 kg/hour fished and are generally low. CPUEs calculated for female fishers are comparative for the sheltered coastal reef and lagoon fishing, but lower if combining lagoon and outer reef (Figure 5.11). Interestingly, CPUEs calculated for the outer-reef fishers are lower than those for fishers who combine lagoon and outer-reef fishing in one trip.

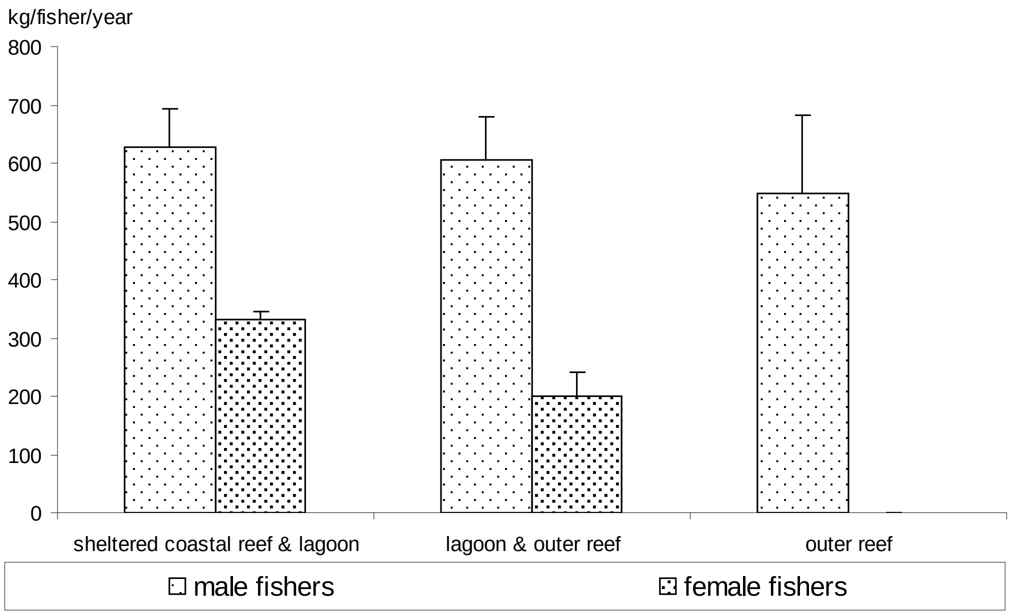

Figure 5.10: Average annual catch (kg/year, +SE) per fisher by gender and habitat in Lakeba (based on reported catch only).

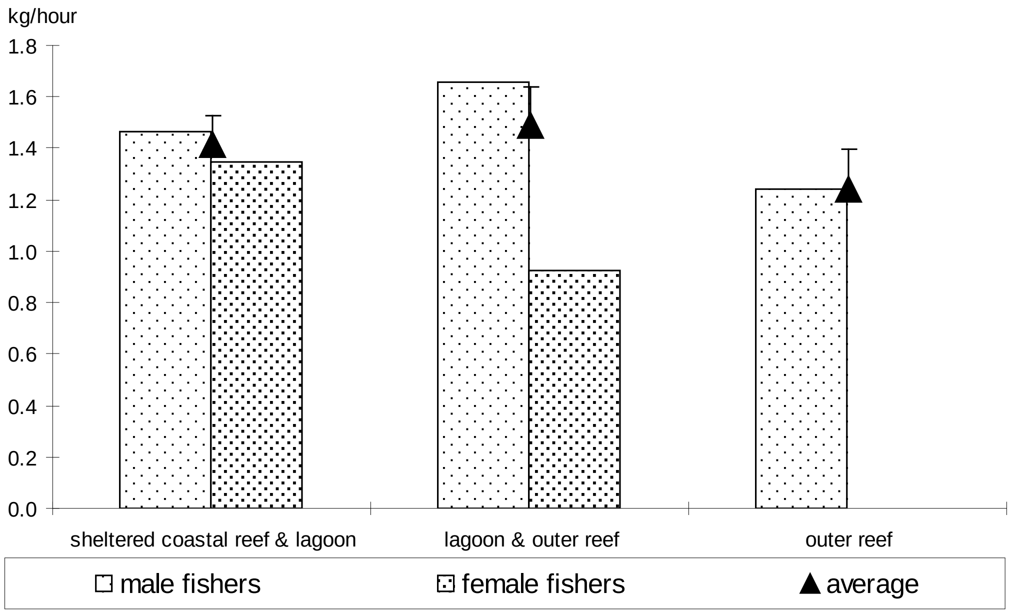

Figure 5.11: Catch per unit effort (kg/hour of total fishing trip) for male and female fishers by habitat type in Lakeba.
Effort includes time spent transporting, fishing and landing catch. Bars represent standard error (+SE).

Figure 5.12 highlights findings from the socioeconomic survey that were reported earlier, i.e. that finfish fishing serves both subsistence and sale. The combined fishing of the sheltered coastal reef and lagoon, and lagoon and outer-reef fishing are conducted more for subsistence purposes, while fishers targeting the outer reef alone mainly pursue commercial interests. Lakeba is a fishing-dependent community that retains a strong, traditional fishing background requiring that people use their knowledge of the species, habitats, winds, moons and tides to guide their daily fishing activities. The market economy has considerable influence on fishing participation, fishing patterns and species targeted by both male and female fishers.

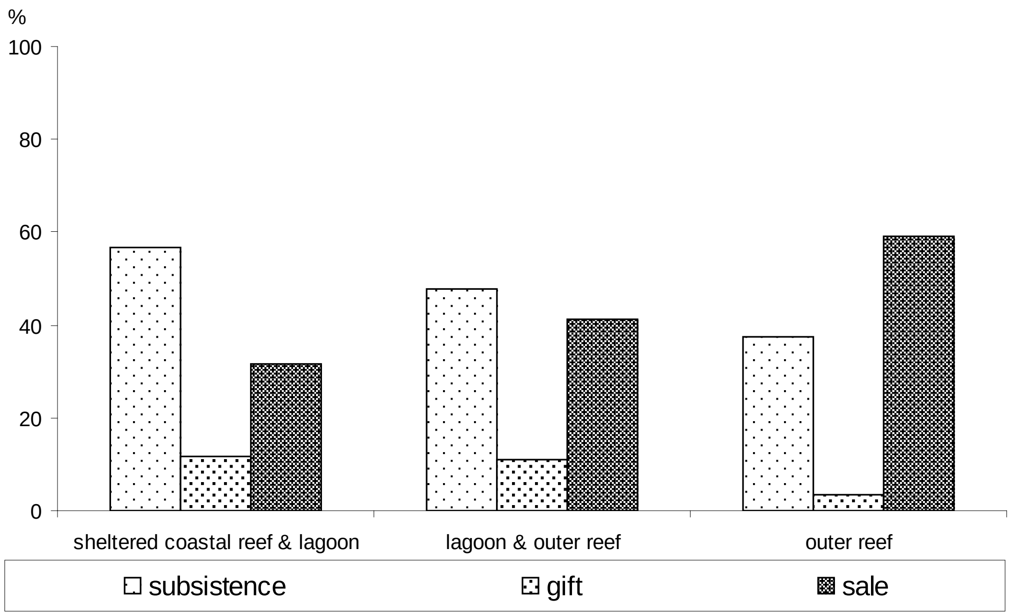

Figure 5.12: The use of finfish catches for subsistence, gifts and sale, by habitat in Lakeba. Proportions are expressed in % of the total number of trips per habitat.

Analysis of the overall finfish fishing productivity per habitat (Figure 5.11) suggests no major difference between fishing the combined sheltered coastal reef and lagoon, and the lagoon and outer-reef habitats. CPUEs were lowest for outer-reef fishing. The data suggest that previous and perhaps current fishing pressure had and continues to have detrimental effects on the resource status. This observation is further supported by the reported average fish sizes (lengths). In fact, the expected trend that sizes increase with distance from shore is not confirmed by the data shown in Figure 5.13. While most average sizes of families caught across the different habitats and combinations are comparative, only the Lethrinidae sizes clearly follow this trend (Figure 5.13). Overall, reported fish sizes are moderate to large, with a length of 25 cm on average.

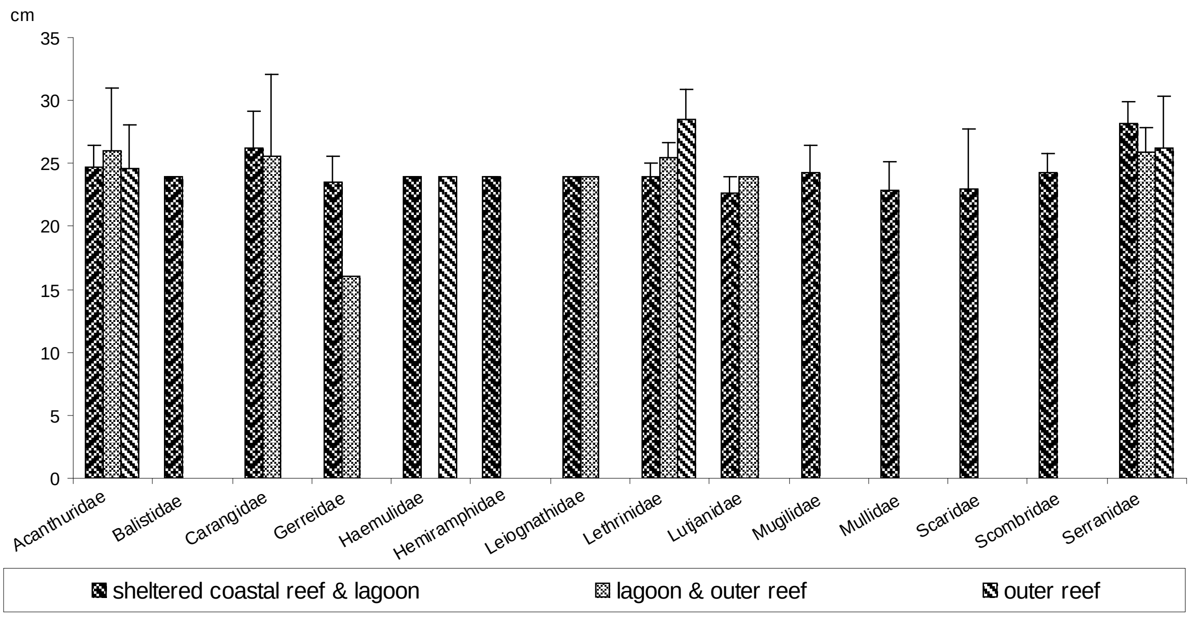

Figure 5.13: Average sizes (cm fork length) of fish caught by family and habitat in Lakeba. Bars represent standard error (+SE).

The parameters selected to assess current fishing pressure on Lakeba reef and lagoon resources are shown in Table 5.4. Due to the available reef surface and total fishing ground, population density, fisher density and catch rates are all low. This picture does not change if we consider the total annual catch rate from Lakeba fishers. However, although poaching and sharing of fishing grounds with neighbouring communities are supposedly marginal in the case of Lakeba, some of the data presented earlier suggest that fishing impact may already be visible.

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

Parameters	Habitat				
	Sheltered coastal reef & lagoon	**Lagoon & outer reef**	**Outer reef**	**Total reef area**	**Total fishing ground**
Fishing ground area (km^2)	20.4	160.7	9.1	108.5	190.2
Density of fishers (number of fishers/km^2 fishing ground) [(1)]	1.7	0.1	0.7	0.5	0.3
Population density (people/km^2) [(2)]				1.3	0.7
Average annual finfish catch (kg/fisher/year) [(3)]	509.58 (±54.77)	515.85 (±81.91)	547.65 (±134.82)		
Total fishing pressure of subsistence catches (t/km^2)				0.1	0.0
Total number of fishers	34	18	6	58	58

Figures in brackets denote standard error; [(1)] total number of fishers is extrapolated from household surveys; [(2)] total population = 141, total number of fishers = 58; total subsistence demand = 9.15 t/year; [(3)] catch figures are based on recorded data from survey respondents only.

5.2.4 Catch composition and volume – invertebrates: Lakeba

Catches reported from invertebrate fishers by wet weight suggest that bêche-de-mer species, i.e. *Holothuria* spp., account for most of the total annual catch volume (Figure 5.14a). However, sampling does not allow exact annual production rates to be calculated. Therefore, Figure 5.14b only displays the reported catch composition by species. Annual catches for traditional species that are mainly targeted for home consumption (Figure 5.14a) and, to some extent, for local sale, are mainly determined by *Anadara* spp., giant clams and octopus. Catches of *Scylla serrata*, lobsters and trochus, as well as many other species, are small by comparison.

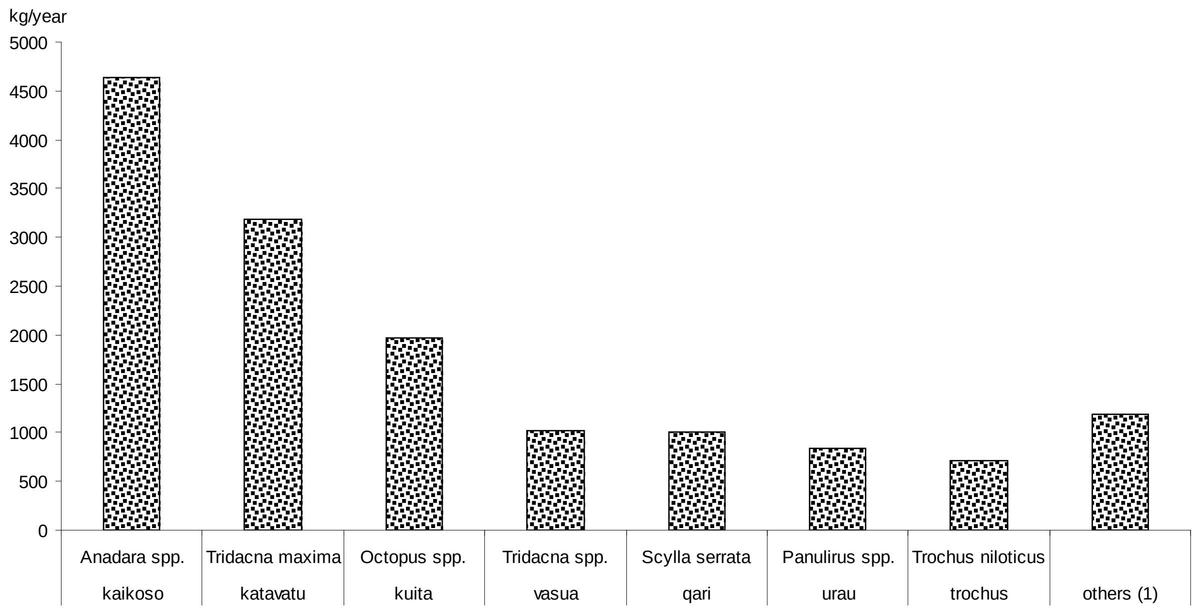

Figure 5.14a: Total annual invertebrate catch (kg wet weight/year) by species (reported catch) in Lakeba.
(1) Others include *sagosago* (*Lambis* spp.), *civa* (*Pinctada fucata*), *seila* (*Gafrarium* spp.), *yaga* (*Lambis lambis*), *keke* (*Anadara* spp.), *tadruku* (*Acanthopleura gemmata*), *lumi* and *nana* (seaweed).

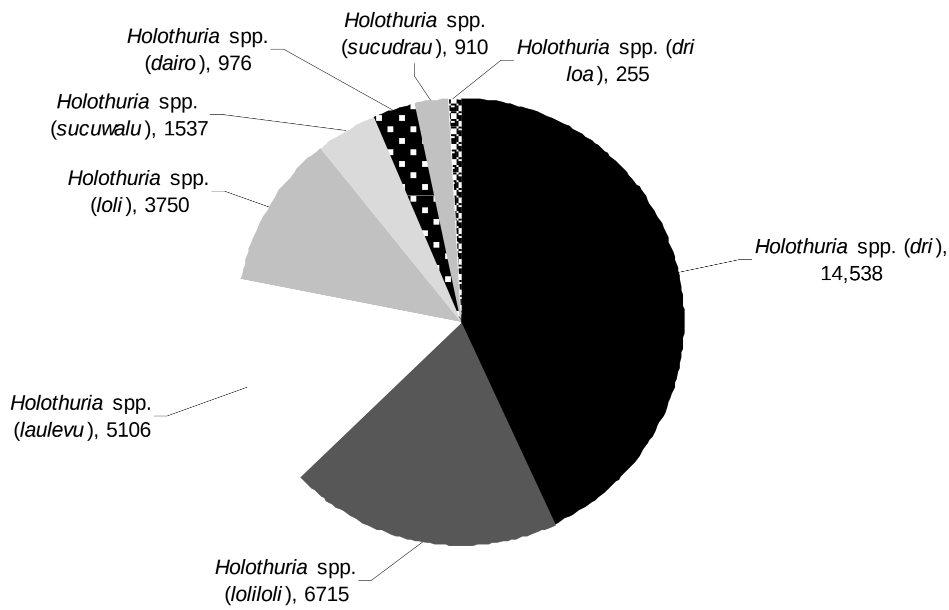

Figure 5.14b: Catch composition of bêche-de-mer fishery in Lakeba.

Figure 5.15 shows that Mali fishers have access to a wide range of habitats and that these are often combined in one fishing trip. The number of target species identified by vernacular name, however, is not as varied as one may expect. Among the traditional fisheries, the combination of soft benthos, intertidal flats and reeftops are represented by 7–8 vernacular names, others with less. There are at least eight different species of bêche-de-mer identified by distinct vernacular names; however, these represent only *Holothuria* spp.

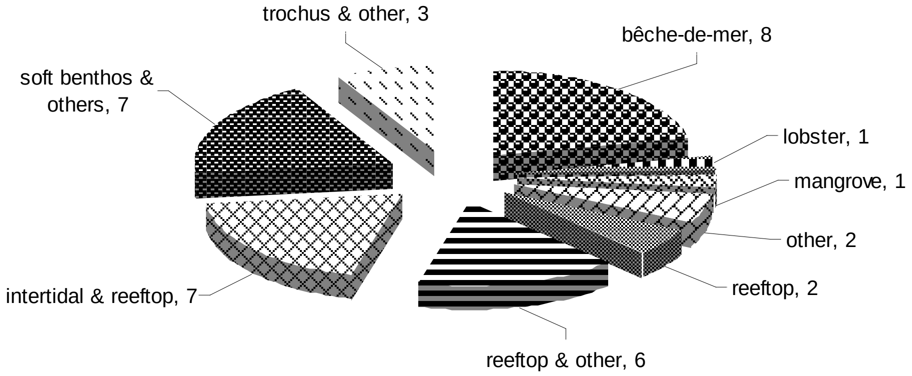

Figure 5.15: Number of vernacular names recorded for each invertebrate fishery in Lakeba.
'Other' refers to the giant clam and octopus fisheries.

Analysis of the average annual catch per fisher by gender and fishery (Figure 5.16) reveals the substantial difference between the commercial bêche-de-mer fishery and all other fisheries. Impact by gender group is highest for female fishers for the combined gleaning of soft benthos, intertidal flats and reeftops in all possible combinations. Male fishers' main target species by annual production are bêche-de-mer species, followed by reeftop, clams and octopus ('other') and trochus. Because the sample data do not allow quantification of the bêche-de-mer fishery, caution is advised in comparing this fishery to other fisheries.

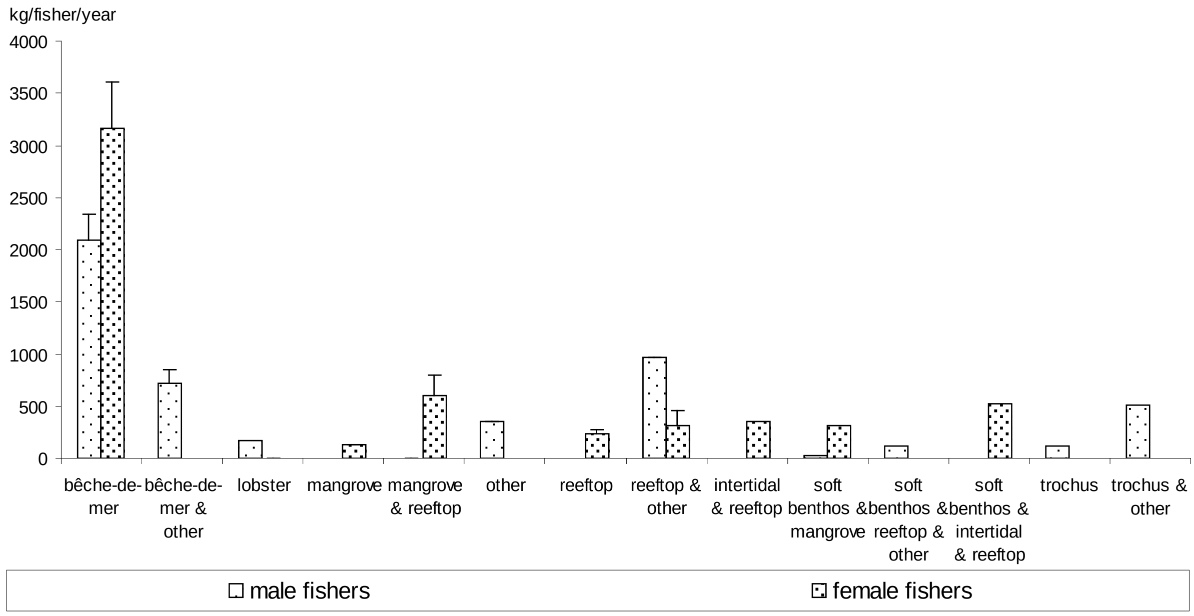

Figure 5.16: Average annual invertebrate catch (kg wet weight/year) by fisher, gender and fishery in Lakeba.
Data based on individual fisher surveys. Figures refer to the proportion of all fishers who target each habitat (n = 15 for males, n = 17 for females). 'Other' refers to the giant clam and octopus fisheries.

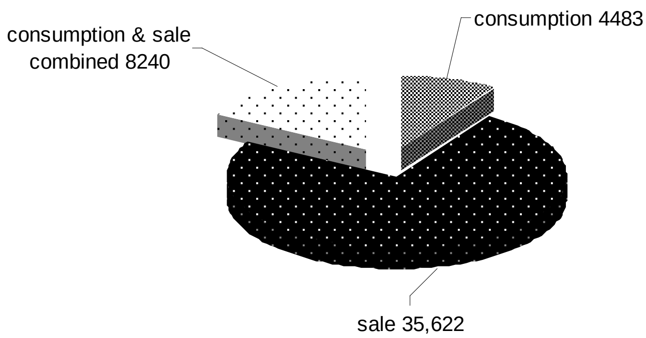

Figure 5.17: Total annual invertebrate biomass (kg wet weight/year) used for consumption, sale, and consumption and sale combined (reported catch) in Lakeba.

The fact that the Lakeba community is highly dependent on marine resources for income also shows in Figure 5.17, which shows that most invertebrates are caught for sale, notably bêche-de-mer and, to a lesser extent, lobsters, clams and 'others' for the local markets at Labasa. If we assume that half of the catches reported for both sale and home consumption are sold, the commercial proportion of the total invertebrate catch is about 82%.

As mentioned earlier, both male and female fishers from Lakeba are very involved in invertebrate fisheries, but male fishers account for the highest impact, i.e. 59% (wet weight) (Figure 5.18). Most male invertebrate fishers target bêche-de-mer and, by comparison, their annual catch from any of the other fisheries is small. However, female fishers target a wide range of habitats, mostly in combination, with the highest impact (by wet weight) collected from the soft-benthos and intertidal habitats combined with mangroves or any other easily accessible habitat. By comparison, female fishers also substantially contribute to bêche-de-mer collection, which comprises ~20% of their total annual impact by wet weight.

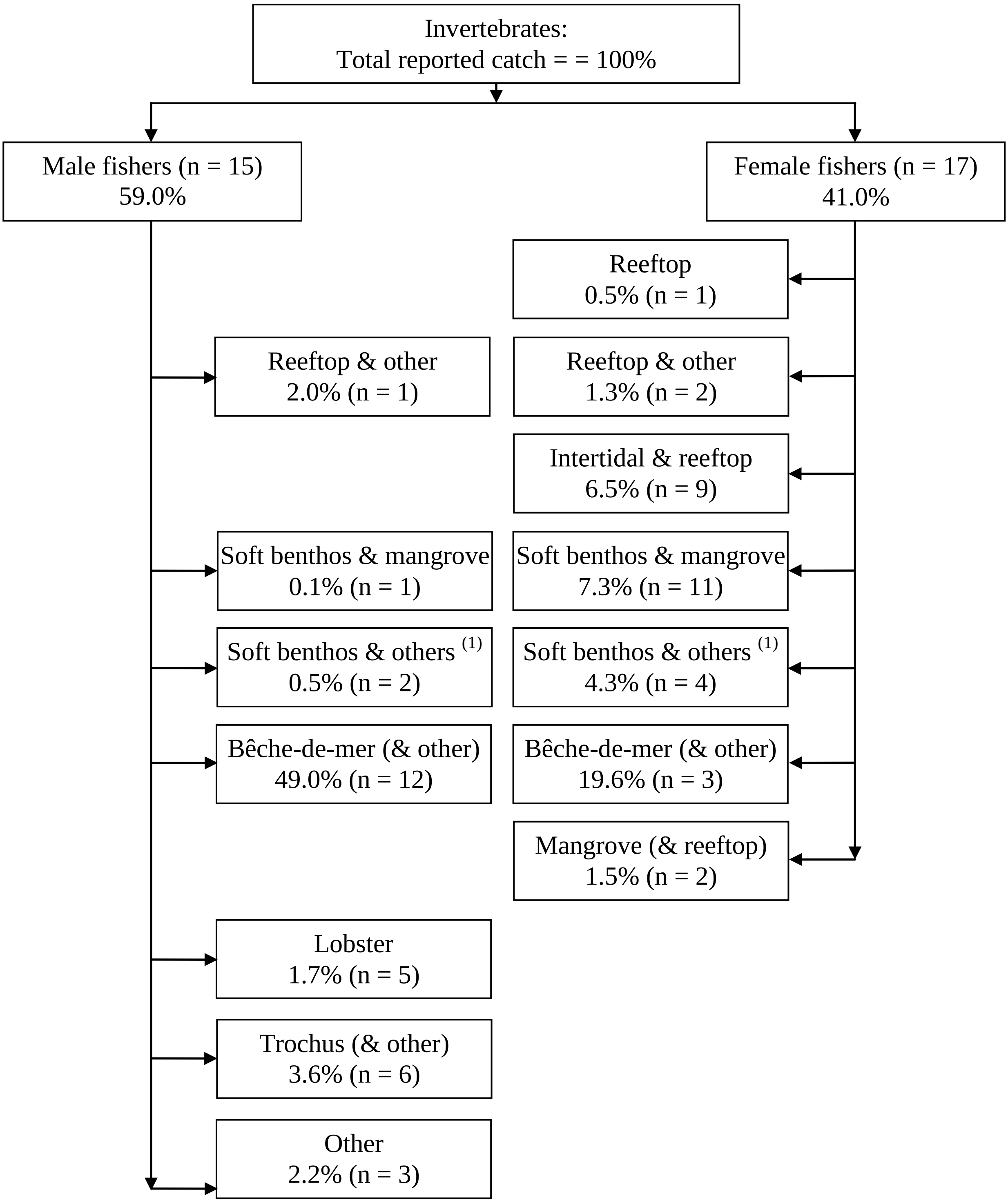

Figure 5.18: Total annual invertebrate catch (tonnes) and proportion (%) by fishery and gender (reported catch) in Lakeba.
n is the total number of interviews conducted per each fishery; total number of interviews may exceed total number of fishers surveyed as one fisher may target more than one fishery and thus respond to more than one fishery survey. 'Other' refers to giant clam and octopus fisheries. 'Others' refers to one or more of reeftops, intertidal.

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

Parameters	Fishery / Habitat						
	Reeftop (& other, & intertidal)	Soft benthos & others [(1)]	Mangrove (& reeftop)	Bêche-de-mer (& other)	Lobster	Trochus (& other)	Other
Fishing ground area (km^2)	20.4						
Number of fishers (per fishery) [(1)]	24	32	4	30	10	12	6
Density of fishers (number of fishers/km^2 fishing ground)	1.2						
Average annual invertebrate catch (kg/fisher/year) [(2)]	350.2 (±145.0) – 230.2 (n/a)	120.0 (±59.2) – 517.6 (±189.6)	125.9 (n/a)	n/a	168.6 (±43.8)	116.6 (±16.7) – 504.6 (±162.2)	354.78 (±101.1)

Figures in brackets denote standard error; n/a = no information available or standard error not calculated; [(1)] total number of fishers is extrapolated from household surveys; [(2)] catch figures are based on recorded data from survey respondents only; ‘other’ refers to giant clam and octopus fisheries and ‘others’ may include one or more of mangrove, reeftop, intertidal.

Taking into account the total sheltered coastal reef surface areas for any reeftop invertebrate fishery, the fisher-density parameters calculated are low (Table 5.5). Also, the average annual catch rate for most fisheries is low. Bêche-de-mer fishery data are not reported here, as our sampling does not permit accurate quantitative calculations. Although parameters calculated to assess current fishing pressure suggest that there is not much adverse effect from the current level of fishing activities, this picture may be misleading. The Lakeba fishing ground area has presumably been heavily accessed over the past decades and may also be accessed by other fishers, although people reported few problems with poachers or external fishers. However, the community and its fishing grounds are not far from the greater Labasa area and the fishing ground allocated to the community by customary law is large and cannot be efficiently patrolled. The suggestion that the resources may be depleted may be supported by the relatively few vernacular names reported for both the traditional and commercial fisheries by a community that is highly dependent on marine resources for both food and income and that traditionally has a food preference for many invertebrate species.

5.2.5 Management issues: Lakeba

All fishing rights areas or *qoliqoli* in Fiji Islands fall under traditional customary rights of use, and these usually include the areas up to the barrier reef immediately beyond a village, whereas waters up to the high-water mark belong to the State. The *qoliqoli* areas are owned by the *vanua* (a term which describes the total collective areas of fishing areas of several clans and villages) or sometimes ownership is in smaller units. The *qoliqoli* of the Lakeba community spans a large area with people fishing into adjacent fishing grounds under an unwritten agreement of shared resource use.

Traditional management mechanisms have been used in almost all situations and locations in Fiji Islands in the past. Modernisation and the market economy have, in many cases, changed the balance of resource use and management in the last few decades resulting in there being a greater need for some form of management, especially at the community level. Under customary marine tenure (CMT), resource owners have jurisdiction over their fishing areas (*qoliqoli*). Although ownership of fishing areas up to the high-water mark rests with the State, this is currently being reviewed with new structures, and ownership to revert to traditional owners of fishing rights. This will mean more management authority and decision-making rests in the hands of the resource owners. The fishing ground of the Lakeba community is part of the bigger fishing area of the Macuata province.

The management measures currently in place in Lakeba at the time of the survey were implemented and planned at the provincial level with the support of the communities concerned. These measures include the implementation of fishing bans on coastal reef systems in the province; thus there is no fishing recorded in the coastal reef habitat. However, people do fish in the area immediately outside the banned areas and these permitted areas are still referred to in this case as coastal reef areas. The traditional Fiji Island institutional set-up operates at a hierarchical level, which includes the village, district and provincial level in the modern administrative system whereas, in the traditional systems, there is the *vanua*, the *tikina makawa* (villages or clans) and *tokatoka* (households). Management has been implemented at the village, district and provincial levels in some cases. The result of all these measures (as was the case in Lakeba) was a very high awareness of the need for management and the need to sustain resources for future generations at the community level. Policing, monitoring and the provision of alternative livelihoods when the fisheries are closed were the challenges for the management initiatives currently in place.

At the time of the survey, there was a province-wide management strategy in place in the Macuata province and this included a ban on all types of fishing from coastal reef areas and other associated habitats. These bans were implemented and monitored in the Lakeba community with assistance from the Fisheries Department and FLMMA, a group of fisheries managers and practitioners actively involved in coastal management in Fiji Islands. In addition to this there existed traditional resource-use mechanisms, which guided people's harvests of resources.

5.2.6 Discussion and conclusions: socioeconomics in Lakeba

Lakeba is a rural coastal community significantly dependent on fisheries resources for food and income. Despite difficulties in transportation, fishing still offers the main source of income, reflecting the lack of income alternatives due to the isolation of the community. Fishing is carried out by both males and females, with males dominating the highly valuable commercial invertebrate fisheries and most of the commercial finfish fishing. Post-harvest and processing activities are usually undertaken by females, who also do most of the selling and distribution. Invertebrates are usually sold at the Labasa market, while fish is either sold to middle sellers who come to buy from the village, or is regularly sold to the Fisheries Department's fish-buying centres.

People significantly depend on middle sellers and buyers, thus the Fisheries Department could beneficially take a more pro-active role in securing buyers and commercial outlets and finding ways to add value to fisheries products before they reach the markets.

In summary:

- The Lakeba community has its highest dependency on fisheries for income while other sectors, e.g. handicrafts and agricultural produce, play much lesser roles in generating first income.

- The Lakeba community has a high food dependency particularly on finfish, but also on invertebrates; however, people also benefit from good local food production.

- The household expenditure level is even lower than the generally low average household expenditure level found in all sites studied in Fiji Islands. More than 40% of all households receive remittances, but the annual amount received is low.

- Finfish and invertebrate fishers target many habitats and often combine two or more habitats in one fishing trip. Most impact is on the sheltered coastal reef and lagoon, and lagoon and outer reef rather than on outer reef alone.

- Both male and female fishers participate in finfish fishing and invertebrate collection. Male fishers are the most important finfish fishers, also targeting habitats further from shore, while females are more involved in handlining and gillnetting the nearshore habitats, mainly the sheltered coastal reef and lagoon. Female fishers are heavily engaged in traditional invertebrate collection, but male fishers who pursue free-diving for invertebrates account for the highest impact by wet weight. This is also true for bêche-de-mer fishing.

- While annual catch rates do not vary substantially, CPUEs are lowest for outer-reef fishing.

- Average reported fish sizes (length) are moderate to large. For most families these lengths do not change per habitat; the expected increase in size with increasing distance from shore only applies to fish from the Lethrinidae family.

- Bêche-de-mer is the most important invertebrate fishery by wet weight and for income generation; however, traditional species, including *Anadara*, giant clams and octopus, are important for both home consumption and small-scale, local commercial sale.

- Fishing pressure parameters calculated for both finfish and invertebrates suggest low current fishing pressure; however, these figures may be misleading given the previous fishing impact. Poaching or pressure from neighbouring communities is not considered a problem.

The existing traditional protocol and communal arrangements have supported implementation of management strategies that are perceived as successful by Lakeba fishers. Also, restricted fishing zones are usually respected and alternative fishing areas are targeted. Although modern fishing gears are used, traditional knowledge and skills are still used by the people, including their understanding of the winds and moons. Females, especially, still use traditional skills for invertebrate gleaning and for catching finfish close to shore.

Management has been implemented on a province-wide basis, with coastal reef areas declared ‘no-fishing areas’. Compliance with the management strategies in place has been good. Fishing, therefore, is centered on the offshore reefs and inner lagoon areas close to the coastal reef areas. Indications of increased sizes and numbers for both finfish and invertebrates were discussed by respondents as evidence of the success of these management strategies, which were also thought to have had an impact on the abundance and availability of species that were perceived to be in decline.

Motorised boats are often used and the community was highly dependent on these boats for both fishing and transportation.

Although management strategies are already in place, there is a need to strengthen these existing strategies and empower those responsible for management at the community level, and a need for better monitoring and for taking more initiatives. There is also a need to provide more alternatives for income and agricultural production. In the case of Lakeba, a livelihood approach could help to identify alternative income-generation activities that would definitely require better transport connection with Labasa. In addition, people could be better trained and skilled in processing their marine produce, particularly bêche-de-mer, to increase their revenue and to reduce pressure on these resources.

5.3 Finfish resource surveys: Lakeba

Lakeba is a rural, coastal village located at the northernmost tip of the island of Vanua Levu, at 16°12' S and 179°44' E. All four types of reefs were present to allow the normal PROCFish methodology to be followed. A total of 24 stations were sampled between 20 and 25 June 2004 (5 coastal reefs, 6 intermediate reefs, 7 back-reefs and 6 outer reefs, Figure 5.19).

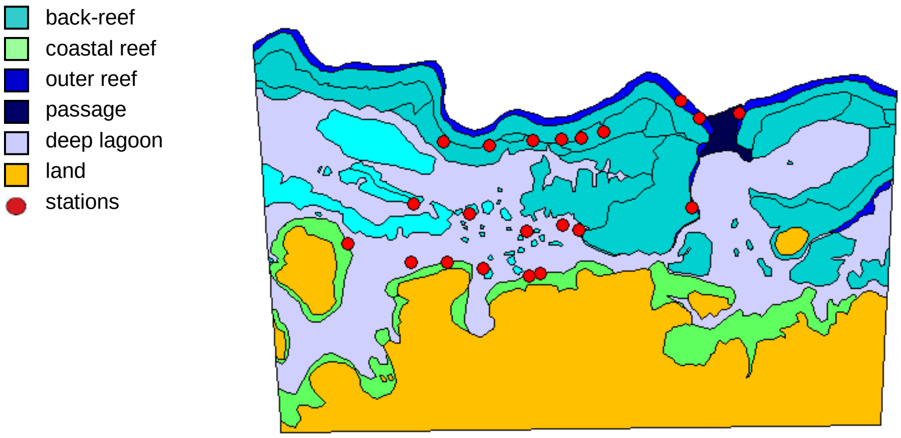

Figure 5.19: Habitat types and transect locations for finfish assessment in Lakeba.

5.3.1 Finfish assessment results: Lakeba

A total of 22 families, 51 genera, 144 species and 8358 fish were recorded in the 24 transects (See Appendix 3.4.2 for list of species.). Only data on the 14 most dominant families (See Appendix 1.2 for species selection.) are presented below, representing 39 genera, 127 species and 7775 individuals.

Finfish resources varied greatly among the four reef environments found in Lakeba (Table 5.6). The coastal reef displayed the highest biodiversity (46 species/transect) and density (0.8 fish/m^2) and second-highest biomass (127 g/m^2) but the smallest size ratio (53%) among all reef habitats. The outer reefs displayed the highest sizes (23 cm FL), size ratio (73%) and biomass (380 g/m^2), more than four times higher than the lowest value, which was recorded in the back-reefs. The back-reefs also displayed the lowest biodiversity (27 species/transect).

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

Parameters	Habitat				
	Sheltered coastal reef [(1)]	Intermediate reef [(1)]	Back-reef [(1)]	Outer reef [(1)]	All reefs [(2)]
Number of transects	5	6	7	6	24
Total habitat area (km^2)	20.4	13.3	65.7	7.3	106.7
Depth (m)	2 (1–4) [(3)]	2 (1–3) [(3)]	1 (1–2) [(3)]	7 (4–10) [(3)]	2 (1–10) [(3)]
Soft bottom (% cover)	8 ±2	18 ±4	9 ±3	0 ±0	9
Rubble & boulders (% cover)	22 ±7	26 ±6	58 ±12	4 ±6	48
Hard bottom (% cover)	51 ±5	41 ±6	29 ±10	76 ±8	34
Live coral (% cover)	17 ±5	14 ±5	4 ±1	16 ±5	8
Soft coral (% cover)	1 ±1	1 ±1	0 ±0	3 ±1	1
Biodiversity (species/transect)	46 ±6	33 ±4	27 ±5	41 ±4	36 ±3
Density (fish/m^2)	0.8 ±0.1	0.5 ±0.1	0.5 ±0.1	0.6 ±0.1	0.5
Size (cm FL) [(4)]	17 ±1	18 ±1	16 ±1	23 ±1	17
Size ratio (%)	53 ±2	60 ±2	54 ±2	73 ±3	54
Biomass (g/m^2)	126.9 ±39.0	98.8 ±44.5	81.5 ±39.8	380.2 ±149.0	104.9

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

Sheltered coastal reef environment: Lakeba

The coastal reef environment of Lakeba was dominated by Acanthuridae, Scaridae, Siganidae and Lutjanidae and, only for density, Chaetodontidae (Figure 5.20). The four main families were represented by 32 species; particularly high biomass and abundance were recorded for *Lutjanus fulvus*, *Ctenochaetus striatus*, *Chlorurus bleekeri*, *Siganus doliatus*, *Scarus rivulatus*, *Scarus psittacus* and *Scarus dimidiatus* (Table 5.7). This reef environment was highly dominated by hard bottom (51%) and rubble (22%), with very little soft bottom (8%) and live coral (17%, Table 5.6).

Table 5.7: Finfish species contributing most to main families in terms of densities and biomass in the sheltered coastal reef environment of Lakeba

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.07 ±0.01	9.4 ±4.0
Scaridae	*Chlorurus bleekeri*	Bleeker's parrotfish	0.06 ±0.01	12.1 ±5.4
	Scarus rivulatus	Rivulated parrotfish	0.03 ±0.01	6.1 ±2.4
	Scarus psittacus	Common parrotfish	0.03 ±0.01	9.3 ±3.4
	Scarus ghobban	Bluebarred parrotfish	0.03 ±0.01	5.7 ±2.7
Siganidae	*Siganus doliatus*	Barred spinefoot	0.06 ±0.01	5.6 ±3.1
Lutjanidae	*Lutjanus fulvus*	Flametail snapper	0.08 ±0.03	15.2 ±6.8

The density of finfish in the coastal reef of Lakeba was the highest among all reef habitats. However, biomass was second to the outer-reef value, which, in comparison, was almost twice as high. Size and size ratios were the lowest and similar to the back-reef values. Biodiversity, however, was the highest of all the reefs. The trophic structure in Lakeba coastal reef was only slightly dominated by herbivorous fish, represented by three major families, Acanthuridae, Scaridae and Siganidae. Carnivores were represented predominantly by Lutjanidae, probably due to the particular composition of the substrate, which was strongly dominated by hard bottom and rubble with very little cover of soft bottom, which would favour Lethrinidae and Mullidae species. Small values of size ratio were recorded for Acanthuridae, Mullidae, Labridae and Lethrinidae.

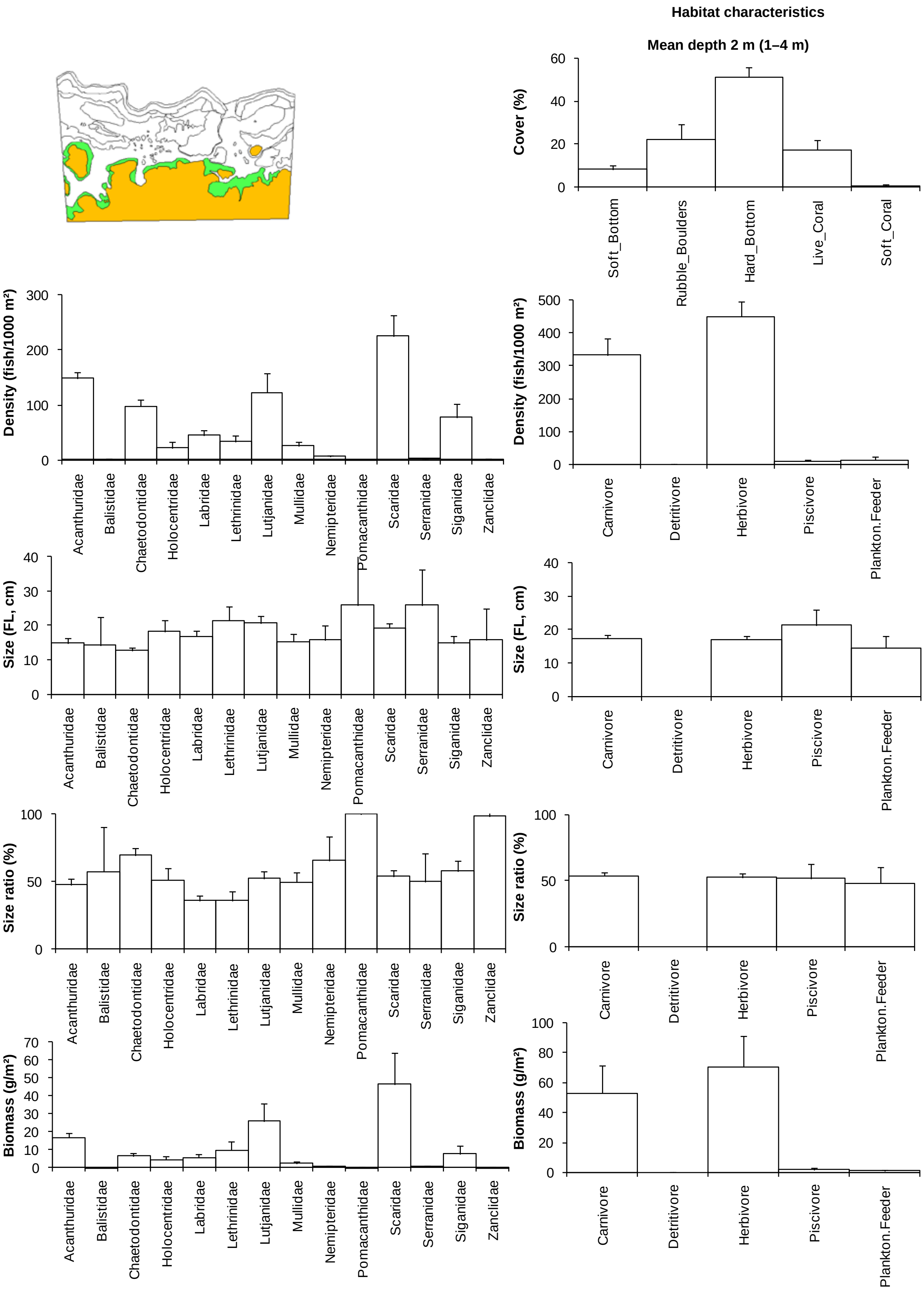

Figure 5.20: Profile of finfish resources in the sheltered coastal reef environment of Lakeba.
Bars represent standard error (+SE); FL = fork length.

Intermediate-reef environment: Lakeba

The intermediate reef of Lakeba was dominated by the herbivorous families Acanthuridae, Scaridae and Siganidae (Figure 5.21). These families were represented by 27 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Acanthurus blochii*, *Siganus doliatus*, *Chlorurus bleekeri*, *Scarus psittacus* and *S. dimidiatus* (Table 5.8). Most of the substrate was occupied by hard bottom and rubble (67% of total substrate) and only small amounts of soft bottom (18%) and live coral (14%) were present (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 intermediate-reef environment of Lakeba

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.06 ±0.02	9.5 ±4.4
	Acanthurus blochii	Ringtail surgeonfish	0.04 ±0.02	16.3 ±9.1
Scaridae	*Chlorurus bleekeri*	Bleeker's parrotfish	0.03 ±0.01	8.3 ±5.0
	Scarus psittacus	Common parrotfish	0.02 ±0.01	5.9 ±1.9
	Scarus dimidiatus	Yellow-barred parrotfish	0.02 ±0.01	4.1 ±1.9
Siganidae	*Siganus doliatus*	Barred spinefoot	0.04 ±0.01	5.9 ±2.5

The density of finfish in the intermediate reefs of Lakeba was the lowest at the site and similar to that in the back-reefs. Size and size ratio were second only to outer-reef values and biomass was lower than in the coastal reef but higher than in the back-reefs. Biodiversity was only the second-lowest, higher only than the back-reef value. The trophic structure was dominated by herbivorous fish, represented primarily by three major families: Acanthuridae, Scaridae and Siganidae, similarly to in the coastal reefs. Carnivores were represented in small densities and by equal amounts of Lethrinidae, Lutjanidae, Mullidae and Labridae. Piscivores, e.g. Serranidae, were practically absent. Small values of size ratio were recorded for Holocentridae, Labridae and, especially, Lethrinidae.

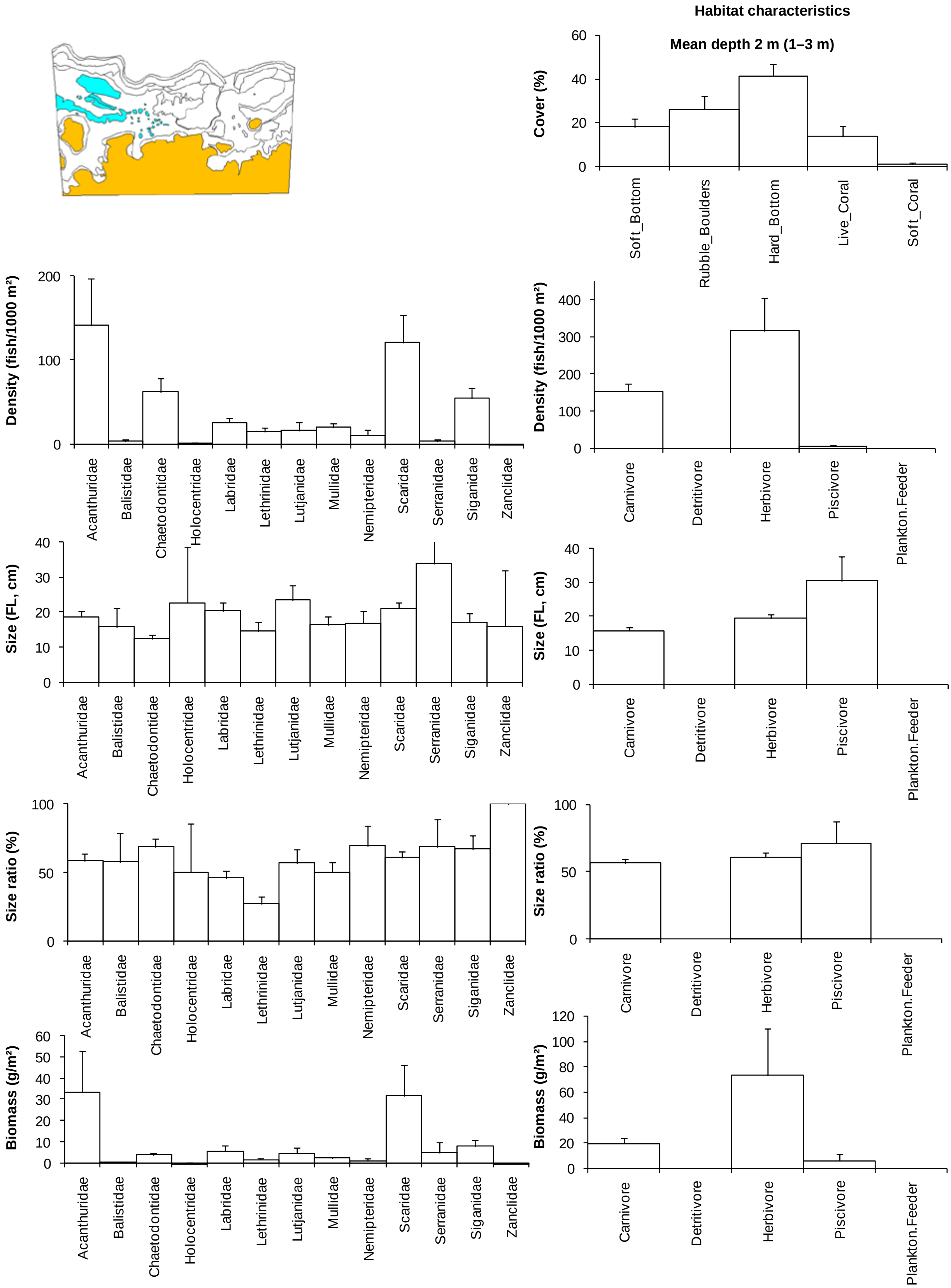

Figure 5.21: Profile of finfish resources in the intermediate-reef environment of Lakeba.
Bars represent standard error (+SE); FL = fork length.

Back-reef environment: Lakeba

The back-reef of Lakeba was largely dominated by the herbivorous Scaridae, followed by Acanthuridae (Figure 5.22). Lutjanidae were important only in terms of biomass. These three families were represented by 26 species; particularly high biomass and abundance were recorded for *Scarus psittacus*, *Chlorurus sordidus*, *Ctenochaetus striatus* and *Lutjanus gibbus* (Table 5.8). Most of the substrate was occupied by rubble (58%) and hard bottom (29%) and only very little live coral (4%) and soft bottom (9%) were present (Table 5.6 and Figure 5.22).

Table 5.8: Finfish species contributing most to main families in terms of densities and biomass in the back-reef environment of Lakeba

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Scaridae	*Scarus psittacus*	Common parrotfish	0.08 ±0.02	5.8 ±2.9
	Chlorurus sordidus	Daisy parrotfish	0.07 ±0.03	6.7 ±3.0
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.06 ±0.03	12.3 ±6.4
Lutjanidae	*Lutjanus gibbus*	Humpback snapper	0.02 ±0.02	17.3 ±16.5

The density, size, biomass and biodiversity of finfish in the back-reef of Lakeba were the lowest among all reefs at the site. The trophic structure was dominated by herbivorous fish, Scaridae. Acanthuridae and Siganidae were less important numerically. Carnivores were represented mainly by Lutjanidae, with the high biomass due to the high concentration of *Lutjanus gibbus*, which usually prefers hard bottom, in high cover in the back-reefs. Labridae, Mullidae, Scaridae and, especially, Lethrinidae, displayed very low values of size ratio, suggesting an impact from fishing.

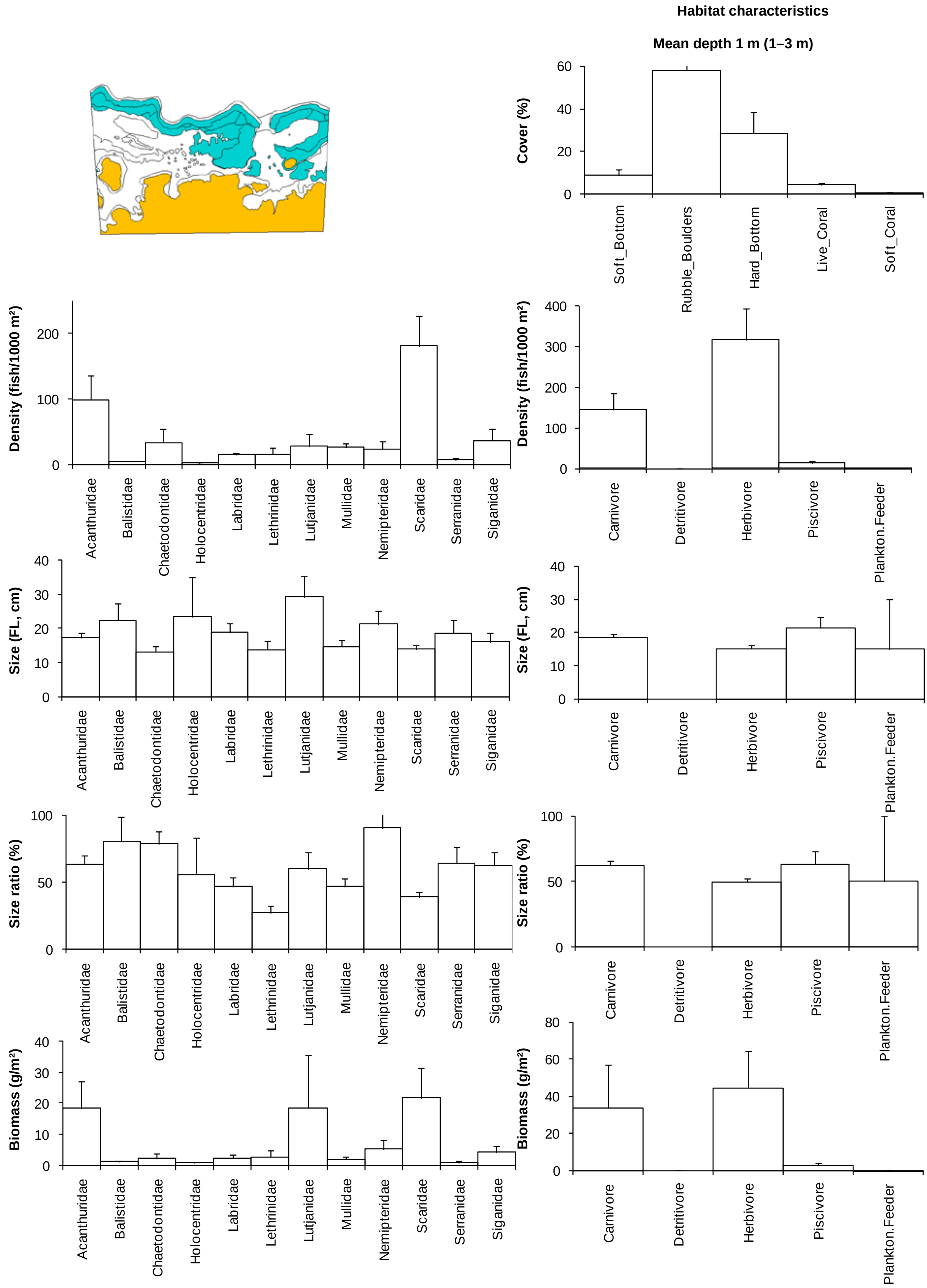

Figure 5.22: Profile of finfish resources in the back-reef environment of Lakeba.
Bars represent standard error (+SE); FL = fork length.

Outer-reef environment: Lakeba

The outer reef of Lakeba was largely dominated by the herbivorous Acanthuridae, displaying a density three times higher than at the other reefs, and by Scaridae, the most important in terms of biomass (Figure 5.23). These two families were represented by 31 species; particularly high biomass and abundance were recorded for *Ctenochaetus striatus*, *Chlorurus sordidus*, *Acanthurus nigricans*, *Naso lituratus* and *A. lineatus* (Table 5.9). The substrate was dominated by hard bottom (76%), with a relatively good live-coral cover (16%). Soft bottom was completely lacking (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 Lakeba

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.21 ±0.03	56.4 ±12.4
	Acanthurus nigricans	Whitecheek surgeonfish	0.04 ±0.03	8.6 ±6.1
	Naso lituratus	Orangespine unicornfish	0.03 ±0.01	19.7 ±7.9
	Acanthurus lineatus	Lined surgeonfish	0.02 ±0.01	15.0 ±8.9
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.04 ±0.02	14.9 ±5.8
	Scarus niger	Black parrotfish	0.02 ±0.02	20.2 ±20.2

The density and biodiversity of finfish in the outer reef of Lakeba were lower than the top values recorded in the sheltered coastal reefs. However, size, size ratio and biomass were the highest among all reefs at the site. The high value of biomass was, however, partially due to the presence of a school of *Bolbometopon muricatum*. Species composition was quite varied. Trophic structure was dominated by herbivorous fish, represented primarily by Acanthuridae, with very large numbers of *Ctenochaetus striatus*, and Scaridae (more important in terms of biomass). Carnivores were represented mainly by Lutjanidae and Labridae, due to the particular composition of the substrate, strongly dominated by hard bottom and corals with no soft bottom, which would favour Lethrinidae and Mullidae species. Small values of size ratio were recorded only for Labridae.

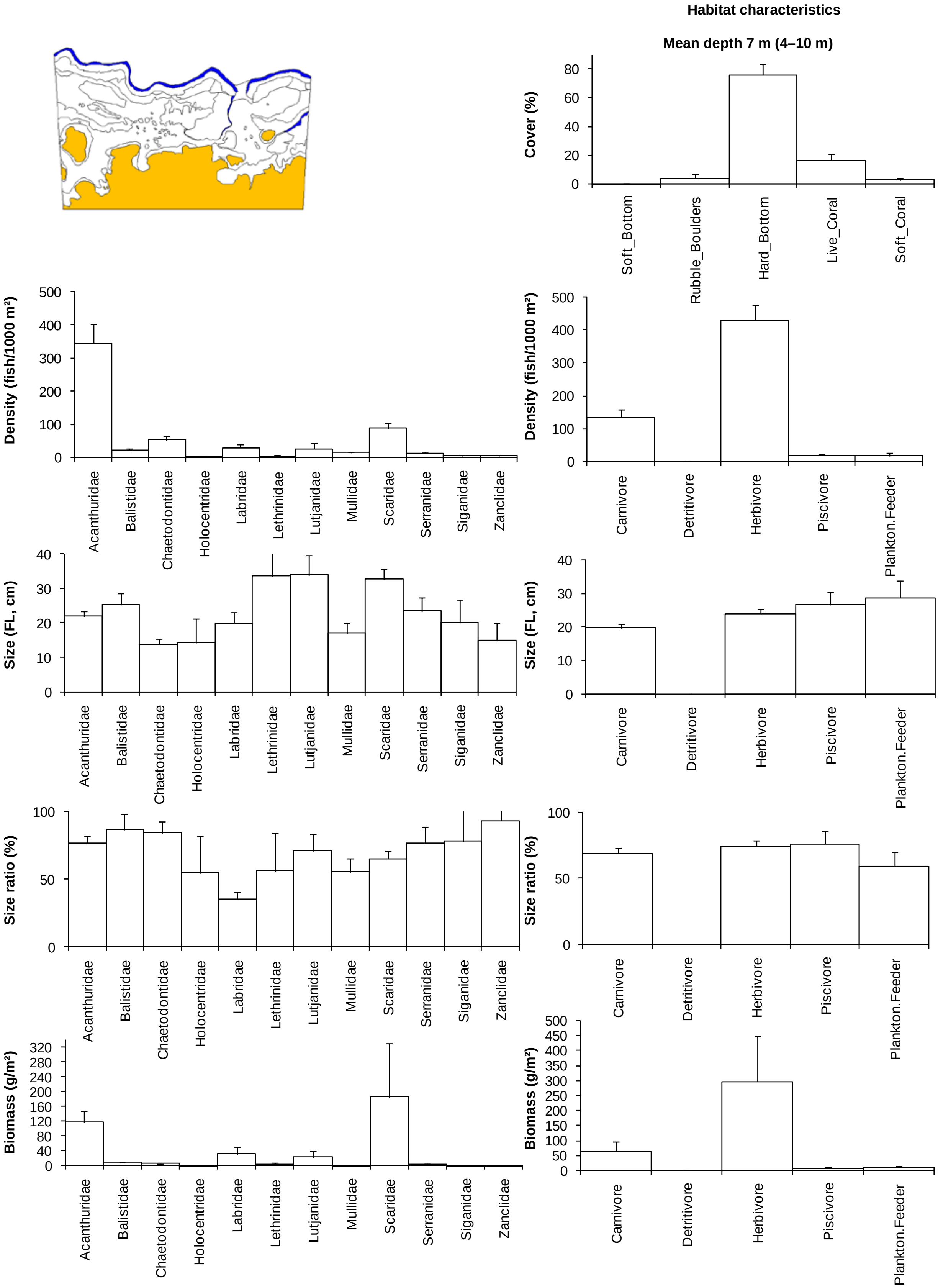

Figure 5.23: Profile of finfish resources in the outer-reef environment of Lakeba.
Bars represent standard error (+SE); FL = fork length.

Overall reef environment: Lakeba

Overall, the fish assemblage of Lakeba was dominated by Scaridae and Acanthuridae. The most important carnivores were of the Lutjanidae family, but of comparable importance to Acanthuridae only in terms of biomass (Figure 5.24). These three most abundant families were represented by a total of 45 species, dominated (in terms of biomass and density) by *Ctenochaetus striatus*, *Acanthurus lineatus*, *A. nigricans*, *Chlorurus sordidus* and *Lutjanus gibbus* (Table 5.10). The average substrate at this site was strongly dominated by rubble and boulders (48%), with a high cover of hard bottom (34%) and very poor cover of live coral and soft bottom. The overall fish assemblage in Lakeba shared characteristics of mainly coastal reefs (55% of total habitat), then of back-reefs (27%), outer reefs (15%) and, finally and only in very limited amount, intermediate reefs (2%).

Table 5.10: Finfish species contributing most to main families in terms of densities and biomass across all reefs of Lakeba (weighted average)

Family	Species	Common name	Density (fish/m^2)	Biomass (g/m^2)
Acanthuridae	*Ctenochaetus striatus*	Striated surgeonfish	0.13	19.2
	Acanthurus lineatus	Surgeonfish	0.06	18.9
	Acanthurus nigricans	Whitecheek surgeonfish	0.02	2.3
Scaridae	*Chlorurus sordidus*	Daisy parrotfish	0.02	1.5
Lutjanidae	*Lutjanus gibbus*	Little spinefoot	0.01	1.5

Overall, Lakeba appeared to support an average finfish resource, with density, size and size ratio similar to values at Dromuna and Muaivuso but lower than in Mali, and biomass second only to that in Mali (104 g/m^2). Biodiversity was, however, the lowest recorded among the four sites (36 species/transect versus 40 in all other three reefs). Detailed assessment at the family level confirmed a rather low diversity of the fish community, composed mostly of herbivores with very few carnivores. The trophic composition, heavily dominated by herbivores (especially in density terms), was probably a consequence of the type of substrate, which was mainly constituted of bare rock. However, some families displayed what could be the first sign of fishing impact: size ratios were below the 50% threshold for Labridae, Lethrinidae and Scaridae.

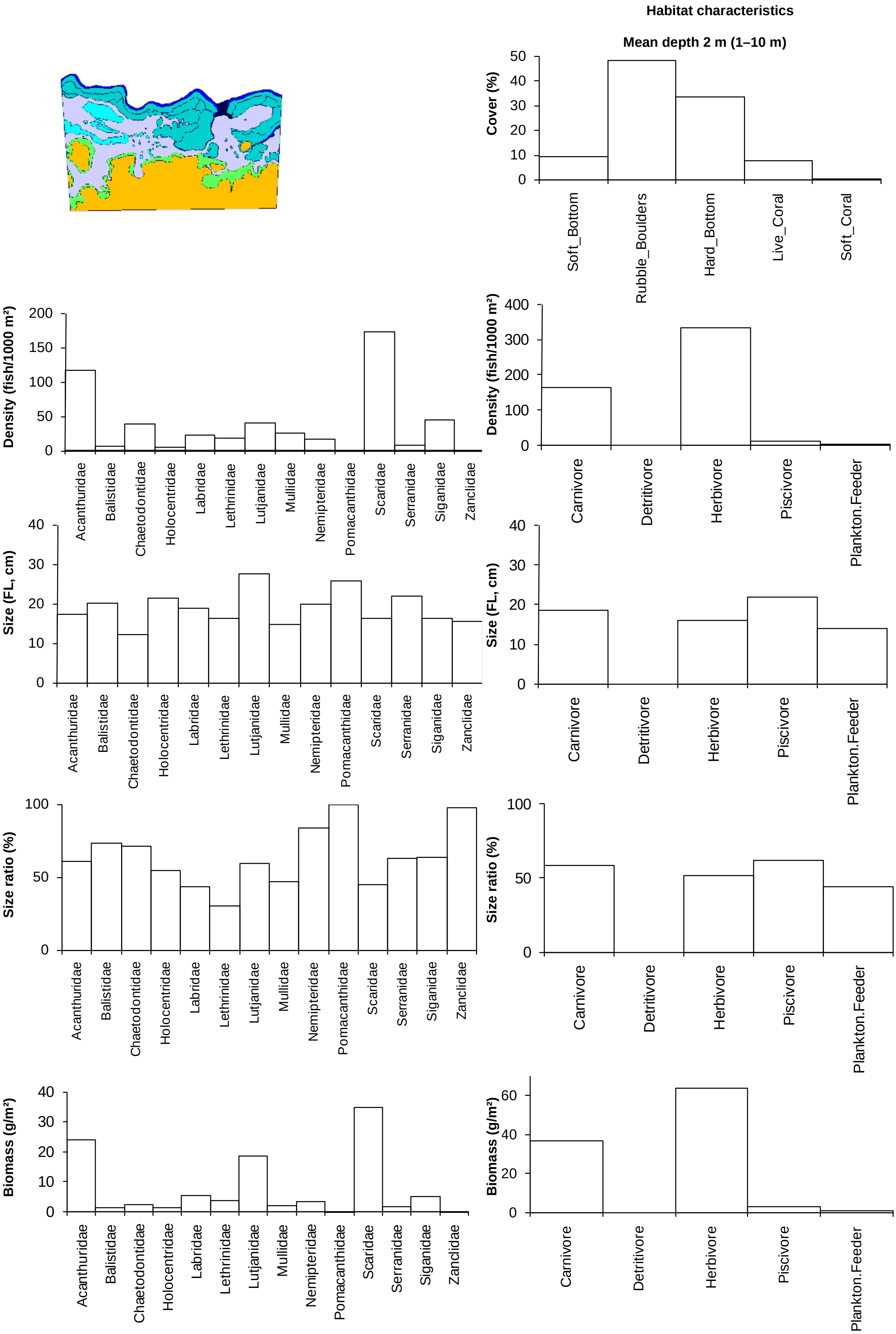

Figure 5.24: Profile of finfish resources in the combined reef habitats of Lakeba (weighted average).
FL = fork length.

5.3.2 Discussion and conclusions: finfish resources in Lakeba

Overall, the finfish resources of Lakeba appeared to be in average condition, with highest density, and size and size ratio similar to values at Dromuna and Muaivuso, but lower than at Mali. Biomass was second only to the value in Mali (104 g/m^2). However, biodiversity was the lowest recorded among the four sites. Detailed assessment at the family level confirmed a rather low diversity of the fish community, composed mainly of herbivores with very little importance of carnivores. In three habitats, the fish community was dominated by the three major herbivore families, Scaridae, Acanthuridae and Siganidae. In the outer reefs, however, the picture was slightly different, showing a heavy numerical dominance of Acanthuridae, mainly represented by *Ctenochaetus striatus* and *Acanthurus lineatus*. This trophic composition, heavily dominated by herbivores (especially in terms of density), was probably a consequence of the type of substrate, which was mainly constituted of bare rock. Although the general status was average, some families displayed what could be the first sign of fishing impact: size ratios were below the 50% threshold for Labridae, Lethrinidae and Scaridae. Lethrinidae, similarly to in the other villages, were one of the most frequently caught fish families. Lakeba is highly dependent on fishing for income generation and displayed quite a high level of catches as well as the highest number of boats, resulting in a high fishing pressure on the resources.

- Overall, Lakeba finfish resources appeared to be in average condition. The reef habitat was very poor in terms of live coral and soft bottom, and this most probably determined the type of fish composition, which was highly dominated by herbivores.

- The trophic community was mainly composed of the herbivores Acanthuridae, Scaridae and Siganidae. Carnivores were mostly represented by Lutjanidae, especially in the coastal and back-reefs.

- Size ratios were below half of their maximum values for Labridae, Lethrinidae and Scaridae, suggesting an impact from fishing

5.4 Invertebrate resource surveys: Lakeba

The diversity and abundance of invertebrate species at Lakeba were independently determined using a range of survey techniques (Table 5.12a for 2003 survey, Table 5.12b for 2009 survey), broad-scale assessment (using the 'manta tow' technique; locations shown in Figure 5.25a for 2003, 5.25b for 2009) and finer-scale assessment of specific reef and benthic habitats (Figures 5.26a, 5.27a and 5.28a for 2003 and Figures 5.26b, 5.27b and 5.28b for 2009).

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

Table 5.12a: Number of stations and replicate measures completed in Lakeba in 2003

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	12	72 transects
Reef-benthos transects (RBt)	0	0 transect
Soft-benthos transects (SBt)	15	90 transects
Soft-benthos infaunal quadrats (SBq)	18	144 quadrat groups
Mother-of-pearl transects (MOPt)	4	24 transects
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches	3 RFs 0 RFs_w	18 search periods 0 search period
Sea cucumber night searches (Ns)	2	12 search periods
Sea cucumber day searches (Ds)	0	0 search period

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

Table 5.12b: Number of stations and replicate measures completed in Lakeba in 2009

Survey method	Stations	Replicate measures
Broad-scale transects (B-S)	7	36 transects
Reef-benthos transects (RBt)	16	99 transects
Soft-benthos transects (SBt)	4	24 transects
Soft-benthos infaunal quadrats (SBq)	9	72 quadrat groups
Mother-of-pearl transects (MOPt)	0	0 transect
Mother-of-pearl searches (MOPs)	1	6 search periods
Reef-front searches	2 RFs 0 RFs_w	12 search periods 0 search period
Sea cucumber night searches (Ns)	2	6 search periods
Sea cucumber day searches (Ds)	1	6 search periods

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

Figure 5.25a: Broad-scale survey stations for invertebrates in Lakeba in 2003.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 5.25b: Broad-scale survey stations for invertebrates in Lakeba in 2009.
Data from broad-scale surveys conducted using 'manta-tow' board;
black triangles: transect start waypoints.

Figure 5.26a: Fine-scale soft-benthos transect survey stations for invertebrates in Lakeba in 2003.
Black stars: soft-benthos transect stations (SBt).

Figure 5.26b: Fine-scale reef-benthos transect survey stations and soft-benthos transect survey stations for invertebrates in Lakeba in 2009.
Black circles: reef-benthos transect stations (RBt);
black stars: soft-benthos transect stations (SBt).

Figure 5.27a: Fine-scale survey stations for invertebrates in Lakeba in 2003.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
black squares: mother-of-pearl transect stations (MOPt);
grey circles: sea cucumber night search stations (Ns).

Figure 5.27b: Fine-scale survey stations for invertebrates in Lakeba in 2009.
Inverted black triangles: reef-front search stations (RFs);
grey squares: mother-of-pearl search stations (MOPs);
grey circles: sea cucumber night search stations (Ns).

Figure 5.28a: Fine-scale survey stations for invertebrates in Lakeba in 2003.
Inverted black triangles: soft-benthos infaunal quadrat stations (SBq).

Figure 5.28b: Fine-scale survey stations for invertebrates in Lakeba in 2009.
Inverted black triangles: soft-benthos infaunal quadrat stations (SBq).

In 2003, fifty-two species or species groupings (groups of species within a genus) were recorded in the Lakeba invertebrate surveys. Among these were 1 crustacean, 12 bivalves, 12 gastropods, 19 sea cucumbers, 4 starfish and 2 urchins (Appendix 4.4.1 for 2003).

In 2009, forty-two species or species groupings were recorded. Among these were 1 crustacean, 6 bivalves, 12 gastropods, 17 sea cucumbers, 3 starfish and 2 urchins (Appendix 4.4.1 for 2009). Information on key families and species is detailed below.

5.4.1 2003–2009 stock status trends – giant clams: Lakeba

The lagoon was extensive at Lakeba (149.6 km²), but comprised mainly sandy bottom, with only small patches of hard benthos seen in the intermediate areas and the back-reef (19.1 km², extensive, connected sheltered reef benthos was difficult to find). Habitat suitable for giant clams was, therefore, not extensive for all species; however, the complex lagoon provided areas for the larger, more free-living species (i.e. those not found within limestone substrates).

There was dynamic water flow through most of the outer lagoon and across the barrier reef but, closer to land, river outflows largely affected the water quality, there was less dynamic mixing in the embayments and in front of the mangroves, and a land influence predominated. Outside the lagoon, the more exposed reef front and slope covered approximately 6.4 km² (lineal distance 27.3 km), and was largely oceanic-influenced but not heavily impacted by swells at the time of survey.

In the 2003 survey, the elongate clam *Tridacna maxima* and the fluted clam *T. squamosa* were noted. Broad-scale sampling provided an overview of giant clam distribution; *T. maxima* and *T. squamosa* had a similar occurrence, and were recorded in 7 and 5 of the 72 transects respectively, although *T. squamosa* was recorded over more stations (Figure 5.29a).

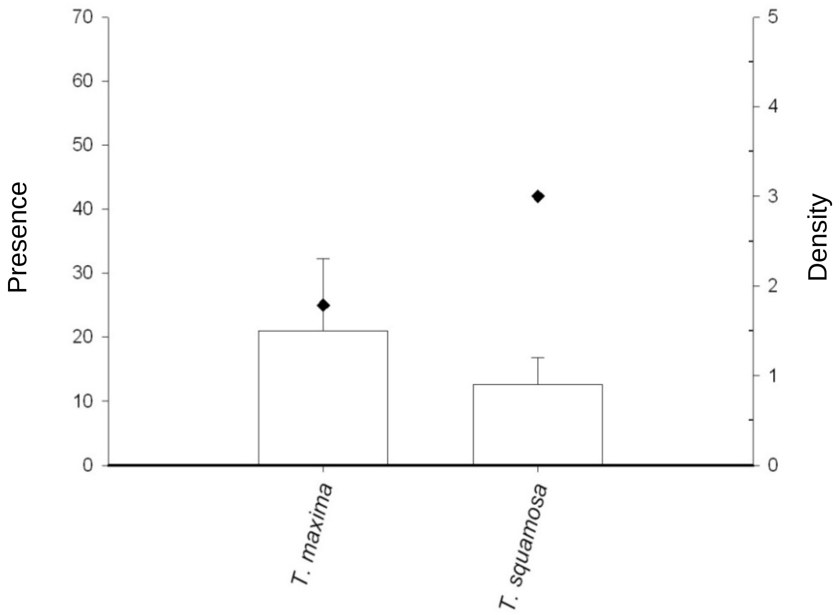

Figure 5.29a: Presence and mean density of giant clam species at Lakeba based on B-S survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

Finer-scale surveys could not target any large, interconnected areas of reef inside the lagoon. However, mother-of-pearl stations were completed on the reef front (MOPs and MOPt) and, in these, both *T. maxima* and *T. squamosa* were noted (Figure 5.29b). In this case, *T. maxima* was present in 60% of survey stations, with a mean station density of 18.9 /ha ±1.5 at the three stations where this species was recorded. *T. squamosa* was rare, recorded at a single station at a mean density of 22.7 /ha (in 3 of a total of 30 transects).

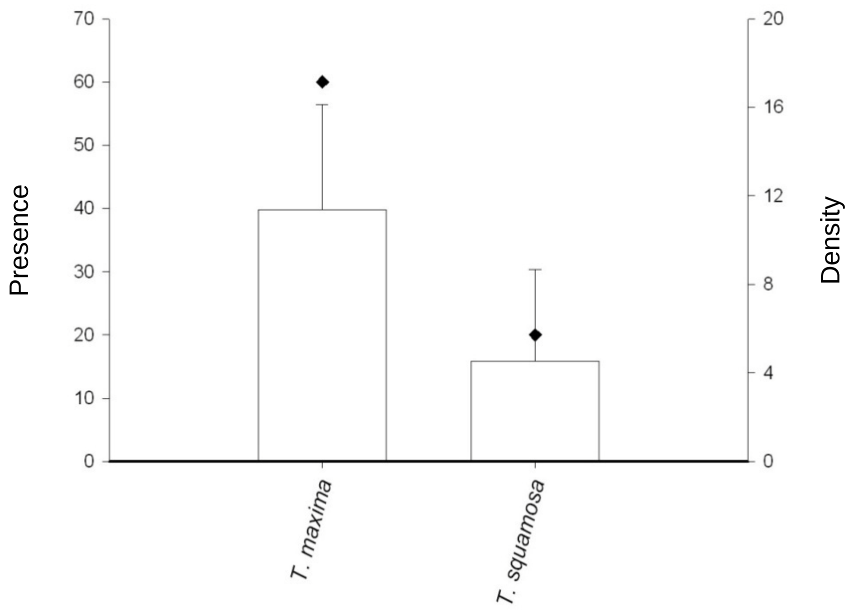

Figure 5.29b: Presence and mean density of giant clam species at Lakeba based on MOP survey in 2003.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

In the 2009 surveys, *T. maxima* and *T. squamosa* were also noted, but none were recorded during the broad-scale survey. However, at the fine-scale station surveyed inside the lagoon, both species were recorded sporadically (respectively at 44% and 6% of RBt stations) and at very low densities (respectively 25.2 /ha ±8.3 and 2.6 /ha ±2.6) (Figure 5.29c). Four specimens of *T. maxima* were also recorded outside the barrier reef during the RFs survey.

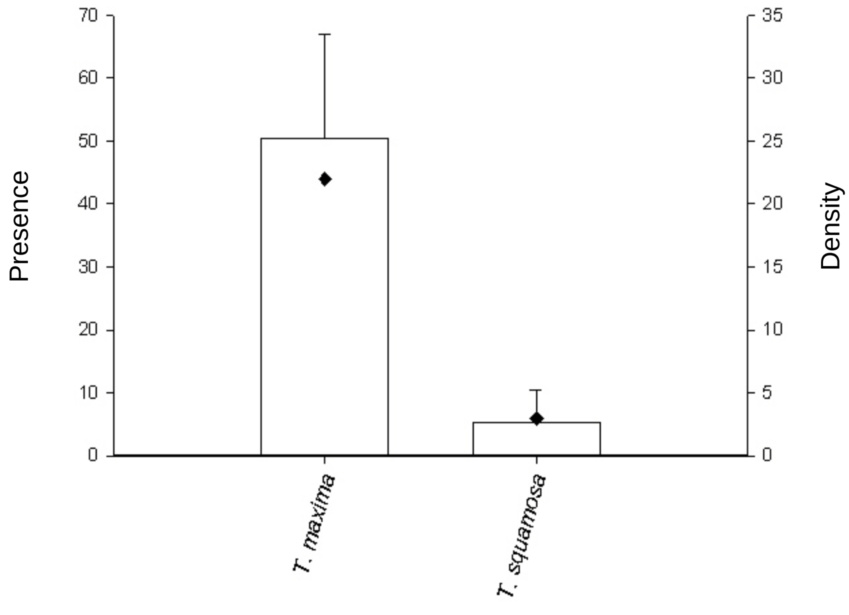

Figure 5.29c: Presence and mean density of giant clam species at Lakeba based on RBt survey in 2009.
Presence is measured as % of stations surveyed where clams were present and denoted by black diamonds; density is measured in numbers per hectare and is represented by bars (+SE).

In 2003, a total of 13 *T. maxima* (mean length 20.2 cm ±1.8) and eight *T. squamosa* (mean length 16.2 cm ±1.4) were recorded during fine-scale and broad-scale assessments (Figure 5.30a).

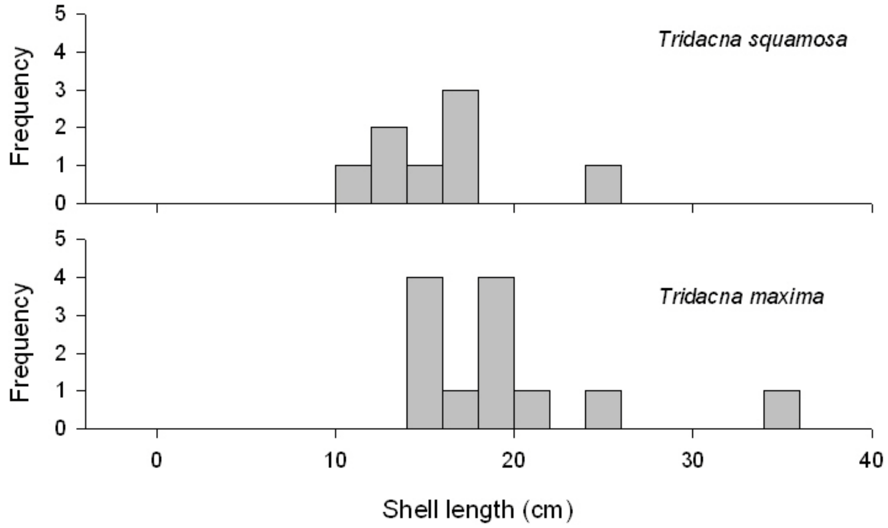

Figure 5.30a: Size frequency histograms of giant clam shell length (cm) from independent surveys at Lakeba in 2003.

In 2003, it was not clear from the surveys whether a complete range of clam lengths was present at Lakeba, although large-sized *T. maxima* clams and smaller-sized *T. squamosa* clams were noted on the outer-reef slope. The mean size of *T. maxima* recorded represents a clam of over 10 years old, while the average size of the faster growing *T. squamosa* (which grows to an asymptotic length L_∞ of ~40 cm) represents a clam ~4–5 years old (Figure 5.30a).

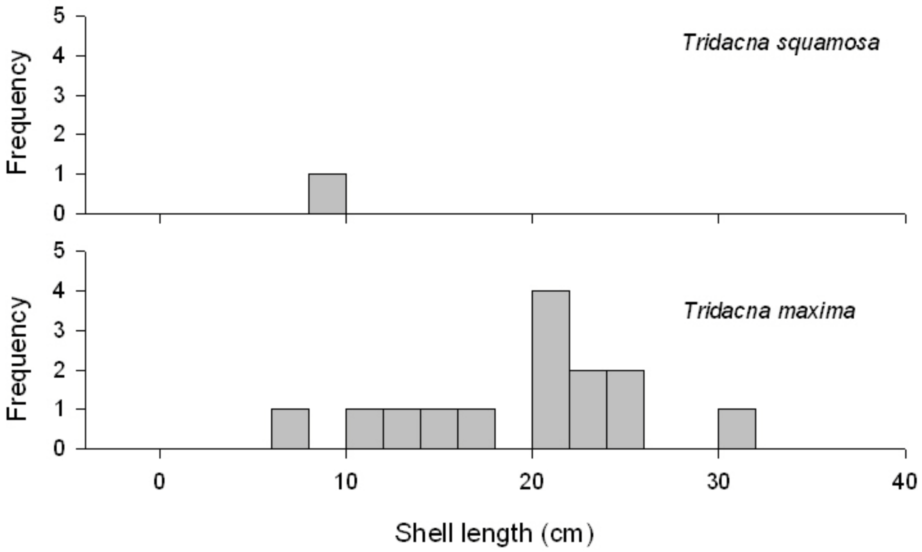

Figure 5.30b: Size frequency histograms of giant clam shell length (cm) from independent surveys at Lakeba in 2009.

In 2009, 14 *T. maxima* clams (mean length 20.1 cm ±1.7) and only one *T. squamosa* (length 10.0 cm) were recorded during the survey (Figure 5.30b). As in 2003, the average size for *T. maxima* was large, but the size frequency profile in 2009 was quite different. Young specimens were recorded, showing that the limited stock had still been recruiting in the recent past, but it is possible that recruitment is very limited due to the scarcity of the specimens. Most of the clams were recorded away from the accessible parts of the fishing ground, which might explain the large average size.

In summary, in Lakeba as in the other three Fiji Islands sites, *T. maxima* and *T. squamosa* were the only two species of giant clam found. The stocks of both resources remain at the lowest level in comparison with the other sites in the region. The density of *T. maxima*, however, was better than that of *T. squamosa*, which is common in all the sites assessed in the region (*T. maxima* being the most common species). The average size of *T. maxima* was relatively large (>20 cm), but clams were scattered over the large reef, potentially hidden from fishers. The young *T. maxima* clams recorded in both surveys indicate active breeding and, considering the less favourable environments found in Lakeba (predominantly sand), stronger management effort is needed to protect this resource.

5.4.2 2003–2009 stock status trends – mother-of-pearl species (MOP): Lakeba

Lakeba has a moderately extensive suitable habitat for the commercial topshell, *Trochus niloticus*, that is predominantly restricted to the outer reef (lineal distance ~27.3 km). Although the reefs within the lagoon at Lakeba are not extensive, this section of the lagoon is part of a larger lagoon system (151 km in length), which has a lineal reef front in excess of 215 km.

In the 2003 survey, *T. niloticus* were recorded at the barrier reef (Table 5.13a). The highest-density stations were recorded in lagoon and barrier-reef shallows. The highest-density station recorded at Lakeba was 104 /ha for MOPt and 28 /ha for RFs, both on the west side of Tilagica passage. In well defined MOPt surveys, this equates to five trochus per station.

Table 5.13a: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Lakeba in 2003
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	1.2	0.5	7/12 = 58	8/72 = 11
MOPt	0	0	0/4 = 0	0/24 = 0
MOPs	0	0	0/1 = 0	0/6 = 0
Tectus pyramis				
B-S	0.7	0.4	3/12 = 25	3/72 = 4
MOPt	10.4	10.4	1/4 = 25	2/24 = 8
MOPs	22.7		1/1 = 100	3/6 = 50
Trochus niloticus				
B-S	0	0	0/12 = 0	0/72 = 0
MOPt	72.9	27.6	3/4 = 75	10/24 = 42
MOPs	37.9		1/1 = 100	5/6 = 83

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

In 2009, *T. niloticus* were moderately common but found at low to very low densities, mostly on the back-reef (Table 5.13b). At RBt stations, the average density was 40.8 /ha ±17.5, with a maximum density recorded on the back-reef (278 /ha), east of Tilagica passage.

No aggregations were recorded on the outer slope; therefore, no transect stations were conducted at depth (MOPt).

Table 5.13b: Presence and mean density of *Pinctada margaritifera*, *Tectus pyramis* and *Trochus niloticus* in Lakeba in 2009
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	1.2	0.8	2/7 = 29	3/36 = 8
RBt	6.9	3.8	3/16 = 19	3/99 = 3
RFs	0	0	0/2 = 0	0/12 = 0
MOPs	0	0	0/1 = 0	0/6 = 0
Tectus pyramis				
B-S	0	0	0/7 = 0	0/36 = 0
RBt	48.6	13.7	11/16 = 69	19/99 = 19
RFs	1.7	1.7	½ = 50	1/12 = 8
MOPs	74.9		1/1 = 100	6/6 = 100
Trochus niloticus				
B-S	0	0	0/7 = 0	0/36 = 0
RBt	40.8	17.5	8/16 = 50	14/99 = 14
RFs	3.5	0	2/2 = 100	2/12 = 17
MOPs	6.2		1/1 = 100	1/6 = 17

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

In 2003, the mean size (basal width) of *T. niloticus* was 10.1 cm ±0.5 (n = 19) from survey, but a full range of trochus sizes was represented (Figure 5.31a). Trochus from fishers' catches ranged from 6.6 cm to 12.7 cm basal width (average 9.8 cm ±0.2, n = 87). This catch was recorded from six fishers working the outer reefs on a banana-style fibreglass hull. The catch rate (shells per hour) averaged 16.8 ±3.2 from three hours of fishing. As can be seen from the length frequency graph, trochus are still recruiting.

The length frequency graph (Figure 5.31a) reveals that a full range of trochus sizes was still in the water at Lakeba, and that small, juvenile shells were still present and entering the fishing size classes (recruitment). For this cryptic species, younger shells are normally only picked up in surveys from the size of about 5.5 cm, when small trochus are emerging from a cryptic style of life, and joining the main stock. In addition to having young shells, signalling recruitment, there were also older, large shells in the fishery.

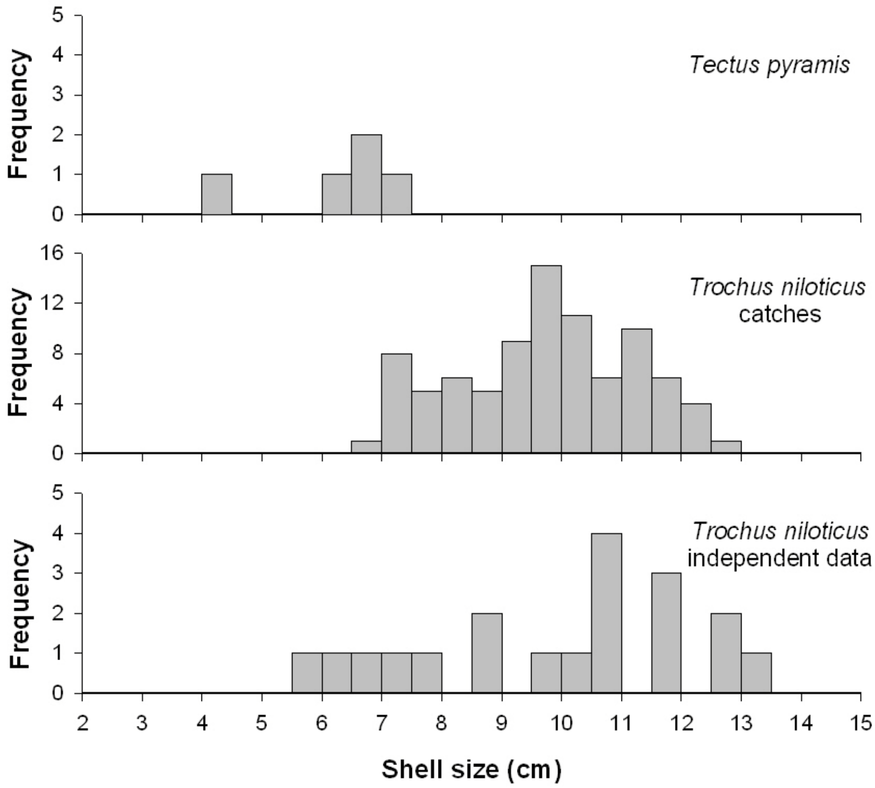

Figure 5.31a: Size frequency histograms of *Tectus pyramis* and *Trochus niloticus* basal shell length (cm) from fishers' catches and from independent surveys at Lakeba in 2003.

In 2009, the mean basal size for *T. niloticus* was 8.7 cm ±0.7 (n = 22 specimens). All size classes, from juveniles of 4.0 cm to large, old specimens of 14.0 cm, were present, showing continuous recruitment during the previous decade (Figure 5.31b).

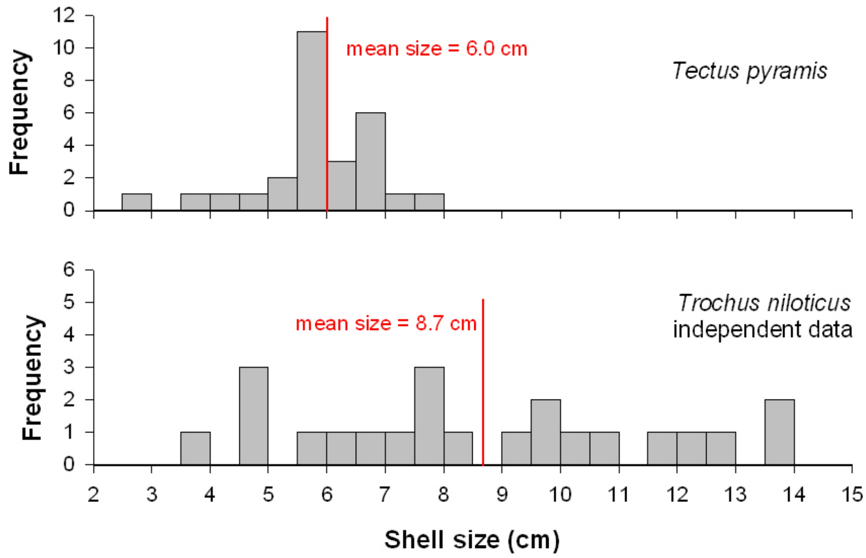

Figure 5.31b: Size frequency histograms of *Tectus pyramis* and *Trochus niloticus* basal shell length (cm) from independent surveys at Lakeba in 2009.

In 2003, the green topshell, *Tectus pyramis* (of low commercial value), a species closely related to trochus, with similar distribution and life-history characteristics, was also recorded in surveys (Table 5.13a). The presence and density of this species was low. Although some agents have started to buy *T. pyramis* as a cheap substitute for trochus for blank manufacture (far fewer blanks can be cut from a similar-sized shell), no *T. pyramis* were recorded in creel surveys.

In 2009, *T. pyramis* was recorded more commonly than in 2003 (present in 69% of RBt stations), but still at low density (Table 5.13b).

In 2003, *Pinctada margaritifera*, a normally cryptic and sparsely distributed pearl oyster species, was recorded in seven broad-scale stations (in 11% of transects, see Table 5.13a). The mean size of these blacklip pearl oysters recorded from independent survey was 15.8 cm ±0.5 (n = 8). Taking into account the cryptic nature of *P. margaritifera* and its general low density in open reef systems characteristic of Melanesia, these results describe a medium occurrence of *P. margaritifera*.

In 2009, the blacklip pearl oyster was not common (present in 8% of B-S stations) and recorded at a low average density of 1.2 specimens/ha ±0.8. The average size was 14.0 cm ±1.2 but this was based only on three specimens.

5.4.3 2003–2009 stock status trends – infaunal species and groups: Lakeba

Infaunal shell beds were well suited to the fishing ground of Lakeba. This area was the more enclosed end of a major lagoon system, subject to a large land influence and with extensive areas of soft benthos. Lakeba was also fringed by mangroves (Mangroves were located on much of the shoreline of Vanua Levu.) and seagrass and concentrations of in-ground resources were well targeted by the fishers, both in front of the village and at embayments to the north. The predominant target shells were *Anadara* spp. (*kaikoso*).

In 2003, fine-scale infaunal stations (quadrat surveys) were completed at three main locations in the fishery (Figure 5.28a), which held the main target species, *Anadara* spp. (arc shells), at a range of densities (2–3.7 individuals/m²), with a mean station density of 2.7 /m² ±0.5.

Kaikoso (arc shells) were common, being recorded across all the locations sampled (in 89% of stations), but their presence was also patchy in all locations (only noted in 38% of quadrat groupings; see Methods). The greatest density of *Anadara* spp. was noted in the northeastern embayment (average density 3.7 /m² ±1.0), where the station with the highest density had *kaikoso* at 4.5 /m² (dense seagrass and soft ground, very characteristic of a depositional environment). In addition to *Anadara* spp., other resource species noted in infaunal surveys included *Pitar prora*, *Pinna* sp., *Modiolus* sp. and *Atrina vexillum*.

In 2009, nine soft-benthos infaunal stations were surveyed at the main fishing grounds. (Stations were completed in two of the three areas assessed in 2003; see Figure 5.28b). *Anadara* spp. were well distributed over the fishing ground and recorded in 78% of SBq stations. Densities for *Anadara* spp. (*Anadara antiquata* and *Anadara* sp.) were found to have increased since 2003 to the high density of 17.3 /m² ±4.8. Lakeba is the only site of the four Fiji Islands sites assessed where the *Anadara* spp. resource has increased since 2003.

In the 2003 survey, the mean lengths of *Anadara* spp. ranged from 5.3 cm to 6.0 cm for the three locations sampled, and significantly more shells were recorded in the embayed easterly seagrass location (Figure 5.28a). Tebano (2005) recorded similar mean shell lengths at Abaiang in his 1994 study (5.5 cm ±0.6 SD, 4.9 cm ±0.6 SD and 5.0 cm ±0.4 SD).

Creel surveys also gave us an indication on the status of the fishery. In this case, fishers (generally women and children), were collecting between 378 and 621 arc shells per trip (4 fishers), and indicated that they could collect well over 100 shells per hour. The size of the shells that they collected ranged from 3.2 to 8.5 cm (mean length 6 cm ±0.04 and mean weight 82.2 g ±1.8) (Figure 5.32a). In addition to arc shells, other resource species were also taken: *Gafrarium* sp., *Cerithium aluco*, *Lingula* sp., *Periglypta puerpera* and *Vasticardium* sp. These species were all targeted in smaller numbers.

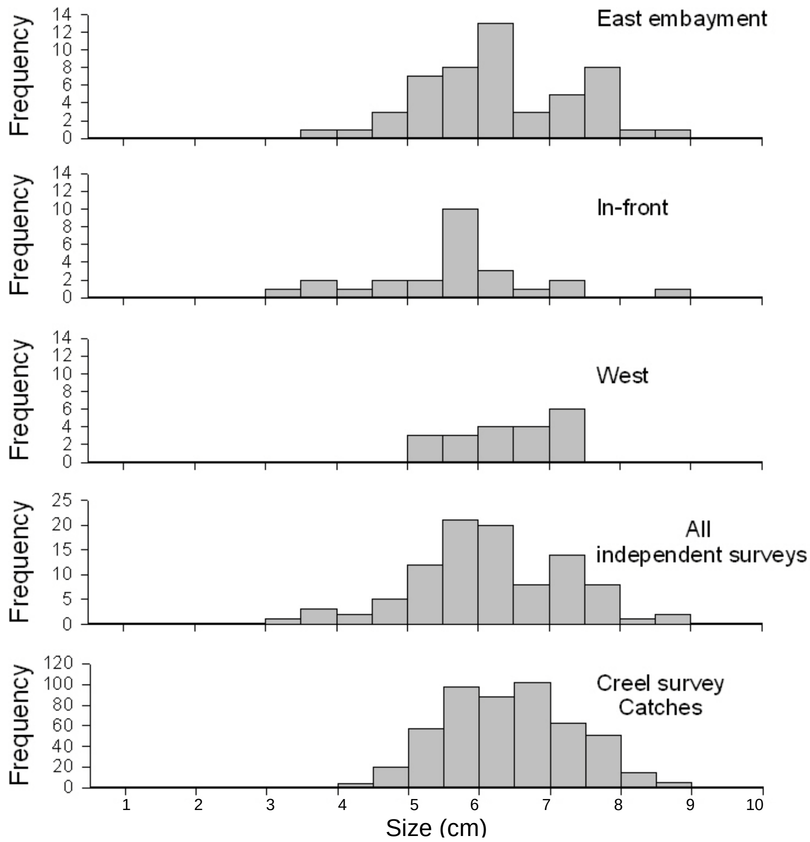

Figure 5.32a: Size frequency histograms of arc shell *Anadara* spp. length (cm) at various sites and in creel survey at Lakeba in 2003.

In the 2009 survey, the size of arc shells ranged from 1.5 cm to 9.0 cm. The mean length was 5.5 cm ±0.1 (n = 291), which is similar to that observed in 2003 (Figure 5.32b).

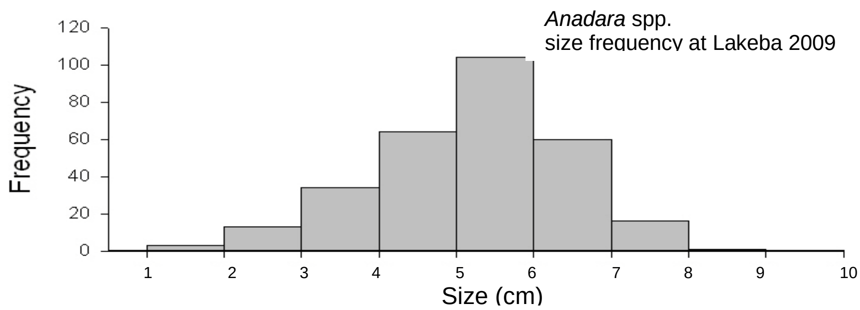

Figure 5.32b: Size frequency histogram of arc shell *Anadara* spp. length (cm) at Lakeba in 2009.

No creel survey was completed in 2009.

The arc shell (*Anadara* spp., *kaikoso*) resource of Lakeba was a highlight of all the results of the Fiji Islands sites. The resource shows a major improvement since 2003, with density increasing from 2.7 shells/m² ±0.5 to 17.3 shells/m² ±4.8 in 2009 (an increase of >600%). The *Anadara* resource of Lakeba is healthy at the moment but a sustainable harvest system must be developed to help the community to manage this resource.

5.4.4 2003–2009 stock status trends – other gastropods and bivalves: Lakeba

In 2003, *yaga* (or *ega*), the smaller spider conch (both *Lambis lambis* and *L. crocata*) were recorded in broad-scale surveys at low-to-moderate density. In soft-benthos transect stations the mean density was higher at 44.4 ±16.0 /ha (Appendices 4.4.2–4.4.3 for 2003). Six specimens of the larger Seba's conch (*L. truncata*) were noted, but no aggregations of the small strawberry conch (*Strombus luhuanus*).

In 2009, two species of *Lambis* were recorded (*L. lambis* and *L. truncata*). *L. lambis* was recorded at low density (5.2 /ha ±3.6) at RBt stations, while *L. truncata* was recorded at moderate density (10.4 /ha ±6.0). *Strombus luhuanus* was sporadically found and recorded at the low-to-moderate density of 68.6 /ha ±26.0 at RBt stations.

Turbo spp. (turban shells) are commonly collected along exposed reef fronts in the Pacific but were not common in the 2003 survey. Only a single *Turbo argyrostomus* and three *T. crassus* specimens were noted.

In the 2009 survey, turban shells were anecdotally recorded, with only three specimens of *Turbo chrysostomus* and one specimen of *T. argyrostomus* recorded.

Other resource species targeted by fishers (e.g. *Cerithium*, *Charonia*, *Conus*, *Cypraea* and *Tutufa*) were recorded during independent surveys (Appendices 4.4.1–4.4.9 for 2003 and 2009). Data on other bivalves in broad-scale and fine-scale benthos surveys, such as *Atrina*, *Hyotissa*, *Modiolus*, *Pinna*, *Pitar* and *Spondylus* are also in Appendices 4.4.1–4.4.9 for 2003 and 2009.

In 2003, creel surveys were conducted at Lakeba of fishers targeting mangroves, infaunal species from seagrass, and MOP species on the reef front (Appendix 4.4.11 for 2003). A list of the species collected is given in Table 5.14a.

Table 5.14a: List of species noted in catches during creel surveys in Lakeba in 2003

Group	Genus	Species	Number
Bêche-de-mer	*Actinopyga*	*mauritiana*	3
Bêche-de-mer	*Holothuria*	*nobilis*	1
Bêche-de-mer	*Thelenota*	*ananas*	1
Bivalve	*Anadara*	*antiquata*	2686
Bivalve	*Anadara*	spp.	6
Bivalve	*Chama*	spp.	17
Bivalve	*Gafrarium*	spp.	4
Bivalve	*Isognomon*	*ephippium*	1
Bivalve	*Periglypta*	*puerpera*	1
Bivalve	*Spondylus*	*squamosus*	1
Bivalve	*Vasticardium*	spp.	1
Crustacean (Crab)	*Scylla*	spp.	6
Crustacean (Crab)	*Thalamita*	*crenata*	116
Gastropod	*Cerithium*	*aluco*	19
Gastropod	*Lambis*	*lambis*	5
Gastropod	*Polinices*	*mammilla*	1
Gastropod	*Saccostrea*	*cuccullata*	1
Gastropod	*Trochus*	*niloticus*	309
Brachiopod	*Lingula*	spp.	1

One species that is eaten in the Pacific Islands but not often reported, is the Brachiopod lamp shell, *Lingula* sp. (*voce* or *dova*). These filter feeders burrow into the sediment and leave a slit-shaped opening; these openings were noted at high density beside the mangrove right outside the village.

In 2009, creel surveys were conducted of three groups of fishers. Due to lack of time during these surveys, only bêche-de-mer were recorded. *Anadara* spp., lobsters, seaweed and *Lambis lambis* were also collected but no data on these other resources were collected. The catch composition (Figure 5.33) reveals the global depletion of the high-value sea cucumber species, with 75% of the catch made up of the two low-value species *Holothuria atra* and *H. edulis* (Table 5.14b).

Table 5.14b: List of species noted in catches during creel surveys in Lakeba in 2009

Group	Genus	Species	Count
Bêche-de-mer	*Bohadschia*	*argus*	4
Bêche-de-mer	*Holothuria*	*atra*	55
Bêche-de-mer	*Holothuria*	*edulis*	30
Bêche-de-mer	*Holothuria*	*fuscogilva*	5
Bêche-de-mer	*Holothuria*	*nobilis*	2
Bêche-de-mer	*Stichopus*	*chloronotus*	11
Bêche-de-mer	*Stichopus*	*hermanni*	2
Bêche-de-mer	*Thelenota*	*ananas*	4

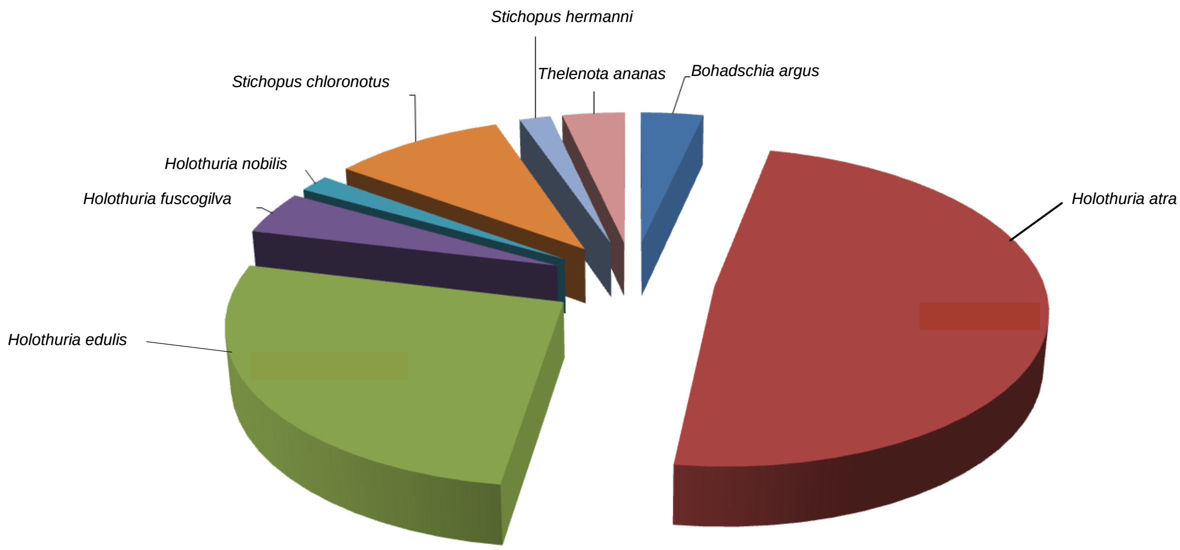

Figure 5.33: Species composition of bêche-de-mer catches at Lakeba in 2009.

5.4.5 2003–2009 stock status trends – lobsters and crabs: Lakeba

Lobster species have cryptic, nocturnal, seasonal and lunar behaviours, which make them difficult to monitor in a widespread invertebrate survey. Any snap-shot survey, such as the PROCFish survey, is unable to accurately monitor these resources; and no dedicated survey method was developed, as the results would not reflect the real status of the stocks. However, ten lobsters were recorded in general broad-scale and reef-front searches in 2003, most of which were juveniles. Six lobsters (*Panulirus versicolor*) were recorded at RBt stations in 2009. No slipper lobsters (*Parribacus* spp.) or sand lobsters (*Lysiosquillina* spp.) were noted in either survey.

Mud crabs (*Scylla serrata*) and a number of other shore crabs, such as *Thalamita crenata*, were present at Lakeba; however, an independent snap-shot survey would not supply a reliable indication of crab abundance and was not conducted in either survey period. In 2003, a creel survey of fishers showed that *Thalamita crenata* was common when targeted. This portunid crab commonly forages during daytime, thus differing from the majority of swimming crabs, and fishers were able to collect large numbers on short fishing trips close the village (48–68 crabs per trip). *Scylla serrata* was less common, and was collected by one fisher at a rate of 1.5 crabs per hour. The local village Cooperative Store had stopped buying mangrove crabs due to the difficulty of keeping them alive for export to Labasa.

5.4.6 2003–2009 stock status trends – sea cucumbers[9] : Lakeba

Lakeba is found on the north-sloping shoreline of the large land mass of Vanua Levu. Inshore waters near Lakeba village are largely influenced by land inputs in the form of river outflows emptying into the lagoon, although these are shielded by the extensive mangroves. Further offshore the lagoon is more influenced by oceanic factors and water movement around the

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

passages is significant. However, in general, the system is shallow and soft sediments predominate.

The open lagoon has a full range of environments suitable for sea cucumbers, from restricted, embayed areas of shallow lagoon, to wave-impacted reef-fronts outside the barrier. Reef margins and mixed hard and soft benthos provide suitable habitat for these deposit feeders.

In both the 2003 and 2009 surveys, species presence and density were determined through broad-scale, fine-scale and dedicated survey methods (Tables 5.12a and b; also see Methods). Despite the lack of extensive hard benthos, there was a wide range of environments found in the vicinity of Lakeba. In 2003, 17 species of commercial sea cucumbers and one indicator species were recorded during in-water assessments and one extra species was recorded in fishers' catches (*Holothuria nobilis*) (Table 5.15a).

In 2009, 17 species of commercial sea cucumber species were recorded but no *Synapta* spp. (indicator species) were recorded. The total number of commercial species recorded in Lakeba in 2003 and 2009 is 19. In 2009, two major species, *Holothuria fuscogilva* (white teatfish) and *Actinopyga miliaris* (blackfish) were not recorded despite being recorded in 2003. In contrast, *Holothuria nobilis* (black teatfish), a high-value species, and *Thelenota anax* (amberfish), a deep-water species, were recorded in 2009 but not in 2003.

Common sea cucumber species associated with reef, the low-value flowerfish (*Bohadschia graeffei*) and the medium-value leopardfish (*B. argus*), were rare in the 2003 survey (recorded in 4–8% of broad-scale transects).

In 2009, these two species were also rare (recorded in 0% and 9% of broad-scale transects and 13% and 6% of soft-benthos transect stations).

The high-value black teatfish (*H. nobilis*), which is found on both inshore and back-reefs and at a range of depths (but predominantly in shallow water), was absent from records at Lakeba in 2003. Mitigating this result is the fact that this species is usually found at low density (<15 /ha) and associated with limestone benthos, which was not common at Lakeba. However, this species is also an indicator of fishing pressure due to its value and the fact that it is easily targeted by fishers working in shallow water on snorkel. This was the case when we interviewed trochus fishers returning from fishing MOP shell, in that they had only a single specimen in the boat (after the equivalent of 18 hours of fishing).

In 2009, two *H. nobilis* specimens were recorded, one during the broad-scale assessment and one during the deep dive. This illustrates again the rarity of the species at this site, due to fishing pressure as described in 2003.

In 2003, the medium/high-value greenfish (*Stichopus chloronotus*) was also not common, and only noted in broad-scale stations (in 8% of transects) at a low average density of 1.8 /ha ±0.7.

In 2009, *S. chloronotus* was also found to be uncommon and at low average density (in 9% of broad-scale transects; density 2.8 /ha ±1.9).

The mix of the oceanic influence and significant nutrient flows from Vanua Levu created benthos well suited to the surf redfish (*Actinopyga mauritiana*) at the barrier reef. In 2003, this species was noted in surveys but the average density was low, <5 /ha. In 2009, this species was recorded only once at RFs stations. These low densities are to be compared with densities recorded in other parts of the Pacific where this species is not overfished and reaches in excess of 600 /ha.

Unlike at the sites at Viti Levu, the deep-water redfish (*Actinopyga echinites*) was not found in high-density aggregations on the sandy back-reef either in the 2003 or 2009 surveys.

More protected areas of soft benthos, with small patches of hard benthos and rubble, were noted in the lagoon. These areas had shallows of seagrass, rubble covered in fleshy algae (*Sargassum*) and silty limestone banks with some coral. Most reef habitat was quite 'rich' and, where there was some relief and complexity, was suitable for the species most characteristic of the sea cucumber industry in Fiji Islands, the *dri* or blackfish, *A. miliaris*. In 2003, no blackfish were noted in day searches but they were noted at low-to-moderate density in night searches (as was the stonefish, *A. lecanora*).

In 2009, *A. miliaris* was absent from the survey despite two dedicated sea-cucumber night search stations completed.

Small numbers of elephant trunkfish (*Holothuria fuscopunctata*), snakefish (*H. coluber*) and brown sandfish (*Bohadschia vitiensis*) were recorded in both the 2003 and 2009 surveys. Snakefish is especially characteristic of 'richness' in a sedimentary system, as it is mostly recorded in places with significant organic deposits and rich silts.

In 2003, the lower-value lollyfish (*H. atra*) was moderately common (in ~40% broad-scale transects) but at low density (28.9 ±5.9 /ha), except in seagrass beds, where it occurred at moderate density (1463.9 ±467.3 /ha at SBt stations). Pinkfish (*H. edulis*), another low-value species, was relatively common (in 32% of B-S transects) and at moderate density.

In 2009, *H. atra* had a similar distribution to that observed in 2003, but a much lower density, especially at soft-benthos transect stations (22.7 /ha ±7.4). Pinkfish was rarer than in 2003 (present at 11% of B-S transects) but found locally at higher density than in 2003 (208.3 /ha ±121.5 at SBt stations).

Deep dives on SCUBA (sea cucumber day searches) can obtain a preliminary assessment of deep-water stocks such as the high-value white teatfish (*H. fuscogilva*), the prickly redfish (*Thelenota ananas*) and the lower-value amberfish (*T. anax*). In 2003, no deep survey stations were completed but seven white teatfish (*H. fuscogilva*) specimens were noted in a deep-water pool while on B-S surveys. Three prickly redfish (*T. ananas*) specimens were noted but amberfish (*T. anax*) was absent from surveys.

In 2009, one deep dive was completed. It revealed three species of sea cucumber: *H. nobilis*, which was only recorded once in the shallows, *T. ananas* and *T. anax*, which were absent from the 2003 survey (This is a typical deep-water survey that can be assessed mostly on scuba). This single deep-water station did not record any of the highly-prized *H. fuscogilva*, which is also absent from the shallow. All three species were recorded at very low density.
No creel survey was conducted for sea cucumber fishing; however, in 2003, an agent was interviewed regarding the nature and level of activity in the fishery at the time. The agent, Mr Maika Ralavo, explained that he operated using a radio telephone connection with his contacts in Labasa and employed ten divers to fish for product from Delavadra; there were

another ten teenage divers and an agent in Salevukoso. He explained that most agents employed professional divers. He stated that lollyfish was the most important catch by weight, followed by *dri loli* (blackfish), leopardfish, curryfish and brown sandfish. White teatfish remained the highest income earner followed by *dri loli*, *loa loa* (*H. nobilis*), then *sucandrau* (prickly redfish) and greenfish. He explained that both brown sandfish and sandfish (*H. scabra*) were eaten locally.

Lakeba is rich in sea cucumber habitats, and diversity was better than in all other sites, with a total of 19 commercial sea cucumber species. This is in contrast to Muaivuso, which had 12; Mali (8) and Dromuna (17). One of Lakeba's highly valued species, *A. miliaris* (*dri*) was recorded in 2003 but was absent in the 2009 survey. Even if more night assessments may have revealed the species, it is locally considered commercially extinct. *Dri* had been protected for four years inside the MPA prior to the opening to fishing in 2007 for the Church conference. In 2009, some *H. fuscogilva* were collected by fishers inside the middle lagoon. The stock of *S. horrens*, known in Lakeba as 'caterpillar' was present at relatively good densities. This species was present on the seagrass bed at Tilagica Island, and this area was declared a new MPA in 2009. Only one specimen of *H. scabra* (*dairo*) was recorded; Lakeba possesses extensive habitat suitable for this species to thrive but, unfortunately, overfishing is pushing the resource to the verge of extinction in this area.

In general, the abundance of sea cucumbers in Lakeba was low across all value grades in 2003 and 2009. Densities in 2009 dropped even lower than in 2003; even the lowest-value species were being heavily targeted. *H. atra* and *H. edulis* were the most important sea cucumber species in the catch of Lakeba fishers.

<u>Management considerations for sea cucumber</u>

Resource custodians are trying their best to manage their resources but their effort may not be successful to save their declining resources. When resource owners are not able to control the exploitation rate of the resource, the best option that can help them is a national action.

Subsistence use of sea cucumbers should be stopped immediately.

The ban on commercial use of *dairo* (*H. scabra*) should be reviewed to include subsistence use. Subsistence use today is equally as devastating on the resources as commercial harvesting. Thus *H. scabra* can no longer be exempt from national management policies and regulations.

A national ban on the sea cucumber fishery is recommended to assist the conservation effort at Lakeba. There should be no discretionary exemptions for exploitation except for research purposes. This ban should be enforced for all species at the village, provincial and national level. Once stocks have rebuilt to a significant level, the fishery can recommence at more reasonable rates of harvest to be determined by a national fishery plan.

A national sea cucumber fishery management plan should be developed to guide the industry to the future.

5.4.7 2003–2009 stock status trends – other echinoderms: Lakeba

No edible slate urchins (*Heterocentrotus mammillatus*) or collector urchins (*Tripneustes gratilla*) were recorded during either the 2003 or the 2009 surveys at Lakeba. No collector urchins were noted in creel surveys from gleaners of shallow-water seagrass areas, despite this species being suited to this environment. Both *Echinometra mathaei* and *Echinothrix diadema* were found at moderate-to-high density on occasion in the 2003 survey. In 2009 only a few *Echinometra mathaei* and *Echinothrix diadema* were sporadically recorded.

In 2003, the blue starfish (*Linckia laevigata*) was very common (in 83% of B-S transects) and at moderately high densities (mean of 178.5 /ha ±26.5 on B-S transects). In 2009, it was common (in 56% of B-S transects) and at a lower density (75.5 /ha ±25.9 on B-S transects).

A range of coralivore (coral eating) starfish were recorded at Lakeba. In 2003, the cushion star (*Culcita novaeguineae*, n = 27), the Kenya or dough-boy star (*Choriaster granulatus*, n = 5) and the crown-of-thorns starfish (*Acanthaster planci*, COTS, n = 5) were sporadically recorded. In 2009, *Culcita novaeguineae* (n = 8) and *Acanthaster planci* (n = 1) were recorded. None of these starfish pose a threat to coral health at their present density.

Marine protected area (MPA)

The management of the MPA in Lakeba has been a problem. An area of the inner reef flat of the Cakaunikuita reef, which was an MPA from 2003, was opened in 2007 to harvest sea cucumbers to raise funds for the Methodist Church Conference. Subsequently, the area returned to open-access. In January 2009, a new MPA was established on learning of the arrival of the SPC–Fiji Fisheries–USP survey team in February, but in a different area (Tilagica Island). A recommended potential MPA area would be from the old MPA across to Tilagica Island and straight out to the reef slope to protect a wider habitat for different resources.

Table 5.15a: Sea cucumber species records for Lakeba in 2003

Species	Common name	Commercial value [5]	B-S transects n = 72			SBt stations n = 15			Other stations SBq = 18; RFs = 3			Other stations Ns = 2; MOPt = 4		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deep water redfish	M/H												
Actinopyga lecanora	Stonefish	M/H	0.2	13.4	1							8.9	17.8	50 Ns
Actinopyga mauritiana	Surf redfish	M/H							3.9	5.9	67 RFs			
Actinopyga miliaris	Blackfish	M/H				2.8	41.7	7				13.3	26.7	50 Ns
Bohadschia argus	Leopardfish	M	1.3	15.4	8									
Bohadschia graeffei	Flowerfish	L	0.6	13.3	4							10.4	41.7	25 MOPt
Bohadschia similis	False sandfish	L				22.2	111.1	20	0	0.5	6 SBq			
Bohadschia vitiensis	Brown sandfish	L	0.6	21.4	3									
Holothuria atra	Lollyfish	L	29.4	72.9	40	1466.7	1833.3	80						
Holothuria coluber	Snakefish	L	0.2	14.3	1	5.6	41.7	13						
Holothuria edulis	Pinkfish	L	97.8	306.2	32	44.4	222.2	20						
Holothuria fuscogilva [4]	White teatfish	H	1	25.1	4									
Holothuria fuscopunctata	Elephant trunkfish	M	0.6	13.3	4									
Holothuria leucospilota	Black fringed fish	L												
Holothuria nobilis [4]	Black teatfish	H												
Holothuria scabra	Sandfish	H				30.6	152.8	20						
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	1.8	21.4	8									
Stichopus hermanni	Curryfish	H/M	0.4	14.3	3									
Stichopus horrens	Peanutfish	H/M										84.4	84.4	100 Ns
Synapta spp.	-	-				5.6	41.7	13						
Thelenota ananas	Prickly redfish	H	0.5	12.7	4									
Thelenota anax	Amberfish	M												

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

Table 5.15b: Sea cucumber species records for Lakeba in 2009

Species	Common name	Commercial value [5]	B-S transects n = 36			Other stations RBt = 16; SBt = 4			Other stations SBq = 9; RFs = 2; MOPs = 1			Other stations Ds = 4; Ns = 2		
			D [1]	DwP [2]	PP [3]	D	DwP	PP	D	DwP	PP	D	DwP	PP
Actinopyga echinites	Deepwater redfish	M/H												
Actinopyga lecanora	Stonefish	M/H	0.5	16.7	3									
Actinopyga mauritiana	Surf redfish	M/H							1.7	3.5	50 RFs			
Actinopyga miliaris	Blackfish	M/H												
Bohadschia argus	Leopardfish	M				5.2	41.7	13 RBt						
Bohadschia graeffei	Flowerfish	L	1.9	22.2	9	1.7	27.8	6 RBt						
Bohadschia similis	False sandfish	L							*	*	* SBq	11.4	22.8	50 Ns
Bohadschia vitiensis	Brown sandfish	L										22.8	22.8	100 Ns
Holothuria atra	Lollyfish	L	22.7	58.3	39	62.5 41.7	333.3 166.7	17 RBt 25 SBt	*	*	*SBq	11.4	22.8	50 Ns
Holothuria coluber	Snakefish	L				7.8	125.0	6 RBt						
Holothuria edulis	Pinkfish	L	11.1	100.0	11	44.3 208.3	177.1 416.7	25 RBt 50 SBt						
Holothuria fuscogilva [4]	White teatfish	H												
Holothuria fuscopunctata	Elephant trunkfish	M	0.5	16.7	3	1.7	27.8	6 RBt						
Holothuria leucospilota	-	L												
Holothuria nobilis [4]	Black teatfish	H	0.5	16.7	3							2.2	2.2	100 Ds
Holothuria scabra	Sandfish	H				10.4	41.7	25 SBt						
Holothuria scabra versicolor	Golden sandfish	H												
Stichopus chloronotus	Greenfish	H/M	2.8	33.3	9	36.5	194.4	17 RBt	6.2	6.2	50 MOPs			
Stichopus hermanni	Curryfish	H/M				2.6	41.7	6 RBt				11.4	22.8	50 Ns
Stichopus horrens	Dragonfish	M/L							*	*	* SBq			
Synapta spp.	-	-												
Thelenota ananas	Prickly redfish	H										4.4	4.4	100 Ds
Thelenota anax	Amberfish	M										2.2	2.2	100 Ds

[1] D = mean density (numbers/ha); [2] DwP = mean density (numbers/ha) for transects or stations where the species was present; [3] PP = percentage presence (units where the species was found); [4] the scientific name of the black teatfish has recently changed from *Holothuria* (*Microthele*) *nobilis* to *H. whitmaei* and the white teatfish (*H. fuscogilva*) may have also changed name before this report is published. [5] L = low value; M = medium value; H= high value; H/M is higher in value than M/H; B-S transects= broad-scale transects; RBt = reef-benthos transect; SBt = soft-benthos transect; SBq = soft-benthos quadrat; RFs = reef-front search; MOPs = mother-of-pearl search; Ds = day search; Ns = night search; * = Species were present at SBq stations but densities are not relevant considering the small area assessed.

5.4.8 Discussion and conclusions: invertebrate resources in Lakeba

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

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

- A wide range of lagoon environments, some of which were suitable for giant clams, were present in the intermediate and outer reaches of the lagoon system in front of Lakeba village. However, there was a general lack of large contiguous reefs, and the majority of the benthos was sedimentary (soft benthos, rubble and some small, isolated reef patches), and was largely land-influenced.

- Only two clam species were recorded at Lakeba in the 2003 and 2009 surveys; the elongate clam (*Tridacna maxima*) and the fluted clam (*T. squamosa*).

- Data on distribution and abundance showed that giant clam stocks were rare across the lagoon both in 2003 and 2009. This is due both to the nature of the environment and the effects of fishing, although it is difficult to know which has the greater influence within such a system. In other countries in the Pacific, larger clams, such as *T. squamosa*, which do not always embed themselves into hard substrate, are often the first to become depleted through fishing and, as we see in front of Lakeba, the number and size range of *T. squamosa* revealed that stocks were impacted by fishing.

- Continued strong management of giant clam stocks, especially the protection of parts of the fishery, will help to maintain recruitment and ensure the current status of clams is not going to degrade further. There is a need to protect some of the remaining stocks to ensure successful fertilisation events (Sperm and eggs fertilise in the water column after release by male and female clams). Clams have a complex development, which means that only the larger (older) individuals develop into females (protandry), and therefore regular harvest of larger clams will lead to a shortage in egg supply and slow collapse of stocks. This is especially true in vulnerable environments such as the generally sandy lagoon system in front of Lakeba, where clams are not naturally concentrated around intermediate reefs.

In summary, the condition of the reefs, distribution, density and length recordings of MOP species revealed the following:

- The barrier reefs at Lakeba provided a moderately extensive and suitable habitat for the commercial topshell, *Trochus niloticus*. As this site is connected to the extensive reef that spans the north of Vanua Levu, there is potential to support a significant population of commercial topshell. Local reef conditions at Lakeba constitute a good habitat for juvenile and adult trochus growth, as reef surfaces are ‘richer’ than those in the more oceanic-influenced atoll systems.

- Trochus shell is found inside the barrier reef on the more favourable back-reef area on the west side of Tilagica passage. On the outer slope of the barrier reef, habitat was moderate to good for habitation but, as in Mali, very few trochus were found on the outer

Cakaulevu reef. Resource depletion due to fishing is the most possible cause but also the outer reef may not be the most favourable area for trochus.

- Data on trochus distribution and density suggest that stocks in Lakeba are presently not abundant and are impacted by past fishing. Within the "core" aggregations identified (where trochus are typically in greatest abundance) there was still significant potential for stocks to increase in number, and no areas were noted where densities reached 500 shells/ha, a threshold density that can be considered a minimum measure before commercial harvests can be considered.

- Size class information reveals that in 2009 most sizes were present, which shows that trochus were still spawning and recruiting. Large trochus, which are the main source of future generations, were still present although low in number. Larger female shells (>11cm base width) have the potential to produce far greater numbers of eggs than those just a couple of cm smaller.

- Other mother-of-pearl stocks, such as blacklip pearl oysters (*Pinctada margaritifera*) were recorded in surveys at low (2009) to moderate (2003) density.

- The arc shell (*Anadara* spp.) resource status showed a major increase in the 2009 results. Density in 2003 was 2.7 shells/m^2 ±0.5 while in 2009 it was 17.3 shells/m^2 ±4.8. The 2009 survey may have targeted the best aggregations; however, this result indicates that the resource is healthy. Developing a sustainable harvest system now is of paramount importance to ensure the sustainability of the resource.

- Density improvement at the inner reef flat of Cakaunikuita may be assisted by the MPA, which was established from 2003 to 2007.

In summary, the environment for sea cucumbers, their distribution, density and length recordings reveal the following:

- Habitat for sea cucumbers in the lagoon at Lakeba is both extensive in scale and varied in structure and environment. The large lagoon system is predominantly protected and land-influenced (suitable for these deposit-feeding resources) but more exposed, oceanic areas are also found near the barrier and on the reef slope. There is a relative shortage of hard benthos in the lagoon but, in general, a full range of habitats is present.

- The number of species of sea cucumbers recorded at Lakeba (n total = 19), was relatively good, illustrating the variety of habitats present at Lakeba. It is likely that more extensive diving in deep water and more time spent in searching the intermediate reefs or surveying the mangroves would increase the total number of species recorded (species number recorded at all Fiji Islands sites = 25).

- *Actinopyga miliaris* (blackfish) or *dri* was not recorded in 2009, although local fishers reported that the species was harvested in 2007. *Holothuria fuscogilva* was not recorded during the 2009 underwater survey but was recorded in the catch of fishers. *H. nobilis* and *Thelenota anax* were both recorded in 2009 but not in 2003.

- In general the abundance of sea cucumbers was very low across all value grades. Even the lowest-value species were not at high density in 2003, and interviews with agents supported the assumption that a wide range of value classes of sea cucumber were being actively targeted. In 2009 the survey reported overall lower estimated densities, showing that sea-cucumber resources are at a much more depleted level than in 2003.

- The 2003 preliminary survey suggested that the occurrence and density of sea cucumbers was too low for commercial collection, and that fishing should be halted for an extended period to allow stocks to rebuild. The 2009 survey confirmed that the fishery should be urgently closed, as most species stocks are at critically low levels. Lakeba presents a very suitable site for a significant sea cucumber fishery and, once stocks have rebuilt to significant numbers, the fishery can recommence at more reasonable rates of harvest.

5.5 Overall recommendations for Lakeba

- The community-based management and monitoring in place in Lakeba be strengthened to ensure the sustainability of finfish and invertebrate resources for the future.

- The community continue to support the marine protected area (MPA) and expand the area covered if possible, especially to cover the habitats of the giant clams *Tridacna maxima* and *T. squamosa* on the eastern side of Tilagica passage, and the existing trochus stocks.

- An awareness programme be developed and implemented to educate people and communities on the need for management to sustain resources on a long-term basis.

- Strong management of giant clam stocks be implemented to enable sufficient recruitment to maintain the current status.

- Introduction of other giant clam species be considered.

- Some larger clams be collected and placed in the MPA for protection to allow them to spawn and regenerate or rebuild stocks over time.

- The trochus stocks be protected from fishing for at least five years so they can benefit from the increased spawning activity that a higher-density base population will provide, thus allowing stocks to rebuild to a minimum of 500–600 shells/ha before commercial harvests are considered.

- Trochus be re-introduced to Lakeba reef to develop a stronger spawning stock on the outer reefs of the barrier in front of the village and either side of Tilagica passage.

- The management of sea cucumbers be strengthened, and a total ban on fishing implemented (with no exceptions) and enforced to allow all of the commercial species to recover.

- Regulations on the harvesting of juvenile and egg-bearing female lobsters and crustaceans in general be urgently developed and adopted.

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APPENDIX 1: SURVEY METHODS

1.1 Socioeconomic surveys, questionnaires and average invertebrate wet weights

1.1.1 Socioeconomic survey methods

Preparation

The PROCFish/C socioeconomic survey is planned in close cooperation with local counterparts from national fisheries authorities. It makes use of information gathered during the selection process for the four sites chosen for each of the PROCFish/C participating countries and territories, as well as any information obtained by resource assessments, if these precede the survey.

Information is gathered regarding the target communities, with preparatory work for a particular socioeconomic field survey carried out by the local fisheries counterparts, the project's attachment, or another person charged with facilitating and/or participating in the socioeconomic survey. In the process of carrying out the surveys, training opportunities are provided for local fisheries staff in the PROCFish/C socioeconomic field survey methodology.

Staff are careful to respect local cultural and traditional practices, and follow any local protocols while implementing the field surveys. The aim is to cause minimal disturbance to community life, and surveys have consequently been modified to suit local habits, with both the time interviews are held and the length of the interviews adjusted in various communities. In addition, an effort is made to hold community meetings to inform and brief community members in conjunction with each socioeconomic field survey.

Approach

The design of the socioeconomic survey stems from the project focus, which is on rural coastal communities in which traditional social structures are to some degree intact. Consequently, survey questions assume that the primary sectors (and fisheries in particular) are of importance to communities, and that communities currently depend on coastal marine resources for their subsistence needs. As urbanisation increases, other factors gain in importance, such as migration, as well as external influences that work in opposition to a subsistence-based socioeconomic system in the Pacific (e.g. the drive to maximise income, changes in lifestyle and diet, and increased dependence on imported foods). The latter are not considered in this survey.

The project utilises a 'snapshot approach' that provides 5–7 working days per site (with four sites per country). This timeframe generally allows about 25 households (and a corresponding number of associated finfish and invertebrate fishers) to be covered by the survey. The total number of finfish and invertebrate fishers interviewed also depends on the complexity of the fisheries practised by a particular community, the degree to which both sexes are engaged in finfish and invertebrate fisheries, and the size of the total target population. Data from finfish and invertebrate fisher interviews are grouped by habitat and fishery, respectively. Thus, the project's time and budget and the complexity of a particular site's fisheries are what determine the level of data representation: the larger the population and the number of fishers, and the more diversified the finfish and invertebrate fisheries, the lower the level of representation that can be achieved. It is crucial that this limitation be taken into consideration, because the data gathered through each survey and the emerging distribution patterns are extrapolated to estimate the total annual impact of all fishing activity reported for the entire community at each site.

If possible, people involved in marketing (at local, regional or international scale) who operate in targeted communities are also surveyed (e.g. agents, middlemen, shop owners).

Key informants are targeted in each community to collect general information on the nature of local fisheries and to learn about the major players in each of the fisheries that is of concern, and about fishing rights and local problems. The number of key informants interviewed depends on the complexity and heterogeneity of the community's socioeconomic system and its fisheries.

At each site the extent of the community to be covered by the socioeconomic survey is determined by the size, nature and use of the fishing grounds. This selection process is highly dependent on local marine tenure rights. For example, in the case of community-owned fishing rights, a fishing community includes all villages that have access to a particular fishing ground. If the fisheries of all the villages concerned are comparable, one or two villages may be selected as representative samples, and consequently surveyed. Results will then be extrapolated to include all villages accessing the same fishing grounds under the same marine tenure system.

In an open access system, geographical distance may be used to determine which fishing communities realistically have access to a certain area. Alternatively, in the case of smaller islands, the entire island and its adjacent fishing grounds may be considered as one site. In this case a large number of villages may have access to the fishing ground, and representative villages, or a cross-section of the population of all villages, are selected to be included in the survey.

In addition, fishers (particularly invertebrate fishers) are regularly asked how many people external to the surveyed community also harvest from the same fishing grounds and/or are engaged in the same fisheries. If responses provide a concise pattern, the magnitude of additional impact possibly imposed by these external fishers is determined and discussed.

Sampling

Most of the households included in the survey are chosen by simple random selection, as are the finfish and invertebrate fishers associated with any of these households. In addition, important participants in one or several particular fisheries may be selected for complementary surveying. Random sampling is used to provide an average and representative picture of the fishery situation in each community, including those who do not fish, those engaged in finfish and/or invertebrate fishing for subsistence, and those engaged in fishing activities on a small-scale artisanal basis. This assumption applies provided that selected communities are mostly traditional, relatively small (~100–300 households) and (from a socioeconomic point of view) largely homogenous. Similarly, gender and participation patterns (types of fishers by gender and fishery) revealed through the surveys are assumed to be representative of the entire community. Accordingly, harvest figures reported by male and female fishers participating in a community's various fisheries may be extrapolated to assess the impacts resulting from the entire community, sample size permitting (at least 25–30% of all households).

Data collection and analysis

Data collection is performed using a standard set of questionnaires developed by PROCFish/C's socioeconomic component, which include a household survey (key socioeconomic parameters and consumption patterns), finfish fisheries survey, invertebrate fisheries survey, marketing of finfish survey, marketing of invertebrates survey, and general information questionnaire (for key informants). In addition, further observations and relevant details are noted and recorded in a non-standardised format. The complete set of questionnaires used is attached as Appendix 1.1.2.

Most of the data are collected in the context of face-to-face interviews. Names of people interviewed are recorded on each questionnaire to facilitate cross-identification of fishers and households during data collection and to ensure that each fisher interview is complemented by a household interview. Linking data from household and fishery surveys is essential to permit joint data analysis. However, all names are suppressed once the data entry has been finalised, and thus the information provided by respondents remains anonymous.

Questionnaires are fully structured and closed, although open questions may be added on a case-to-case situation. If translation is required, each interview is conducted jointly by the leader of the project's socioeconomic team and the local counterpart. In cases where no translation is needed, the project's socioeconomist may work individually. Selected interviews may be conducted by trainees receiving advanced field training, but trainees are monitored by project staff in case clarification or support is needed.

The questionnaires are designed to allow a minimum dataset to be developed for each site, one that allows:
- the community's dependency on marine resources to be characterised;
- assessment of the community's engagement in and the possible impact of finfish and invertebrate harvesting; and
- comparison of socioeconomic information with data collected through PROCFish/C resource surveys.

Household survey

The major objectives of the household survey are to:

- **collect recent demographic information** (needed to calculate seafood consumption);
- **determine the number of fishers per household, by gender and type of fishing activity** (needed to assess a community's total fishing impact); and
- **assess the community's relative dependency on marine resources** (in terms of ranked source(s) of income, household expenditure level, agricultural alternatives for subsistence and income (e.g. land, livestock), external financial input (i.e. remittances), assets related to fishing (number and type of boat(s)), and seafood consumption patterns by frequency, quantity and type).

The demographic assessment focuses only on permanent residents, and excludes any family members who are absent more often than they are present, who do not normally share the household's meals or who only join on a short-term visitor basis (for example, students during school holidays, or emigrant workers returning for home leave).

The number of fishers per household distinguishes three categories of adult ≥(15 years) fishers for each gender: (1) exclusive finfish fishers, (2) exclusive invertebrate fishers, and (3) fishers who pursue both finfish and invertebrate fisheries. This question also establishes the percentage of households that do not fish at all. We use this pattern (i.e. the total number of fishers by type and gender) to determine the number of female and male fishers, and the percentage of these who practise either finfish or invertebrate fisheries exclusively, or who practise both. The share of adult men and women pursuing each of the three fishery categories is presented as a percentage of all fishers. Figures for the total number of people in each fishery category, by gender, are also used to calculate total fishing impact (see below).

The role of fisheries as a source of income in a community is established by a ranking system. Generally, rural coastal communities represent a combined system of traditional (subsistence) and cash-generating activities. The latter are often diversified, mostly involving the primary sector, and are closely associated with traditional subsistence activities. Cash flow is often irregular, tailored to meet seasonal or occasional needs (school and church fees, funerals, weddings, etc.). Ranking of different sources of income by order of importance is therefore a better way to render useful information than trying to quantify total cash income over a certain time period. Depending on the degree of diversification, multiple entries are common. It is also possible for one household to record two different activities (such as fisheries and agriculture) as equally important (i.e. both are ranked as a first source of income, as they equally and importantly contribute to acquisition of cash within the household). In order to demonstrate the degree of diversification and allow for multiple entries, the role that each sector plays is presented as a percentage of the total number of households surveyed. Consequently, the sum of all figures may exceed 100%. Income sources include fisheries, agriculture, salaries, and 'others', with the latter including primarily handicrafts, but sometimes also small private businesses such as shops or kava bars.

Cash income is often generated in parallel by various members of one household and may also be administered by many, making it difficult to establish the overall expenditure level. On the other hand, the head of the household and/or the woman in charge of managing and organising the household are typically aware and in control of a certain amount of money that is needed to ensure basic and common household needs are met. We therefore ask for the level of average household expenditure only, on a weekly, bi-weekly or monthly basis, depending on the payment interval common in a particular community. Expenditures quoted in local currency are converted into US dollars (USD) to enable regional comparison. Conversion factors used are indicated.

Geomorphologic differences between low and high islands influence the role that agriculture plays in a community, but differences in land tenure systems and the particulars of each site are also important, and the latter factors are used in determining the percentage of households that have access to gardens and agricultural land, the average size of these areas, and the type (and if possible number) of livestock that are at the disposal of an average household. A community whose members are equally engaged in agriculture and fisheries will either show distinct groups of fishers and farmers/gardeners, or reveal active and non-active fishing seasons in response to the agricultural calendar.

The frequency and amount of remittances received from family members working elsewhere in the country or overseas enable us to assess the degree to which principles of the MIRAB economy apply. MIRAB was coined to characterise an economy dependent on migration, remittances, foreign aid and government bureaucracy as its major sources of revenue (Small and Dixon 2004; Bertram 1999; Bertram and Watters 1985). A high influx of foreign financing, and in particular remittances, is considered to yield flexible and stable economic conditions at the community level (Evans 2001), and may also substitute for or reduce the need for local income-generating activities, such as fishing.

The number of boats per household is indicative of the level of isolation, and is generally higher for communities that are located on small islands and far from the nearest regional centre and market. The nature of the boats (e.g. non-motorised, handmade dugout canoes, dugouts equipped with sails, and the number and size of any motorised boats) provides insights into the level of investment, and usually relates to the household expenditure level. Having access to boats that are less sensitive to sea conditions and equipped with outboard engines provides greater choice of which fishing grounds to target, decreases isolation and increases independence in terms of transport, and hence provides fishing and marketing advantages. Larger and more powerful boats may also have a multiplication factor, as they accommodate bigger fishing parties. In this context it should be noted that information on boats is usually complemented by a separate boat inventory performed by interviewing key informants and senior members of the community. If possible, we prefer to use the information from the complementary boat inventory surveys rather than extrapolating data from household surveys, in order to minimise extrapolation errors.

A variety of data are collected to characterise the seafood consumption of each community. We distinguish between fresh fish (with an emphasis on reef and lagoon fish species), invertebrates and canned fish. Because meals are usually prepared for and shared by all household members, and certain dishes may be prepared in the morning but consumed throughout the day, we ask for the average quantity prepared for one day’s consumption. In the case of fresh fish we ask for the number of fish per size class, or the total weight, usually consumed. However, the weight is rarely known, as most communities are largely self-sufficient in fresh fish supply and local, non-metric units are used for marketing of fish (heap, string, bag, etc.). Information on the number of size classes consumed allows calculation of weight using length–weight relationships, which are known for most finfish species (FishBase 2000, refer to Letourneur *et al.* 1998; Kulbicki pers. com.). Size classes (using fork length) are identified using size charts (Figure A1.1.1).

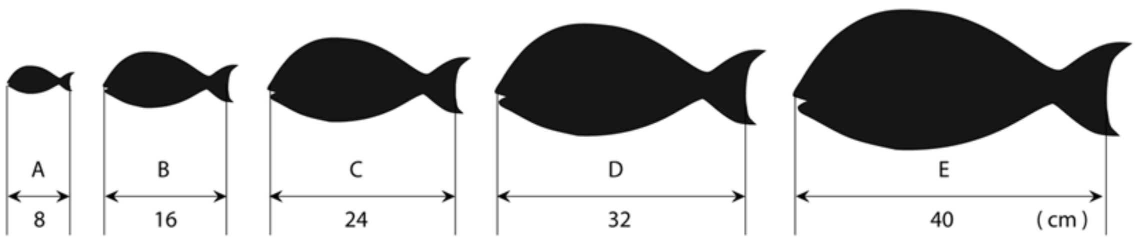

Figure A1.1.1: Finfish size field survey chart for estimating average length of reef and lagoon fish (including five size classes from A = 8 cm to E = 40 cm, in 8 cm intervals).

The frequency of all consumption data is adjusted downwards by 17% (a factor of 0.83 determined on the basis that about two months of the year are not used for fishing due to festivities, funerals and bad weather conditions) to take into account exceptional periods throughout the year when the supply of fresh fish is limited or when usual fish eating patterns are interrupted.

Equation for fresh finfish:

$$F_{wj} = \sum_{i=1}^{n} (N_{ij} \bullet W_i) \bullet 0.8 \bullet F_{dj} \bullet 52 \bullet 0.83$$

F_{wj} = finfish net weight consumption (kg edible meat/household/year) for household_j
n = number of size classes
N_{ij} = number of fish of size class_i for household_j
W_i = weight (kg) of size class_i
0.8 = correction factor for non-edible fish parts
F_{dj} = frequency of finfish consumption (days/week) of household_j
52 = total number of weeks/year
0.83 = correction factor for frequency of consumption

For invertebrates, respondents provide numbers and sizes or weight (kg) per species or species groups usually consumed. Our calculation automatically transfers these data entries per species/species group into wet weight using an index of average wet weight per unit and species/species group (Appendix 1.1.3).[1] The total wet weight is then automatically further broken down into edible and non-edible proportions. Because edible and non-edible proportions may vary considerably, this calculation is done for each species/species group individually (e.g. compare an octopus that consists almost entirely of edible parts with a giant clam that has most of its wet weight captured in its non-edible shell).

Equation for invertebrates:

$$Inv_{wj} = \sum_{i=1}^{n} E_{p\,i} \bullet (N_{ij} \bullet W_{wi}) \bullet F_{dj} \bullet 52 \bullet 0.83$$

Inv_{wj} = invertebrate weight consumption (kg edible meat/household/year) of household_j
E_{pi} = percentage edible (1 = 100%) for species/species group_i (Appendix 1.1.3)
N_{ij} = number of invertebrates for species/species group_i for household_j
n = number of species/species group consumed by household_j
W_{wi} = wet weight (kg) of unit (piece) for invertebrate species/species group_i
1000 = to convert g invertebrate weight into kg
F_{dj} = frequency of invertebrate consumption (days/week) for household_j
52 = total number of weeks/year
0.83 = correction factor for consumption frequency

[1] The index used here mainly consists of estimated average wet weights and ratios of edible and non-edible parts per species/species group. At present, SPC's Reef Fishery Observatory is making efforts to improve this index so as to allow further specification of wet weight and edible proportion as a function of size per species/species group. The software will be updated and users informed about changes once input data are available.

Appendix 1: Survey methods
Socioeconomics

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

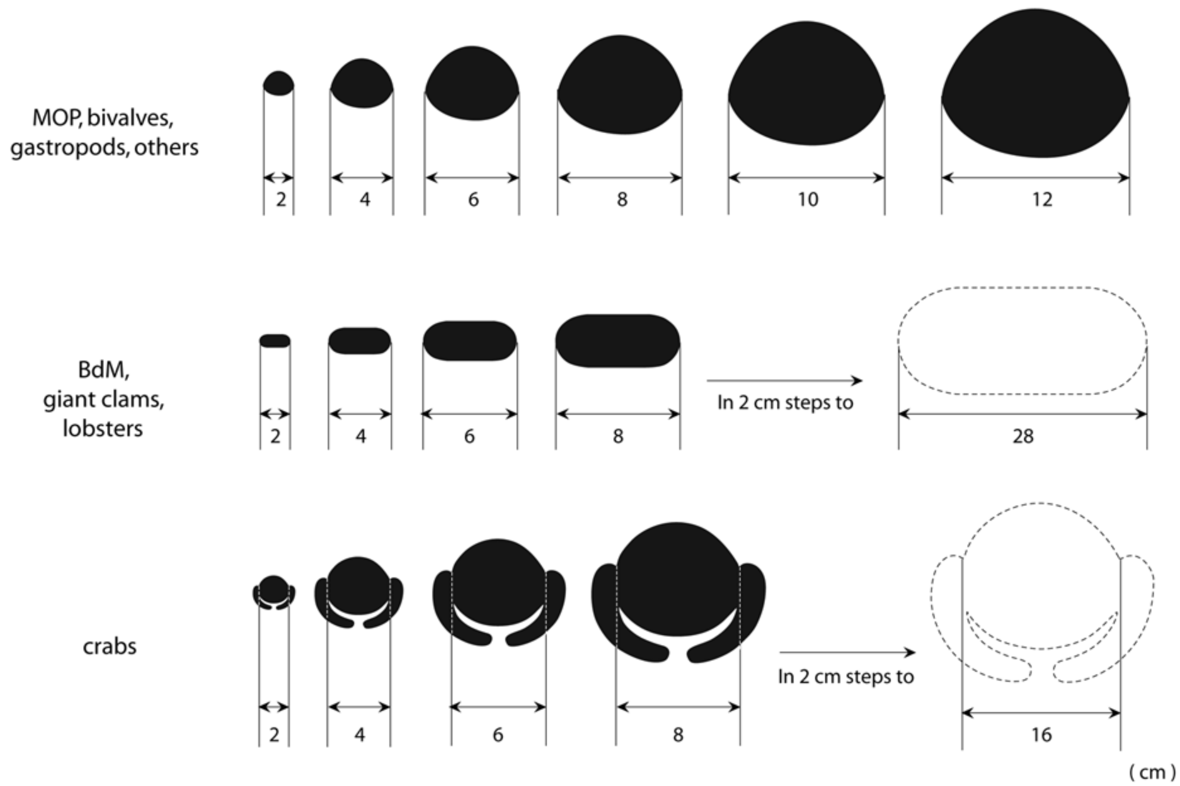

Figure A1.1.2: Invertebrate size field survey chart for estimating average length of different species groups (2 cm size intervals).

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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.

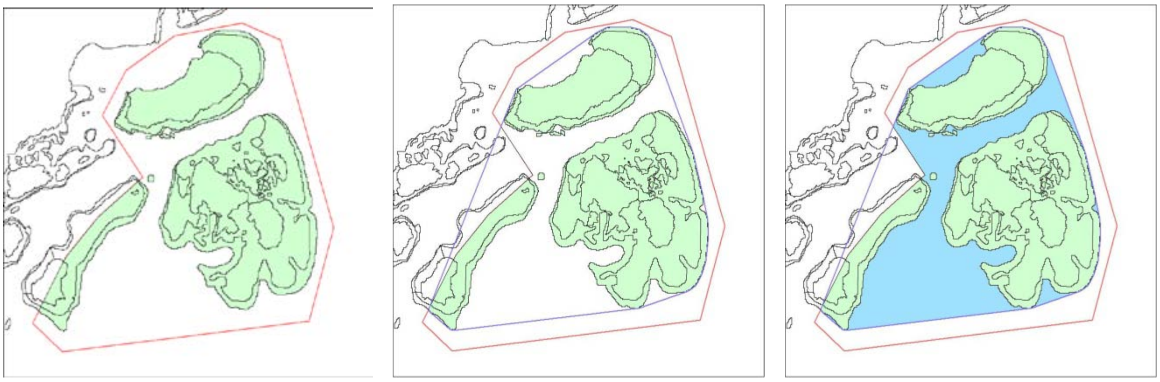

Figure A1.1.3: Determination of lagoon area.
The fishing ground (in red) is initially delineated using information from fishers. Reef areas within the fishing area (in green; interpreted from satellite data) are then identified. The remaining non-reef areas within the fishing grounds are labelled as 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 <u>invertebrate fishing strategies</u> 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 <u>species composition of an average catch</u> 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? *(must be living there; tick box)* male ☐ female ☐

2. How old is the head of household? *(enter year of birth)* ☐

3. How many people ALWAYS live in your household? *(enter number)* ☐

4. How many are male and how many are female? (*tick box and enter age in years or year of birth)*

male	age	female	age
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐

5. Does this household have any agricultural land?

yes ☐ no ☐

6. How much (*for this household only*)?

for permanent/regular cultivation ☐ (unit)

for permanent/regular livestock ☐ (unit)

type of animals__________ no. ☐

7. How many fishers live in your household? ☐
(*enter number of people who go fishing/collecting regularly*)

invertebrate fishers		finfish fishers		invertebrate & finfish fishers	
M	F	M	F	M	F
☐	☐	☐	☐	☐	☐

8. Does this household own a boat? yes ☐ no ☐

9a. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9b. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP
9c. Canoe	☐	length?	☐	metres/feet		
Sailboat	☐	length?	☐	metres/feet		
Boat with outboard engine	☐	length?	☐	metres/feet	☐	HP

10. Where does the CASH money in this household come from? (*rank options, 1 = most money, 2 = second important income source, 3 = 3rd important income source, 4 = 4th important income source*)

Fishing/seafood collection ☐

Agriculture (crops & livestock) ☐

Salary ☐

Others (handicrafts, etc.) ☐ specify: ____________________

11. Do you get remittances? yes ☐ no ☐

12. How often?

1 per month	1 per 3 months	1 per 6 months	other *(specify)*
☐	☐	☐	☐

13. How much? *(enter amount)* Every time? (currency) [ ]

14. How much CASH money do you use on average for household expenditures (food, fuel for cooking, school bus, etc.)?

(currency) [ ] per week/2-weekly/month (or? specify_______)

15. What is the educational level of your household members?

no. of people	having achieved:
[ ]	elementary/primary education
[ ]	secondary education
[ ]	tertiary education (college, university, special schools, etc.)

CONSUMPTION SURVEY

16. During an average/normal week, on how many days do you prepare fish, other seafood and canned fish for your family? *(tick box)*

	7 days	6 days	5 days	4 days	3 days	2 days	1 day	other, specify
Fresh fish	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other seafood	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Canned fish	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

17. Mainly at	breakfast	lunch	supper
Fresh fish	[ ]	[ ]	[ ]
Other seafood	[ ]	[ ]	[ ]
Canned fish	[ ]	[ ]	[ ]

18. How much do you cook on average per day for your household? *(tick box)*

	number	kg	size: A	B	C	D	E	>E (cm)
Fresh fish	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

Other seafood

name:	no.	size	kg	plastic bag ¼	½	¾	1
______________________	☐	☐	☐	☐	☐	☐	☐
______________________	☐	☐	☐	☐	☐	☐	☐
______________________	☐	☐	☐	☐	☐	☐	☐
______________________	☐	☐	☐	☐	☐	☐	☐

19. Canned fish   No. of cans: ☐   Size of can: ☐ small

☐ medium

☐ big

20. Where do you normally get your fish and seafood from?

Fish:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ______________________

Which is the most important source? ☐ caught ☐ given ☐ bought

Invertebrates:

☐ caught by myself/member of this household

☐ get it from somebody in the family/village (no money paid)

☐ buy it at ______________________

Which is the most important source? ☐ caught ☐ given ☐ bought

21. Which is the last day you had fish? ______________________

22. Which is the last day you had other seafood? ______________________

–THANK YOU–

FISHING (FINFISH) AND MARKETING SURVEY

Name: ______________________ F ☐ M ☐ **HH NO.** ☐

Name of head of household: _________________________ Village: ________________

Surveyor's name: _______________________ Date: ________________

1. Which areas do you fish?

coastal reef	lagoon	outer reef	mangrove	pelagic
☐	☐	☐	☐	☐

2. Do you go to only one habitat per trip?

Yes ☐ no ☐

3. If no, how many and which habitats do you visit during an average trip?

total no.	habitats:	coastal reef	lagoon	mangrove	outer reef
☐		☐	☐	☐	☐

4. How often (days/week) do you fish in each of the habitats visited?

coastal reef	lagoon	mangrove	outer reef	
☐	☐	☐	☐	___________/times per week/month
☐	☐	☐	☐	___________/times per week/month
☐	☐	☐	☐	___________/times per week/month

5. Do you use a boat for fishing?

	Always	sometimes	never
coastal reef	☐	☐	☐
lagoon	☐	☐	☐
mangrove	☐	☐	☐
outer reef	☐	☐	☐

6. If you use a boat, which one?

1 { canoe (paddle) ☐ sailing ☐
motorised ☐ HP outboard ☐ 4-stroke engine ☐ }

coastal reef ☐ lagoon ☐ outer reef ☐

2
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

3
- canoe (paddle) ☐ sailing ☐
- motorised ☐ HP outboard ☐ 4-stroke engine ☐

coastal reef ☐ lagoon ☐ outer reef ☐

7. How many fishers ALWAYS go fishing with you?

Names:____
____
____
____

INFORMATION BY FISHERY **Name of fisher: ______________** **HH NO.** ☐

coastal reef ☐ lagoon ☐ mangrove ☐ outer reef ☐

1. HOW OFTEN do you normally go out FISHING for this habitat? *(tick box)*

Every Day	5 days/ week	4 days/ week	3 days/ week	2 days/ week	1 day/ week	other, specify:
☐	☐	☐	☐	☐	☐	____________________

2. What time do you spend fishing this habitat per average trip? ____________________
(if the fisher can't specify, tick a box)

<2 hrs	2–6 hrs	6–12 hrs	>12 hrs
☐	☐	☐	☐

3. WHEN do you go fishing? *(tick box)* day ☐ night ☐ day & night ☐

4. Do you go all year?

Yes ☐ no ☐

5. If no, which months don't you fish?

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

6. Which fishing techniques do you use (*in the habitat referred to here*)?

☐ handline

☐ castnet ☐ gillnet

☐ spear (dive) ☐ longline

☐ trolling ☐ spear (handheld) walking ☐ canoe ☐

☐ deep bottom line ☐ poison: which one? ______________

☐ other, specify: ____

7. Do you use more than one technique per trip for this habitat? If yes, which ones usually?

☐ one technique/trip ☐ more than one technique/trip:

____

8. Do you use ice on your fishing trips?

always sometimes never

is it homemade? or bought?

9. What is your average catch (kg) per trip? Kg <u>OR:</u>

size class:	A	B	C	D	E	>E (cm)
number:						

10. Do you sell fish? yes no

11. Do you give fish as a gift (for no money)? yes no

12. Do you use your catch for family consumption? yes no

13. How much of your usual catch do you keep for family consumption?

kg <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no						

and the rest you gift? yes

how much? kg <u>OR:</u>

size class	A	B	C	D	E	>E (cm)
no.						

and/or sell? yes

how much? kg <u>OR</u>:

size class	A	B	C	D	E	>E (cm)
no.						

14. What sizes of fish do you use for your family consumption, what for sale and what do you give away without getting any money?

size classes:	all	A	B	C	D	E	and larger (no. and cm)
consumption	☐	☐	☐	☐	☐	☐	☐
sale	☐	☐	☐	☐	☐	☐	☐
give away	☐	☐	☐	☐	☐	☐	☐

15. You sell where?

☐ inside village ☐ outside village where? ___________________________

and to whom?

market ☐ agents/middlemen ☐ shop owners ☐ others ☐ ___________

16. In an average catch what fish do you catch, and how much of each species? *(write down the species in the table)*

technique usually used:_____________________ boat type usually used:________________
habitat usually fished: ____

Specify the number by size

Name of fish	kg	A	B	C	D	E	>E cm

20. Do you also fish invertebrates?

Yes ☐ no ☐ <u>if yes</u> for consumption? ☐ sale? ☐

–THANK YOU–

INVERTEBRATE FISHING AND MARKETING SURVEY
FISHERS

HH NO. ☐

Name: ____

Gender: ☐ female ☐ male Age: ☐

Village: ____

Date: ________________ Surveyor's name: ___________________

Invertebrates = everything that is not a fish with fins!

1. Which type of fisheries do you do?

☐ seagrass gleaning ☐ mangrove & mud gleaning

☐ sand & beach gleaning ☐ reeftop gleaning

☐ bêche-de mer diving ☐ mother-of-pearl diving trochus, pearl shell, etc.

☐ lobster diving ☐ other, such as clams, octopus

2. *(if more than one fishery in question 1):* Do you usually go fishing at only one of the fisheries or do you visit several during one fishing trip?

☐ one only ☐ several

If several fisheries at a time, which ones do you combine?

----

3. How often do you go gleaning/diving (*tick as from questions 1 and 2 above and watch for combinations*) and for how long, and do you also finfish at the same time?

(if the fisher can't specify, tick the box)

	times/week		duration in hours <2	2–4	4–6	>6	glean/dive at D	N	D&N	fish no. of months/year
☐ seagrass gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mangrove & mud gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ sand & beach gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ reeftop gleaning	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ bêche-de-mer diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ lobster diving	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ mother-of-pearl diving trochus, pearl shell, etc.	☐	____	☐	☐	☐	☐	☐	☐	☐	________
☐ other diving (clams, octopus)	☐	____	☐	☐	☐	☐	☐	☐	☐	________

D = day, N = night, D&N = day and night (no preference but fish with tide)

4. Do you sometimes go gleaning/fishing for invertebrates outside your village fishing grounds?

yes ☐ no ☐

If yes, where? ____

5. Do you finfish? yes ☐ no ☐

for: ☐ consumption? ☐ sale?

at the same time? yes ☐ no ☐

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

GLEANING: seagrass ☐ mangrove & mud ☐ sand & beach ☐ reeftop ☐

DIVING: bêche-de-mer ☐ lobster ☐ mother-of-pearl, trochus, pearl shell, etc. ☐ other (clams, octopus) ☐

SHEET 1: EACH FISHERY PER FISHER INTERVIEWED: ☐ **HH NO. __Name of fisher: _____________** **gender: F** ☐ **M** ☐

What transport do you mainly use? ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

How many fishers are usually on a trip? (total no.) ☐ walk ☐ canoe (no engine) ☐ motorised boat (HP) ☐ sailboat

Species vernacular/common name and scientific code if possible	**Average quantity/trip**							**Used for** (specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given) gift = giving away for no money		
	total number/ trip	weight/trip					average size cm	cons.	gift	sale
		total kg	plastic bag unit							
			1	3/4	1/2	1/4				

Appendix 1: Survey methods
Socioeconomics

Species vernacular/common name and scientific code if possible	**Average quantity/trip**							**Used for** (specify how much from average for each category (cons., given or sold), and the main size for sale and cons. or given) gift = giving away for no money		
	total number/ trip	weight/trip					average size cm	cons.	gift	sale
		total kg	plastic bag unit							
			1	3/4	1/2	1/4				

INVERTEBRATE FISHING AND MARKETING SURVEY – FISHERS

GLEANING: seagrass ☐ mangrove & mud ☐ sand & beach ☐ reeftop ☐

DIVING: bêche-de-mer ☐ lobster ☐ mother-of-pearl, trochus, pearl shell, etc. ☐ other (clams, octopus) ☐

SHEET 2: SPECIES SOLD PER FISHER INTERVIEWED: **HH NO**. ☐ **Name of fisher:** ________________________

Copy all species that have been named for 'SALE' in previous sheet

Who markets your products? ☐ you ☐ your wife ☐ your husband ☐ a group of fishers ☐ other __________________

Species for sale – copy from sheet 2 (for each fishery per fisher) above	Processing level of product sold (see list)	Where do you sell? (see list)	How often? Days/week?	How much each time? Quantity/unit	Price

**FISHERIES (FINFISH AND INVERTEBRATE AND SOCIOECONOMICS)
GENERAL INFORMATION SURVEY**

Target group: key people, groups of fishers, fisheries officers, etc.

1. Are there management rules that apply to your fisheries? Do they specifically target finfish or invertebrates, or do they target both sectors?

a) legal/Ministry of Fisheries

b) traditional/community/village determined:

2. What do you think – do people obey:

traditional/village management rules?

mostly ☐ sometimes ☐ hardly ☐

legal/Ministry of Fisheries management rules?

mostly ☐ sometimes ☐ hardly ☐

3. Are there any particular rules that you know people do not respect or follow at all? And do you know why?

4. What are the main techniques used by the community for:

a) finfishing

gillnets – most-used mesh sizes:

What is usually used for bait? And is it bought or caught?

b) invertebrate fishing → ***see end!***

5. Please give a quick inventory and characteristics of boats used in the community (length, material, motors, etc.).

Seasonality of species

What are the **FINFISH** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

Seasonality of species

What are the **INVERTEBRATE** species that you do not catch during the total year? Can you specify the particular months that they are **NOT** fished?

Vernacular name	Scientific name(s)	Months NOT fished

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 cucullata	35	35	65	12.25	Bivalves
Saccostrea sp.	35	35	65	12.25	Bivalves
Scylla serrata	700	35	65	245	Crustacean
Serpulorbis sp.	5	25	75	1.25	Gastropods
Sipunculus indicus	50	10	90	5	Seaworm
Spondylus squamosus	40	35	65	14	Bivalves
Stichopus chloronotus	100	10	90	10	BdM (1)
Stichopus sp.	543	10	90	54.3	BdM (1)
Strombus gibberulus gibbosus	25	25	75	6.25	Gastropods
Strombus luhuanus	25	25	75	6.25	Gastropods
Tapes literatus	20	35	65	7	Bivalves
Tectus pyramis, Trochus niloticus	300	25	75	75	Gastropods
Tellina palatum	21	35	65	7.35	Bivalves
Tellina sp.	20	35	65	7	Bivalves

1.1.3 Average wet weight applied for selected invertebrate species groups (continued)

Unit weights used in conversions for invertebrates.

Scientific names	g/piece	% edible part	% non-edible part	Edible part (g/piece)	Group
Terebra sp.	37.5	25	75	9.39	Gastropods
Thais armigera	20	25	75	5	Gastropods
Thais sp.	20	25	75	5	Gastropods
Thelenota ananas	2500	10	90	250	BdM (1)
Thelenota anax	2000	10	90	200	BdM (1)
Tridacna maxima	500	19	81	95	Giant clams
Tridacna sp.	500	19	81	95	Giant clams
Trochus niloticus	200	25	75	50	Gastropods
Turbo crassus	80	25	75	20	Gastropods
Turbo marmoratus	20	25	75	5	Gastropods
Turbo setosus	20	25	75	5	Gastropods
Turbo sp.	20	25	75	5	Gastropods

BdM = Bêche-de-mer; (1) edible part of dried Bêche-de-mer, i.e. drying process consumes about 90% of total wet weight; hence 10% are considered as the edible part only.

1.2 Methods used to assess the status of finfish resources

Fish counts

In order to count and size fish in selected sites, we use the **distance-sampling underwater visual census (D-UVC)** method (Kulbicki and Sarramegna 1999, Kulbicki *et al.* 2000), fully described in Labrosse *et al.* (2002). Briefly, the method consists of recording the species name, abundance, body length and the distance to the transect line for each fish or group of fish observed; the transect consists of a 50 m line, represented on the seafloor by an underwater tape (Figure A1.2.1). For security reasons, two divers are required to conduct a survey, each diver counting fish on a different side of the transect. Mathematical models are then used to estimate fish density (number of fish per unit area) and biomass (weight of fish per unit area) from the counts.

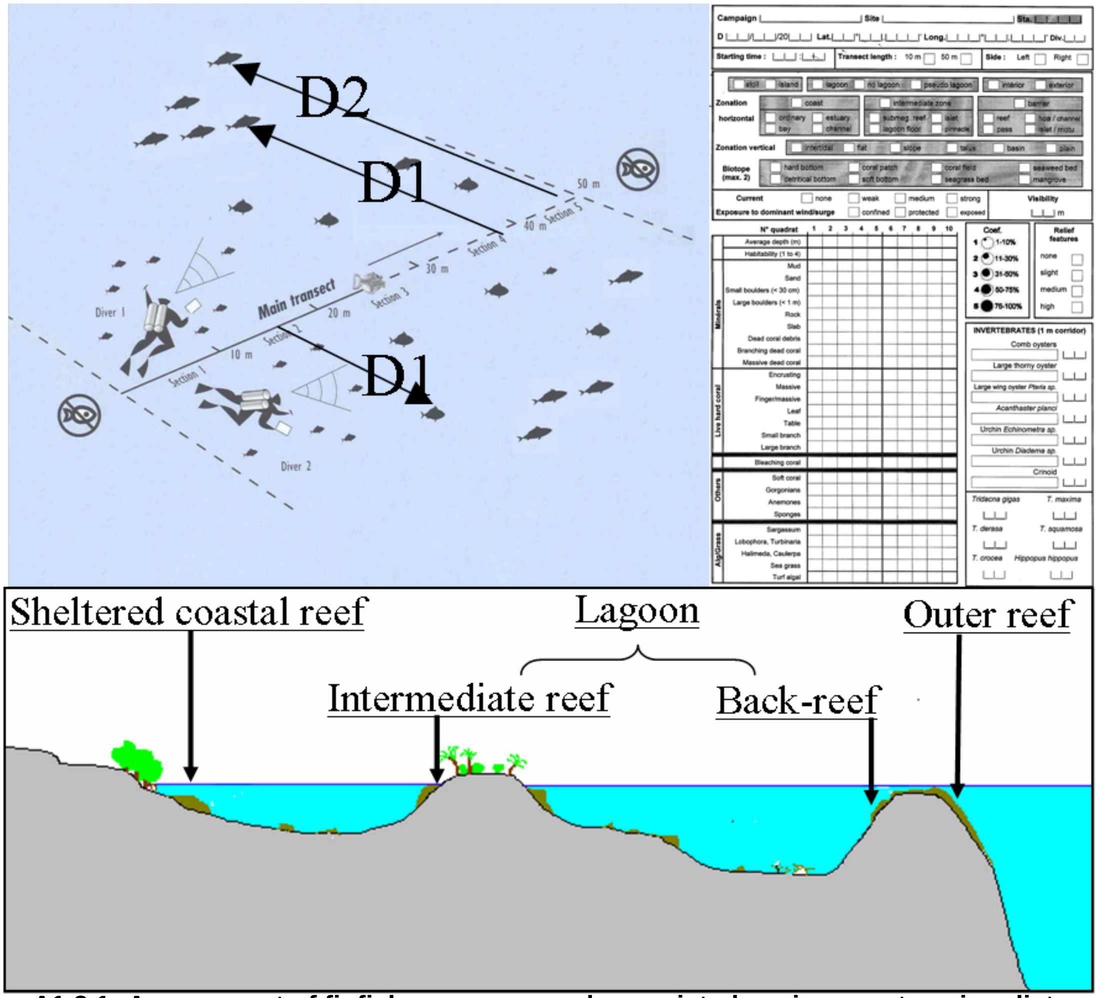


Figure A1.2.1: Assessment of finfish resources and associated environments using distance-sampling underwater visual censuses (D-UVC).
Each diver records the number of fish, fish size, distance of fish to the transect line, and habitat quality, using pre-printed underwater paper. At each site, surveys are conducted along 24 transects, with six transects in each of the four main geomorphologic coral reef structures: sheltered coastal reefs, intermediate reefs and back-reefs (lumped into the 'lagoon reef' category of socioeconomic assessment), and outer reefs. D1 is the distance of an observed fish from the transect line. If a school of fish is observed, D1 is the distance from the transect line to the closest fish; D2 the distance to the furthest fish.

Species selection

Only reef fish of interest for consumption or sale and species that could potentially serve as indicators of coral reef health are surveyed (see Table A1.2.1; Appendix 3.2 provides a full list of counted species and abundance for each site surveyed).

Table A1.2.1: List of finfish species surveyed by distance sampling underwater visual census (D-UVC)
Most frequently observed families on which reports are based are highlighted in yellow.

Family	Selected species
Acanthuridae	All species
Aulostomidae	*Aulostomus chinensis*
Balistidae	All species
Belonidae	All species
Caesionidae	All species
Carangidae	All species
Carcharhinidae	All species
Chaetodontidae	All species
Chanidae	All species
Dasyatidae	All species
Diodontidae	All species
Echeneidae	All species
Ephippidae	All species
Fistulariidae	All species
Gerreidae	*Gerres* spp.
Haemulidae	All species
Holocentridae	All species
Kyphosidae	All species
Labridae	*Bodianus axillaris, Bodianus loxozonus, Bodianus perditio, Bodianus* spp., *Cheilinus:* all species, *Choerodon:* all species, *Coris aygula, Coris gaimard, Epibulus insidiator, Hemigymnus:* all species, *Oxycheilinus diagrammus, Oxycheilinus* spp.
Lethrinidae	All species
Lutjanidae	All species
Monacanthidae	*Aluterus scriptus*
Mugilidae	All species
Mullidae	All species
Muraenidae	All species
Myliobatidae	All species
Nemipteridae	All species
Pomacanthidae	*Pomacanthus semicirculatus, Pygoplites diacanthus*
Priacanthidae	All species
Scaridae	All species
Scombridae	All species
Serranidae	Epinephelinae: all species
Siganidae	All species
Sphyraenidae	All species
Tetraodontidae	*Arothron*: all species
Zanclidae	All species

Analysis of percentage occurrence in surveys at both regional and national levels indicates that of the initial 36 surveyed families, only 15 families are frequently seen in country counts. Since low percentage occurrence could either be due to rarity (which is of interest) or low detectability (representing a methodological bias), we decided to restrict our analysis to the 15 most frequently observed families, for which we can guarantee that D-UVC is an efficient resource assessment method.

These are:

- Acanthuridae (surgeonfish)
- Balistidae (triggerfish)
- Chaetodontidae (butterflyfish)
- Holocentridae (squirrelfish)
- Kyphosidae (drummer and seachubs)
- Labridae (wrasse)
- Lethrinidae (sea bream and emperor)
- Lutjanidae (snapper and seaperch)
- Mullidae (goatfish)
- Nemipteridae (coral bream and butterfish)
- Pomacanthidae (angelfish)
- Scaridae (parrotfish)
- Serranidae (grouper, rockcod, seabass)
- Siganidae (rabbitfish)
- Zanclidae (moorish idol).

Substrate

We used the **medium-scale approach** (MSA) to record substrate characteristics along transects where finfish were counted by D-UVC. MSA has been developed by Clua *et al.* (2006) to specifically complement D-UVC surveys. Briefly, the method consists of recording depth, habitat complexity, and 23 substrate parameters within ten 5 x 5 m quadrats located on each side of a 50 m transect, for a total of 20 quadrats per transect (Figure A1.2.1). The transect's habitat characteristics are then calculated by averaging substrate records over the 20 quadrats.

Parameters of interest

In this report, the status of finfish resources has been characterised using the following seven parameters:

- **biodiversity –** the number of families, genera and species counted in D-UVC transects;
- **density** (fish/m^2) – estimated from fish abundance in D-UVC;
- **size** (cm fork length) – direct record of fish size by D-UVC;
- **size ratio** (%) – the ratio between fish size and maximum reported size of the species. This ratio can range from nearly zero when fish are very small to nearly 100 when a given fish has reached the greatest size reported for the species. Maximum reported size (and source of reference) for each species are stored in our database;
- **biomass** (g/m^2) – obtained by combining densities, size, and weight–size ratios (Weight–size ratio coefficients are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit);
- **community structure –** density, size and biomass compared among families; and

- **trophic structure –** density, size and biomass compared among trophic groups. Trophic groups are stored in our database and were provided by Mr Michel Kulbicki, IRD Noumea, Coreus research unit. Each species was classified into one of five broad trophic groups: 1) carnivore (feed predominantly on zoobenthos), 2) detritivore (feed predominantly on detritus), 3) herbivore (feed predominantly on plants), 4) piscivore (feed predominantly on nekton, other fish and cephalopods) and 5) plankton feeder (feed predominantly on zooplankton). More details on fish diet can be found online at: http://www.fishbase.org/manual/english/FishbaseThe_FOOD_ITEMS_Table.htm.

The relationship between environment quality and resource status has not been fully explored at this stage of the project, as this task requires complex statistical analyses on the regional dataset. Rather, the living resources assessed at all sites in each country are placed in an environmental context via the description of several crucial habitat parameters. These are obtained by grouping the original 23 substrate parameters recorded by divers into the following six parameters:

- **depth** (m)
- **soft bottom** (% cover) – sum of substrate components:
  (1) mud (sediment particles <0.1 mm), and
  (2) sand and gravel (0.1 mm <hard particles <30 mm)
- **rubble and boulders** (% cover) – sum of substrate components:
  (3) dead coral debris (carbonated structures of heterogeneous size, broken and removed from their original locations),
  (4) small boulders (diameter <30 cm), and
  (5) large boulders (diameter <1 m)
- **hard bottom** (% cover) – sum of substrate components:
  (6) slab and pavement (flat hard substratum with no relief), rock (massive minerals) and eroded dead coral (carbonated edifices that have lost their coral colony shape),
  (7) dead coral (dead carbonated edifices that are still in place and retain a general coral shape), and
  (8) bleaching coral
- **live coral** (% cover) – sum of substrate components:
  (9) encrusting live coral,
  (10) massive and sub-massive live corals,
  (11) digitate live coral,
  (12) branching live coral,
  (13) foliose live coral,
  (14) tabulate live coral, and
  (15) *Millepora* spp.
- **soft coral** (% cover) – substrate component:
  (16) soft coral.

Sampling design

Coral reef ecosystems are complex and diverse. The NASA Millennium Coral Reef Mapping Project (MCRMP) has identified and classified coral reefs of the world in about 1,000 categories. These very detailed categories can be used directly to try to explain the status of living resources or be lumped into more general categories to fit a study's particular needs. For the needs of the finfish resource assessment, MCRMP reef types were grouped into the four main coralline geomorphologic structures found in the Pacific (Figure A1.2.2):

- **sheltered coastal reef**: reef that fringes the land but is located inside a lagoon or a pseudo-lagoon
- **lagoon reef**:
  - **intermediate reef** – patch reef that is located inside a lagoon or a pseudo-lagoon, and
  - **back-reef** – inner/lagoon side of outer reef
- **outer reef**: ocean side of fringing or barrier reefs.

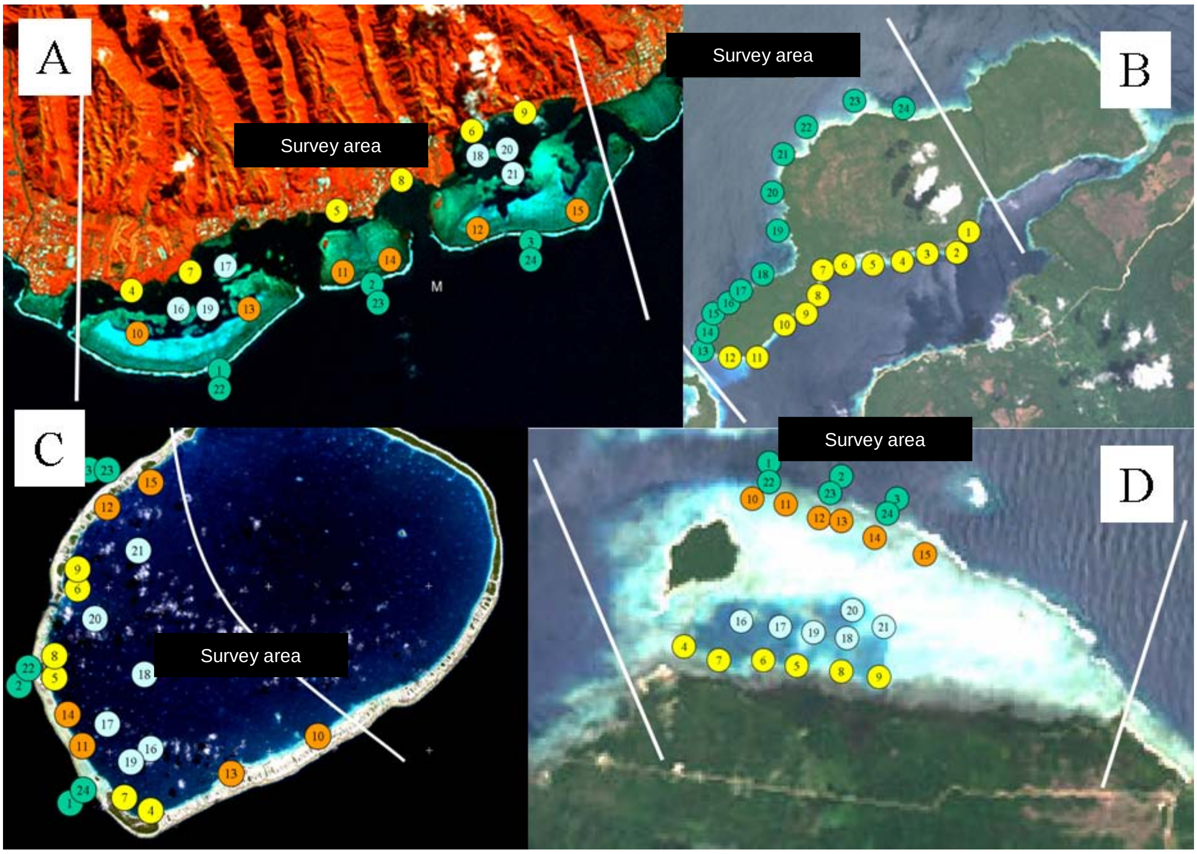


Figure A1.2.2: Position of the 24 D-UVC transects surveyed in A) an island with a lagoon, B) an island with a pseudo-lagoon C) an atoll and D) an island with an extensive reef enclosing a small lagoon pool.
Sheltered coastal reef transects are in yellow, lagoon intermediate-reef transects in blue, lagoon back-reef transects in orange and outer-reef transects in green. Transect locations are determined using satellite imagery prior to going into the field, which greatly enhances fieldwork efficiency. The white lines delimit the borders of the survey area.

Fish and associated habitat parameters are recorded along 24 transects per site, with a balanced design among the main geomorphologic structures present at a given site (Figure A1.2.2). For example, our design results in at least six transects in each of the sheltered coastal, lagoon intermediate, lagoon back-reef, and outer reefs of islands with lagoons (Figure A1.2.2A) or 12 transects in each of the sheltered coastal and outer reefs of islands with pseudo-lagoons (Figure A1.2.2B). This balanced, stratified and yet flexible sampling design was chosen to optimise the quality of the assessment, given the logistical and time constraints that stem from the number and diversity of sites that have to be covered over the life of the project. The exact position of transects is determined in advance using satellite imagery, to assist in locating the exact positions in the field; this maximises accuracy and allows replication for monitoring purposes (Figure A1.2.2).

Appendix 1: Survey methods
Finfish

Scaling

Maps from the Millennium Project allow the calculation of reef areas in each studied site, and those areas can be used to scale (using weighted averages) the resource assessment at any spatial level. For example, the average biomass (or density) of finfish at site (i.e. village) level would be calculated by relating the biomass (or density) recorded in each of the habitats sampled at the site ('the data') to the proportion of surface of each type of reef over the total reef present in the site ('the weights'), by using a weighted average formula. The result is a village-level figure for finfish biomass that is representative of both the intrinsic characteristics of the resource and its spatial distribution. Technically, the weight given to the average biomass (or density) of each habitat corresponds to the ratio between the total area of that reef habitat (e.g. the area of sheltered coastal reef) and the total area of reef present (e.g. the area of sheltered coastal reef + the area of intermediate reef, etc.). Thus the calculated weighted biomass value for the site would be:

$$B_{Vk} = \sum j_l \, [B_{Hj} \bullet S_{Hj}] / \sum_j S_{Hj}$$

Where:

B_{Vk} = computed biomass or fish stock for village k
B_{Hj} = average biomass in habitat H_j
S_{Hj} = surface of that habitat H_j

A comparative approach only

Density and biomass estimated by D-UVC for each species recorded in the country are given in Appendix 3.2. However, it should be stressed that, since estimates of fish density and biomass (and other parameters) are largely dependent upon the assessment method used (this is true for any assessment), the resource assessment provided in this report can only be used for management in a comparative manner. Densities, biomass and other figures given in this report provide only estimates of the available resource; it would be a great mistake (possibly leading to mismanagement) to consider these as true indicators of the actual available resource.

Appendix 1: Survey methods
Finfish

Campaign |________________| Site |__________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|' Long.|__|__|__|°|__|__|,|__|__|__|' WT |__|__|__|

Starting time : |__|__| :|__|__| — Visibility |__|__| m — Side : Left ☐ Right ☐

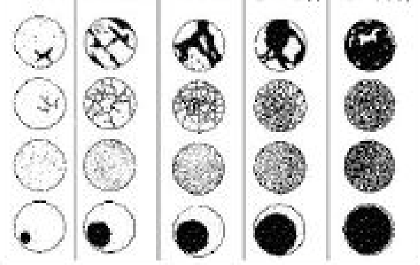
☐ coast		☐ intermediate zone		☐ barrier	
☐ linear	☐ cape	☐ submerg. reef	☐ pinnacle	☐ outer slope	☐ pass
☐ bay mouth	☐ back of bay	☐ near surf. reef	☐ islet lagoon	☐ reef crest	☐ hoa/channel
☐ estuary	☐ channel	☐ lagoon floor	☐ islet fringing reef	☐ back reef	☐ motu

☐ intertidal ☐ flat ☐ gentle slope ☐ steep slope ☐ talus ☐ basin ☐ lagoon plain

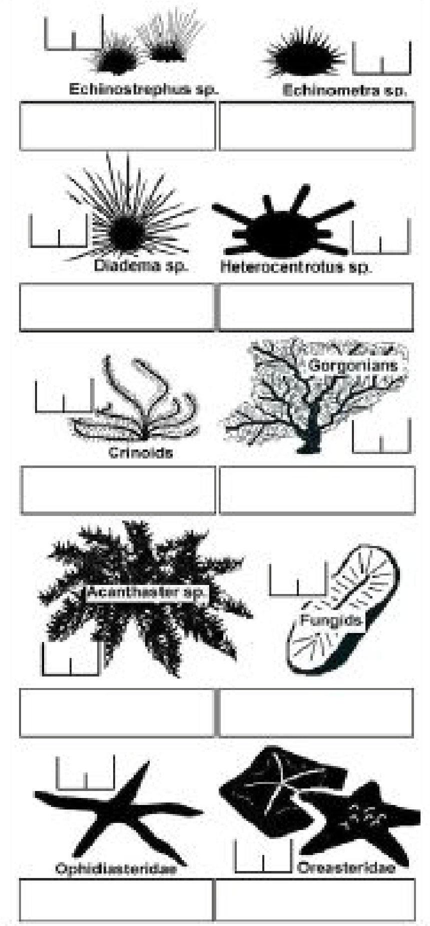
☐ hard bottom ☐ large coral patches ☐ small coral patches ☐ coral field ☐ seaweed bed
☐ detritical bottom ☐ soft bottom ☐ seagrass bed ☐ mangrove

	current	relief features	exposure to dominant wind	oceanic influence	terrigenous influence
none	☐	☐	☐	☐	☐
medium	☐	☐	☐	☐	☐
strong	☐	☐	☐	☐	☐

1	2	3	4	5
1-10%	11-30%	31-50%	51-75%	76-100%



	Quadrat limits	0	5	10	15	20	25	30	35	40	45	50
	Average depth (m)											
	Habitability (1 to 4)											
General coverage	Mud											
	Sand											
	Dead coral debris											
	Small boulders (< 30 cm)											
	Large boulders (< 1 m)											
	Eroded dead coral, rock											
	Old dead coral in place											
	Bleaching coral											
	(1) Live corals											
	(2) Soft invertebrates											
(1) Live corals	Encrusting											
	Massive											
	Digitate											
	Branch											
	Foliose											
	Tabulate											
	Millepora sp.											
(2)	Soft corals											
	Sponges											
Grass/alg	Cyanophyceae											
	Sea grass											
	Encrusting algae											
	Small macro-algae											
	Large macro-algae											
	Drifting algae											
	Micro-algae, Turf											
	Others :											



Finfish

Campaign |____________________| Site |______________________________| Diver |__|__| Transect |__|__|__|

D |__|__|/|__|__|/20|__|__| Lat.|__|__|°|__|__|,|__|__|__|’ Long.|__|__|__|°|__|__|,|__|__|__|’ Left ☐ Right ☐

ST	SCIENTIFIC NAME	NBER	LGT	D1	D2	COMMENTS

1.3 Invertebrate resource survey methods

1.3.1 Methods used to assess the status of invertebrate resources

Introduction

Coastal communities in the Pacific access a range of invertebrate resources. Within the PROCFish/C study, a range of survey methods were used to provide information on key invertebrate species commonly targeted. These provide information on the status of resources at scales relevant to species (or species groups) and the fishing grounds being studied that can be compared across sites, countries and the region, in order to assess relative status.

Species data resulting from the resource survey are combined with results from the socioeconomic survey of fishing activity to describe invertebrate fishing activity within specific 'fisheries'. Whereas descriptions of commercially orientated fisheries are generally recognisable in the literature (e.g. the sea cucumber fishery), results from non-commercial stocks and subsistence-orientated fishing activities (e.g. general reef gleaning) will also be presented as part of the results, so as to give managers a general picture of invertebrate fishery status at study sites.

Field methods

We examined invertebrate stocks (and fisheries) for approximately seven days at each site, with at least two research officers (SPC Invertebrate Biologist and Fisheries Officer) plus officers from the local fisheries department. The work completed at each site was determined by the availability of local habitats and access to fishing activity.

Two types of survey were conducted: fishery-dependent surveys and fishery independent surveys.

- Fishery-dependent surveys rely on information from those engaged in the fishery, e.g. catch data;
- Fishery-independent surveys are conducted by the researchers independently of the activity of the fisheries sector.

Fishery-dependent surveys were completed whenever the opportunity arose. This involved accompanying fishers to target areas for the collection of invertebrate resources (e.g. reef-benthos, soft-benthos, trochus habitat). The location of the fishing activity was marked (using a GPS) and the catch composition and catch per unit effort (CPUE) recorded (kg/hour).

This record was useful in helping to determine the species complement targeted by fishers, particularly in less well-defined 'gleaning' fisheries. A CPUE record, with related information on individual animal sizes and weights, provided an additional dataset to expand records from reported catches (as recorded by the socioeconomic survey). In addition, size and weight measures collected through fishery-dependent surveys were compared with records from fishery-independent surveys, in order to assess which sizes fishers were targeting.

For a number of reasons, not all fisheries lend themselves to independent snapshot assessments: density measures may be difficult to obtain (e.g. crab fisheries in mangrove systems) or searches may be greatly influenced by conditions (e.g. weather, tide and lunar conditions influence lobster fishing). In the case of crab or shoreline fisheries, searches are very subjective and weather and tidal conditions affect the outcome. In such cases, observed and reported catch records were used to determine the status of species and fisheries.

A further reason for accompanying groups of fishers was to gain a first-hand insight into local fishing activities and facilitate the informal exchange of ideas and information. By talking to fishers in the fishing grounds, information useful for guiding independent resource assessment was generally more forthcoming than when trying to gather information using maps and aerial photographs while in the village. Fishery-independent surveys were not conducted randomly over a defined site ‘study’ area. Therefore assistance from knowledgeable fishers in locating areas where fishing was common was helpful in selecting areas for fishery-independent surveys.

A series of fishery-independent surveys (direct, in-water resource assessments) were conducted to determine the status of targeted invertebrate stocks. These surveys needed to be wide ranging within sites to overcome the fact that distribution patterns of target invertebrate species can be strongly influenced by habitat, and well replicated as invertebrates are often highly aggregated (even within a single habitat type).

PROCFish/C assessments do not aim to determine the size of invertebrate populations at study sites. Instead, these assessments aim to determine the status of invertebrates within the main fishing grounds or areas of naturally higher abundance. The implications of this approach are important, as the haphazard measures taken in main fishing grounds are indicative of stock health in these locations only and should not be extrapolated across all habitats within a study site to gain population estimates.

This approach was adopted due to the limited time allocated for surveys and the study’s goal of ‘assessing the status of invertebrate resources’ (as opposed to estimating the standing stock). Making judgements on the status of stocks from such data relies on the assumption that the state of these estimates of ‘unit stock’[2] reflects the health of the fishery. For example, an overexploited trochus fishery would be unlikely to have high-density ‘patches’ of trochus, just as a depleted shallow-reef gleaning fishery would not hold high densities of large clams. Conversely, a fishery under no stress would be unlikely to be depleted or show skewed size ratios that reflected losses of the adult component of the stock.

In addition to examining the density of species, information on spatial distribution and size/weight was collected, to add confidence to the study’s inferences.

The basic assumption that looking at a unit stock will give a reliable picture of the status of that stock is not without weaknesses. Resource stocks may appear healthy within a much-restricted range following stress from fishing or environmental disturbance (e.g. a cyclone), and historical information on stock status is not usually available for such remote locations. The lack of historical datasets also precludes speculation on ‘missing’ species, which may be ‘fished-out’ or still remain in remnant populations at isolated locations within study sites.

[2] As used here, ‘unit stock’ refers to the biomass and cohorts of adults of a species in a given area that is subject to a well-defined fishery, and is believed to be distinct and have limited interchange of adults from biomasses or cohorts of the same species in adjacent areas (Gulland 1983).

As mentioned, specific independent assessments were not conducted for mud crab and shore crabs (mangrove fishery), lobster or shoreline stocks (e.g. nerites, surf clams and crabs), as limited access or the variability of snapshot assessments would have limited relevance for comparative assessments.

Generic terminology used for surveys: site, station and replicates

Various methods were used to conduct fishery-independent assessments. At each site, surveys were generally made within specific areas (termed 'stations'). At least six replicate measures were made at each station (termed 'transects', 'searches' or 'quadrats', depending on the resource and method) (Figure A1.3.1).

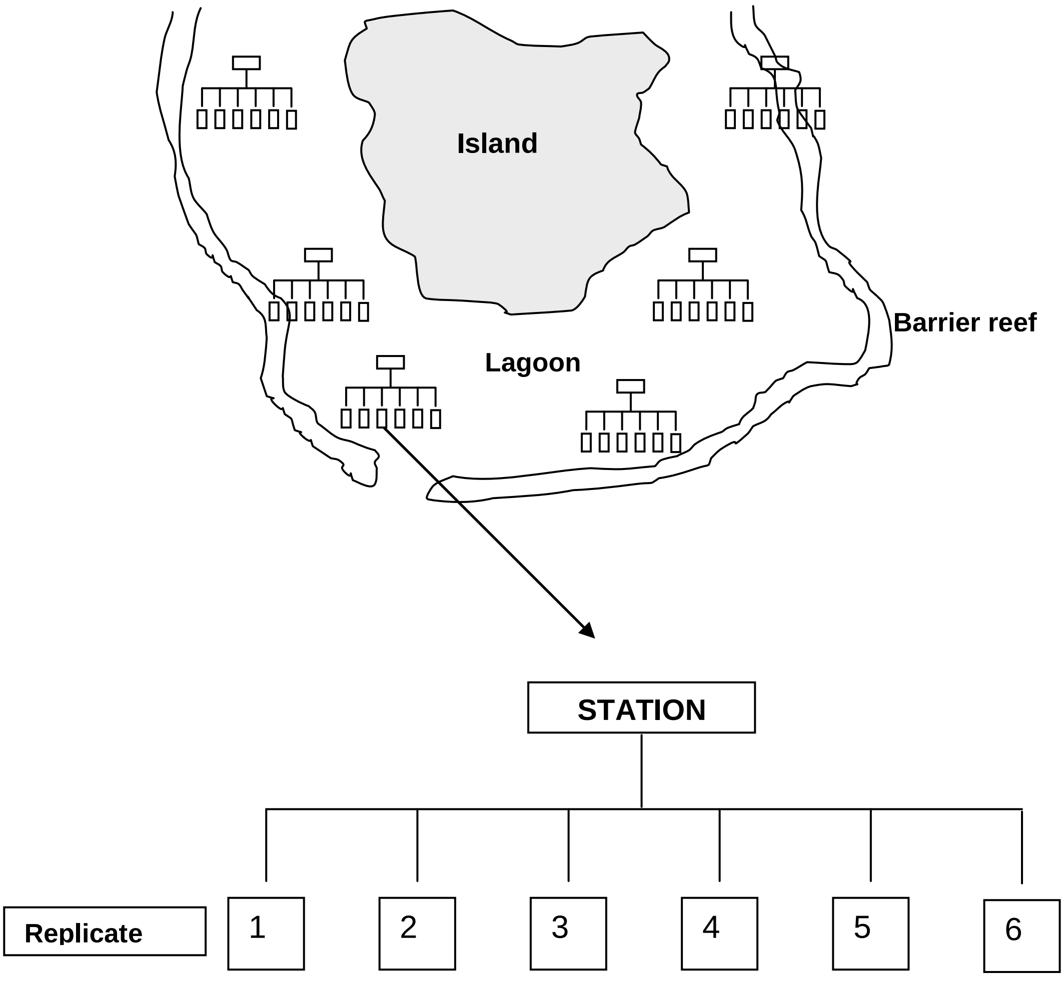


Figure A1.3.1: Stations and replicate measures at a given site.
Note: a replicate measure could be a transect, search period or quadrat group.

Invertebrate species diversity, spatial distribution and abundance were determined using fishery-independent surveys at stations over broad-scale and more targeted surveys. Broad-scale surveys aimed to record a range of macro invertebrates across sites, whereas more targeted surveys concentrated on specific habitats and groups of important resource species.

Recordings of habitat are generally taken for all replicates within stations (see Appendix 1.3.3). Comparison of species complements and densities among stations and sites does not factor in fundamental differences in macro and micro habitat, as there is presently no established method that can be used to make allowances for these variations. The complete dataset from PROCFish/C will be a valuable resource to assess such habitat effects, and by identifying salient habitat factors that reliably affect resource abundance, we may be able to account for these habitat differences when inferring 'status' of important species groups. This will be examined once the full Pacific dataset has been collected.

More detailed explanations of the various survey methods are given below.

Broad-scale survey

Manta 'tow-board' transect surveys

A general assessment of large sedentary invertebrates and habitat was conducted using a tow-board technique adapted from English *et al.* (1997), with a snorkeller towed at low speed (<2.5 km/hour). This is a slower speed than is generally used for manta transects, and is less than half the normal walking pace of a pedestrian.

Where possible, manta surveys were completed at 12 stations per site. Stations were positioned near land masses on fringing reefs (inner stations), within the lagoon system (middle stations) and in areas most influenced by oceanic conditions (outer stations). Replicate measures within stations (called transects) were conducted at depths between 1 m and <10 m of water (mostly 1.5–6 m), covering broken ground (coral stone and sand) and at the edges of reefs. Transects were not conducted in areas that were too shallow for an outboard-powered boat (<1 m) or adjacent to wave-impacted reef.

Each transect covered a distance of ~300 m (thus the total of six transects covered a linear distance of ~2 km). This distance was calibrated using the odometer function within the trip computer option of a Garmin 76Map® GPS. Waypoints were recorded at the start and end of each transect to an accuracy of ≤10 m. The abundance and size estimations for large sedentary invertebrates were taken within a 2 m swathe of benthos for each transect. Broad-based assessments at each station took approximately one hour to complete (7–8 minutes per transect × 6, plus recording and moving time between transects). Hand tally counters and board-mounted bank counters (three tally units) were used to assist with enumerating common species.

The tow-board surveys differed from traditional manta surveys by utilising a lower speed and concentrating on a smaller swathe on the benthos. The slower speed, reduced swathe and greater length of tows used within PROCFish/C protocols were adopted to maximise efficiency when spotting and identifying cryptic invertebrates, while covering areas that were large enough to make representative measures.

Targeted surveys

Reef- and soft-benthos transect surveys (RBt and SBt), and soft-benthos quadrats (SBq)

To assess the range, abundance, size and condition of invertebrate species and their habitat with greater accuracy at smaller scales, reef- and soft-benthos assessments were conducted within fishing areas and suitable habitat. Reef benthos and soft benthos are not mutually exclusive, in that coral reefs generally have patches of sand, while soft-benthos seagrass areas can be strewn with rubble or contain patches of coral. However, these survey stations (each covering approximately 5000 m^2) were selected in areas representative of the habitat (those generally accessed by fishers, although MPAs were examined on occasion). Six 40 m transects (1 m swathe) were examined per station to record most epi-benthic invertebrate resources and some sea stars and urchin species (as potential indicators of habitat condition). Transects were randomly positioned but laid across environmental gradients where possible (e.g. across reefs and not along reef edges). A single waypoint was recorded for each station (to an accuracy of ≤10 m) and habitat recordings were made for each transect (see Figure A1.3.2 and Appendix 1.3.2).

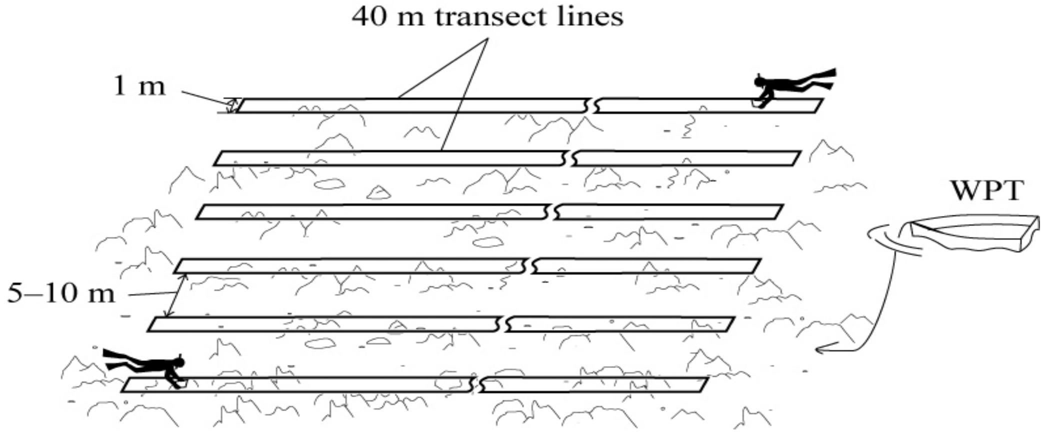


Figure A1.3.2: Example of a reef-benthos transect station (RBt).

To record infaunal resources, quadrats (SBq) were used within a 40 m × 2 m strip transect to measure densities of molluscs (mainly bivalves) in soft-benthos 'shell bed' areas. Four 25 cm^2 quadrats (one quadrat group) were dug to approximately 5–8 cm to retrieve and measure infaunal target species and potential indicator species. Eight randomly spaced quadrat groups were sampled along the 40 m transect line (Figure A1.3.3). A single waypoint and habitat recording was taken for each infaunal station.

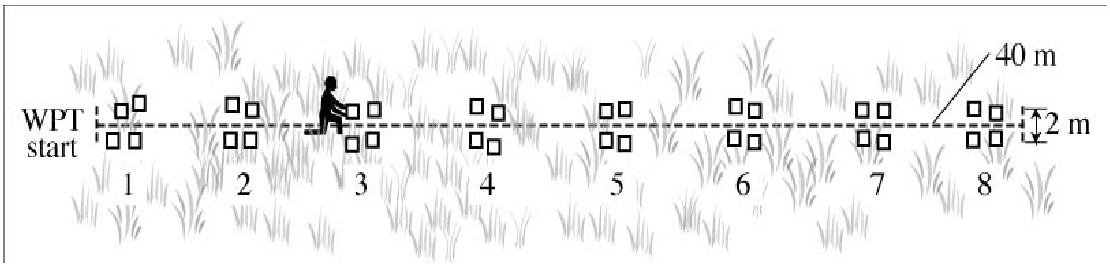


Figure A1.3.3: Soft-benthos (infaunal) quadrat station (SBq).
Single quadrats are 25 cm x 25 cm in size and four make up one 'quadrat group'.

<u>Mother-of-pearl (MOP) or sea cucumber (BdM) fisheries</u>

To assess fisheries such as those for trochus or sea cucumbers, results from broad-scale, reef- and soft-benthos assessments were used. However, other specific surveys were incorporated into the work programme, to more closely target species or species groups not well represented in the primary assessments.

<u>Reef-front searches (RFs and RFs_w)</u>

If swell conditions allowed, three 5-min search periods (30 min total) were conducted along exposed reef edges (RFs) where trochus (*Trochus niloticus*) and surf redfish (*Actinopyga* *mauritiana*) generally aggregate (Figure A1.3.4). Due to the dynamic conditions of the reef front, it was not generally possible to lay transects, but the start and end waypoints of reef-front searches were recorded, and two snorkellers recorded the abundance (generally not size measures) of large sedentary species (concentrating on trochus, surf redfish, gastropods and clams).

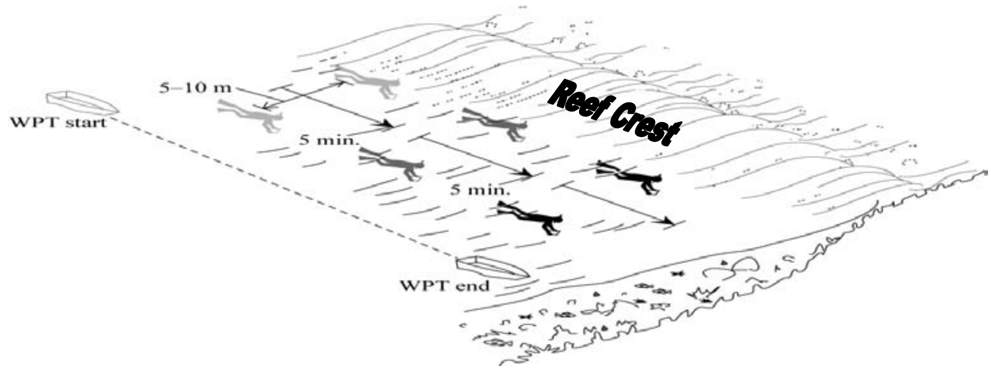


Figure A1.3.4: Reef-front search (RFs) station.

On occasions when it was too dangerous to conduct in-water reef-front searches (due to swell conditions or limited access) and the reeftop was accessible, searches were conducted on foot along the top of the reef front (RFs_w). In this case, two officers walked side by side (5–10 m apart) in the pools and cuts parallel to the reef front. This search was conducted at low tide, as close as was safe to the wave zone. In this style of assessment, reef-front counts of sea cucumbers, gastropod shells, urchins and clams were made during three 5-min search periods (total of 30 minutes search per station).

In the case of *Trochus niloticus*, reef-benthos transects, reef-front searches and local advice (trochus areas identified by local fishers) led us to reef-slope and shoal areas that were surveyed using SCUBA. Initially, searches were undertaken using SCUBA, although SCUBA transects (greater recording accuracy for density) were adopted if trochus were shown to be present at reasonable densities.

Mother-of-pearl search (MOPs)

Initially, two divers (using SCUBA) actively searched for trochus for three 5-min search periods (30 min total). Distance searched was estimated from marked GPS start and end waypoints. If more than three individual shells were found on these searches, the stock was considered dense enough to proceed with the more defined area assessment technique (MOPt).

Mother-of-pearl transects (MOPt)

Also on SCUBA, this method used six 40-m transects (2 m swathe) run perpendicular to the reef edge and not exceeding 15 m in depth (Figure A1.3.5). In most cases the depth ranged between 2 and 6 m, although dives could reach 12 m at some sites where more shallow-water habitat or stocks could not be found. In cases where the reef dropped off steeply, more oblique transect lines were followed. On MOP transect stations, a hip-mounted (or handheld) Chainman® measurement system (thread release) was used to measure out the 40 m. This allowed a hands-free mode of survey and saved time and energy in the often dynamic conditions where *Trochus niloticus* are found.

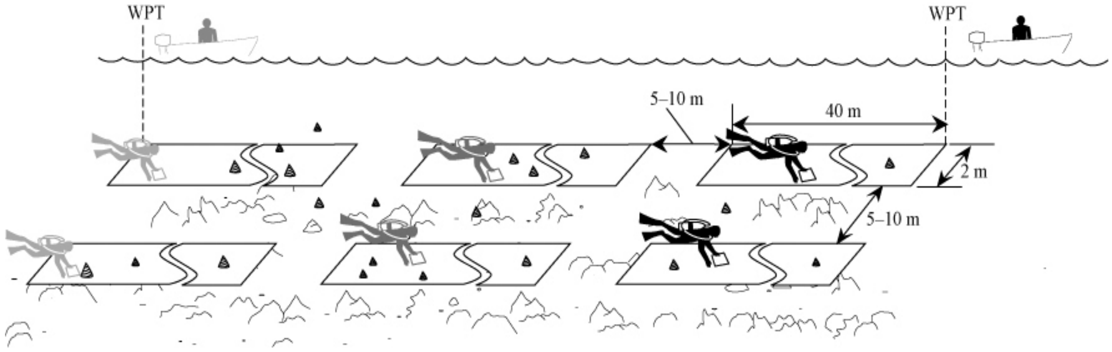


Figure A1.3.5: Mother-of-pearl transect station (MOPt).

<u>Sea cucumber day search (Ds)</u>

When possible, dives to 25–35 m were made to establish if white teatfish (*Holothuria (Microthele) fuscogilva*) populations were present and give an indication of abundance. In these searches two divers recorded the number and sizes of valuable deep-water sea cucumber species within three 5-min search periods (30 min total). This assessment from deep water does not yield sufficient presence/absence data for a very reliable inference on the status (i.e. 'health') of this and other deeper-water species.

<u>Sea cucumber night search (Ns)</u>

In the case of sea cucumber fisheries, dedicated night searches (Ns) for sea cucumbers and other echinoderms were conducted (using snorkel) for predominantly nocturnal species (blackfish *Actinopyga miliaris*, *A. lecanora*, and *Stichopus horrens*). Sea cucumbers were collected for three 5-min search periods by two snorkellers (30 min total), and if possible weighed (length and width measures for *A. miliaris* and *A. lecanora* are more dependent on the condition than the age of an individual).

Reporting style

For country site reports, results highlight the presence and distribution of species of interest, and their density at scales that yield a representative picture. Generally speaking, mean densities (average of all records) are presented, although on occasion mean densities for areas of aggregation ('patches') are also given. The later density figure is taken from records (stations or transects, as stated) where the species of interest is present (with an abundance >zero). Presentation of the relative occurrence and densities (without the inclusion of zero records) can be useful when assessing the status of aggregations within some invertebrate stocks.

An example and explanation of the reporting style adopted for invertebrate results follows.

1. The mean density range of *Tridacna* spp. on broad-scale stations (n = 8) was 10–120 per ha.

Density range includes results from all stations. In this case, replicates in each station are added and divided by the number of replicates for that station to give a mean. The lowest and highest station averages (here 10 and 120) are presented for the range. The number in brackets (n = 8) highlights the number of stations examined.

2. The mean density (per ha, ±SE) of all *Tridacna* clam species observed in broad-scale transects (n = 48) was 127.8 ±21.8 (occurrence in 29% of transects).

Mean density is the arithmetic mean, or average of measures across all replicates taken (in this case broad-scale transects). On occasion mean densities are reported for stations or transects where the species of interest is found at an abundance greater than zero. In this case the arithmetic mean would only include stations (or replicates) where the species of interest was found (excluding zero replicates). If this was presented for stations, even stations with a single clam from six transects would be included. (Note: a full breakdown of data is presented in the appendices.)

Written after the mean density figure is a descriptor that highlights variability in the figures used to calculate the mean. Standard error[3] (SE) is used in this example to highlight variability in the records that generated the mean density (SE = (standard deviation of records)/√n). This figure provides an indication of the dispersion of the data when trying to estimate a population mean (the larger the standard error, the greater variation of data points around the mean presented).

Following the variability descriptor is a presence/absence indicator for the total dataset of measures. The presence/absence figure describes the percentage of stations or replicates with a recording >0 in the total dataset; in this case 29% of all transects held *Tridacna* spp., which equated to 14 of a possible 48 transects (14/48*100 = 29%).

3. The mean length (cm, ±SE) of *T. maxima* was 12.4 ±1.1 (n = 114).

The number of units used in the calculation is indicated by *n*. In the last case, 114 clams were measured.

[3] In order to derive confidence limits around the mean, a transformation (usually y = log (x+1)) needs to be applied to data, as samples are generally non-normally distributed. Confidence limits of 95% can be generated through other methods (bootstrapping methods) and will be presented in the final report where appropriate.

1.3.2 General fauna invertebrate recording sheet with instructions to users

DATE		RECORDER		Pg No	

STATION NAME																		
WPT - WIDTH																		
RELIEF / COMPLEXITY **1–5**																		
OCEAN INFLUENCE **1–5**																		
DEPTH (M)																		
% SOFT SED (M – S – CS)																		
% RUBBLE / BOULDERS																		
% CONSOL RUBBLE / PAVE																		
% CORAL *LIVE*																		
% CORAL *DEAD*																		
SOFT / SPONGE / FUNGIDS																		
ALGAE *CCA*																		
CORALLINE																		
OTHER																		
GRASS																		
EPIPHYTES **1–5** / SILT **1–5**																		
bleaching: % of																		
entered /	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/

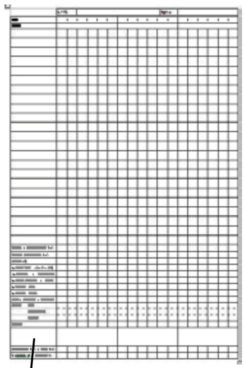
Figure A1.3.6: Sample of the invertebrate fauna survey sheet.

The sheet above (Figure A1.3.6) has been modified to fit on this page (the original has more line space (rows) for entering species data). When recording abundance or length data against species names, columns are used for individual transects or 5-min search replicates. If more space is needed, more than a single column can be used for a single replicate.

A separate sheet is used by a recorder in the boat to note information from handheld GPS equipment. In addition to the positional information, this boat sheet has space for manta transect distance (from GPS odometer function) and for sketches and comments.

1.3.3 Habitat section of invertebrate recording sheet with instructions to users

Figure A1.3.7 depicts the habitat part of the form used during invertebrate surveys; it is split into seven broad categories.



RELIEF / COMPLEXITY **1–5**							1
OCEAN INFLUENCE **1–5**							2
DEPTH (M)							3
% SOFT SED (M– S – CS)							4
% RUBBLE / BOULDERS							4
% CONS RUBBLE / PAVE							4
% CORAL *LIVE*							4
% CORAL *DEAD*							4
SOFT / SPONGE / FUNGIDS							5
ALGAE *CCA*							5
CORALLINE							5
OTHER							5
GRASS							5
							5
EPIPHYTES **1–5** / SILT **1–5**							6
BLEACHING: % OF BENTHOS							7

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

Appendix 1: Survey methods
Invertebrates

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.

Appendix 1: Survey methods
Invertebrates

Consolidated rubble is attached, cemented pieces of coral stone and limestone debris. We tend to use ‘rubble’ for pieces or piles loose in the sediment of seagrass, etc., and ‘consolidated rubble’ for areas that are not flat pavement but concreted rubble on reeftops and cemented talus slopes.

Pavement is solid, substantial, fixed, flat stone (generally limestone) benthos.

Coral live is any live hard coral.

Coral dead is coral that is recognisable as coral even if it is long dead. Note that long-dead and *eroded* coral that is found in flat pavements is called ‘pavement’ and when it is found in loose pieces or blocks it is termed ‘rubble’ or ‘boulders’ (depending on size).

Cover – what is on top of the substrate (section 5 of form)

This cannot exceed 100%, but can be anything from 0 to 100%. Surveyors give scores in blocks of 5%, so e.g. 5, 10, 15, 20 (%) etc. and not 2, 13, 17, 56.

Elements to consider:

Cover	Soft coral
Cover	Sponge
Cover	Fungids
Cover	Crustose-nongeniculate coralline algae
Cover	Coralline algae
Cover	Other (algae like sargassum, caulerpa and padina)
Cover	Seagrass

Soft coral is all soft corals but not Zoanthids or anemones.

Sponge includes half-buried sponges in seagrass beds – only sections seen on the surface are noted.

Fungids are fungids.

Crustose – nongeniculate coralline algae are pink rock. Crustose or nongeniculate coralline algae (NCA) are red algae that deposit calcium carbonate in their cell walls. Generally they are members of the division Rhodophyta.

Coralline algae – halimeda are red coralline algae (often seen in balls – *Galaxaura*). (Note: AIMS lists *halimeda* and other coralline algae as macro algae along with fleshy algae not having $CaCo_3$ deposits.)

Other algae include fleshy algae such as *Turbinaria*, *Padina* and *Dictyota*. Surveyors describe coverage by taking a bird’s-eye view of what is covered, not by delineating the spatial area of the algae colony within the transect (i.e. differences in very low or high density are accounted for). The large space on the form is used to write species information if known.

Seagrass includes seagrass such as *Halodule*, *Thalassia*, *Halophila* and *Syringodium*. Surveyors note types by species if possible or by structure (i.e. flat versus reed grass), and describe coverage by taking a bird's-eye view of what benthos is covered, not by delineating the spatial area of the grass meadow within the transect (i.e. differences in very low or high density are accounted for).

Cover continued – epiphytes and silt (section 6 of form)

Epiphytes 1–5 grade are mainly turf algae – turf that grows on hard and soft substrates, but also on algae and grasses. The growth is usually fine-stranded filamentous algae that have few noticeable distinguishing features (more like fuzz).

1 = none
2 = small areas or light coverage
3 = patchy, medium coverage
4 = large areas or heavier coverage
5 = very strong coverage, long and thick almost choking epiphytes – normally including strands of blue-green algae as well

Silt 1–5 grade (or a similar fine-structured material sometimes termed 'marine snow') consists of fine particles that slowly settle out from the water but are easily re-suspended. When re-suspended, silt tends to make the water murky and does not settle quickly like sand does. Sand particles are not silt and should not be included here when seen on outer-reef platforms that are wave affected.

1 = clear surfaces
2 = little silt seen
3 = medium amount of silt-covered surfaces
4 = large areas covered in silt
5 = surfaces heavily covered in silt

Bleaching (section 7 of form)

The percentage of bleached live coral is recorded in numbers from 1 to 100% (Not 5% blocks). This is the percentage of benthos that is dying hard coral (just-bleached) or very recently dead hard coral showing obvious signs of recent bleaching.

APPENDIX 2: SOCIOECONOMIC SURVEY DATA

2.1 Dromuna socioeconomic survey data

2.1.1 Annual catch (kg) of fish groups per habitat – Dromuna

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Kanace	Mugilidae	*Valamugil* spp.	1228	12.0
Kabatia	Lethrinidae	*Lethrinus harak*	963	9.4
Cumu	Balistidae	*Balistoides viridescens*	690	6.8
Kawago	Lethrinidae	*Lethrinus lentjan*	609	6.0
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	597	5.8
Kaikai	Leiognathidae	*Leiognathus equulus*	520	5.1
Cucu	Holocentridae	*Myripristis* spp.	376	3.7
Sabutu	Lethrinidae	*Lethrinus* spp.	353	3.5
Matu	Gerreidae	*Gerres* spp.	346	3.4
Nuqa	Siganidae	*Siganus vermiculatus*	323	3.2
Bo	Lutjanidae	*Lutjanus bohar*, *Lutjanus gibbus*	311	3.0
Ulavi	Scaridae	*Scarus rubroviolaceus*	284	2.8
Kawakawa	Serranidae	*Cephalopholis argus*	261	2.6
Cebe	Leiognathidae	*Leiognathus equulus*	252	2.5
Saqa	Carangidae	*Caranx ignobilis*	252	2.5
Damu	Lutjanidae	*Lutjanus argentimaculatus*	246	2.4
Kake	Lutjanidae	*Lutjanus monostigma*	233	2.3
Tanabe	Lutjanidae	*Lutjanus fulvus*	210	2.1
Coco	Holocentridae	*Myripristis* spp.	189	1.8
Buse	Hemiramphidae	*Hyporhamphus dussumieri*	179	1.7
Seni kawakawa	Serranidae	*Epinephelus merra*	158	1.5
Vilu	Carangidae	*Gnathanodon speciosus*	156	1.5
Molisa	Mugilidae	*Valamugil* spp.	156	1.5
Kacika	Lethrinidae	*Lethrinus xanthochilus*	147	1.4
Sinusinu	Serranidae	*Epinephelus* spp.	130	1.3
Salala	Scombridae	*Rastrelliger brachysoma*	107	1.0
Ki	Mullidae	*Upeneus vittatus*	101	1.0
Kilikili	Mullidae	*Upeneus* spp.	86	0.8
Matumau	Gerreidae	*Gerres* spp.	76	0.7
Yawa	Chanidae	*Chanos chanos*	75	0.7
Qitawa	Terapontidae	*Terapon jarbua*	67	0.7
Laidamo	Acanthuridae	*Acanthurus* spp.	63	0.6
Kasala	Serranidae	*Epinephelus miliaris*	55	0.5
Matulau			50	0.5
Donu	Serranidae	*Plectropomus leopardus*	50	0.5
Dole	Carangidae	*Selar* spp.	50	0.5
Ose	Mullidae	*Mulloidichthys vanicolensis*	50	0.5
Kela	Carangidae	*Caranx* spp.	50	0.5
Sokisoki	Diodontidae	*Diodon hystrix*	50	0.5
Mataroko	Mullidae	*Parupeneus* spp.	44	0.4

2.1.1 Annual catch (kg) of fish groups per habitat – Dromuna (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)				
Ogo	Sphyraenidae	*Sphyraena qenie*, *Sphyraena barracuda*	27	0.3
Lau	Lethrinidae	*Lethrinus* spp.	27	0.3
Mu			19	0.2
Total:			**10,217**	**100.0**
Lagoon & outer reef				
Sabutu	Lethrinidae	*Lethrinus* spp.	647	19.2
Saqa	Carangidae	*Caranx ignobilis*	473	14.0
Damu	Lutjanidae	*Lutjanus argentimaculatus*	335	9.9
Kanace	Mugilidae	*Valamugil* spp.	284	8.4
Bo	Lutjanidae	*Lutjanus bohar*, *Lutjanus gibbus*	273	8.1
Saku	Belonidae	*Tylosurus* spp.	210	6.2
Kabatia	Lethrinidae	*Lethrinus harak*	210	6.2
Lele	Acanthuridae	*Acanthurus* spp.	139	4.1
Donu	Serranidae	*Plectropomus leopardus*	130	3.9
Salala	Scombridae	*Rastrelliger brachysoma*	113	3.4
Kawakawa	Serranidae	*Cephalopholis argus*	113	3.4
Cucu	Holocentridae	*Myripristis* spp.	84	2.5
Matu	Gerreidae	*Gerres* spp.	84	2.5
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	80	2.4
Kasala	Serranidae	*Epinephelus miliaris*	76	2.2
Kilikili	Mullidae	*Upeneus* spp.	50	1.5
Nuqa	Siganidae	*Siganus vermiculatus*	25	0.7
Tanabe	Lutjanidae	*Lutjanus fulvus*	25	0.7
Lau	Lethrinidae	*Lethrinus* spp.	25	0.7
Total:			**3377**	**100.0**
Outer reef				
Saqa	Carangidae	*Caranx ignobilis*	284	13.7
Kawago	Lethrinidae	*Lethrinus lentjan*	248	12.0
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	246	11.9
Matulau			191	9.3
Nuqa	Siganidae	*Siganus vermiculatus*	181	8.8
Ulavi	Scaridae	*Scarus rubroviolaceus*	181	8.8
Laidamo	Acanthuridae	*Acanthurus* spp.	133	6.4
Ogo	Sphyraenidae	*Sphyraena qenie*, *Sphyraena barracuda*	110	5.3
Seni kawakawa	Serranidae	*Epinephelus merra*	78	3.8
Saku	Belonidae	*Tylosurus* spp.	78	3.8
Kabatia	Lethrinidae	*Lethrinus harak*	76	3.7
Coco	Holocentridae	*Myripristis* spp.	63	3.1
Sabutu	Lethrinidae	*Lethrinus* spp.	55	2.7
Ose	Mullidae	*Mulloidichthys vanicolensis*	50	2.4
Walu	Scombridae	*Scomberomorus commerson*	50	2.4
Ta	Acanthuridae	*Naso unicornis*	27	1.3
Sokisoki	Diodontidae	*Diodon hystrix*	13	0.6
Total:			**2063**	**100.0**

2.1.1 Annual catch (kg) of fish groups per habitat – Dromuna (continued)

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef & passage				
Sabutu	Lethrinidae	*Lethrinus* spp.	390	26.0
Kawago	Lethrinidae	*Lethrinus lentjan*	348	23.2
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	209	13.9
Saku	Belonidae	*Tylosurus* spp.	156	10.4
Kawakawa	Serranidae	*Cephalopholis argus*	88	5.9
Ulavi	Scaridae	*Scarus rubroviolaceus*	78	5.2
Lele	Acanthuridae	*Acanthurus* spp.	55	3.7
Ogo	Sphyraenidae	*Sphyraena* qenie, *Sphyraena barracuda*	50	3.4
Matulau			36	2.4
Sinusinu	Serranidae	*Epinephelus* spp.	35	2.3
Vilu	Carangidae	*Gnathanodon speciosus*	27	1.8
Walu	Scombridae	*Scomberomorus commerson*	27	1.8
Total:			**1501**	**100.0**

2.1.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Dromuna

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Bêche-de-mer	Dri	*Holothuria* spp.	36.8
	Vula	*Bohadschia* spp.	24.3
	Tarasea	*Holothuria* spp.	15.4
	Sucudrau	*Holothuria* spp.	9.7
	Sucuwalu	*Holothuria* spp.	5.6
	Mudra	*Actinopyga lecanora*, *Stichopus* spp.	4.1
	Pinati	*Holothuria* spp.	4.1
Lobster	Urau	*Panulirus* spp.	100.0
Mangrove	Qari	*Scylla serrata*	100.0
Other	Vasua	*Tridacna* spp.	88.9
	Yaga	*Lambis lambis*	11.1
Reeftop	Kolakola	*Spondylus* spp.	65.1
	Yaga	*Lambis lambis*	34.2
	Senikavere	*Dolabella* spp.	0.7
	Nama		
Intertidal & reeftop	Dairo	*Holothuria* spp.	28.1
	I sivi	*Pinna bicolor*	26.9
	Kolakola	*Spondylus* spp.	18.9
	Yaga	*Lambis lambis*	13.5
	Qaqa	*Gafrarium tumidum*	7.1
	Golea	*Strombus gibberulus gibbosus*	2.5
	Tadruku	*Acanthopleura gemmata*	2.0
	Bosucu	*Turbo* spp.	1.1
	Nama		
Intertidal & reeftop & other	I sivi	*Pinna bicolor*	77.6
	Golea	*Strombus gibberulus gibbosus*	12.9
	Tadruku	*Acanthopleura gemmata*	5.6
	Bosucu	*Turbo* spp.	3.9
Soft benthos	Kaikoso	*Anadara* spp.	100.0
Soft benthos & mangrove	I sivi	*Pinna bicolor*	35.9
	Qari	*Scylla serrata*	31.4
	Kaikoso	*Anadara* spp.	18.2
	Kolakola	*Spondylus* spp.	12.0
	Bosucu	*Turbo* spp.	2.4
Soft benthos & reeftop	Kolakola	*Spondylus* spp.	44.8
	Yaga	*Lambis lambis*	36.3
	Kaikoso	*Anadara* spp.	13.1
	Tadruku	*Acanthopleura gemmata*	5.4
	Senikavere	*Dolabella* spp.	0.4
	Lumi		
	Nama		
Soft benthos & reeftop & other	Kuita	*Octopus* spp.	72.5
	Yaga	*Lambis lambis*	27.5
	Nama		
Trochus & lobster	Trochus	*Trochus niloticus*	50.0
	Urau	*Panulirus* spp.	50.0

2.1.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Dromuna

Vernacular name	Scientific name	Size class	% of total catch (weight)
Bosucu	*Turbo* spp.	04-06 cm	28.2
		04-08 cm	16.9
		06-08 cm	54.9
Dairo	*Holothuria* spp.	12-14 cm	100.0
Dri	*Holothuria* spp.	12-18 cm	12.5
		14-18 cm	82.5
		16-18 cm	5.0
Golea	*Strombus gibberulus gibbosus*	06 cm	100.0
I sivi	*Pinna bicolor*	10-12 cm	30.8
		10-14 cm	23.1
		12-16 cm	46.2
Kaikoso	*Anadara* spp.	06 cm	100.0
Kolakola	*Spondylus* spp.	06-08 cm	10.0
		08-10 cm	12.0
		08-12 cm	30.0
		10-12 cm	15.0
		12-14 cm	33.0
Kuita	*Octopus* spp.	14-16 cm	100.0
Lumi		01 cm	
Mudra	*Actinopyga lecanora*, *Stichopus* spp.	12-16 cm	100.0
Nama		01 cm	
Pinati	*Holothuria* spp.	12-16 cm	100.0
Qaqa	*Gafrarium tumidum*	06-08 cm	100.0
Qari	*Scylla serrata*	20-22 cm	3.2
		22-26 cm	96.8
Senikavere	*Dolabella* spp.	01 cm	100.0
Sucudrau	*Holothuria* spp.	14-18 cm	52.2
		16-18 cm	47.8
Sucuwalu	*Holothuria* spp.	16-18 cm	100.0
Tadruku	*Acanthopleura gemmata*	03-05 cm	26.1
		04-06 cm	73.9
Tarasea	*Holothuria* spp.	14-18 cm	87.9
		16-18 cm	12.1
Trochus	*Trochus niloticus*	12-14 cm	100.0
Urau	*Panulirus* spp.	20-24 cm	29.4
		22-26 cm	70.6
Vasua	*Tridacna* spp.	18-20 cm	100.0
Vula	*Bohadschia* spp.	12-16 cm	22.6
		12-18 cm	18.9
		14-16 cm	37.7
		14-18 cm	20.8
Yaga	*Lambis lambis*	10-14 cm	30.7
		12-14 cm	41.6
		12-16 cm	27.7

2.2 Muaivuso socioeconomic survey data

2.2.1 Annual catch (kg) of fish groups per habitat – Muaivuso

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Kabatia	Lethrinidae	*Lethrinus harak*	1802	16.1
Kake	Lutjanidae	*Lutjanus monostigma*	995	8.9
Sabutu	Lethrinidae	*Lethrinus* spp.	955	8.5
Kanace	Mugilidae	*Valamugil* spp.	942	8.4
Seni kawakawa	Serranidae	*Epinephelus merra*	792	7.1
Damu	Lutjanidae	*Lutjanus argentimaculatus*	770	6.9
Kaikai	Leiognathidae	*Leiognathus equulus*	610	5.5
Ulavi	Scaridae	*Scarus rubroviolaceus*	574	5.1
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	500	4.5
Salala	Scombridae	*Rastrelliger brachysoma*	435	3.9
Kawakawa	Serranidae	*Cephalopholis argus*	395	3.5
Cucu	Holocentridae	*Myripristis* spp.	329	2.9
Busa	Hemiramphidae	*Hemiramphus far*	276	2.5
Cumu	Balistidae	*Balistoides viridescens*	262	2.3
Laidamo	Acanthuridae	*Acanthurus* spp.	218	1.9
Mataroko	Mullidae	*Parupeneus* spp.	170	1.5
Kawago	Lethrinidae	*Lethrinus lentjan*	168	1.5
Kilikili	Mullidae	*Upeneus* spp.	164	1.5
Nuqa	Siganidae	*Siganus vermiculatus*	164	1.5
			153	1.4
Matu	Gerreidae	*Gerres* spp.	140	1.3
Vai	Dasyatidae	*Dasyatis* spp.	94	0.8
Matumau	Gerreidae	*Gerres* spp.	93	0.8
Molisa	Mugilidae	*Valamugil* spp.	70	0.6
Saqa	Carangidae	*Caranx ignobilis*	53	0.5
Tanabe	Lutjanidae	*Lutjanus fulvus*	47	0.4
Total:			**11,171**	**100.0**
Lagoon & outer reef				
Kawago	Lethrinidae	*Lethrinus lentjan*	539	27.9
Sabutu	Lethrinidae	*Lethrinus* spp.	333	17.2
Kabatia	Lethrinidae	*Lethrinus harak*	234	12.1
Matu	Gerreidae	*Gerres* spp.	205	10.6
Busa	Hemiramphidae	*Hemiramphus far*	157	8.1
Kake	Lutjanidae	*Lutjanus monostigma*	145	7.5
Ulavi	Scaridae	*Scarus rubroviolaceus*	132	6.9
Mataroko	Mullidae	*Parupeneus* spp.	117	6.1
Kaikai	Leiognathidae	*Leiognathus equulus*	70	3.6
Total:			**1931**	**100.0**

2.2.1 Annual catch (kg) of fish groups per habitat – Muaivuso (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef				
Sabutu	Lethrinidae	*Lethrinus* spp.	123	17.4
Kawago	Lethrinidae	*Lethrinus lentjan*	109	15.3
Kawakawa	Serranidae	*Cephalopholis argus*	73	10.3
Kake	Lutjanidae	*Lutjanus monostigma*	70	9.9
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	70	9.9
Kilikili	Mullidae	*Upeneus* spp.	70	9.9
Bo	Lutjanidae	*Lutjanus bohar*, *Lutjanus gibbus*	70	9.9
Nuqa	Siganidae	*Siganus vermiculatus*	62	8.7
Saqa	Carangidae	*Caranx ignobilis*	50	7.0
Ulavi	Scaridae	*Scarus rubroviolaceus*	12	1.7
Total:			**711**	**100.0**

2.2.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Muaivuso

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Bêche-de-mer	Dri	*Holothuria* spp.	23.1
	Tarasea	*Holothuria* spp.	22.3
	Sucudrau	*Holothuria* spp.	19.3
	Loli	*Holothuria* spp.	12.2
	Vula	*Bohadschia* spp.	11.1
	Dairo	*Holothuria* spp.	6.7
	Trochus	*Trochus niloticus*	2.9
	Kuita	*Octopus* spp.	2.4
Other	Kuita	*Octopus* spp.	71.7
	Vasua	*Tridacna* spp.	28.3
Reeftop & other	Kuita	*Octopus* spp.	81.5
	Yaga	*Lambis lambis*	18.5
Reeftop & trochus & other	Trochus	*Trochus niloticus*	57.7
	Kuita	*Octopus* spp.	42.3
Intertidal & reeftop	Cawaki	*Tripneustes gratilla*	42.9
	Melamela	*Pinctada fucata*	23.8
	Kuita	*Octopus* spp.	14.5
	Yaga	*Lambis lambis*	8.7
	Kolakola	*Spondylus* spp.	5.0
	Veyata	*Dolabella auricularia*	4.6
	Voce	*Lingula unguis*	0.5
Soft benthos	Kaikoso	*Anadara* spp.	100.0
Soft benthos & mangrove	Qari	*Scylla serrata*	49.1
	Kaikoso	*Anadara* spp.	26.0
	Cawaki	*Tripneustes gratilla*	19.1
	Sigawale	*Donax cuneatus*	5.7
Soft benthos & reeftop	Cawaki	*Tripneustes gratilla*	53.8
	Yaga	*Lambis lambis*	8.4
	Kuita	*Octopus* spp.	7.9
	Veyata	*Dolabella auricularia*	7.5
	I sivi	*Pinna bicolor*	7.1
	Sigawale	*Donax cuneatus*	5.5
	Kaikoso	*Anadara* spp.	4.3
	Kotia	*Dolabella* spp.	2.5
	Kolakola	*Spondylus* spp.	1.1
	Golea	*Strombus gibberulus gibbosus*	1.1
	Voce	*Lingula unguis*	0.7
	Nama		

2.2.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Muaivuso

Vernacular name	Scientific name	Size class	% of total catch (weight)
Cawaki	*Tripneustes gratilla*	01 cm	100.0
Dairo	*Holothuria* spp.	14-16 cm	100.0
Dri	*Holothuria* spp.	14-16 cm	43.7
		14-18 cm	56.3
Golea	*Strombus gibberulus gibbosus*	04-06 cm	100.0
I sivi	*Pinna bicolor*	12-14 cm	100.0
Kaikoso	*Anadara* spp.	06 cm	100.0
Kolakola	*Spondylus* spp.	10-12 cm	75.8
		12-14 cm	24.2
Kotia	*Dolabella* spp.	01 cm	100.0
Kuita	*Octopus* spp.	12-14 cm	3.3
		14-16 cm	70.2
		14-18 cm	26.5
Loli	*Holothuria* spp.	16-18 cm	100.0
Melamela	*Pinctada fucata*	08-10 cm	55.6
		08-12 cm	44.4
Nama		01 cm	
Qari	*Scylla serrata*	18-22 cm	54.5
		20-24 cm	45.5
Sigawale	*Donax cuneatus*	04-06 cm	100.0
Sucudrau	*Holothuria* spp.	14-18 cm	57.7
		16-18 cm	42.3
Tarasea	*Holothuria* spp.	14-18 cm	100.0
Trochus	*Trochus niloticus*	14-16 cm	40.8
		16-18 cm	59.2
Vasua	*Tridacna* spp.	16-18 cm	100.0
Veyata	*Dolabella auricularia*	01 cm	100.0
Voce	*Lingula unguis*	03-06 cm	100.0
Vula	*Bohadschia* spp.	14-18 cm	100.0
Yaga	*Lambis lambis*	12-14 cm	76.5
		14-16 cm	23.5

2.3 Mali socioeconomic survey data

2.3.1 Annual catch (kg) of fish groups per habitat – Mali

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Kawago	Lethrinidae	*Lethrinus lentjan*	537	11.8
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	528	11.6
Kawakawa	Serranidae	*Cephalopholis argus*	497	10.9
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	459	10.1
Kabatia	Lethrinidae	*Lethrinus harak*	295	6.5
Sabutu	Lethrinidae	*Lethrinus* spp.	289	6.4
Vilu	Carangidae	*Gnathanodon speciosus*	280	6.2
Kacika	Lethrinidae	*Lethrinus xanthochilus*	265	5.8
Yawa	Chanidae	*Chanos chanos*	184	4.0
Dokoni	Lethrinidae	*Lethrinus* spp.	166	3.6
Delabulewa	Haemulidae	*Plectorhinchus* spp.	105	2.3
Nuqa	Siganidae	*Siganus vermiculatus*	94	2.1
Mu			94	2.1
Saqa	Carangidae	*Caranx ignobilis*	92	2.0
Seni kawakawa	Serranidae	*Epinephelus merra*	82	1.8
Damu	Lutjanidae	*Lutjanus argentimaculatus*	70	1.5
Cebe	Leiognathidae	*Leiognathus equulus*	70	1.5
Sinusinu	Serranidae	*Epinephelus* spp.	47	1.0
Busa	Hemiramphidae	*Hemiramphus far*	47	1.0
Sumusumu	Diodontidae	*Diodon liturosus*, *Diodon hystrix*	47	1.0
Matu	Gerreidae	*Gerres* spp.	47	1.0
			47	1.0
Tanabe	Lutjanidae	*Lutjanus fulvus*	47	1.0
Mataroko	Mullidae	*Parupeneus* spp.	35	0.8
Molisa	Mugilidae	*Valamugil* spp.	35	0.8
Kaikai	Leiognathidae	*Leiognathus equulus*	35	0.8
Saku	Belonidae	*Tylosurus* spp.	26	0.6
Kanace	Mugilidae	*Valamugil* spp.	23	0.5
Total:			**4542**	**100.0**
Lagoon				
Sabutu	Lethrinidae	*Lethrinus* spp.	183	25.6
Kabatia	Lethrinidae	*Lethrinus harak*	141	19.7
Sinusinu	Serranidae	*Epinephelus* spp.	105	14.7
Dokoni	Lethrinidae	*Lethrinus* spp.	99	13.8
Yawa	Chanidae	*Chanos chanos*	70	9.8
Moli	Mugilidae	*Valamugil* spp.	70	9.8
Kacika	Lethrinidae	*Lethrinus xanthochilus*	23	3.3
Kasala	Serranidae	*Epinephelus miliaris*	23	3.3
Total:			**715**	**100.0**

2.3.1 Annual catch (kg) of fish groups per habitat – Mali (continued)

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Lagoon & outer reef				
Kacika	Lethrinidae	*Lethrinus xanthochilus*	891	13.0
Sabutu	Lethrinidae	*Lethrinus* spp.	856	12.5
Kawago	Lethrinidae	*Lethrinus lentjan*	706	10.3
Dokoni	Lethrinidae	*Lethrinus* spp.	548	8.0
Vilu	Carangidae	*Gnathanodon speciosus*	462	6.7
Kawakawa	Serranidae	*Cephalopholis argus*	445	6.5
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	268	3.9
Ulavi	Scaridae	*Scarus rubroviolaceus*	252	3.7
Saqa	Carangidae	*Caranx ignobilis*	250	3.6
Seni kawakawa	Serranidae	*Epinephelus merra*	244	3.6
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	219	3.2
Yawa	Chanidae	*Chanos chanos*	219	3.2
Walu	Scombridae	*Scomberomorus commerson*	200	2.9
Lavi	Acanthuridae	*Acanthurus* spp.	192	2.8
Dokonivudi	Lethrinidae	*Lethrinus olivaceus*	185	2.7
Lele	Acanthuridae	*Acanthurus* spp.	166	2.4
I kasa	Muraenesocidae	*Muraenesox* spp.	122	1.8
Ogo	Sphyraenidae	*Sphyraena qenie*, *Sphyraena barracuda*	104	1.5
Busa	Hemiramphidae	*Hemiramphus far*	93	1.4
Kasala	Serranidae	*Epinephelus miliaris*	92	1.3
Kabatia	Lethrinidae	*Lethrinus harak*	70	1.0
Kake	Lutjanidae	*Lutjanus monostigma*	70	1.0
Mu			62	0.9
Toma			54	0.8
Saku	Belonidae	*Tylosurus* spp.	52	0.8
Kanace	Mugilidae	*Valamugil* spp.	31	0.5
Total:			**6854**	**100.0**
Outer reef				
Dokoni	Lethrinidae	*Lethrinus* spp.	148	37.0
Kawago	Lethrinidae	*Lethrinus lentjan*	100	25.0
Kacika	Lethrinidae	*Lethrinus xanthochilus*	74	18.5
Sabutu	Lethrinidae	*Lethrinus* spp.	52	13.0
Saqa	Carangidae	*Caranx ignobilis*	26	6.5
Total:			**401**	**99.9**

2.3.1 Annual catch (kg) of fish groups per habitat – Mali (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef & passage				
Kacika	Lethrinidae	*Lethrinus xanthochilus*	352	19.6
Kawago	Lethrinidae	*Lethrinus lentjan*	326	18.2
Walu	Scombridae	*Scomberomorus commerson*	276	15.4
Dokoni	Lethrinidae	*Lethrinus* spp.	150	8.4
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	150	8.3
Sabutu	Lethrinidae	*Lethrinus* spp.	104	5.8
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	87	4.9
Saku	Belonidae	*Tylosurus* spp.	76	4.2
Dokonivudi	Lethrinidae	*Lethrinus olivaceus*	74	4.1
Ogo	Sphyraenidae	*Sphyraena qenie* *Sphyraena barracuda*	52	2.9
Damu	Lutjanidae	*Lutjanus argentimaculatus*	49	2.8
Yawa	Chanidae	*Chanos chanos*	26	1.4
Saqa	Carangidae	*Caranx ignobilis*	23	1.3
Lele	Acanthuridae	*Acanthurus* spp.	23	1.3
Cumu	Balistidae	*Balistoides viridescens*	23	1.3
Total:			**1793**	**100.0**

2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Mali

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Bêche-de-mer	Dri	*Holothuria* spp.	50.1
	Loli	*Holothuria* spp.	20.7
	Tarasea	*Holothuria* spp.	13.4
	Vula	*Bohadschia* spp.	8.9
	Sucudrau	*Holothuria* spp.	4.6
	Laulevu	*Holothuria* spp.	1.2
	Dri Loa	*Holothuria* spp.	1.0
	Tavunia	*Strombus* spp.	0.1
Lobster	Urau	*Panulirus* spp.	100.0
Mangrove	Qari	*Scylla serrata*	100.0
Other	Vasua	*Tridacna* spp.	61.7
	Kuita	*Octopus* spp.	38.3
Reeftop & trochus & other	Vasua	*Tridacna* spp.	55.6
	Trochus	*Trochus niloticus*	44.4
Intertidal & reeftop	Vasua	*Tridacna* spp.	30.0
	Kuita	*Octopus* spp.	28.9
	I masi	*Conus* spp.	13.5
	Civa	*Pinctada fucata*	11.2
	Sici	*Turbo* spp.	6.0
	Sagosago	*Lambis* spp.	5.6
	Tadruku	*Acanthopleura gemmata*	4.3
	Siu	*Nerita sp*	0.4
Intertidal & reeftop & other	Vasua	*Tridacna* spp.	51.3
	I masi	*Conus* spp.	41.0
	Golea	*Strombus gibberulus gibbosus*	4.3
	Siu	*Nerita sp*	3.4
	Lumi		
Soft benthos & mangrove	Qari	*Scylla serrata*	53.9
	Lairo	*Cardisoma* spp.	27.4
	Tuba	*Cardisoma carnifex*	9.1
	Kaikoso	*Anadara* spp.	7.4
	Yaga	*Lambis lambis*	2.3
Soft benthos & mangrove & reeftop	Sagosago	*Lambis* spp.	76.1
	Sisici	*Nerita polita*	20.3
	Veyata	*Dolabella auricularia*	3.6
Soft benthos & mangrove & intertidal & reeftop	Vasua	*Tridacna* spp.	83.3
	Sagosago	*Lambis* spp.	16.7
	Lumi		
Soft benthos & reeftop	Vasua	*Tridacna* spp.	53.6
	Qari	*Scylla serrata*	42.9
	Tadruku	*Acanthopleura gemmata*	3.6
	Lumi		
	Nama		
Soft benthos & reeftop & other	Vasua	*Tridacna* spp.	50.0
	Qari	*Scylla serrata*	46.7
	Sisici	*Nerita polita*	3.3

2.3.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Mali (continued)

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Soft benthos & intertidal & reeftop	Qari	*Scylla serrata*	48.0
	Kaikoso	*Anadara* spp.	19.8
	Lairo	*Cardisoma* spp.	13.0
	Vasua	*Tridacna* spp.	9.1
	Sagosago	*Lambis* spp.	4.4
	Yaga	*Lambis lambis*	2.5
	Sici	*Turbo* spp.	2.1
	Tadruku	*Acanthopleura gemmata*	1.0
	Lumi		
Trochus	Trochus	*Trochus niloticus*	100.0
Trochus & other	Vasua	*Tridacna* spp.	49.1
	Trochus	*Trochus niloticus*	42.3
	Kuita	*Octopus* spp.	8.6

2.3.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Mali

Vernacular name	Scientific name	Size class	% of total catch (weight)
Civa	*Pinctada fucata*	08-10 cm	100.0
Dri	*Holothuria* spp.	14-18 cm	100.0
Dri Loa	*Holothuria* spp.	14-18 cm	100.0
Golea	*Strombus gibberulus gibbosus*	06 cm	100.0
I masi	*Conus* spp.	08-10 cm	31.0
		08-12 cm	69.0
Kaikoso	*Anadara* spp.	06 cm	100.0
Kuita	*Octopus* spp.	14-16 cm	2.9
		14-18 cm	97.1
Lairo	*Cardisoma* spp.	12-14 cm	61.5
		12-16 cm	38.5
Laulevu	*Holothuria* spp.	14-18 cm	100.0
Loli	*Holothuria* spp.	12-16 cm	16.7
		14-18 cm	5.7
		15-18 cm	77.6
Lumi		01 cm	
Nama		01 cm	
Qari	*Scylla serrata*	16-18 cm	5.2
		18-22 cm	1.2
		18-24 cm	60.1
		20-24 cm	21.8
		22-24 cm	11.8
Sagosago	*Lambis* spp.	10-12 cm	34.8
		12-14 cm	65.2
Sici	*Turbo* spp.	10-14 cm	52.9
		14-16 cm	47.1
Sisici	*Nerita polita*	04-06 cm	100.0
Siu	*Nerita sp*	04-06 cm	84.7
		06-10 cm	15.3
Sucudrau	*Holothuria* spp.	14-18 cm	100.0
Tadruku	*Acanthopleura gemmata*	03-05 cm	39.2
		04-06 cm	60.8
Tarasea	*Holothuria* spp.	15-18 cm	100.0
Tavunia	*Strombus* spp.	06 cm	100.0
Trochus	*Trochus niloticus*	12-14 cm	73.2
		14-16 cm	26.8
Tuba	*Cardisoma carnifex*	14-16 cm	100.0
Urau	*Panulirus* spp.	18-24 cm	65.2
		22-26 cm	34.8
Vasua	*Tridacna* spp.	14-18 cm	5.6
		16-18 cm	5.6
		16-20 cm	22.6
		18-20 cm	17.7
		18-22 cm	48.5
Veyata	*Dolabella auricularia*	01 cm	100.0
Vula	*Bohadschia* spp.	14-18 cm	100.0
Yaga	*Lambis lambis*	12-14 cm	40.7
		12-16 cm	59.3

2.4 Lakeba socioeconomic survey data

2.4.1 Annual catch (kg) of fish groups per habitat – Lakeba

(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Sheltered coastal reef & lagoon				
Kanace	Mugilidae	*Valamugil* spp.	1243	16.1
Kabatia	Lethrinidae	*Lethrinus harak*	681	8.8
Salala	Scombridae	*Rastrelliger brachysoma*	601	7.8
Sabutu	Lethrinidae	*Lethrinus* spp.	597	7.7
Kacika	Lethrinidae	*Lethrinus xanthochilus*	531	6.9
Ta	Acanthuridae	*Naso unicornis*	528	6.8
Bo	Lutjanidae	*Lutjanus bohar*, *Lutjanus gibbus*	335	4.3
Dokoni	Lethrinidae	*Lethrinus* spp.	319	4.1
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	298	3.9
Ulavi	Scaridae	*Scarus rubroviolaceus*	239	3.1
Kasala	Serranidae	*Epinephelus miliaris*	237	3.1
Kawago	Lethrinidae	*Lethrinus lentjan*	207	2.7
Busa	Hemiramphidae	*Hemiramphus far*	191	2.5
Saqa	Carangidae	*Caranx ignobilis*	170	2.2
Cumu	Balistidae	*Balistoides viridescens*	168	2.2
Dole	Carangidae	*Selar* spp.	164	2.1
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	157	2.0
Kaikai	Leiognathidae	*Leiognathus equulus*	135	1.7
Kake	Lutjanidae	*Lutjanus monostigma*	134	1.7
Kawakawa	Serranidae	*Cephalopholis argus*	129	1.7
Matu	Gerreidae	*Gerres* spp.	127	1.6
Ki	Mullidae	*Upeneus vittatus*	111	1.4
Seni kawakawa	Serranidae	*Epinephelus merra*	103	1.3
Kilikili	Mullidae	*Upeneus* spp.	101	1.3
Damu	Lutjanidae	*Lutjanus argentimaculatus*	67	0.9
Molisa	Mugilidae	*Valamugil* spp.	67	0.9
Matumau	Gerreidae	*Gerres* spp.	67	0.9
Total:			**7708**	**100.0**
Lagoon & outer reef				
Kawago	Lethrinidae	*Lethrinus lentjan*	1043	22.4
Sabutu	Lethrinidae	*Lethrinus* spp.	852	18.3
Kabatia	Lethrinidae	*Lethrinus harak*	579	12.4
Kacika	Lethrinidae	*Lethrinus xanthochilus*	476	10.2
Kasala	Serranidae	*Epinephelus miliaris*	406	8.7
Dokoni	Lethrinidae	*Lethrinus* spp.	367	7.9
Seni kawakawa	Serranidae	*Epinephelus merra*	353	7.6
Saqa	Carangidae	*Caranx ignobilis*	331	7.1
Bo	Lutjanidae	*Lutjanus bohar, L. gibbus*	90	1.9
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	89	1.9
Kaikai	Leiognathidae	*Leiognathus equulus*	67	1.4
Matu	Gerreidae	*Gerres* spp.	14	0.3
Total:			**4668**	**100.0**

2.4.1 Annual catch (kg) of fish groups per habitat – Lakeba (continued)
(includes only reported catch data by interviewed finfish fishers)

Vernacular name	Family	Scientific name	Total weight (kg)	% of reported catch
Outer reef				
Kawago	Lethrinidae	*Lethrinus lentjan*	829	37.5
Balagi	Acanthuridae	*Acanthurus nigrofuscus*	636	28.8
Kawakawa	Serranidae	*Cephalopholis argus*	261	11.8
Kabatia	Lethrinidae	*Lethrinus harak*	201	9.1
Seni kawakawa	Serranidae	*Epinephelus merra*	90	4.1
Sabutu	Lethrinidae	*Lethrinus* spp.	71	3.2
Sevaseva	Haemulidae	*Plectorhinchus chaetodonoides*	45	2.0
Dokonivudi	Lethrinidae	*Lethrinus olivaceus*	45	2.0
Kacika	Lethrinidae	*Lethrinus xanthochilus*	34	1.5
Total:			**2210**	**100.0**

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Lakeba

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Bêche-de-mer	Dri	*Holothuria* spp.	43.9
	Loliloli	*Holothuria* spp.	20.7
	Laulevu	*Holothuria* spp.	15.7
	Loli	*Holothuria* spp.	11.6
	Sucuwalu	*Holothuria* spp.	4.7
	Sucudrau	*Holothuria* spp.	1.5
	Dairo	*Holothuria* spp.	1.0
	Dri Loa	*Holothuria* spp.	0.8
Bêche-de-mer & other	Sucudrau	*Holothuria* spp.	57.1
	Dri	*Holothuria* spp.	42.9
Lobster	Urau	*Panulirus* spp.	100.0
Mangrove	Qari	*Scylla serrata*	100.0
Mangrove & reeftop	Kaikoso	*Anadara* spp.	91.0
	Sagosago	*Lambis* spp.	9.0
Other	Vasua	*Tridacna* spp.	84.7
	Kuita	*Octopus* spp.	15.3
Reeftop	Civa	*Pinctada fucata*	60.4
	Kaikoso	*Anadara* spp.	39.6
Reeftop & other	Katavatu	*Tridacna maxima*	55.0
	Kuita	*Octopus* spp.	26.2
	Seila	*Gafrarium* spp.	9.6
	Civa	*Pinctada fucata*	9.2
	Lumi		
	Nama		
Intertidal & reeftop	Katavatu	*Tridacna maxima*	73.5
	Kuita	*Octopus* spp.	15.2
	Sagosago	*Lambis* spp.	5.5
	Yaga	*Lambis lambis*	5.0
	Tadruku	*Acanthopleura gemmata*	0.8
	Lumi		
	Nama		
Soft benthos & mangrove	Kaikoso	*Anadara* spp.	66.6
	Qari	*Scylla serrata*	24.6
	Keke	*Anadara* spp.	3.2
	Seila	*Gafrarium* spp.	2.6
	Sagosago	*Lambis* spp.	2.0
	Yaga	*Lambis lambis*	0.9
	Lumi		
Soft benthos & reeftop & other	Kaikoso	*Anadara* spp.	88.7
	Sagosago	*Lambis* spp.	11.3
	Lumi		
	Nama		
Soft benthos & intertidal & reeftop	Kaikoso	*Anadara* spp.	68.9
	Dairo	*Holothuria* spp.	31.1
	Lumi		
	Nama		
Trochus	Trochus	*Trochus niloticus*	100.0

2.4.2 Invertebrate species caught by fishery with the percentage of annual wet weight caught – Lakeba (continued)

Fishery	Vernacular name	Scientific name	% annual catch (weight)
Trochus & other	Kuita	*Octopus* spp.	60.3
	Trochus	*Trochus niloticus*	31.8
	Vasua	*Tridacna* spp.	7.9

2.4.3 Average length-frequency distribution for invertebrates, with percentage of annual total catch weight – Lakeba

Vernacular name	Scientific name	Size class	% of total catch (weight)
Civa	*Pinctada fucata*	08-12 cm	49.0
		12-14 cm	51.0
Dairo	*Holothuria* spp.	12-14 cm	66.0
		14-18 cm	34.0
Dri	*Holothuria* spp.	14-18 cm	89.0
		15-18 cm	11.0
Dri Loa	*Holothuria* spp.	14-18 cm	100.0
Kaikoso	*Anadara* spp.	06 cm	100.0
Katavatu	*Tridacna maxima*	12-14 cm	55.7
		14-16 cm	44.3
Keke	*Anadara* spp.	06 cm	100.0
Kuita	*Octopus* spp.	12-14 cm	27.9
		14-16 cm	26.8
		14-18 cm	45.3
Laulevu	*Holothuria* spp.	14-18 cm	100.0
Loli	*Holothuria* spp.	14-18 cm	100.0
Loliloli	*Holothuria* spp.	14-18 cm	100.0
Lumi		01 cm	
Nama		01 cm	
Qari	*Scylla serrata*	18-22 cm	12.7
		18-24 cm	69.1
		20-22 cm	18.2
Sagosago	*Lambis* spp.	06-10 cm	19.9
		06-12 cm	33.1
		08-12 cm	8.3
		10-12 cm	16.6
		12-14 cm	22.1
Seila	*Gafrarium* spp.	04-06 cm	100.0
Sucudrau	*Holothuria* spp.	14-18 cm	100.0
Sucuwalu	*Holothuria* spp.	14-18 cm	16.6
		15-18 cm	83.4
Tadruku	*Acanthopleura gemmata*	04-06 cm	100.0
Trochus	*Trochus niloticus*	12-14 cm	81.3
		14-16 cm	18.7
Urau	*Panulirus* spp.	20-26 cm	37.9
		22-24 cm	21.3
		22-26 cm	40.7
Vasua	*Tridacna* spp.	16-18 cm	44.3
		16-20 cm	22.7
		18-22 cm	33.0
Yaga	*Lambis lambis*	10-12 cm	34.1
		12-14 cm	65.9

APPENDIX 3: FINFISH SURVEY DATA

3.1 Dromuna finfish survey data

3.1.1 Coordinates (WGS84) of the 25 D-UVC transects used to assess finfish resource status in Dromuna

Station	Habitat	Latitude	Longitude
TRA01	Back-reef	17°59'01.9212" S	178°45'10.62" E
TRA02	Lagoon	17°59'31.8588" S	178°43'36.9588" E
TRA03	Lagoon	17°59'51.2412" S	178°43'33.8988" E
TRA05	Back-reef	18°00'01.8" S	178°44'33.1188" E
TRA06	Back-reef	17°59'56.2812" S	178°44'24.8388" E
TRA07	Outer reef	18°00'06.5412" S	178°44'49.9812" E
TRA08	Outer reef	18°00'06.5412" S	178°44'49.9812" E
TRA09	Coastal reef	17°58'38.28" S	178°42'40.9788" E
TRA10	Coastal reef	17°58'13.1412" S	178°42'43.2612" E
TRA11	Lagoon	17°57'20.4012" S	178°43'29.1" E
TRA12	Lagoon	17°57'15.0012" S	178°43'34.14" E
TRA13	Coastal reef	17°59'20.76" S	178°41'43.62" E
TRA14	Coastal reef	17°58'59.7" S	178°41'58.8588" E
TRA15	Coastal reef	17°59'11.1012" S	178°42'38.9412" E
TRA16	Coastal reef	17°59'25.0188" S	178°42'40.68" E
TRA17	Coastal reef	17°59'46.2012" S	178°42'31.7412" E
TRA18	Outer reef	18°01'34.6188" S	178°44'40.0812" E
TRA19	Outer reef	18°01'34.6188" S	178°44'40.0812" E
TRA20	Back-reef	18°01'59.7612" S	178°44'29.8212" E
TRA21	Back-reef	18°01'50.2212" S	178°44'11.04" E
TRA22	Outer reef	18°01'15.96" S	178°44'24.54" E
TRA23	Outer reef	18°01'15.96" S	178°44'24.54" E
TRA24	Back-reef	18°02'27.8988" S	178°43'44.4" E
TRA25	Lagoon	18°00'17.5212" S	178°42'13.14" E

3.1.2 Weighted average density and biomass of all finfish species recorded in Dromuna (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus blochii*	0.01073	3.6209
Acanthuridae	*Acanthurus lineatus*	0.00015	0.0426
Acanthuridae	*Acanthurus mata*	0.00001	0.0007
Acanthuridae	*Acanthurus nigricans*	0.00302	0.5598
Acanthuridae	*Acanthurus nigricauda*	0.00440	0.9053
Acanthuridae	*Acanthurus nigrofuscus*	0.00077	0.1200
Acanthuridae	*Acanthurus olivaceus*	0.00033	0.1890
Acanthuridae	*Acanthurus pyroferus*	0.00012	0.0209
Acanthuridae	*Acanthurus thompsoni*	0.00024	0.0642
Acanthuridae	*Acanthurus triostegus*	0.01100	0.9939
Acanthuridae	*Acanthurus xanthopterus*	0.00004	0.0038
Acanthuridae	*Ctenochaetus binotatus*	0.00021	0.0102
Acanthuridae	*Ctenochaetus striatus*	0.05415	11.1391
Acanthuridae	*Ctenochaetus strigosus*	0.00059	0.0615

3.1.2 Weighted average density and biomass of all finfish species recorded in Dromuna (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Naso annulatus*	0.00009	0.0229
Acanthuridae	*Naso brevirostris*	0.00052	0.1202
Acanthuridae	*Naso lituratus*	0.00015	0.0374
Acanthuridae	*Naso unicornis*	0.00008	0.0180
Acanthuridae	*Zebrasoma scopas*	0.00859	0.5504
Acanthuridae	*Zebrasoma veliferum*	0.00665	0.7494
Balistidae	*Balistapus undulatus*	0.00387	0.5160
Balistidae	*Balistoides conspicillum*	0.00001	0.0039
Balistidae	*Balistoides viridescens*	0.00026	0.1022
Balistidae	*Rhinecanthus aculeatus*	0.00021	0.0421
Balistidae	*Sufflamen bursa*	0.00005	0.0050
Balistidae	*Sufflamen chrysopterum*	0.00168	0.1998
Chaetodontidae	*Chaetodon auriga*	0.00160	0.1433
Chaetodontidae	*Chaetodon baronessa*	0.00349	0.2384
Chaetodontidae	*Chaetodon bennetti*	0.00047	0.0370
Chaetodontidae	*Chaetodon citrinellus*	0.00684	0.2768
Chaetodontidae	*Chaetodon ephippium*	0.00489	0.5510
Chaetodontidae	*Chaetodon kleinii*	0.00060	0.0327
Chaetodontidae	*Chaetodon lineolatus*	0.00021	0.0195
Chaetodontidae	*Chaetodon lunula*	0.00036	0.0225
Chaetodontidae	*Chaetodon lunulatus*	0.01264	0.9655
Chaetodontidae	*Chaetodon melannotus*	0.00126	0.0794
Chaetodontidae	*Chaetodon mertensii*	0.00076	0.0370
Chaetodontidae	*Chaetodon ornatissimus*	0.00002	0.0017
Chaetodontidae	*Chaetodon pelewensis*	0.00058	0.0307
Chaetodontidae	*Chaetodon plebeius*	0.00225	0.0935
Chaetodontidae	*Chaetodon rafflesii*	0.00148	0.0801
Chaetodontidae	*Chaetodon reticulatus*	0.00002	0.0017
Chaetodontidae	*Chaetodon semeion*	0.00002	0.0017
Chaetodontidae	*Chaetodon* spp.	0.00022	0.0203
Chaetodontidae	*Chaetodon speculum*	0.00001	0.0009
Chaetodontidae	*Chaetodon ulietensis*	0.00237	0.1538
Chaetodontidae	*Chaetodon unimaculatus*	0.00111	0.1601
Chaetodontidae	*Chaetodon vagabundus*	0.00933	0.7461
Chaetodontidae	*Forcipiger longirostris*	0.00003	0.0027
Chaetodontidae	*Heniochus acuminatus*	0.00050	0.1283
Chaetodontidae	*Heniochus chrysostomus*	0.00476	0.6101
Chaetodontidae	*Heniochus monoceros*	0.00001	0.0036
Chaetodontidae	*Heniochus singularius*	0.00006	0.0158
Chaetodontidae	*Heniochus varius*	0.00301	0.2241
Holocentridae	*Myripristis berndti*	0.00011	0.0278
Holocentridae	*Myripristis kuntee*	0.00005	0.0025
Holocentridae	*Myripristis violacea*	0.00023	0.0274
Holocentridae	*Neoniphon sammara*	0.00255	0.1176
Holocentridae	*Sargocentron caudimaculatum*	0.00025	0.0419
Holocentridae	*Sargocentron spiniferum*	0.00022	0.0573
Labridae	*Bodianus loxozonus*	0.00001	0.0023

3.1.2 Weighted average density and biomass of all finfish species recorded in Dromuna (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Labridae	*Cheilinus chlorourus*	0.01095	0.9951
Labridae	*Cheilinus fasciatus*	0.00169	0.1658
Labridae	*Cheilinus trilobatus*	0.00055	0.1004
Labridae	*Cheilinus undulatus*	0.00001	0.1370
Labridae	*Coris aygula*	0.00104	0.1741
Labridae	*Coris gaimard*	0.00120	0.2319
Labridae	*Hemigymnus fasciatus*	0.00094	0.0822
Labridae	*Hemigymnus melapterus*	0.00575	0.5378
Lethrinidae	*Gnathodentex aureolineatus*	0.00015	0.0136
Lethrinidae	*Lethrinus atkinsoni*	0.00111	0.1358
Lethrinidae	*Lethrinus harak*	0.00469	0.8174
Lethrinidae	*Lethrinus nebulosus*	0.00022	0.0234
Lethrinidae	*Lethrinus obsoletus*	0.00126	0.1066
Lethrinidae	*Lethrinus xanthochilus*	0.00037	0.1106
Lethrinidae	*Monotaxis grandoculis*	0.01229	2.0596
Lutjanidae	*Lutjanus bohar*	0.00005	0.0462
Lutjanidae	*Lutjanus fulviflamma*	0.01158	3.6877
Lutjanidae	*Lutjanus fulvus*	0.00732	1.8134
Lutjanidae	*Lutjanus gibbus*	0.00573	0.3936
Lutjanidae	*Lutjanus kasmira*	0.00001	0.0023
Lutjanidae	*Lutjanus monostigma*	0.00109	0.3490
Lutjanidae	*Lutjanus quinquelineatus*	0.00005	0.0041
Lutjanidae	*Lutjanus russellii*	0.00002	0.0075
Lutjanidae	*Lutjanus semicinctus*	0.00195	0.4923
Lutjanidae	*Macolor niger*	0.00001	0.0005
Mullidae	*Mulloidichthys flavolineatus*	0.00112	0.1152
Mullidae	*Mulloidichthys vanicolensis*	0.00022	0.0078
Mullidae	*Parupeneus barberinoides*	0.01023	0.7940
Mullidae	*Parupeneus barberinus*	0.00811	0.9804
Mullidae	*Parupeneus cyclostomus*	0.00118	0.1901
Mullidae	*Parupeneus multifasciatus*	0.00860	1.0125
Mullidae	*Parupeneus pleurostigma*	0.00174	0.2352
Mullidae	*Parupeneus spilurus*	0.00027	0.0236
Nemipteridae	*Scolopsis bilineata*	0.02337	4.0337
Nemipteridae	*Scolopsis* spp.	0.00010	0.0301
Nemipteridae	*Scolopsis trilineata*	0.00223	0.2613
Scaridae	*Cetoscarus bicolor*	0.00022	0.0153
Scaridae	*Chlorurus bleekeri*	0.00824	1.1010
Scaridae	*Chlorurus frontalis*	0.00004	0.0114
Scaridae	*Chlorurus microrhinos*	0.00008	0.0692
Scaridae	*Chlorurus sordidus*	0.06109	8.8538
Scaridae	*Hipposcarus longiceps*	0.00246	0.7007
Scaridae	*Scarus altipinnis*	0.00094	0.2898
Scaridae	*Scarus chameleon*	0.00359	0.2389
Scaridae	*Scarus dimidiatus*	0.00428	0.5239
Scaridae	*Scarus flavipectoralis*	0.00044	0.1991
Scaridae	*Scarus frenatus*	0.00299	0.8876

3.1.2 Weighted average density and biomass of all finfish species recorded in Dromuna (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Scaridae	*Scarus ghobban*	0.00179	0.4222
Scaridae	*Scarus globiceps*	0.00309	0.6412
Scaridae	*Scarus longipinnis*	0.00003	0.0038
Scaridae	*Scarus niger*	0.00044	0.1639
Scaridae	*Scarus oviceps*	0.00237	0.7258
Scaridae	*Scarus psittacus*	0.03303	2.4074
Scaridae	*Scarus rivulatus*	0.01652	2.6424
Scaridae	*Scarus rubroviolaceus*	0.00007	0.0323
Scaridae	*Scarus schlegeli*	0.01696	3.4843
Scaridae	*Scarus* spp.	0.01150	0.1872
Scaridae	*Scarus spinus*	0.00219	0.0801
Serranidae	*Cephalopholis argus*	0.00002	0.0063
Serranidae	*Cephalopholis miniata*	0.00005	0.0218
Serranidae	*Cephalopholis urodeta*	0.00003	0.0018
Serranidae	*Epinephelus howlandi*	0.00055	0.1265
Serranidae	*Epinephelus merra*	0.00227	0.2274
Serranidae	*Epinephelus polyphekadion*	0.00005	0.0203
Serranidae	*Plectropomus leopardus*	0.00068	0.2600
Siganidae	*Siganus doliatus*	0.01438	2.2412
Siganidae	*Siganus punctatus*	0.00032	0.0951
Siganidae	*Siganus spinus*	0.01612	1.1139
Siganidae	*Siganus vermiculatus*	0.00032	0.1084
Zanclidae	*Zanclus cornutus*	0.00022	0.0301

3.2 Muaivuso finfish survey data

3.2.1 Coordinates (WGS84) of the 18 D-UVC transects used to assess finfish resource status in Muaivuso

Station	Habitat	Latitude	Longitude
TRA01	Outer reef	18°08'50.28" S	178°22'49.1988" E
TRA02	Outer reef	18°08'50.28" S	178°22'49.1988" E
TRA03	Back-reef	18°08'36.42" S	178°22'46.6788" E
TRA04	Back-reef	18°08'11.8788" S	178°22'34.7988" E
TRA05	Outer reef	18°09'15.1812" S	178°22'10.8012" E
TRA06	Outer reef	18°09'15.1812" S	178°22'10.8012" E
TRA07	Back-reef	18°08'35.9988" S	178°22'27.84" E
TRA08	Back-reef	18°09'00.6588" S	178°21'27.36" E
TRA09	Outer reef	18°09'40.14" S	178°21'32.04" E
TRA10	Outer reef	18°09'40.14" S	178°21'32.04" E
TRA11	Back-reef	18°09'39.6" S	178°20'09.1788" E
TRA12	Back-reef	18°09'28.44" S	178°20'34.5012" E
TRA13	Back-reef	18°08'50.7012" S	178°21'53.5212" E
TRA14	Back-reef	18°08'40.2612" S	178°21'57.96" E
TRA15	Back-reef	18°08'55.7412" S	178°21'27.54" E
TRA16	Back-reef	18°08'55.7412" S	178°21'27.54" E
TRA17	Back-reef	18°09'24.0588" S	178°20'06.36" E
TRA18	Back-reef	18°09'09.9" S	178°20'48.3612" E

3.2.2 Weighted average density and biomass of all finfish species recorded in Muaivuso (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus blochii*	0.00678	1.6119
Acanthuridae	*Acanthurus dussumieri*	0.00008	0.0474
Acanthuridae	*Acanthurus lineatus*	0.00138	0.3823
Acanthuridae	*Acanthurus mata*	0.00012	0.0157
Acanthuridae	*Acanthurus nigricauda*	0.00752	1.6033
Acanthuridae	*Acanthurus nigrofuscus*	0.00304	0.2406
Acanthuridae	*Acanthurus pyroferus*	0.00168	0.1888
Acanthuridae	*Acanthurus thompsoni*	0.00264	0.5476
Acanthuridae	*Acanthurus triostegus*	0.00308	0.2679
Acanthuridae	*Acanthurus xanthopterus*	0.00146	0.6378
Acanthuridae	*Ctenochaetus binotatus*	0.00207	0.1307
Acanthuridae	*Ctenochaetus striatus*	0.04911	7.7851
Acanthuridae	*Ctenochaetus strigosus*	0.00039	0.0297
Acanthuridae	*Naso annulatus*	0.00042	0.0987
Acanthuridae	*Naso brevirostris*	0.00025	0.0895
Acanthuridae	*Naso lituratus*	0.00049	0.0819
Acanthuridae	*Naso unicornis*	0.00074	0.3089
Acanthuridae	*Zebrasoma scopas*	0.02226	1.3829
Acanthuridae	*Zebrasoma veliferum*	0.00396	0.3022
Balistidae	*Balistapus undulatus*	0.00112	0.1265
Balistidae	*Melichthys vidua*	0.00008	0.0076
Balistidae	*Rhinecanthus aculeatus*	0.00176	0.2515

3.2.2 Weighted average density and biomass of all finfish species recorded in Muaivuso (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Balistidae	*Sufflamen bursa*	0.00004	0.0043
Balistidae	*Sufflamen chrysopterum*	0.00174	0.2809
Chaetodontidae	*Chaetodon auriga*	0.00366	0.2276
Chaetodontidae	*Chaetodon baronessa*	0.00116	0.0726
Chaetodontidae	*Chaetodon bennetti*	0.00023	0.0088
Chaetodontidae	*Chaetodon citrinellus*	0.00875	0.2997
Chaetodontidae	*Chaetodon ephippium*	0.00319	0.3173
Chaetodontidae	*Chaetodon kleinii*	0.00149	0.0685
Chaetodontidae	*Chaetodon lineolatus*	0.00067	0.1188
Chaetodontidae	*Chaetodon lunula*	0.00115	0.0919
Chaetodontidae	*Chaetodon lunulatus*	0.00576	0.3699
Chaetodontidae	*Chaetodon melannotus*	0.00019	0.0163
Chaetodontidae	*Chaetodon mertensii*	0.00038	0.0149
Chaetodontidae	*Chaetodon pelewensis*	0.00106	0.0517
Chaetodontidae	*Chaetodon plebeius*	0.00024	0.0100
Chaetodontidae	*Chaetodon rafflesii*	0.00059	0.0382
Chaetodontidae	*Chaetodon trifascialis*	0.00019	0.0143
Chaetodontidae	*Chaetodon ulietensis*	0.00141	0.0733
Chaetodontidae	*Chaetodon unimaculatus*	0.00079	0.0994
Chaetodontidae	*Chaetodon vagabundus*	0.00721	0.5277
Chaetodontidae	*Forcipiger longirostris*	0.00079	0.0634
Chaetodontidae	*Heniochus acuminatus*	0.00099	0.2511
Chaetodontidae	*Heniochus chrysostomus*	0.00045	0.0434
Chaetodontidae	*Heniochus monoceros*	0.00024	0.0672
Chaetodontidae	*Heniochus singularius*	0.00038	0.0797
Chaetodontidae	*Heniochus varius*	0.00102	0.1187
Holocentridae	*Myripristis berndti*	0.00049	0.0990
Holocentridae	*Myripristis murdjan*	0.00187	0.1979
Holocentridae	*Neoniphon sammara*	0.00044	0.0255
Holocentridae	*Sargocentron caudimaculatum*	0.00043	0.0586
Holocentridae	*Sargocentron diadema*	0.00015	0.0159
Holocentridae	*Sargocentron spiniferum*	0.00019	0.0640
Kyphosidae	*Kyphosus vaigiensis*	0.00012	0.0416
Labridae	*Bodianus loxozonus*	0.00004	0.0028
Labridae	*Cheilinus chlorourus*	0.00893	1.0391
Labridae	*Cheilinus fasciatus*	0.00173	0.1966
Labridae	*Cheilinus trilobatus*	0.00147	0.3035
Labridae	*Coris aygula*	0.00081	0.0672
Labridae	*Coris gaimard*	0.00044	0.0551
Labridae	*Hemigymnus fasciatus*	0.00094	0.0832
Labridae	*Hemigymnus melapterus*	0.00367	0.3053
Lethrinidae	*Gnathodentex aureolineatus*	0.00073	0.0837
Lethrinidae	*Lethrinus atkinsoni*	0.00470	0.5550
Lethrinidae	*Lethrinus harak*	0.00176	0.2710
Lethrinidae	*Lethrinus obsoletus*	0.00338	0.2641
Lethrinidae	*Lethrinus variegatus*	0.00308	0.2285
Lethrinidae	*Lethrinus xanthochilus*	0.00015	0.0090

3.2.2 Weighted average density and biomass of all finfish species recorded in Muaivuso (continued)
(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Lethrinidae	*Monotaxis grandoculis*	0.01591	1.8287
Lutjanidae	*Lutjanus bohar*	0.00077	0.1528
Lutjanidae	*Lutjanus ehrenbergii*	0.00044	0.0968
Lutjanidae	*Lutjanus fulviflamma*	0.01717	3.2222
Lutjanidae	*Lutjanus fulvus*	0.01331	2.2343
Lutjanidae	*Lutjanus gibbus*	0.00995	1.7344
Lutjanidae	*Lutjanus kasmira*	0.00103	0.0276
Lutjanidae	*Lutjanus monostigma*	0.00132	0.1749
Lutjanidae	*Lutjanus semicinctus*	0.00160	0.3526
Lutjanidae	*Macolor macularis*	0.00008	0.0167
Lutjanidae	*Macolor niger*	0.00008	0.0089
Mullidae	*Mulloidichthys flavolineatus*	0.00705	0.6496
Mullidae	*Mulloidichthys vanicolensis*	0.00132	0.1530
Mullidae	*Parupeneus barberinoides*	0.00675	0.5743
Mullidae	*Parupeneus barberinus*	0.00679	0.6912
Mullidae	*Parupeneus ciliatus*	0.00015	0.0156
Mullidae	*Parupeneus cyclostomus*	0.00155	0.1761
Mullidae	*Parupeneus indicus*	0.00118	0.1087
Mullidae	*Parupeneus multifasciatus*	0.01467	1.2177
Mullidae	*Parupeneus pleurostigma*	0.00220	0.2674
Mullidae	*Parupeneus spilurus*	0.00044	0.0450
Nemipteridae	*Scolopsis bilineata*	0.02192	3.4019
Nemipteridae	*Scolopsis trilineata*	0.00441	0.4888
Scaridae	*Bolbometopon muricatum*	0.00049	0.5399
Scaridae	*Cetoscarus bicolor*	0.00033	0.0414
Scaridae	*Chlorurus bleekeri*	0.01076	1.3963
Scaridae	*Chlorurus microrhinos*	0.00020	0.2433
Scaridae	*Chlorurus sordidus*	0.04775	5.9171
Scaridae	*Hipposcarus longiceps*	0.00265	0.6385
Scaridae	*Scarus altipinnis*	0.00183	0.5306
Scaridae	*Scarus chameleon*	0.00130	0.2109
Scaridae	*Scarus dimidiatus*	0.00298	0.5144
Scaridae	*Scarus flavipectoralis*	0.00016	0.0768
Scaridae	*Scarus forsteni*	0.00008	0.0459
Scaridae	*Scarus frenatus*	0.00027	0.1270
Scaridae	*Scarus ghobban*	0.00451	1.3762
Scaridae	*Scarus globiceps*	0.01500	1.4062
Scaridae	*Scarus longipinnis*	0.00308	0.3105
Scaridae	*Scarus niger*	0.00179	0.8441
Scaridae	*Scarus oviceps*	0.00156	0.2584
Scaridae	*Scarus psittacus*	0.04537	2.8097
Scaridae	*Scarus rivulatus*	0.01390	1.7467
Scaridae	*Scarus rubroviolaceus*	0.00034	0.1619
Scaridae	*Scarus schlegeli*	0.01339	1.1051
Scaridae	*Scarus* spp.	0.00441	0.1645
Scaridae	*Scarus spinus*	0.00096	0.1157
Serranidae	*Cephalopholis argus*	0.00058	0.2116

3.2.2 Weighted average density and biomass of all finfish species recorded in Muaivuso (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Serranidae	*Cephalopholis urodeta*	0.00106	0.1297
Serranidae	*Epinephelus howlandi*	0.00029	0.0785
Serranidae	*Epinephelus maculatus*	0.00019	0.0186
Serranidae	*Epinephelus merra*	0.00132	0.0995
Serranidae	*Variola louti*	0.00012	0.0873
Siganidae	*Siganus doliatus*	0.00157	0.3028
Siganidae	*Siganus punctatus*	0.00174	0.2962
Siganidae	*Siganus spinus*	0.00291	0.2004
Siganidae	*Siganus uspi*	0.00015	0.0100
Zanclidae	*Zanclus cornutus*	0.00387	0.5593

3.3 Mali finfish survey data

3.3.1 Coordinates (WGS84) of the 24 D-UVC transects used to assess finfish resource status in Mali

Station	Habitat	Latitude	Longitude
TRA01	Lagoon	16°21'04.9212" S	179°17'34.26" E
TRA02	Back-reef	16°20'35.9988" S	179°16'10.02" E
TRA03	Lagoon	16°20'52.0188" S	179°15'02.34" E
TRA04	Lagoon	16°20'43.5588" S	179°15'02.2788" E
TRA05	Outer reef	16°17'03.66" S	179°17'05.3988" E
TRA06	Outer reef	16°17'03.7212" S	179°17'05.3988" E
TRA07	Outer reef	16°15'28.5012" S	179°19'33.6" E
TRA08	Outer reef	16°15'28.5012" S	179°19'33.6" E
TRA09	Coastal reef	16°20'25.26" S	179°18'32.4612" E
TRA10	Outer reef	16°14'04.4412" S	179°21'21.3588" E
TRA11	Outer reef	16°14'04.4412" S	179°21'21.3588" E
TRA12	Back-reef	16°16'48.2412" S	179°21'19.98" E
TRA13	Back-reef	16°18'03.4812" S	179°19'32.88" E
TRA14	Back-reef	16°17'38.3388" S	179°14'50.7012" E
TRA15	Back-reef	16°17'25.1412" S	179°14'29.8212" E
TRA16	Coastal reef	16°20'20.6412" S	179°18'52.56" E
TRA17	Coastal reef	16°20'22.02" S	179°19'40.44" E
TRA18	Coastal reef	16°20'05.8812" S	179°20'01.86" E
TRA19	Coastal reef	16°19'56.1" S	179°20'28.3812" E
TRA20	Back-reef	16°17'30.2388" S	179°17'08.34" E
TRA21	Back-reef	16°17'14.7012" S	179°17'35.8188" E
TRA22	Back-reef	16°16'58.44" S	179°18'04.14" E
TRA23	Back-reef	16°16'27.3" S	179°19'04.44" E
TRA24	Coastal reef	16°19'54.5988" S	179°21'22.2588" E

3.3.2 Weighted average density and biomass of all finfish species recorded in Mali (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus auranticavus*	0.00024	0.0217
Acanthuridae	*Acanthurus blochii*	0.02324	13.9017
Acanthuridae	*Acanthurus lineatus*	0.00345	1.6471
Acanthuridae	*Acanthurus mata*	0.00020	0.0581
Acanthuridae	*Acanthurus nigricans*	0.00014	0.0303
Acanthuridae	*Acanthurus nigricauda*	0.00901	2.3994
Acanthuridae	*Acanthurus nigrofuscus*	0.00015	0.0105
Acanthuridae	*Acanthurus olivaceus*	0.01022	4.3955
Acanthuridae	*Acanthurus pyroferus*	0.00018	0.0270
Acanthuridae	*Acanthurus thompsoni*	0.00010	0.0438
Acanthuridae	*Acanthurus triostegus*	0.04225	3.6354
Acanthuridae	*Acanthurus xanthopterus*	0.00013	0.0458
Acanthuridae	*Ctenochaetus binotatus*	0.00122	0.0719
Acanthuridae	*Ctenochaetus striatus*	0.11649	17.0013
Acanthuridae	*Ctenochaetus strigosus*	0.00013	0.0211
Acanthuridae	*Ctenochaetus tominiensis*	0.00481	0.2893

3.3.2 Weighted average density and biomass of all finfish species recorded in Mali (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Naso annulatus*	0.00026	0.0673
Acanthuridae	*Naso brevirostris*	0.00023	0.1237
Acanthuridae	*Naso hexacanthus*	0.00253	1.3580
Acanthuridae	*Naso lituratus*	0.00328	1.4203
Acanthuridae	*Naso lopezi*	0.00006	0.0743
Acanthuridae	*Naso unicornis*	0.00244	1.4483
Acanthuridae	*Naso vlamingii*	0.00013	0.0895
Acanthuridae	*Zebrasoma scopas*	0.00699	0.4895
Acanthuridae	*Zebrasoma veliferum*	0.00359	0.5659
Balistidae	*Balistapus undulatus*	0.00185	0.4565
Balistidae	*Balistoides viridescens*	0.00026	0.2322
Balistidae	*Melichthys vidua*	0.00022	0.0860
Balistidae	*Odonus niger*	0.00145	0.3016
Balistidae	*Pseudobalistes flavimarginatus*	0.00004	0.0824
Balistidae	*Rhinecanthus aculeatus*	0.00100	0.1406
Balistidae	*Sufflamen bursa*	0.00010	0.0162
Balistidae	*Sufflamen chrysopterum*	0.00093	0.1804
Chaetodontidae	*Chaetodon auriga*	0.00169	0.1641
Chaetodontidae	*Chaetodon baronessa*	0.00104	0.0742
Chaetodontidae	*Chaetodon bennetti*	0.00006	0.0058
Chaetodontidae	*Chaetodon citrinellus*	0.01030	0.4632
Chaetodontidae	*Chaetodon ephippium*	0.00205	0.2404
Chaetodontidae	*Chaetodon flavirostris*	0.00003	0.0037
Chaetodontidae	*Chaetodon kleinii*	0.00055	0.0308
Chaetodontidae	*Chaetodon lineolatus*	0.00016	0.0340
Chaetodontidae	*Chaetodon lunulatus*	0.00999	0.6874
Chaetodontidae	*Chaetodon melannotus*	0.00030	0.0299
Chaetodontidae	*Chaetodon mertensii*	0.00234	0.1137
Chaetodontidae	*Chaetodon pelewensis*	0.00093	0.0540
Chaetodontidae	*Chaetodon plebeius*	0.00059	0.0177
Chaetodontidae	*Chaetodon rafflesii*	0.00294	0.2444
Chaetodontidae	*Chaetodon reticulatus*	0.00102	0.1037
Chaetodontidae	*Chaetodon semeion*	0.00038	0.0378
Chaetodontidae	*Chaetodon speculum*	0.00004	0.0042
Chaetodontidae	*Chaetodon trifascialis*	0.00167	0.1270
Chaetodontidae	*Chaetodon ulietensis*	0.00545	0.2709
Chaetodontidae	*Chaetodon unimaculatus*	0.00038	0.0577
Chaetodontidae	*Chaetodon vagabundus*	0.00719	0.6906
Chaetodontidae	*Forcipiger flavissimus*	0.00009	0.0082
Chaetodontidae	*Forcipiger longirostris*	0.00028	0.0231
Chaetodontidae	*Hemitaurichthys polylepis*	0.00099	0.1313
Chaetodontidae	*Heniochus acuminatus*	0.00120	0.3905
Chaetodontidae	*Heniochus chrysostomus*	0.00031	0.0330
Chaetodontidae	*Heniochus monoceros*	0.00013	0.0202
Chaetodontidae	*Heniochus singularius*	0.00033	0.0844
Chaetodontidae	*Heniochus varius*	0.00074	0.0890
Holocentridae	*Myripristis berndti*	0.00006	0.0192

3.3.2 Weighted average density and biomass of all finfish species recorded in Mali (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Holocentridae	*Myripristis murdjan*	0.00006	0.0036
Holocentridae	*Myripristis* spp.	0.00003	0.0007
Holocentridae	*Neoniphon sammara*	0.00004	0.0033
Holocentridae	*Sargocentron caudimaculatum*	0.00104	0.1440
Holocentridae	*Sargocentron* spp.	0.00004	0.0033
Holocentridae	*Sargocentron spiniferum*	0.00056	0.1326
Kyphosidae	*Kyphosus vaigiensis*	0.00009	0.0078
Labridae	*Bodianus axillaris*	0.00003	0.0047
Labridae	*Bodianus loxozonus*	0.00007	0.0000
Labridae	*Cheilinus chlorourus*	0.01102	1.8964
Labridae	*Cheilinus fasciatus*	0.00220	0.3626
Labridae	*Cheilinus undulatus*	0.00042	0.0458
Labridae	*Coris aygula*	0.00072	0.2042
Labridae	*Coris gaimard*	0.00026	0.0578
Labridae	*Hemigymnus fasciatus*	0.00104	0.1194
Labridae	*Hemigymnus melapterus*	0.00622	1.1827
Labridae	*Oxycheilinus digramma*	0.00034	0.0374
Lethrinidae	*Gnathodentex aureolineatus*	0.00045	0.0293
Lethrinidae	*Lethrinus atkinsoni*	0.00028	0.1042
Lethrinidae	*Lethrinus harak*	0.00058	0.1886
Lethrinidae	*Lethrinus lentjan*	0.00002	0.0043
Lethrinidae	*Lethrinus obsoletus*	0.00007	0.0060
Lethrinidae	*Lethrinus variegatus*	0.00241	0.1507
Lethrinidae	*Monotaxis grandoculis*	0.01527	4.0910
Lutjanidae	*Aphareus furca*	0.00004	0.0220
Lutjanidae	*Lutjanus bohar*	0.00116	0.3845
Lutjanidae	*Lutjanus fulviflamma*	0.00008	0.0070
Lutjanidae	*Lutjanus fulvus*	0.00103	0.3190
Lutjanidae	*Lutjanus gibbus*	0.01444	4.7266
Lutjanidae	*Lutjanus kasmira*	0.00004	0.0036
Lutjanidae	*Lutjanus monostigma*	0.00008	0.0367
Lutjanidae	*Lutjanus semicinctus*	0.00828	2.7897
Lutjanidae	*Macolor niger*	0.00011	0.0503
Mullidae	*Mulloidichthys flavolineatus*	0.00036	0.0275
Mullidae	*Parupeneus barberinoides*	0.00062	0.0513
Mullidae	*Parupeneus barberinus*	0.00607	1.6647
Mullidae	*Parupeneus cyclostomus*	0.00350	0.4643
Mullidae	*Parupeneus multifasciatus*	0.01208	1.1575
Mullidae	*Parupeneus pleurostigma*	0.00160	0.1669
Mullidae	*Parupeneus spilurus*	0.00092	0.2258
Nemipteridae	*Scolopsis bilineata*	0.03327	6.0187
Nemipteridae	*Scolopsis trilineata*	0.01743	1.2063
Pomacanthidae	*Pomacanthus semicirculatus*	0.00013	0.0573
Pomacanthidae	*Pygoplites diacanthus*	0.00025	0.1020
Scaridae	*Cetoscarus bicolor*	0.00083	0.4348
Scaridae	*Chlorurus bleekeri*	0.00810	2.5679
Scaridae	*Chlorurus sordidus*	0.08930	13.1174

3.3.2 Weighted average density and biomass of all finfish species recorded in Mali (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Scaridae	*Hipposcarus longiceps*	0.00154	0.7329
Scaridae	*Leptoscarus vaigiensis*	0.00003	0.0168
Scaridae	*Scarus altipinnis*	0.00195	1.2072
Scaridae	*Scarus chameleon*	0.00049	0.0946
Scaridae	*Scarus dimidiatus*	0.00579	1.3484
Scaridae	*Scarus flavipectoralis*	0.00036	0.1287
Scaridae	*Scarus frenatus*	0.00276	1.3529
Scaridae	*Scarus ghobban*	0.00943	3.3082
Scaridae	*Scarus globiceps*	0.00570	1.0790
Scaridae	*Scarus longipinnis*	0.00006	0.0486
Scaridae	*Scarus niger*	0.00163	1.4070
Scaridae	*Scarus oviceps*	0.00739	2.5481
Scaridae	*Scarus psittacus*	0.06150	8.6061
Scaridae	*Scarus rivulatus*	0.02193	2.9717
Scaridae	*Scarus rubroviolaceus*	0.00013	0.0756
Scaridae	*Scarus schlegeli*	0.00659	2.3202
Scaridae	*Scarus spinus*	0.00040	0.1224
Serranidae	*Anyperodon leucogrammicus*	0.00002	0.0053
Serranidae	*Cephalopholis argus*	0.00006	0.0349
Serranidae	*Cephalopholis urodeta*	0.00076	0.0755
Serranidae	*Epinephelus coeruleopunctatus*	0.00007	0.0443
Serranidae	*Epinephelus hexagonatus*	0.00002	0.0033
Serranidae	*Epinephelus howlandi*	0.00003	0.0077
Serranidae	*Epinephelus macrospilos*	0.00024	0.0772
Serranidae	*Epinephelus maculatus*	0.00007	0.0307
Serranidae	*Epinephelus merra*	0.00335	0.3411
Serranidae	*Epinephelus ongus*	0.00002	0.0070
Serranidae	*Epinephelus polyphekadion*	0.00009	0.0305
Serranidae	*Gracila albomarginata*	0.00002	0.0115
Serranidae	*Plectropomus laevis*	0.00002	0.0286
Serranidae	*Plectropomus leopardus*	0.00013	0.1120
Serranidae	*Variola louti*	0.00007	0.0280
Siganidae	*Siganus doliatus*	0.02278	3.6327
Siganidae	*Siganus fuscescens*	0.00013	0.0436
Siganidae	*Siganus niger*	0.00003	0.0073
Siganidae	*Siganus punctatus*	0.00196	0.8310
Siganidae	*Siganus spinus*	0.10280	9.9307
Siganidae	*Siganus vermiculatus*	0.00116	1.0116
Siganidae	*Siganus vulpinus*	0.00023	0.0685
Zanclidae	*Zanclus cornutus*	0.00100	0.1369

3.4 Lakeba finfish survey data

3.4.1 Coordinates (WGS84) of the 25 D-UVC transects used to assess finfish resource status in Lakeba

Station	Habitat	Latitude	Longitude
TRA01	Coastal reef	16°11'52.5588" S	179°41'35.7" E
TRA02	Coastal reef	16°11'54.4812" S	179°41'22.8012" E
TRA03	Lagoon	16°11'46.6188" S	179°40'26.4612" E
TRA04	Coastal reef	16°11'39.1812" S	179°39'42.12" E
TRA06	Lagoon	16°11'00.6" S	179°42'24.2399" E
TRA07	Back-reef	16°09'04.68" S	179°42'54.8388" E
TRA08	Back-reef	16°09'12.8988" S	179°42'26.7012" E
TRA09	Back-reef	16°09'13.86" S	179°42'02.6388" E
TRA10	Back-reef	16°09'14.76" S	179°41'27.3012" E
TRA11	Back-reef	16°09'20.5812" S	179°40'33.78" E
TRA12	Back-reef	16°09'17.2188" S	179°39'37.98" E
TRA13	Outer reef	16°08'28.32" S	179°44'28.32" E
TRA14	Outer reef	16°08'28.32" S	179°44'28.32" E
TRA15	Outer reef	16°08'48.48" S	179°44'52.1988" E
TRA16	Outer reef	16°08'48.48" S	179°44'52.1988" E
TRA17	Outer reef	16°08'43.3212" S	179°45'41.2812" E
TRA18	Outer reef	16°08'43.26" S	179°45'41.22" E
TRA19	Back-reef	16°10'34.7412" S	179°44'42.7812" E
TRA20	Lagoon	16°10'55.3199" S	179°42'03.78" E
TRA21	Lagoon	16°11'02.4" S	179°41'20.2812" E
TRA22	Lagoon	16°10'41.9412" S	179°40'09.2388" E
TRA23	Lagoon	16°10'30.72" S	179°39'00.65988" E
TRA24	Coastal reef	16°11'17.0988" S	179°37'39.4212" E
TRA25	Coastal reef	16°11'38.8788" S	179°38'57.9012" E

3.4.2 Weighted average density and biomass of all finfish species recorded in Lakeba (using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Acanthurus blochii*	0.01474	4.7749
Acanthuridae	*Acanthurus lineatus*	0.00258	1.2852
Acanthuridae	*Acanthurus nigricans*	0.00261	0.5889
Acanthuridae	*Acanthurus nigricauda*	0.00537	0.7912
Acanthuridae	*Acanthurus nigrofuscus*	0.00039	0.0242
Acanthuridae	*Acanthurus olivaceus*	0.00023	0.0292
Acanthuridae	*Acanthurus thompsoni*	0.00007	0.0216
Acanthuridae	*Acanthurus triostegus*	0.01358	1.0211
Acanthuridae	*Acanthurus xanthopterus*	0.00027	0.0786
Acanthuridae	*Ctenochaetus binotatus*	0.00005	0.0031
Acanthuridae	*Ctenochaetus striatus*	0.06389	12.2981
Acanthuridae	*Naso annulatus*	0.00044	0.3743
Acanthuridae	*Naso brevirostris*	0.00011	0.1614
Acanthuridae	*Naso lituratus*	0.00251	1.6983
Acanthuridae	*Naso unicornis*	0.00082	0.3757
Acanthuridae	*Zebrasoma scopas*	0.00616	0.4312

3.4.2 Weighted average density and biomass of all finfish species recorded in Lakeba (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Acanthuridae	*Zebrasoma veliferum*	0.00276	0.2256
Balistidae	*Balistapus undulatus*	0.00242	0.8959
Balistidae	*Balistoides conspicillum*	0.00002	0.0246
Balistidae	*Balistoides viridescens*	0.00005	0.0137
Balistidae	*Melichthys vidua*	0.00046	0.2831
Balistidae	*Rhinecanthus aculeatus*	0.00130	0.1224
Balistidae	*Sufflamen bursa*	0.00005	0.0099
Balistidae	*Sufflamen chrysopterum*	0.00103	0.1535
Chaetodontidae	*Chaetodon auriga*	0.00272	0.1572
Chaetodontidae	*Chaetodon baronessa*	0.00059	0.0445
Chaetodontidae	*Chaetodon bennetti*	0.00037	0.0287
Chaetodontidae	*Chaetodon citrinellus*	0.00564	0.1719
Chaetodontidae	*Chaetodon ephippium*	0.00472	0.3370
Chaetodontidae	*Chaetodon flavirostris*	0.00005	0.0046
Chaetodontidae	*Chaetodon lunula*	0.00081	0.0649
Chaetodontidae	*Chaetodon lunulatus*	0.00664	0.4063
Chaetodontidae	*Chaetodon melannotus*	0.00031	0.0096
Chaetodontidae	*Chaetodon mertensii*	0.00019	0.0089
Chaetodontidae	*Chaetodon pelewensis*	0.00014	0.0083
Chaetodontidae	*Chaetodon plebeius*	0.00011	0.0053
Chaetodontidae	*Chaetodon rafflesii*	0.00155	0.0923
Chaetodontidae	*Chaetodon reticulatus*	0.00026	0.0209
Chaetodontidae	*Chaetodon semeion*	0.00052	0.0431
Chaetodontidae	*Chaetodon trifascialis*	0.00023	0.0179
Chaetodontidae	*Chaetodon ulietensis*	0.00304	0.1425
Chaetodontidae	*Chaetodon unimaculatus*	0.00059	0.0736
Chaetodontidae	*Chaetodon vagabundus*	0.00548	0.3284
Chaetodontidae	*Forcipiger flavissimus*	0.00009	0.0122
Chaetodontidae	*Forcipiger longirostris*	0.00014	0.0083
Chaetodontidae	*Heniochus acuminatus*	0.00076	0.1359
Chaetodontidae	*Heniochus chrysostomus*	0.00022	0.0219
Chaetodontidae	*Heniochus monoceros*	0.00087	0.1401
Chaetodontidae	*Heniochus singularius*	0.00058	0.1082
Chaetodontidae	*Heniochus varius*	0.00195	0.1511
Holocentridae	*Myripristis adusta*	0.00027	0.0480
Holocentridae	*Myripristis berndti*	0.00058	0.0737
Holocentridae	*Myripristis murdjan*	0.00021	0.0186
Holocentridae	*Neoniphon sammara*	0.00142	0.0753
Holocentridae	*Sargocentron caudimaculatum*	0.00002	0.0016
Holocentridae	*Sargocentron spiniferum*	0.00258	1.0576
Labridae	*Cheilinus chlorourus*	0.01039	1.3252
Labridae	*Cheilinus fasciatus*	0.00133	0.3599
Labridae	*Cheilinus trilobatus*	0.00110	0.4881
Labridae	*Cheilinus undulatus*	0.00039	2.0235
Labridae	*Coris aygula*	0.00021	0.0397
Labridae	*Hemigymnus fasciatus*	0.00157	0.1118
Labridae	*Hemigymnus melapterus*	0.00723	1.0950

3.4.2 Weighted average density and biomass of all finfish species recorded in Lakeba (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Labridae	*Oxycheilinus digramma*	0.00010	0.0352
Lethrinidae	*Lethrinus atkinsoni*	0.00316	0.6601
Lethrinidae	*Lethrinus harak*	0.00107	0.2618
Lethrinidae	*Lethrinus obsoletus*	0.00125	0.1319
Lethrinidae	*Lethrinus xanthochilus*	0.00021	0.0644
Lethrinidae	*Monotaxis grandoculis*	0.01291	2.7482
Lutjanidae	*Aphareus furca*	0.00011	0.0772
Lutjanidae	*Lutjanus bohar*	0.00078	0.2868
Lutjanidae	*Lutjanus fulviflamma*	0.00324	0.8565
Lutjanidae	*Lutjanus fulvus*	0.01167	2.3030
Lutjanidae	*Lutjanus gibbus*	0.02077	14.1339
Lutjanidae	*Lutjanus monostigma*	0.00033	0.2143
Lutjanidae	*Lutjanus quinquelineatus*	0.00016	0.0049
Lutjanidae	*Lutjanus semicinctus*	0.00225	0.6356
Lutjanidae	*Macolor niger*	0.00011	0.0250
Mullidae	*Mulloidichthys flavolineatus*	0.00021	0.0161
Mullidae	*Parupeneus barberinoides*	0.00035	0.0432
Mullidae	*Parupeneus barberinus*	0.00187	0.1132
Mullidae	*Parupeneus cyclostomus*	0.00038	0.0781
Mullidae	*Parupeneus indicus*	0.00011	0.0370
Mullidae	*Parupeneus multifasciatus*	0.02172	1.6398
Mullidae	*Parupeneus pleurostigma*	0.00016	0.0175
Mullidae	*Parupeneus spilurus*	0.00021	0.0272
Nemipteridae	*Scolopsis bilineata*	0.01053	2.1263
Nemipteridae	*Scolopsis temporalis*	0.00006	0.0131
Nemipteridae	*Scolopsis trilineata*	0.00627	1.3535
Pomacanthidae	*Pygoplites diacanthus*	0.00011	0.0448
Scaridae	*Bolbometopon muricatum*	0.00062	10.2823
Scaridae	*Cetoscarus bicolor*	0.00032	0.4897
Scaridae	*Chlorurus bleekeri*	0.01328	3.1743
Scaridae	*Chlorurus sordidus*	0.05388	6.1457
Scaridae	*Hipposcarus longiceps*	0.00124	0.6542
Scaridae	*Scarus altipinnis*	0.00037	0.0859
Scaridae	*Scarus chameleon*	0.00062	0.1200
Scaridae	*Scarus dimidiatus*	0.00860	2.0725
Scaridae	*Scarus flavipectoralis*	0.00040	0.0821
Scaridae	*Scarus frenatus*	0.00074	0.5438
Scaridae	*Scarus ghobban*	0.00654	1.8217
Scaridae	*Scarus globiceps*	0.00249	0.2257
Scaridae	*Scarus niger*	0.00034	0.2236
Scaridae	*Scarus oviceps*	0.00372	1.1278
Scaridae	*Scarus psittacus*	0.05830	4.6810
Scaridae	*Scarus rivulatus*	0.01879	2.0622
Scaridae	*Scarus rubroviolaceus*	0.00027	0.3442
Scaridae	*Scarus schlegeli*	0.00251	0.5894
Scaridae	*Scarus spinus*	0.00083	0.1820
Serranidae	*Cephalopholis argus*	0.00078	0.4458

3.4.2 Weighted average density and biomass of all finfish species recorded in Lakeba (continued)

(using distance-sampling underwater visual censuses (D-UVC))

Family	Species	Density (fish/m²)	Biomass (g/m²)
Serranidae	*Cephalopholis urodeta*	0.00096	0.1825
Serranidae	*Epinephelus coeruleopunctatus*	0.00006	0.0086
Serranidae	*Epinephelus hexagonatus*	0.00006	0.0139
Serranidae	*Epinephelus howlandi*	0.00005	0.0166
Serranidae	*Epinephelus macrospilos*	0.00006	0.0124
Serranidae	*Epinephelus merra*	0.00452	0.3321
Serranidae	*Epinephelus polyphekadion*	0.00016	0.2196
Serranidae	*Plectropomus laevis*	0.00008	0.1267
Serranidae	*Plectropomus leopardus*	0.00010	0.0304
Serranidae	*Variola louti*	0.00005	0.4388
Siganidae	*Siganus doliatus*	0.01598	2.2302
Siganidae	*Siganus punctatus*	0.00296	1.2652
Siganidae	*Siganus spinus*	0.02541	1.5523
Siganidae	*Siganus vermiculatus*	0.00044	0.1543
Zanclidae	*Zanclus cornutus*	0.00057	0.0830

APPENDIX 4: INVERTEBRATE SURVEY DATA

4.1 Dromuna invertebrate survey data

4.1.1a Invertebrate species recorded in different assessments in Dromuna in 2003

Group	Species	Broad scale	Reef benthos	Soft benthos
Bêche-de-mer	*Actinopyga echinites*			+
Bêche-de-mer	*Actinopyga lecanora*	+		
Bêche-de-mer	*Actinopyga miliaris*			+
Bêche-de-mer	*Bohadschia argus*	+	+	
Bêche-de-mer	*Bohadschia graeffei*	+		+
Bêche-de-mer	*Bohadschia similis*			+
Bêche-de-mer	*Bohadschia vitiensis*	+		+
Bêche-de-mer	*Holothuria atra*	+		+
Bêche-de-mer	*Holothuria edulis*	+	+	
Bêche-de-mer	*Holothuria fuscogilva*	+		
Bêche-de-mer	*Holothuria leucospilota*	+		
Bêche-de-mer	*Holothuria nobilis*	+	+	
Bêche-de-mer	*Holothuria scabra*			+
Bêche-de-mer	*Stichopus chloronotus*	+	+	
Bêche-de-mer	*Stichopus hermanni*	+		+
Bêche-de-mer	*Stichopus horrens*			+
Bêche-de-mer	*Synapta* spp.	+		+
Bêche-de-mer	*Thelenota ananas*	+		
Bivalve	*Anadara antiquata*			+
Bivalve	*Atrina vexillum*	+		+
Bivalve	*Gafrarium tumidum*			+
Bivalve	*Hyotissa* spp.	+		
Bivalve	*Modiolus* spp.			+
Bivalve	*Periglypta puerpera*			+
Bivalve	*Pinctada margaritifera*	+		
Bivalve	*Pinna bicolor*			+
Bivalve	*Pitar prora*			+
Bivalve	*Pitar* spp.			+
Bivalve	*Spondylus* spp.	+		
Bivalve	*Spondylus squamosus*			+
Bivalve	*Tellina palatum*			+
Bivalve	*Trachycardium* spp.			+
Bivalve	*Tridacna maxima*	+	+	
Bivalve	*Tridacna squamosa*	+		
Cnidarian	*Cassiopea andromeda*	+		+
Crustacean	*Panulirus versicolor*	+	+	
Gastropod	*Cerithium nodulosum*	+		+
Gastropod	*Conus* spp.	+	+	+
Gastropod	*Cypraea annulus*			+
Gastropod	*Cypraea caputserpensis*		+	
Gastropod	*Cypraea* spp.			+
Gastropod	*Cypraea tigris*	+	+	+
Gastropod	*Dolabella auricularia*			+
Gastropod	*Lambis lambis*	+		+

+ = presence of the species.

4.1.1a Invertebrate species recorded in different assessments in Dromuna in 2003 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos
Gastropod	*Lambis truncata*	+	+	
Gastropod	*Latirolagena smaragdula*		+	
Gastropod	*Polinices* spp.			+
Gastropod	*Strombus gibberulus gibbosus*	+		+
Gastropod	*Strombus labiatus*			+
Gastropod	*Strombus luhuanus*	+		
Gastropod	*Tectus pyramis*	+	+	
Gastropod	*Trochus niloticus*	+	+	
Gastropod	*Trochus* spp.		+	
Gastropod	*Turbo chrysostomus*		+	
Gastropod	*Turbo crassus*		+	
Gastropod	*Vasum ceramicum*		+	
Star	*Acanthaster planci*	+		
Star	*Archaster typicus*			+
Star	*Culcita novaeguineae*	+		
Star	*Linckia laevigata*	+	+	+
Urchin	*Echinometra mathaei*	+	+	+
Urchin	*Echinothrix calamaris*		+	
Urchin	*Echinothrix diadema*	+	+	+
Urchin	*Mespilia globulus*			+
Urchin	*Tripneustes gratilla*	+	+	+

+ = presence of the species.

4.1.1b Invertebrate species recorded in different assessments in Dromuna in 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga lecanora*				+
Bêche-de-mer	*Actinopyga mauritiana*		+		
Bêche-de-mer	*Actinopyga miliaris*	+			+
Bêche-de-mer	*Bohadschia argus*	+	+		+
Bêche-de-mer	*Bohadschia graeffei*	+	+		+
Bêche-de-mer	*Bohadschia similis*			+	
Bêche-de-mer	*Bohadschia vitiensis*	+			+
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria edulis*	+	+		+
Bêche-de-mer	*Holothuria fuscogilva*	+			+
Bêche-de-mer	*Holothuria fuscopunctata*		+		
Bêche-de-mer	*Holothuria scabra*		+	+	
Bêche-de-mer	*Stichopus chloronotus*	+	+		+
Bêche-de-mer	*Stichopus hermanni*	+		+	+
Bêche-de-mer	*Stichopus horrens*				+
Bêche-de-mer	*Synapta* spp.	+		+	
Bêche-de-mer	*Thelenota ananas*	+			
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Anadara* spp.			+	
Bivalve	*Atrina vexillum*	+			
Bivalve	*Pinctada margaritifera*	+			

+ = presence of the species.

4.1.1b Invertebrate species recorded in different assessments in Dromuna in 2009 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		+
Cnidarian	*Stichodactyla* spp.				+
Gastropod	*Cassis cornuta*	+			
Gastropod	*Conus imperialis*		+		
Gastropod	*Conus litteratus*	+			
Gastropod	*Conus marmoreus*		+		
Gastropod	*Conus* spp.	+	+		+
Gastropod	*Cypraea tigris*		+		+
Gastropod	*Lambis lambis*	+	+		
Gastropod	*Lambis truncata*	+			+
Gastropod	*Ovula ovum*				+
Gastropod	*Strombus luhuanus*	+			
Gastropod	*Tectus pyramis*		+		+
Gastropod	*Trochus niloticus*		+		+
Gastropod	*Turbo chrysostomus*		+		
Gastropod	*Turbo* spp.		+		
Gastropod	*Tutufa bubo*				+
Gastropod	*Tutufa rubeta*	+			
Gastropod	*Vasum ceramicum*	+	+		+
Star	*Acanthaster planci*	+	+		
Star	*Culcita novaeguineae*	+			
Star	*Linckia laevigata*	+	+		+
Urchin	*Echinometra mathaei*				+
Urchin	*Echinothrix diadema*	+			
Urchin	*Heterocentrotus mammillatus*				+
Urchin	*Mespilia globulus*			+	
Urchin	*Toxopneustes pileolus*	+			

+ = presence of the species.

4.1.2a Dromuna 2003 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	0.8	0.5	38	14.3	0.0	2	0.7	0.5	6	2.2	0.2	2
Actinopyga lecanora	0.8	0.8	38	28.6		1	0.7	0.7	6	4.1		1
Atrina vexillum	1.5	1.0	38	28.6	0.0	2	1.5	0.9	6	4.4	0.3	2
Bohadschia argus	7.5	1.8	38	20.4	2.0	14	7.4	2.7	6	11.1	2.0	4
Bohadschia graeffei	2.6	1.1	38	16.7	2.4	6	2.3	0.8	6	3.4	0.7	4
Bohadschia vitiensis	28.2	20.0	38	119.0	80.1	9	25.9	21.1	6	38.8	30.8	4
Cassiopea andromeda	0.8	0.5	38	14.3	0.0	2	0.8	0.8	6	4.8		1
Cerithium nodulosum	0.4	0.4	38	14.3		1	0.4	0.4	6	2.4		1
Conus spp.	6.4	2.2	38	24.3	5.2	10	6.5	1.7	6	7.8	1.4	5
Culcita novaeguineae	3.0	1.2	38	19.0	3.0	6	3.0	1.4	6	4.5	1.6	4
Cypraea tigris	0.8	0.8	38	28.6		1	0.8	0.8	6	4.8		1
Echinometra mathaei	0.4	0.4	38	14.3		1	0.4	0.4	6	2.4		1
Echinothrix diadema	7.5	3.2	38	57.1	4.5	5	7.9	6.2	6	23.8	14.3	2
Holothuria atra	22.6	4.5	38	35.7	5.6	24	23.1	7.6	6	27.7	7.4	5
Holothuria edulis	4.5	1.5	38	21.4	2.7	8	4.6	2.5	6	7.0	3.3	4
Holothuria fuscogilva	0.4	0.4	38	14.3		1	0.4	0.4	6	2.4		1
Holothuria leucospilota	0.4	0.4	38	14.3		1	0.3	0.3	6	2.0		1
Holothuria nobilis	0.8	0.8	38	28.6		1	0.4	0.4	6	2.2		1
Hyotissa spp.	0.8	0.5	38	14.3	0.0	2	0.8	0.8	6	4.8		1
Lambis lambis	4.9	1.8	38	26.5	3.7	7	4.5	3.4	6	13.5	6.9	2
Lambis truncata	0.4	0.4	38	14.3		1	0.4	0.4	6	2.4		1
Linckia laevigata	83.8	18.2	38	132.7	23.8	24	80.7	34.8	6	96.8	37.7	5
Panulirus versicolor	0.4	0.4	38	14.3		1	0.4	0.4	6	2.4		1
Pinctada margaritifera	6.0	1.9	38	25.4	3.2	9	5.8	1.8	6	7.0	1.7	5
Spondylus spp.	5.3	2.5	38	33.3	10.2	6	5.4	2.5	6	10.7	1.8	3
Stichopus chloronotus	1.9	1.0	38	17.9	3.6	4	2.0	1.0	6	4.0	0.8	3
Stichopus hermanni	0.4	0.4	38	14.3		1	0.3	0.3	6	2.0		1
Strombus gibberulus gibbosus	0.4	0.4	38	14.3		1	0.4	0.4	6	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.

4.1.2a Dromuna 2003 broad-scale assessment data review (continued)
Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Strombus luhuanus	17.3	8.5	38	82.1	32.1	8	17.4	13.8	6	34.7	25.5	3
Synapta spp.	1.1	0.8	38	21.4	7.1	2	1.0	1.0	6	6.1		1
Tectus pyramis	1.5	0.7	38	14.3	0.0	4	1.6	1.0	6	4.8	0.0	2
Thelenota ananas	0.8	0.5	38	14.3	0.0	2	0.7	0.7	6	4.4		1
Tridacna maxima	6.0	1.7	38	20.8	2.2	11	6.2	2.9	6	7.5	3.2	5
Tridacna squamosa	2.6	1.4	38	25.0	6.8	4	2.6	1.4	6	5.3	1.6	3
Tripneustes gratilla	0.4	0.4	38	14.3		1	0.3	0.3	6	2.0		1
Trochus niloticus	0.8	0.5	38	14.3	0.0	2	0.8	0.5	6	2.4	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.

4.1.2b Dromuna 2009 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	6.3	2.1	48	30.0	6.0	10	6.3	2.9	8	12.5	3.7	4
Actinopyga miliaris	0.3	0.3	48	16.7		1	0.3	0.3	8	2.8		1
Atrina vexillum	0.3	0.3	48	16.7		1	0.3	0.3	8	2.8		1
Bohadschia argus	1.0	0.6	48	16.7	0.0	3	1.0	0.5	8	2.8	0.0	3
Bohadschia graeffei	2.4	1.0	48	19.4	2.8	6	2.4	1.8	8	9.7	4.2	2
Bohadschia vitiensis	8.0	2.3	48	27.4	5.1	14	8.0	4.1	8	12.8	5.7	5
Cassis cornuta	0.7	0.7	48	33.3		1	0.7	0.7	8	5.6		1
Conus litteratus	6.3	1.9	48	27.3	4.1	11	6.3	2.7	8	8.3	3.1	6
Conus spp.	0.7	0.5	48	16.7	0.0	2	0.7	0.7	8	5.6		1
Culcita novaeguineae	2.4	1.1	48	23.3	4.1	5	2.4	1.4	8	6.5	2.4	3
Echinothrix diadema	1.4	0.8	48	22.2	5.6	3	1.4	1.4	8	11.1		1
Holothuria atra	33.0	7.5	48	68.8	11.6	23	33.0	10.8	8	37.7	11.2	7
Holothuria edulis	5.9	2.1	48	35.4	5.8	8	5.9	4.8	8	15.7	11.6	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.2b Dromuna 2009 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
Holothuria fuscogilva	0.3	0.3	48	16.7		1	0.3	0.3	8	2.8		1
Lambis lambis	4.2	2.6	48	40.0	19.4	5	4.2	3.4	8	11.1	8.3	3
Lambis truncata	0.3	0.3	48	16.7		1	0.3	0.3	8	2.8		1
Linckia laevigata	62.8	11.0	48	88.7	13.2	34	62.8	18.5	8	62.8	18.5	8
Pinctada margaritifera	1.4	0.7	48	16.7	0.0	4	1.4	0.5	8	2.8	0.0	4
Stichopus chloronotus	3.1	2.5	48	50.0	33.3	3	3.1	2.4	8	8.3	5.6	3
Stichopus hermanni	2.8	1.7	48	44.4	14.7	3	2.8	2.8	8	22.2		1
Strombus luhuanus	1.0	0.8	48	25.0	8.3	2	1.0	1.0	8	8.3		1
Synapta spp.	1.0	0.8	48	25.0	8.3	2	1.0	0.7	8	4.2	1.4	2
Thelenota ananas	1.0	0.8	48	25.0	8.3	2	1.0	1.0	8	8.3		1
Toxopneustes pileolus	2.1	2.1	48	100.0		1	2.1	2.1	8	16.7		1
Tridacna maxima	1.7	0.7	48	16.7	0.0	5	1.7	0.7	8	3.5	0.7	4
Tridacna squamosa	0.7	0.5	48	16.7	0.0	2	0.7	0.5	8	2.8	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3a Dromuna 2003 reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	41.7	22.6	18	250.0	0.0	3	41.7	41.7	3	125.0		1
Conus spp.	69.4	33.9	18	312.5	62.5	4	69.4	50.1	3	104.2	62.5	2
Cypraea caputserpensis	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Cypraea tigris	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Echinometra mathaei	791.7	203.4	18	1017.9	227.7	14	791.7	524.3	3	791.7	524.3	3
Echinothrix calamaris	41.7	41.7	18	750.0		1	41.7	41.7	3	125.0		1
Echinothrix diadema	1833.3	387.7	18	2538.5	381.7	13	1833.3	987.2	3	1833.3	987.2	3
Holothuria edulis	27.8	19.1	18	250.0	0.0	2	27.8	13.9	3	41.7	0.0	2
Holothuria nobilis	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Lambis truncata	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Latirolagena smaragdula	111.1	73.5	18	666.7	300.5	3	111.1	111.1	3	333.3		1
Linckia laevigata	361.1	105.5	18	722.2	121.1	9	361.1	182.2	3	541.7	41.7	2
Panulirus versicolor	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Stichopus chloronotus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Tectus pyramis	208.3	101.6	18	937.5	187.5	4	208.3	208.3	3	625.0		1
Tridacna maxima	55.6	25.2	18	250.0	0.0	4	55.6	36.7	3	83.3	41.7	2
Tripneustes gratilla	111.1	50.4	18	400.0	100.0	5	111.1	91.1	3	166.7	125.0	2
Trochus niloticus	41.7	22.6	18	250.0	0.0	3	41.7	41.7	3	125.0		1
Trochus spp.	27.8	27.8	18	500.0		1	27.8	27.8	3	83.3		1
Turbo chrysostomus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Turbo crassus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Vasum ceramicum	125.0	64.7	18	562.5	157.3	4	125.0	125.0	3	375.0		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.3b Dromuna 2009 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	24.3	15.0	72	437.5	187.5	4	24.3	14.0	12	72.9	31.3	4
Actinopyga mauritiana	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Bohadschia argus	24.3	13.2	72	437.5	119.7	4	24.3	20.8	12	145.8	104.2	2
Bohadschia graeffei	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Bohadschia vitiensis	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus imperialis	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Conus marmoreus	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Conus spp.	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Cypraea tigris	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Holothuria atra	66.0	20.4	72	365.4	67.1	13	66.0	24.3	12	113.1	31.1	7
Holothuria edulis	59.0	23.5	72	531.3	119.9	8	59.0	48.2	12	236.1	174.0	3
Holothuria fuscopunctata	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Lambis lambis	10.4	5.9	72	250.0	0.0	3	10.4	10.4	12	125.0		1
Linckia laevigata	555.6	102.1	72	1081.1	155.6	37	555.6	203.6	12	833.3	254.2	8
Pinctada margaritifera	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Stichopus chloronotus	13.9	6.8	72	250.0	0.0	4	13.9	7.8	12	55.6	13.9	3
Tectus pyramis	24.3	11.2	72	350.0	61.2	5	24.3	18.1	12	145.8	62.5	2
Tridacna maxima	27.8	9.3	72	250.0	0.0	8	27.8	7.8	12	47.6	6.0	7
Tridacna squamosa	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Trochus niloticus	13.9	8.4	72	333.3	83.3	3	13.9	9.4	12	83.3	0.0	2
Turbo chrysostomus	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Turbo spp.	6.9	4.9	72	250.0	0.0	2	6.9	4.7	12	41.7	0.0	2
Tutufa bubo	3.5	3.5	72	250.0		1	3.5	3.5	12	41.7		1
Vasum ceramicum	10.4	10.4	72	750.0		1	10.4	10.4	12	125.0		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.4a Dromuna 2003 soft-benthos transect (SBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga echinites	34.9	17.8	43	375.0	72.2	4	35.7	19.1	7	83.3	24.1	3
Actinopyga miliaris	261.6	75.3	43	703.1	148.3	16	267.0	160.5	7	373.8	210.1	5
Anadara antiquata	1139.5	435.1	43	3062.5	1015.9	16	1166.7	857.3	7	1633.3	1163.2	5
Archaster typicus	34.9	13.4	43	250.0	0.0	6	35.7	35.7	7	250.0		1
Atrina vexillum	11.6	8.1	43	250.0	0.0	2	10.2	10.2	7	71.4		1
Bohadschia graeffei	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Bohadschia similis	296.5	90.5	43	850.0	191.8	15	303.6	151.0	7	708.3	127.3	3
Bohadschia vitiensis	52.3	17.8	43	281.3	31.3	8	53.6	28.3	7	93.8	39.4	4
Cassiopea andromeda	52.3	19.6	43	321.4	46.1	7	51.0	24.2	7	89.3	30.1	4
Cerithium nodulosum	11.6	11.6	43	500.0		1	11.9	11.9	7	83.3		1
Conus spp.	11.6	8.1	43	250.0	0.0	2	11.1	7.2	7	38.7	3.0	2
Cypraea annulus	11.6	8.1	43	250.0	0.0	2	11.9	7.7	7	41.7	0.0	2
Cypraea spp.	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Cypraea tigris	34.9	13.4	43	250.0	0.0	6	34.9	14.1	7	61.0	12.9	4
Dolabella auricularia	127.9	49.5	43	550.0	152.8	10	131.0	53.4	7	229.2	49.6	4
Echinometra mathaei	93.0	37.2	43	666.7	83.3	6	95.2	62.1	7	333.3	41.7	2
Echinothrix diadema	5.8	5.8	43	250.0		1	5.1	5.1	7	35.7		1
Gafrarium tumidum	11.6	11.6	43	500.0		1	11.9	11.9	7	83.3		1
Holothuria atra	81.4	24.6	43	318.2	48.7	11	83.3	39.6	7	145.8	49.6	4
Holothuria scabra	284.9	77.4	43	816.7	143.2	15	291.7	163.2	7	510.4	236.5	4
Lambis lambis	145.3	43.4	43	520.8	89.5	12	146.3	93.7	7	341.3	167.8	3
Linckia laevigata	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Mespilia globulus	1581.4	472.5	43	3578.9	884.2	19	1617.3	941.8	7	2264.3	1223.4	5
Modiolus spp.	29.1	17.1	43	416.7	83.3	3	29.8	29.8	7	208.3		1
Periglypta puerpera	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Pinna bicolor	46.5	20.8	43	400.0	61.2	5	47.6	29.4	7	111.1	50.1	3
Pitar prora	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Pitar spp.	5.8	5.8	43	250.0		1	6.0	6.0	7	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.

4.1.4a Dromuna 2003 soft-benthos transect (SBt) 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
Polinices spp.	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Spondylus squamosus	343.0	83.6	43	867.6	134.1	17	349.5	160.8	7	611.6	192.5	4
Stichopus hermanni	476.7	111.2	43	1138.9	169.4	18	488.1	259.5	7	854.2	362.6	4
Stichopus horrens	29.1	14.9	43	312.5	62.5	4	28.9	17.4	7	67.5	28.8	3
Strombus gibberulus gibbosus	11.6	8.1	43	250.0	0.0	2	11.1	7.2	7	38.7	3.0	2
Strombus labiatus	58.1	27.4	43	500.0	111.8	5	56.1	32.2	7	131.0	48.5	3
Synapta spp.	2127.9	332.0	43	2951.6	364.7	31	2148.8	739.8	7	3008.3	709.2	5
Tellina palatum	5.8	5.8	43	250.0		1	6.0	6.0	7	41.7		1
Trachycardium spp.	17.4	9.8	43	250.0	0.0	3	16.2	10.9	7	56.5	14.9	2
Tripneustes gratilla	5.8	5.8	43	250.0		1	6.0	6.0	7	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.

4.1.4b Dromuna 2009 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
Bohadschia argus	8.3	8.3	30	250.0		1	8.3	8.3	5	41.7		1
Holothuria scabra	25.0	18.4	30	375.0	125.0	2	25.0	25.0	5	125.0		1
Stichopus hermanni	50.0	30.3	30	500.0	144.3	3	50.0	50.0	5	250.0		1
Synapta spp.	25.0	13.9	30	250.0	0.0	3	25.0	16.7	5	62.5	20.8	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.5a Dromuna 2003 soft-benthos quadrats (SBq) assessment data review
Station: 8 quadrat groups (4 quadrats/group)

Species	Quadrat group			Quadrat group _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Anadara antiquata	9.94	2.76	192	14.03	3.45	87	9.94	2.76	24	14.03	3.45	17
Gafrarium tumidum	0.27	0.11	192	1.08	0.24	11	0.27	0.11	24	1.08	0.24	6
Holothuria scabra	0.02	0.02	192	0.50	0.00	1	0.02	0.02	24	0.50	0.00	1
Modiolus spp.	0.38	0.28	192	3.00	1.80	8	0.38	0.28	24	3.00	1.80	3
Periglypta puerpera	0.02	0.02	192	0.50	0.00	1	0.02	0.02	24	0.50	0.00	1
Pitar prora	0.04	0.03	192	0.50	0.00	2	0.04	0.03	24	0.50	0.00	2
Strombus gibberulus gibbosus	0.02	0.02	192	0.50	0.00	1	0.02	0.02	24	0.50	0.00	1
Tellina palatum	0.02	0.02	192	0.50	0.00	1	0.02	0.02	24	0.50	0.00	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.

4.1.5b Dromuna 2009 soft-benthos quadrats (SBq) assessment data review
Station: 8 quadrat groups (4 quadrats/group)

Species	Quadrat group			Quadrat group _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Anadara spp.	1.75	0.66	32	1.75	0.66	10	1.75	0.66	4	1.75	0.66	4
Bohadschia similis	0.13	0.13	32	0.50	0.00	1	0.13	0.13	4	0.50	0.00	1
Fragum unedo	0.13	0.13	32	0.50	0.00	1	0.13	0.13	4	0.50	0.00	1
Mespilia globulus	1.50	0.65	32	2.00	0.58	8	1.50	0.65	4	2.00	0.58	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.6 Dromuna 2009 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
Conus spp.	3.5	2.5	18	31.3	10.4	2	3.5	2.0	3	5.2	1.7	2
Cypraea tigris	2.3	1.6	18	20.9	0.0	2	2.3	1.2	3	3.5	0.0	2
Echinometra mathaei	7.0	4.1	18	41.7	12.0	3	7.0	7.0	3	20.9		1
Heterocentrotus mammillatus	1.2	1.2	18	20.9		1	1.2	1.2	3	3.5		1
Stichopus chloronotus	2.3	1.6	18	20.9	0.0	2	2.3	1.2	3	3.5	0.0	2
Tectus pyramis	3.5	1.9	18	20.9	0.0	3	3.5	2.0	3	5.2	1.7	2
Tridacna maxima	3.5	1.9	18	20.9	0.0	3	3.5	2.0	3	5.2	1.7	2
Tridacna squamosa	1.2	1.2	18	20.9		1	1.2	1.2	3	3.5		1
Trochus niloticus	7.0	2.9	18	25.0	4.2	5	7.0	4.0	3	10.4	3.5	2
Vasum ceramicum	5.8	5.8	18	104.3		1	5.8	5.8	3	17.4		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.

4.1.7 Dromuna 2009 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
Bohadschia graeffei	15.6	7.2	12	46.8	9.4	4	15.6	3.1	2	15.6	3.1	2
Cypraea tigris	3.1	3.1	12	37.5		1	3.1	3.1	2	6.2		1
Lambis truncata	3.1	3.1	12	37.5		1	3.1	3.1	2	6.2		1
Ovula ovum	6.2	6.2	12	74.9		1	6.2	6.2	2	12.5		1
Stichodactyla spp.	12.5	9.6	12	74.9	37.5	2	12.5	12.5	2	25.0		1
Stichopus chloronotus	3.1	3.1	12	37.5		1	3.1	3.1	2	6.2		1
Tectus pyramis	9.4	6.7	12	56.2	18.7	2	9.4	9.4	2	18.7		1
Tridacna maxima	3.1	3.1	12	37.5		1	3.1	3.1	2	6.2		1
Tridacna squamosa	6.2	4.2	12	37.5	0.0	2	6.2	6.2	2	12.5		1
Trochus niloticus	12.5	7.0	12	49.9	12.5	3	12.5	6.2	2	12.5	6.2	2
Tutufa bubo	3.1	3.1	12	37.5		1	3.1	3.1	2	6.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.8 Dromuna 2009 sea cucumber night search (Ns) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga lecanora	5.1	3.5	27	68.5	0.0	2	5.1	2.5	3	7.6	0.0	2
Actinopyga mauritiana	2.5	2.5	27	68.5		1	2.5	2.5	3	7.6		1
Actinopyga miliaris	73.6	16.7	27	116.8	20.1	17	73.6	37.4	3	110.4	11.4	2
Bohadschia vitiensis	12.7	6.4	27	85.6	17.1	4	12.7	9.1	3	19.0	11.4	2
Holothuria edulis	5.1	5.1	27	137.0		1	5.1	5.1	3	15.2		1
Stichopus hermanni	2.5	2.5	27	68.5		1	2.5	2.5	3	7.6		1
Stichopus horrens	2.5	2.5	27	68.5		1	2.5	2.5	3	7.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.1.9 Dromuna 2009 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	8.8	3.8	12	21.2	5.3	5	8.8	4.4	2	8.8	4.4	2
Holothuria edulis	2.2	1.5	12	13.2	0.0	2	2.2	2.2	2	4.4		1
Holothuria fuscogilva	2.2	1.5	12	13.2	0.0	2	2.2	0.0	2	2.2	0.0	2
Linckia laevigata	11.0	11.0	12	132.3		1	11.0	11.0	2	22.0		1
Thelenota anax	1.1	1.1	12	13.2		1	1.1	1.1	2	2.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.1.10a Dromuna 2003 species size review – all survey methods

Species	Mean length (cm)	SE	n measured	n total
Anadara antiquata	4.8	0.0	609	673
Stichopus hermanni	11.1	0.3	83	83
Spondylus squamosus	8.6	0.2	59	59
Bohadschia similis	10.5	0.4	51	51
Holothuria scabra	12.4	0.3	50	50
Actinopyga miliaris	7.4	0.2	45	45
Lambis lambis	13.0	0.4	38	38
Bohadschia vitiensis	16.2	1.0	28	84
Modiolus spp.	3.7	0.2	23	23
Dolabella auricularia	9.7	0.3	22	22
Tridacna maxima	17.6	1.4	20	20
Bohadschia argus	26.4	1.1	18	22
Tectus pyramis	5.6	0.2	18	19
Pinctada margaritifera	14.6	0.6	15	15
Gafrarium tumidum	4.0	0.2	15	15
Holothuria atra	14.0	1.2	14	74
Echinometra mathaei	6.3	0.3	11	74
Strombus labiatus	3.3	0.1	10	10
Tripneustes gratilla	8.2	0.5	9	10
Vasum ceramicum	7.8	0.9	9	9
Conus spp.	5.5	0.7	7	24
Cypraea tigris	8.1	0.4	7	9
Tridacna squamosa	24.1	3.3	7	7
Stichopus chloronotus	24.0	1.0	6	6
Actinopyga echinites	10.4	1.0	6	6
Stichopus horrens	9.5	1.4	5	5
Trochus niloticus	8.6	1.5	5	5
Bohadschia graeffei	22.4	4.1	4	7
Strombus gibberulus gibbosus	4.0	0.1	4	4
Trachycardium spp.	5.8	2.5	3	3
Cerithium nodulosum	5.6	0.2	3	3
Pitar prora	3.5	0.7	3	3
Atrina vexillum	20.0	3.0	2	6
Periglypta puerpera	8.7	0.9	2	2
Trochus spp.	3.1	0.0	2	2
Lambis truncata	24.8	0.2	2	2
Panulirus versicolor	17.1	8.0	2	2
Cypraea annulus	1.6	0.5	2	2
Thelenota ananas	28.0	0.0	2	2
Tellina palatum	4.4	0.5	2	2
Actinopyga lecanora	12.0	10.0	2	2
Holothuria nobilis	20.5	4.5	2	2
Polinices spp.	2.2		1	1
Turbo crassus	6.8		1	1
Turbo chrysostomus	3.0		1	1
Pitar spp.	9.1		1	1
Synapta spp.				369
Mespilia globulus				272

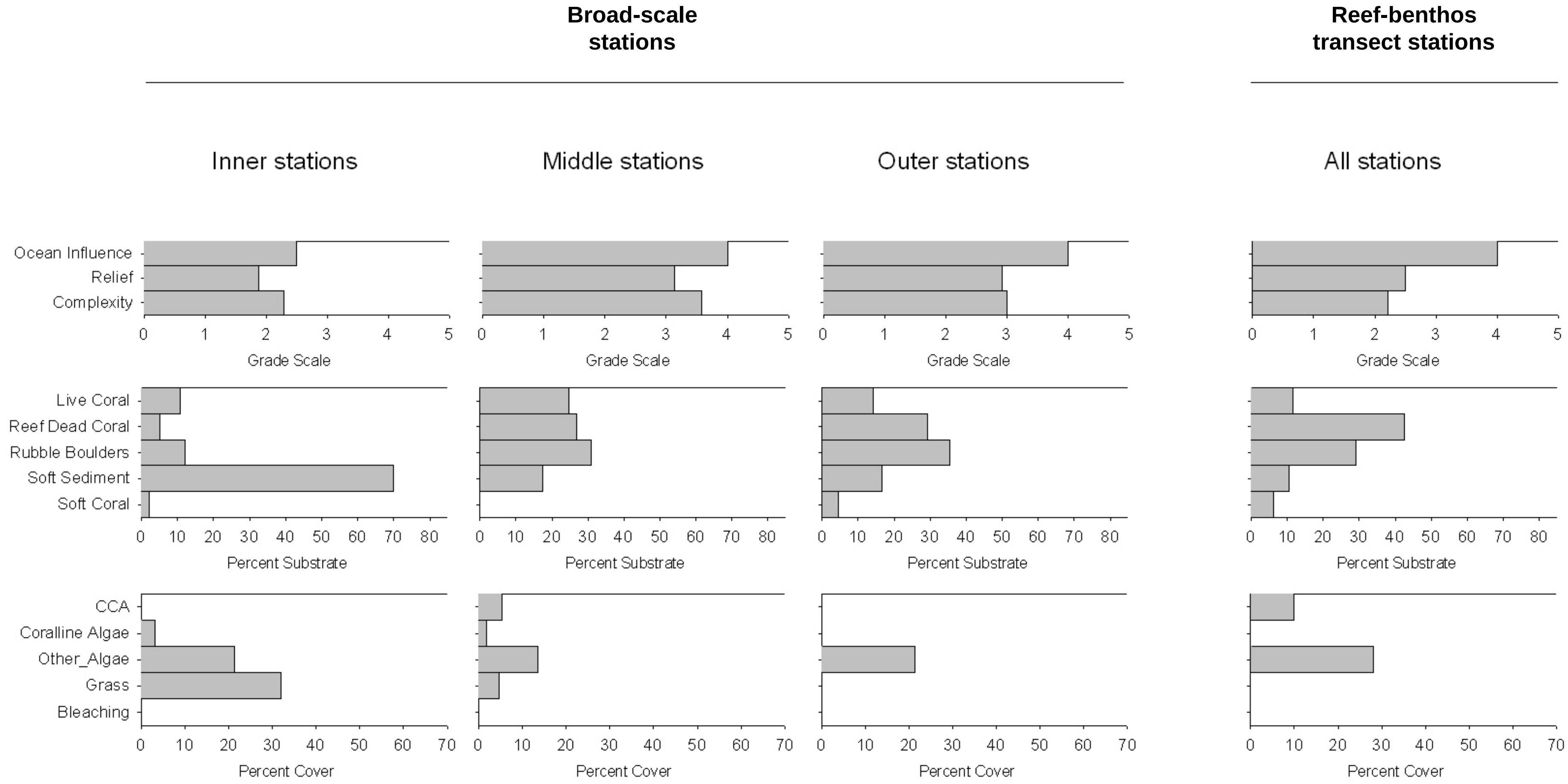
4.1.10a Dromuna 2003 species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n measured	n total
Linckia laevigata				239
Echinothrix diadema				153
Strombus luhuanus				44
Spondylus spp.				14
Holothuria edulis				14
Cassiopea andromeda				11
Pinna bicolor				8
Culcita novaeguineae				8
Latirolagena smaragdula				8
Archaster typicus				6
Echinothrix calamaris				3
Acanthaster planci				2
Hyotissa spp.				2
Holothuria leucospilota				1
Cypraea spp.				1
Cypraea caputserpensis				1
Holothuria fuscogilva				1

4.1.10b Dromuna 2009 species size review – all survey methods

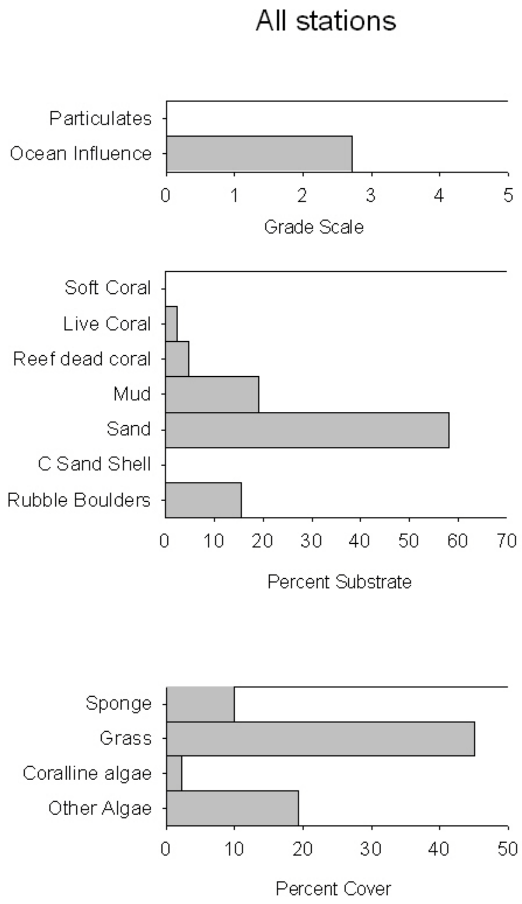
Species	Mean length (cm)	SE	n measured	n total
Actinopyga miliaris	12.7	0.7	29	30
Holothuria atra	17.1	1.2	19	114
Holothuria edulis	23.7	1.2	17	38
Bohadschia argus	28.7	2.5	16	19
Anadara spp.	5.9	0.2	14	14
Trochus niloticus	9.6	0.4	13	14
Tectus pyramis	6.6	0.2	12	13
Tridacna maxima	18.6	2.9	9	17
Stichopus hermanni	22.7	3.3	7	15
Stichopus chloronotus	19.7	2.5	6	16
Bohadschia graeffei	21.0	1.9	5	13
Tridacna squamosa	26.8	5.5	5	7
Bohadschia vitiensis	23.7	1.3	3	29
Lambis lambis	14.7	1.5	3	15
Vasum ceramicum	8.0	1.2	3	9
Conus spp.	6.3	1.8	3	7
Holothuria fuscogilva	27.3	6.3	3	3
Holothuria scabra	12.8	0.2	3	3
Cypraea tigris	8.5	0.5	2	4
Tutufa bubo	24.5	5.5	2	3
Turbo spp.	3.0	0.0	2	2
Actinopyga lecanora	18.5	0.5	2	2
Conus marmoreus	8.3	0.8	2	2
Actinopyga mauritiana	18.5	1.5	2	2
Pinctada margaritifera	11.0		1	5
Lambis truncata	25.0		1	2
Thelenota anax	60.0		1	1
Bohadschia similis	16.0		1	1
Conus imperialis	6.0		1	1
Holothuria fuscopunctata	22.0		1	1
Turbo chrysostomus	6.0		1	1
Stichopus horrens	22.0		1	1
Linckia laevigata				351
Acanthaster planci				25
Conus litteratus				18
Mespilia globulus				12
Culcita novaeguineae				7
Synapta spp.				6
Toxopneustes pileolus				6
Echinometra mathaei				6
Stichodactyla spp.				4
Echinothrix diadema				4
Thelenota ananas				3
Strombus luhuanus				3
Cassis cornuta				2
Ovula ovum				2
Heterocentrotus mammillatus				1
Atrina vexillum				1
Fragum unedo				1

4.1.11a Habitat descriptors for independent assessment – Dromuna 2003

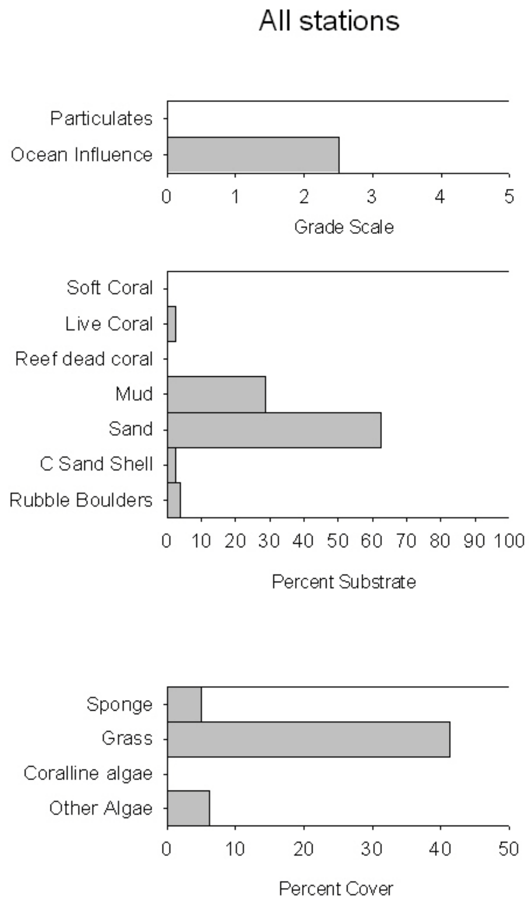


4.1.11a Habitat descriptors for independent assessment – Dromuna 2003 (continued)

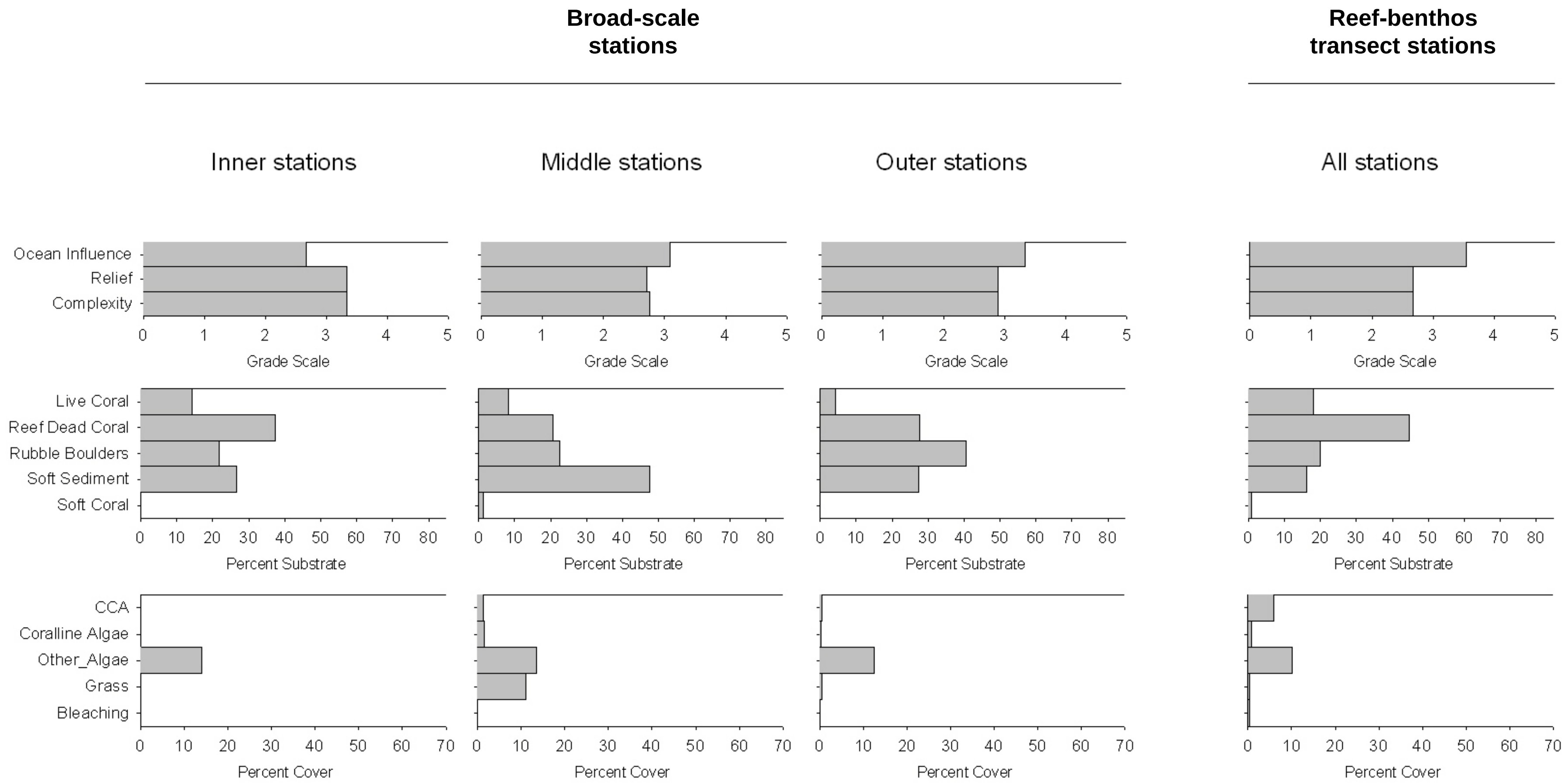
Soft-benthos transect stations



Soft-benthos quadrat stations

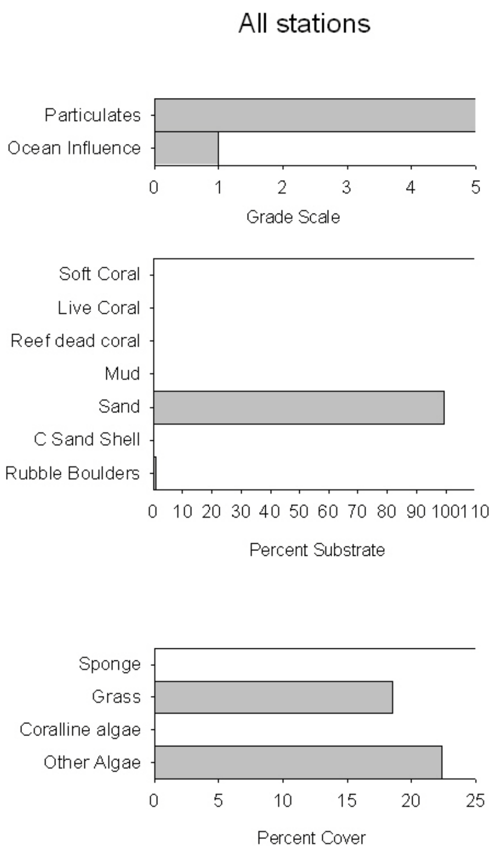


4.1.11b Habitat descriptors for independent assessment – Dromuna 2009

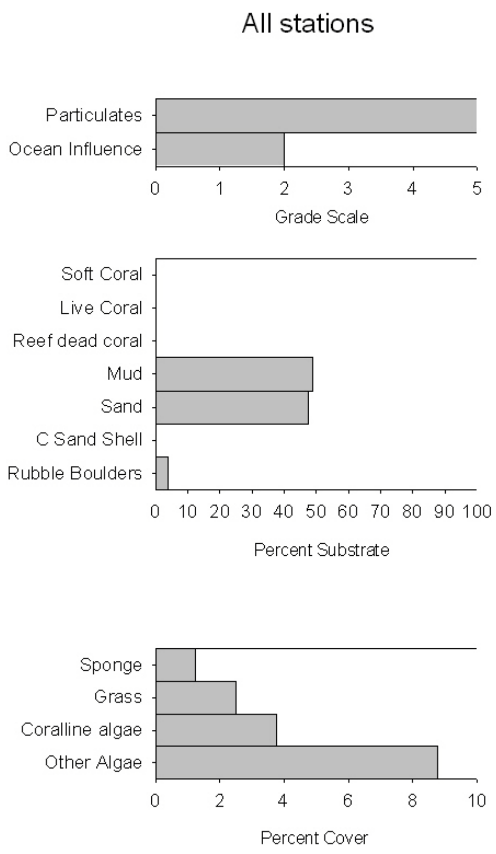


4.1.11b Habitat descriptors for independent assessment – Dromuna 2009 (continued)

Soft-benthos transect stations



Soft-benthos quadrat stations



4.1.12 Dromuna 2003 catch assessment – creel survey – data review

Per fisher CPUE – number of individuals caught per hour, Catches made on 4 February 2003.

Fisher	Time (min)	*H. atra*	*A. echinities*	*S. hermanni*	*A. lecanora*	*H. leucospilota*	*A. miliaris*	*H. scabra*	*B. vitiensis*
Alesi Kaibau	260	0.0	0.0	0.0	0.0	0.0	7.6	25.4	4.6
Isoar Raicabe	260	0.0	0.0	0.0	0.5	0.0	39.5	2.1	16.6
Jone Sorowagali	260	0.0	0.0	0.0	2.1	0.0	54.0	0.7	8.8
Luci Naidolavu	260	0.0	0.0	11.5	0.9	0.0	4.4	0.2	9.5
Maraia Ramatau	260	0.0	0.0	0.0	0.9	0.0	69.7	0.5	12.0
Mata Tiko	260	0.0	3.0	0.0	1.4	0.0	79.2	0.2	11.8
Mere	180	1.0	0.0	10.3	0.0	0.3	1.0	5.0	2.0
Meroni Ratulailai	260	0.0	0.0	0.0	0.0	0.0	5.5	27.5	0.0
Mili Voraki	260	0.0	0.0	0.0	0.0	0.0	3.9	18.7	0.0
Naitini Katalaini	260	0.0	0.0	0.0	0.2	0.0	44.1	0.5	12.9
Neumai	260	0.0	0.0	0.0	0.0	0.0	4.6	47.3	0.0
S. Rokomarawa	260	0.0	0.0	0.0	1.2	0.0	47.8	0.5	11.5
Sanivalati Tova	260	0.0	0.0	0.0	0.7	0.0	21.9	0.0	0.0
Savenaca Komai	260	0.0	10.4	0.0	0.0	0.0	9.2	0.2	0.0
Taua Alifereti	260	0.0	0.0	0.0	0.9	0.0	21.0	0.0	3.9
V. Vakamelei	260	0.0	0.0	0.0	0.2	0.0	88.8	2.1	19.4
Vani Marama	260	0.0	0.0	0.0	0.0	0.0	24.2	35.8	1.4
Villy Pawa	260	0.0	0.0	0.0	0.0	0.0	3.2	0.2	19.4
Wati Savaira	260	0.0	0.0	0.0	1.8	0.0	83.3	0.0	14.8

Per fisher CPUE – catch per hour, Catches made on 6 February 2003.

Fisher	Time (min)	*A antiquata*	*Lambis* spp..	*H. scabra*	*S. squamosus*	*A. vexillum*	*Algae: C. racemosa*
Joana Leloma	45	298.7	0.0	0.0	0.0	1.3	0.0
Naomi Toka	45	178.7	2.7	0.0	0.0	2.7	0.0
Savaira	60	0.0	0.0	0.0	0.0	0.0	1.0
Sovaia Toka	45	261.3	0.0	1.3	1.3	1.3	0.0
Vakaola Sekibureta	45	0.0	145.3	0.0	1.3	0.0	0.0
Wati Liku	60	0.0	0.0	0.0	0.0	0.0	1.0

4.1.13 Village prices for invertebrate products

Local name	Common name	Scientific name	Product	Price /kg (FJD)	Comments
Mali, Vanua Levu					
Sici	Trochus	*Trochus niloticus*	Shell		Inactive fishery
Uradina	Lobster	*Panulirus sp*	Fresh	17.00	
Qari	Mud crab	*Scylla serrata*	Live	12.00	
Lakeba, Vanua Levu					
Driloli	Lollyfish	*Holothuria atra*	Full dry	11.00	
Lolia	Pinkfish	*Holothuria edulis*	Full dry	11.00	
Laulevu	Curryfish	*Stichopus hermanni*	Full dry	50.00	
			1st cook	25.00	
Dri	Blackfish	*Actinopyga miliaris*	Full dry	50.00	
			1st cook	25.00	
			Raw (whole)	6.00	
Vula	Brown sandfish	*Bohadschia vitiensis*	Full dry	25.00	
Tarasea	Surf redfish	*Actinopyga mauritiana*	Full dry	50.00	
Drivatu	White ass	*Actinopyga lecanora*	Full dry	50.00	
Caterpiller	peanutfish	*Stichopus horrens*	Full dry	2.00	
Sucudrau	Amberfish	*Thelenota anax*	Full dry	1.00 /pc	
Greenfish	Greenfish	*Stichopus chloronotus*	Full dry	30.00	
			1st cook	6.00	
Vula	Tigerfish	*Bohadschia argus*	Full dry	25.00	
			Raw	2.00	
Loaloa	Black teatfish	*Holothuria nobilis*	Full dry	40.00	
			Raw	4.00 /pc	
Sucuwalu	White teatfish	*Holothuria fuscogilva*	Full dry Raw (l)	40.00 10.00–20.00 /pc	
Dairo	Sandfish	*Holothuria scabra*			Inactive fishery
Sucudrau	Prickly redfish	*Thelenota ananas*	Raw	1.00 /pc	
Dairo nicakau	Elephant trunkfish	*Holothuria fuscopunctata*	Raw	90c /pc	
Nama	Sea grape	*Caulerpa racemosa*	Raw	3.00 /heap	
Kaikoso	Ark shell	*Anadara antiquata*	Live	3.00 /heap	
Kuita	Octopus	*Octopus sp*	Fresh (m-l)	10.00 /pc	Sold as bait @ 5-7.00/kg
Cici	Trochus	*Trochus niloticus*		5.00	Last harvest 2007, 300 kg
Dromuna, Viti Levu					
Dri	Blackfish	*Actinopyga miliaris*	Raw (l)	5.00	
			Raw (s)	4.00	
		Bohadschia vitiensis	Raw	4.00	
Laulevu	Curryfish	*Stichopus hermanni*	1st cook	4.00	
	Tigerfish	*Bohadschia argus*	Raw	3.00 /pc	
Caterpiller	Dragonfish	*Stichopus horrens*	Raw	23.00	
Lairo	Land crab	*Cardisoma carnifex*	Bundle/rope	10.00	
Ura	Rock lobster	*Panulirus sp*		17.00–18.00	
Qari	Mud crab	*Scylla serrata*		12.00	
Muaivuso, Viti Levu					
Cawake	Collector urchin	*Tripneustes gratilla*			Sold at Suva market
Sea cucumber					No active fishing, MPA

Larger = l; small = s; medium = m.

4.2 Muaivuso invertebrate survey data

4.2.1a Invertebrate species recorded in different assessments in Muaivuso in 2003

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga echinites*	+	+	+	
Bêche-de-mer	*Actinopyga mauritiana*		+		
Bêche-de-mer	*Actinopyga miliaris*		+	+	
Bêche-de-mer	*Bohadschia argus*	+	+	+	+
Bêche-de-mer	*Bohadschia graeffei*	+	+		+
Bêche-de-mer	*Bohadschia similis*		+	+	
Bêche-de-mer	*Bohadschia vitiensis*	+		+	
Bêche-de-mer	*Euapta* spp.		+		
Bêche-de-mer	*Holothuria atra*	+	+	+	
Bêche-de-mer	*Holothuria coluber*	+		+	
Bêche-de-mer	*Holothuria edulis*	+		+	
Bêche-de-mer	*Holothuria fuscopunctata*	+			
Bêche-de-mer	*Holothuria hilla*		+		
Bêche-de-mer	*Holothuria leucospilota*		+	+	
Bêche-de-mer	*Holothuria nobilis*	+	+	+	
Bêche-de-mer	*Holothuria pervicax*		+	+	
Bêche-de-mer	*Holothuria scabra*			+	
Bêche-de-mer	*Holothuria* spp.		+		
Bêche-de-mer	*Stichopus chloronotus*	+	+	+	
Bêche-de-mer	*Stichopus hermanni*			+	
Bêche-de-mer	*Stichopus horrens*		+		
Bêche-de-mer	*Synapta* spp.		+	+	
Bêche-de-mer	*Thelenota ananas*	+			
Bêche-de-mer	*Thelenota anax*	+			
Bivalve	*Anadara antiquata*			+	
Bivalve	*Chama* spp.			+	
Bivalve	*Fragum unedo*			+	
Bivalve	*Hyotissa* spp.			+	
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Pinna bicolor*			+	
Bivalve	*Pinna* spp.			+	
Bivalve	*Spondylus* spp.	+		+	
Bivalve	*Tridacna maxima*				+
Bivalve	*Tridacna squamosa*	+		+	
Crustacean	*Dardanus* spp.		+	+	
Gastropod	*Bulla ampulla*		+		
Gastropod	*Cerithium aluco*			+	
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Cerithium* spp.		+	+	
Gastropod	*Conus flavidus*		+	+	
Gastropod	*Conus leopardus*			+	
Gastropod	*Conus litteratus*			+	
Gastropod	*Conus miles*		+		
Gastropod	*Conus* spp.	+	+	+	+
Gastropod	*Conus textile*		+		
Gastropod	*Cypraea annulus*			+	

+ = presence of the species.

4.2.1a Invertebrate species recorded in different assessments in Muaivuso in 2003 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Cypraea mappa mappa*		+		
Gastropod	*Cypraea* spp.				+
Gastropod	*Cypraea tigris*			+	
Gastropod	*Dolabella auricularia*		+	+	
Gastropod	*Drupa* spp.			+	
Gastropod	*Lambis lambis*	+		+	
Gastropod	*Nassarius* spp.			+	
Gastropod	*Strombus gibberulus gibbosus*			+	
Gastropod	*Strombus labiatus*			+	
Gastropod	*Strombus lentiginosus*		+		
Gastropod	*Strombus luhuanus*		+		
Gastropod	*Tectus pyramis*		+		+
Gastropod	*Terebra* spp.		+	+	
Gastropod	*Trochus niloticus*			+	+
Gastropod	*Trochus* spp.		+	+	
Gastropod	*Turbo chrysostomus*		+		+
Gastropod	*Turbo crassus*		+		
Star	*Acanthaster planci*	+			
Star	*Choriaster granulatus*	+	+	+	
Star	*Culcita novaeguineae*	+		+	+
Star	*Linckia laevigata*	+	+	+	+
Urchin	*Echinometra mathaei*	+	+	+	+
Urchin	*Echinothrix calamaris*		+	+	
Urchin	*Echinothrix diadema*	+			
Urchin	*Eucidaris* spp.		+		
Urchin	*Mespilia globulus*			+	
Urchin	*Toxopneustes pileolus*		+	+	
Urchin	*Tripneustes gratilla*	+	+	+	

+ = presence of the species.

4.2.1b Invertebrate species recorded in different assessments in Muaivuso in 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Bohadschia argus*	+	+		
Bêche-de-mer	*Bohadschia graeffei*		+	+	
Bêche-de-mer	*Bohadschia vitiensis*	+		+	
Bêche-de-mer	*Holothuria atra*	+	+	+	
Bêche-de-mer	*Holothuria edulis*	+	+		
Bêche-de-mer	*Holothuria nobilis*			+	
Bêche-de-mer	*Holothuria scabra*			+	
Bêche-de-mer	*Holothuria scabra versicolor*			+	
Bêche-de-mer	*Stichopus chloronotus*	+	+	+	
Bêche-de-mer	*Synapta* spp.	+		+	
Bivalve	*Fragum unedo*			+	
Bivalve	*Pinctada margaritifera*	+			
Bivalve	*Tridacna maxima*	+		+	
Gastropod	*Conus* spp.		+	+	
Gastropod	*Cypraea tigris*			+	
Gastropod	*Lambis lambis*			+	
Gastropod	*Latirolagena smaragdula*		+		
Gastropod	*Strombus luhuanus*			+	
Gastropod	*Tectus pyramis*		+		+
Gastropod	*Trochus maculata*		+		
Gastropod	*Trochus niloticus*		+	+	
Star	*Acanthaster planci*	+	+	+	+
Star	*Culcita novaeguineae*			+	
Star	*Linckia laevigata*	+	+	+	+
Star	*Protoreaster nodosus*	+	+	+	
Urchin	*Echinometra mathaei*		+		
Urchin	*Echinothrix diadema*	+	+	+	+
Urchin	*Heterocentrotus mammillatus*	+			
Urchin	*Mespilia globulus*			+	
Urchin	*Toxopneustes pileolus*	+		+	
Urchin	*Tripneustes gratilla*	+		+	

+ = presence of the species.

4.2.1c Invertebrate species recorded in different assessments in Muaivuso MPA 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Bohadschia argus*	+	+		
Bêche-de-mer	*Bohadschia graeffei*		+		
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria coluber*		+		
Bêche-de-mer	*Holothuria edulis*	+	+		+
Bêche-de-mer	*Holothuria nobilis*		+		+
Bêche-de-mer	*Stichopus chloronotus*	+	+		
Bêche-de-mer	*Stichopus hermanni*	+			
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Spondylus* spp.		+		
Bivalve	*Tridacna maxima*		+		
Bivalve	*Tridacna squamosa*		+		
Cnidarians	*Stichodactyla* spp.	+			
Crustacean	*Panulirus versicolor*		+		
Gastropod	*Conus* spp.		+		
Gastropod	*Cypraea tigris*	+			
Gastropod	*Lambis truncata*	+			
Gastropod	*Tectus pyramis*		+		
Gastropod	*Trochus niloticus*	+	+		
Star	*Acanthaster planci*	+	+		
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*		+		
Urchin	*Echinothrix diadema*	+	+		
Urchin	*Tripneustes gratilla*		+		

+ = presence of the species.

4.2.2a Muaivuso 2003 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	3.2	3.2	26	83.3		1	3.2	3.2	4	12.8		1
Actinopyga echinites	0.6	0.6	26	16.7		1	0.6	0.6	4	2.6		1
Bohadschia argus	15.0	3.3	26	26.0	3.7	15	14.5	6.0	4	14.5	6.0	4
Bohadschia graeffei	25.6	10.7	26	60.6	21.4	11	26.2	16.8	4	34.9	20.2	3
Bohadschia vitiensis	5.5	2.6	26	28.6	7.8	5	5.1	5.1	4	20.4		1
Choriaster granulatus	10.6	3.8	26	30.7	7.2	9	10.4	5.4	4	10.4	5.4	4
Conus spp.	4.9	2.1	26	25.2	4.1	5	4.2	2.2	4	5.6	2.4	3
Culcita novaeguineae	8.4	3.4	26	36.5	7.0	6	7.0	4.5	4	7.0	4.5	4
Echinometra mathaei	14.5	12.8	26	125.4	104.1	3	8.0	5.9	4	10.7	7.5	3
Echinothrix diadema	11.2	7.7	26	58.1	35.6	5	8.4	3.7	4	8.4	3.7	4
Holothuria atra	12.1	4.7	26	34.9	9.8	9	10.4	5.5	4	13.8	6.1	3
Holothuria coluber	15.9	5.3	26	51.7	8.0	8	15.0	6.2	4	15.0	6.2	4
Holothuria edulis	24.5	6.4	26	48.9	8.5	13	23.7	12.3	4	31.6	13.3	3
Holothuria fuscopunctata	4.9	2.1	26	25.7	2.9	5	4.1	2.4	4	8.2	0.1	2
Holothuria nobilis	0.5	0.5	26	14.3		1	0.6	0.6	4	2.4		1
Lambis lambis	1.3	1.3	26	33.3		1	0.6	0.6	4	2.6		1
Linckia laevigata	183.1	43.5	26	226.6	49.3	21	183.8	83.0	4	183.8	83.0	4
Pinctada margaritifera	1.2	0.8	26	15.5	1.2	2	1.2	0.7	4	2.5	0.1	2
Spondylus spp.	1.9	1.4	26	25.0	8.3	2	1.3	1.3	4	5.1		1
Stichopus chloronotus	4.8	2.9	26	41.7	12.7	3	4.0	2.5	4	7.9	2.4	2
Thelenota ananas	2.8	1.4	26	18.5	3.4	4	2.4	0.2	4	2.4	0.2	4
Thelenota anax	2.9	1.4	26	19.0	3.2	4	3.3	1.3	4	4.4	1.0	3
Tridacna squamosa	0.6	0.6	26	16.7		1	0.6	0.6	4	2.6		1
Tripneustes gratilla	7.0	5.2	26	45.2	29.4	4	4.4	3.7	4	8.7	6.7	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.2b Muaivuso 2009 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	52.1	35.0	8	208.3	41.7	2	38.8	38.8	2	77.7		1
Bohadschia argus	2.1	2.1	8	16.7		1	4.2	4.2	2	8.3		1
Bohadschia vitiensis	15.6	11.6	8	62.5	29.2	2	6.2	6.2	2	12.4		1
Echinothrix diadema	354.2	232.6	8	1416.7	100.0	2	708.3	708.3	2	1416.7		1
Heterocentrotus mammillatus	2.1	2.1	8	16.7		1	4.2	4.2	2	8.3		1
Holothuria atra	58.3	22.3	8	93.3	23.9	5	51.3	26.3	2	51.3	26.3	2
Holothuria edulis	42.2	24.5	8	112.5	40.5	3	23.3	23.3	2	46.6		1
Linckia laevigata	338.1	78.8	8	338.1	78.8	8	224.4	182.7	2	224.4	182.7	2
Pinctada margaritifera	2.1	2.1	8	16.7		1	4.2	4.2	2	8.3		1
Protoreaster nodosus	2.1	2.1	8	16.7		1	4.2	4.2	2	8.3		1
Stichopus chloronotus	11.5	11.5	8	91.7		1	3.1	3.1	2	6.2		1
Toxopneustes pileolus	6.3	4.4	8	25.0	8.3	2	12.5	12.5	2	25.0		1
Tridacna maxima	2.1	2.1	8	16.7		1	4.2	4.2	2	8.3		1
Tripneustes gratilla	6.3	6.3	8	50.0		1	12.5	12.5	2	25.0		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.2c Muaivuso 2009 MPA 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	1.6	1.6	14	21.7		1	1.5	1.5	3	4.4		1
Bohadschia argus	8.7	2.4	14	17.4	0.7	7	8.0	2.0	3	8.0	2.0	3
Cypraea tigris	2.7	1.9	14	19.2	2.5	2	2.4	1.3	3	3.6	0.8	2
Echinothrix diadema	191.7	84.6	14	447.2	143.5	6	223.9	202.9	3	223.9	202.9	3
Holothuria atra	528.9	276.7	14	617.1	317.2	12	422.9	371.2	3	422.9	371.2	3
Holothuria edulis	13.8	5.5	14	38.7	6.3	5	11.3	7.3	3	16.9	8.1	2
Lambis truncata	1.2	1.2	14	16.7		1	1.5	1.5	3	4.4		1
Linckia laevigata	492.0	177.4	14	492.0	177.4	14	437.4	175.7	3	437.4	175.7	3
Stichodactyla spp.	1.2	1.2	14	16.7		1	1.5	1.5	3	4.4		1
Stichopus chloronotus	17.0	9.7	14	59.6	24.3	4	13.5	11.4	3	20.3	15.8	2
Stichopus hermanni	2.4	1.6	14	16.7	0.0	2	1.9	1.9	3	5.6		1
Synapta spp.	2.4	2.4	14	33.3		1	2.8	2.8	3	8.3		1
Toxopneustes pileolus	1.2	1.2	14	16.7		1	1.4	1.4	3	4.2		1
Tripneustes gratilla	319.0	156.5	14	1116.7	272.9	4	372.2	372.2	3	1116.7		1
Trochus niloticus	1.2	1.2	14	16.7		1	1.5	1.5	3	4.4		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.2.3a Muaivuso 2003 reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga echinites	7916.7	2386.8	18	11,875.0	2 988.9	12	7916.7	5538.0	3	11,875.0	6708.3	2
Actinopyga mauritiana	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Actinopyga miliaris	69.4	33.9	18	312.5	62.5	4	69.4	36.7	3	104.2	20.8	2
Bohadschia argus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Bohadschia graeffei	138.9	46.2	18	357.1	50.5	7	138.9	77.3	3	138.9	77.3	3
Bohadschia similis	138.9	67.7	18	500.0	158.1	5	138.9	138.9	3	416.7		1
Bulla ampulla	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Cerithium nodulosum	222.2	121.1	18	1000.0	338.5	4	222.2	111.1	3	333.3	0.0	2
Cerithium spp.	97.2	61.1	18	583.3	220.5	3	97.2	50.1	3	145.8	20.8	2
Choriaster granulatus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Conus flavidus	55.6	32.3	18	333.3	83.3	3	55.6	27.8	3	83.3	0.0	2
Conus miles	41.7	22.6	18	250.0	0.0	3	41.7	24.1	3	62.5	20.8	2
Conus spp.	263.9	91.4	18	527.8	134.7	9	263.9	160.2	3	263.9	160.2	3
Conus textile	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Cypraea mappa mappa	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Dardanus spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Dolabella auricularia	55.6	25.2	18	250.0	0.0	4	55.6	55.6	3	166.7		1
Echinometra mathaei	375.0	101.6	18	613.6	118.5	11	375.0	133.9	3	375.0	133.9	3
Echinothrix calamaris	55.6	32.3	18	333.3	83.3	3	55.6	27.8	3	83.3	0.0	2
Euapta spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Eucidaris spp.	41.7	30.3	18	375.0	125.0	2	41.7	41.7	3	125.0		1
Holothuria atra	277.8	75.3	18	416.7	88.8	12	277.8	69.4	3	277.8	69.4	3
Holothuria hilla	1708.3	351.4	18	2365.4	335.7	13	1708.3	819.0	3	1708.3	819.0	3
Holothuria leucospilota	333.3	144.3	18	1000.0	281.4	6	333.3	220.5	3	500.0	250.0	2
Holothuria nobilis	27.8	19.1	18	250.0	0.0	2	27.8	27.8	3	83.3		1
Holothuria pervicax	111.1	76.2	18	1000.0	0.0	2	111.1	111.1	3	333.3		1
Holothuria spp.	347.2	137.3	18	1041.7	218.1	6	347.2	218.3	3	520.8	229.2	2
Linckia laevigata	916.7	211.0	18	1100.0	224.7	15	916.7	292.7	3	916.7	292.7	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3a Muaivuso 2003 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
Pinctada margaritifera	27.8	27.8	18	500.0		1	27.8	27.8	3	83.3		1
Stichopus chloronotus	236.1	47.3	18	354.2	37.2	12	236.1	91.1	3	236.1	91.1	3
Stichopus horrens	27.8	27.8	18	500.0		1	27.8	27.8	3	83.3		1
Strombus lentiginosus	27.8	19.1	18	250.0	0.0	2	27.8	13.9	3	41.7	0.0	2
Strombus luhuanus	41.7	30.3	18	375.0	125.0	2	41.7	24.1	3	62.5	20.8	2
Synapta spp.	1208.3	331.0	18	2 175.0	372.8	10	1208.3	664.5	3	1812.5	479.2	2
Tectus pyramis	97.2	50.1	18	437.5	119.7	4	97.2	77.3	3	145.8	104.2	2
Terebra spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Toxopneustes pileolus	222.2	94.6	18	666.7	178.7	6	222.2	100.2	3	222.2	100.2	3
Tripneustes gratilla	14,263.9	3808.6	18	14,263.9	3808.6	18	14,263.9	9 752.1	3	14,263.9	9752.1	3
Trochus spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Turbo chrysostomus	69.4	27.2	18	250.0	0.0	5	69.4	13.9	3	69.4	13.9	3
Turbo crassus	97.2	57.7	18	583.3	166.7	3	97.2	77.3	3	145.8	104.2	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3b Muaivuso 2009 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	111.1	70.7	18	500.0	250.0	4	111.1	91.1	3	166.7	125.0	2
Bohadschia argus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Bohadschia graeffei	277.8	92.4	18	625.0	125.0	8	277.8	218.3	3	416.7	291.7	2
Conus spp.	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Echinometra mathaei	208.3	95.3	18	625.0	201.6	6	208.3	208.3	3	625.0		1
Echinothrix diadema	27.8	27.8	18	500.0		1	27.8	27.8	3	83.3		1
Holothuria atra	27.8	19.1	18	250.0	0.0	2	27.8	13.9	3	41.7	0.0	2
Holothuria edulis	83.3	40.4	18	375.0	72.2	4	83.3	48.1	3	125.0	41.7	2
Latirolagena smaragdula	41.7	22.6	18	250.0	0.0	3	41.7	41.7	3	125.0		1
Linckia laevigata	1736.1	378.9	18	2 604.2	356.8	12	1 736.1	897.6	3	2 604.2	395.8	2
Protoreaster nodosus	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Stichopus chloronotus	55.6	32.3	18	333.3	83.3	3	55.6	55.6	3	166.7		1
Tectus pyramis	55.6	55.6	18	1 000.0		1	55.6	55.6	3	166.7		1
Trochus maculata	13.9	13.9	18	250.0		1	13.9	13.9	3	41.7		1
Trochus niloticus	41.7	22.6	18	250.0	0.0	3	41.7	24.1	3	62.5	20.8	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.3c Muaivuso 2009 MPA 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	160.7	43.3	42	482.1	76.2	14	160.7	61.3	7	160.7	61.3	7
Bohadschia argus	23.8	11.5	42	250.0	0.0	4	23.8	17.9	7	83.3	41.7	2
Bohadschia graeffei	71.4	21.4	42	300.0	33.3	10	71.4	28.3	7	100.0	31.2	5
Conus spp.	17.9	13.2	42	375.0	125.0	2	17.9	17.9	7	125.0		1
Echinometra mathaei	952.4	657.9	42	6666.7	4150.6	6	952.4	918.1	7	3333.3	3125.0	2
Echinothrix diadema	11.9	8.3	42	250.0	0.0	2	11.9	11.9	7	83.3		1
Holothuria atra	565.5	152.4	42	950.0	226.8	25	565.5	272.9	7	659.7	303.0	6
Holothuria coluber	17.9	17.9	42	750.0		1	17.9	17.9	7	125.0		1
Holothuria edulis	148.8	45.9	42	568.2	95.9	11	148.8	73.2	7	208.3	90.3	5
Holothuria nobilis	11.9	8.3	42	250.0	0.0	2	11.9	11.9	7	83.3		1
Linckia laevigata	2029.8	249.0	42	2304.1	250.2	37	2029.8	438.3	7	2029.8	438.3	7
Panulirus versicolor	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Spondylus spp.	17.9	10.1	42	250.0	0.0	3	17.9	17.9	7	125.0		1
Stichopus chloronotus	440.5	175.6	42	1321.4	449.7	14	440.5	385.2	7	513.9	447.4	6
Tectus pyramis	35.7	20.1	42	375.0	125.0	4	35.7	24.8	7	125.0	41.7	2
Tridacna maxima	41.7	14.6	42	250.0	0.0	7	41.7	12.9	7	58.3	10.2	5
Tridacna squamosa	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Tripneustes gratilla	6.0	6.0	42	250.0		1	6.0	6.0	7	41.7		1
Trochus niloticus	65.5	33.1	42	458.3	163.5	6	65.5	58.8	7	229.2	187.5	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

Appendix 4: Invertebrate survey data
Muaivuso

4.2.4a Muaivuso 2003 soft-benthos transect (SBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga echinites	65.9	15.0	91	315.8	32.2	19	65.5	14.8	15	89.3	14.4	11
Actinopyga miliaris	82.4	16.6	91	340.9	26.2	22	82.1	27.2	15	154.0	34.5	8
Anadara antiquata	22.0	12.1	91	500.0	144.3	4	22.2	11.4	15	83.3	24.1	4
Bohadschia argus	11.0	5.4	91	250.0	0.0	4	11.1	6.4	15	55.6	13.9	3
Bohadschia similis	675.8	190.3	91	2050.0	493.7	30	683.3	348.0	15	1025.0	493.6	10
Bohadschia vitiensis	71.4	15.3	91	309.5	29.4	21	71.8	17.5	15	97.9	18.2	11
Cerithium aluco	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Cerithium spp.	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Choriaster granulatus	16.5	7.6	91	300.0	50.0	5	16.7	7.9	15	62.5	12.0	4
Conus flavidus	8.2	4.7	91	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
Conus leopardus	5.5	3.9	91	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Conus litteratus	5.5	3.9	91	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Conus spp.	30.2	9.4	91	275.0	25.0	10	30.6	17.9	15	114.6	49.2	4
Culcita novaeguineae	22.0	8.4	91	285.7	35.7	7	22.2	9.8	15	66.7	16.7	5
Cypraea annulus	38.5	27.9	91	700.0	450.0	5	38.9	30.6	15	194.4	132.5	3
Cypraea tigris	52.2	13.3	91	316.7	29.5	15	52.0	13.7	15	97.5	8.2	8
Dardanus spp.	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Dolabella auricularia	8.2	6.1	91	375.0	125.0	2	8.3	8.3	15	125.0		1
Drupa spp.	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Echinometra mathaei	3783.0	670.4	91	6375.0	987.1	54	3818.3	1 381.8	15	4772.8	1619.8	12
Echinothrix calamaris	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Holothuria atra	30.2	10.2	91	305.6	36.7	9	30.6	14.4	15	76.4	27.3	6
Holothuria coluber	38.5	15.6	91	437.5	103.0	8	38.9	23.9	15	145.8	69.1	4
Holothuria edulis	8.2	4.7	91	250.0	0.0	3	8.3	6.0	15	62.5	20.8	2
Holothuria leucospilota	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Holothuria nobilis	5.5	3.9	91	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Holothuria pervicax	8.2	6.1	91	375.0	125.0	2	8.3	8.3	15	125.0		1
Holothuria scabra	159.3	36.1	91	517.9	85.2	28	160.3	69.7	15	267.2	102.9	9

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.4a Muaivuso 2003 soft-benthos transect (SBt) 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
Hyotissa spp.	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Lambis lambis	71.4	20.8	91	406.3	75.3	16	71.8	35.6	15	119.7	54.6	9
Linckia laevigata	129.1	24.8	91	435.2	45.4	27	130.2	34.5	15	177.5	37.9	11
Mespilia globulus	5840.7	1445.8	91	24,159.1	3998.0	22	5654.8	3098.8	15	14,136.9	6575.2	6
Nassarius spp.	5.5	5.5	91	500.0		1	5.6	5.6	15	83.3		1
Pinna bicolor	44.0	15.4	91	444.4	69.4	9	44.4	22.8	15	111.1	46.5	6
Pinna spp.	5.5	5.5	91	500.0		1	5.6	5.6	15	83.3		1
Spondylus spp.	63.2	16.8	91	359.4	50.9	16	63.5	22.6	15	95.2	29.3	10
Stichopus chloronotus	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Stichopus hermanni	19.2	7.0	91	250.0	0.0	7	19.4	8.0	15	58.3	10.2	5
Strombus gibberulus gibbosus	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Strombus labiatus	5.5	3.9	91	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Synapta spp.	1497.3	193.4	91	1946.4	225.2	70	1500.8	298.7	15	1608.0	299.5	14
Terebra spp.	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Toxopneustes pileolus	24.7	8.8	91	281.3	31.3	8	24.2	8.6	15	60.5	8.6	6
Tridacna squamosa	2.7	2.7	91	250.0		1	2.8	2.8	15	41.7		1
Tripneustes gratilla	673.1	116.5	91	1250.0	179.6	49	677.8	235.1	15	924.2	287.7	11
Trochus niloticus	8.2	4.7	91	250.0	0.0	3	8.3	6.0	15	62.5	20.8	2
Trochus spp.	24.7	11.8	91	450.0	93.5	5	25.0	17.2	15	187.5	20.8	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.4b Muaivuso 2009 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
Acanthaster planci	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Bohadschia graeffei	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Bohadschia vitiensis	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Conus spp.	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Culcita novaeguineae	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Cypraea tigris	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Echinothrix diadema	88.0	45.4	54	1187.5	236.6	4	88.0	88.0	9	791.7		1
Fragum unedo	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Holothuria atra	60.2	18.6	54	325.0	38.2	10	60.2	19.8	9	90.3	19.9	6
Holothuria nobilis	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Holothuria scabra	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Holothuria scabra versicolor	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Lambis lambis	18.5	11.2	54	333.3	83.3	3	18.5	10.1	9	55.6	13.9	3
Linckia laevigata	203.7	96.2	54	733.3	313.8	15	203.7	139.1	9	366.7	234.0	5
Mespilia globulus	305.6	157.3	54	2750.0	1008.3	6	305.6	275.7	9	1375.0	1125.0	2
Protoreaster nodosus	13.9	7.9	54	250.0	0.0	3	13.9	13.9	9	125.0		1
Stichopus chloronotus	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Strombus luhuanus	18.5	18.5	54	1 000.0		1	18.5	18.5	9	166.7		1
Synapta spp.	268.5	88.9	54	966.7	243.8	15	268.5	135.0	9	402.8	181.5	6
Toxopneustes pileolus	88.0	41.9	54	950.0	215.1	5	88.0	88.0	9	791.7		1
Tridacna maxima	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1
Tripneustes gratilla	263.9	76.9	54	890.6	182.5	16	263.9	138.7	9	593.8	224.0	4
Trochus niloticus	4.6	4.6	54	250.0		1	4.6	4.6	9	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.2.5 Muaivuso 2003 soft-benthos quadrats (SBq) assessment data review

Station: 8 quadrat groups (4 quadrats/group)

Species	Quadrat group			Quadrat group _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Anadara antiquata	0.01	0.01	24	0.03	0.00	1	0.01	0.01	3	0.03	0.00	1
Bohadschia similis	0.14	0.14	24	0.41	0.00	3	0.14	0.14	3	0.41	0.00	1
Bohadschia vitiensis	0.01	0.01	24	0.03	0.00	1	0.01	0.01	3	0.03	0.00	1
Chama spp.	0.01	0.01	24	0.03	0.00	1	0.01	0.01	3	0.03	0.00	1
Fragum unedo	0.02	0.01	24	0.03	0.00	1	0.02	0.01	3	0.03	0.00	2
Strombus gibberulus gibbosus	2.21	0.52	24	2.21	0.52	16	2.21	0.52	3	2.21	0.52	3
Strombus labiatus	0.02	0.02	24	0.06	0.00	1	0.02	0.02	3	0.06	0.00	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.

4.2.6a Muaivuso 2003 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
Echinometra mathaei	6.2	6.2	6	37.5		1	6.2		1	6.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.6b Muaivuso 2009 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
Acanthaster planci	12.5	12.5	6	74.9		1	12.5		1	12.5		1
Echinothrix diadema	6.2	6.2	6	37.5		1	6.2		1	6.2		1
Linckia laevigata	6.2	6.2	6	37.5		1	6.2		1	6.2		1
Tectus pyramis	6.2	6.2	6	37.5		1	6.2		1	6.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.2.7 Muaivuso 2003 mother-of-pearl transect (MOPt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Bohadschia graeffei	52.1	19.8	24	178.6	37.2	7	52.1	21.7	4	69.4	18.4	3
Conus spp.	31.3	18.8	24	250.0	72.2	3	31.3	31.3	4	125.0		1
Culcita novaeguineae	10.4	7.2	24	125.0	0.0	2	10.4	10.4	4	41.7		1
Cypraea spp.	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Linckia laevigata	20.8	12.3	24	166.7	41.7	3	20.8	12.0	4	41.7	0.0	2
Tectus pyramis	145.8	41.0	24	291.7	56.2	12	145.8	64.2	4	145.8	64.2	4
Tridacna maxima	20.8	12.3	24	166.7	41.7	3	20.8	20.8	4	83.3		1
Trochus niloticus	67.7	21.3	24	180.6	30.3	9	67.7	35.5	4	90.3	38.7	3
Turbo chrysostomus	270.8	57.6	24	433.3	60.8	15	270.8	68.6	4	270.8	68.6	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.8 Muaivuso 2009 MPA sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria edulis	2.2	2.2	6	13.2		1	2.2		1	2.2		1
Holothuria nobilis	2.2	2.2	6	13.2		1	2.2		1	2.2		1
Thelenota anax	17.6	6.5	6	26.5	5.4	4	17.6		1	17.6		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number; SE = standard error.

4.2.9a Muaivuso 2003 species size review – all survey methods

Species	Mean length (cm)	SE	n measured	n total
Tripneustes gratilla	7.8	0.0	1196	1279
Actinopyga echinites	7.8	0.1	270	595
Bohadschia similis	17.0	0.3	215	269
Strombus gibberulus gibbosus	3.3	0.0	145	213
Linckia laevigata	12.6	0.5	83	430
Holothuria hilla	11.9	0.5	67	123
Holothuria scabra	19.2	0.6	58	58
Actinopyga miliaris	14.3	0.6	35	35
Conus spp.	6.7	0.5	31	43
Bohadschia vitiensis	17.9	0.6	28	37
Holothuria atra	17.8	1.5	26	48
Lambis lambis	13.9	0.5	26	27
Toxopneustes pileolus	9.1	0.3	25	25
Holothuria spp.	8.7	0.3	25	25
Holothuria leucospilota	16.4	0.7	24	25
Spondylus spp.	8.4	0.8	23	25
Cypraea tigris	6.8	0.2	19	19
Stichopus chloronotus	13.1	0.9	18	24
Cerithium nodulosum	8.0	0.2	16	16
Echinometra mathaei	4.6	0.2	13	1418
Holothuria coluber	27.8	1.9	11	39
Bohadschia argus	19.8	1.5	11	32
Bohadschia graeffei	12.8	1.4	10	62
Trochus spp.	2.5	0.2	10	10
Anadara antiquata	6.1	0.6	9	9
Cerithium spp.	8.1	0.3	8	8
Tectus pyramis	5.0	0.3	7	35
Choriaster granulatus	14.8	0.5	7	24
Dolabella auricularia	10.2	0.8	7	7
Stichopus hermanni	25.0	2.0	7	7
Turbo crassus	5.0	0.9	7	7
Conus flavidus	5.0	0.9	7	7
Turbo chrysostomus	4.0	0.4	5	57
Holothuria nobilis	13.8	1.9	5	5
Strombus labiatus	3.2	0.1	4	4
Holothuria edulis	19.3	1.9	3	46
Culcita novaeguineae	17.8	0.8	3	23
Trochus niloticus	8.0	2.5	3	16
Holothuria pervicax	21.5	3.9	3	11
Holothuria fuscopunctata	34.3	1.2	3	7
Thelenota anax	39.3	0.3	3	5
Pinctada margaritifera	9.1	2.5	3	4
Thelenota ananas	22.7	4.1	3	4
Eucidaris spp.	2.2	0.1	3	3
Strombus luhuanus	5.8	0.3	3	3
Conus miles	4.1	0.4	3	3
Stichopus horrens	9.6	0.6	2	2
Nassarius spp.	2.7	0.0	2	2

4.2.9a Muaivuso 2003 species size review – all survey methods (continued)

Species	Mean length (cm)	SE	n measured	n total
Tridacna squamosa	20.6	1.5	2	2
Fragum unedo	2.5	0.1	2	2
Terebra spp.	6.3	2.1	2	2
Pinna spp.	10.5	0.5	2	2
Strombus lentiginosus	7.2	1.0	2	2
Conus litteratus	2.8	0.3	2	2
Conus leopardus	7.4	3.8	2	2
Cypraea annulus	1.2		1	14
Cerithium aluco	7.6		1	1
Conus textile	6.5		1	1
Bulla ampulla	2.2		1	1
Drupa spp.	2.1		1	1
Actinopyga mauritiana	6.5		1	1
Hyotissa spp.	14.1		1	1
Euapta spp.	4.5		1	1
Chama spp.	10.0		1	1
Cypraea mappa mappa	5.8		1	1
Mespilia globulus				2126
Synapta spp.				632
Pinna bicolor				16
Echinothrix diadema				13
Acanthaster planci				5
Echinothrix calamaris				5
Tridacna maxima				4
Dardanus spp.				2
Cypraea spp.				1

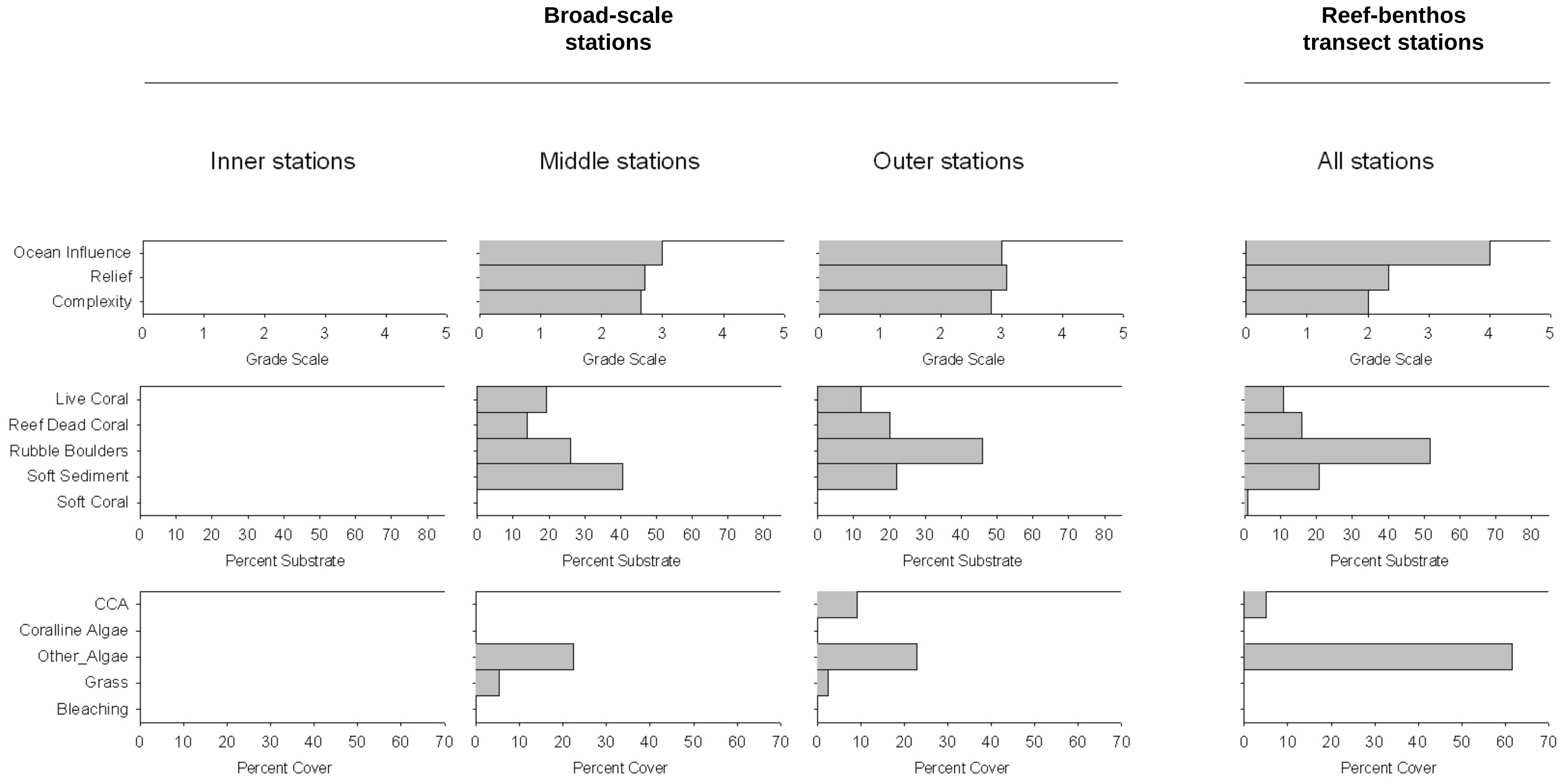
4.2.9b Muaivuso 2009 species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Holothuria atra	15.9	1.1	29	43
Bohadschia graeffei	25.1	1.1	17	21
Holothuria edulis	17.6	1.4	16	21
Stichopus chloronotus	17.7	2.1	6	7
Tectus pyramis	5.8	0.2	5	5
Bohadschia vitiensis	15.4	1.9	5	5
Trochus niloticus	5.4	1.2	4	4
Lambis lambis	10.3	0.9	4	4
Strombus luhuanus	4.3	0.1	4	4
Latirolagena smaragdula	5.0	0.0	3	3
Conus spp.	6.0	1.5	2	2
Holothuria nobilis	12.0		1	1
Cypraea tigris	9.0		1	1
Holothuria scabra versicolor	18.0		1	1
Fragum unedo	4.0		1	1
Trochus maculata	3.0		1	1
Tridacna maxima	11.0		1	2
Holothuria scabra	19.0		1	1
Bohadschia argus	20.0		1	2
Linckia laevigata			0	306
Echinothrix diadema			0	192
Mespilia globulus			0	66
Tripneustes gratilla			0	60
Synapta spp.			0	58
Acanthaster planci			0	36
Toxopneustes pileolus			0	22
Echinometra mathaei			0	15
Protoreaster nodosus			0	5
Pinctada margaritifera			0	1
Culcita novaeguineae			0	1
Heterocentrotus mammillatus			0	1

4.2.9c Muaivuso 2009 MPA species size review — all survey methods

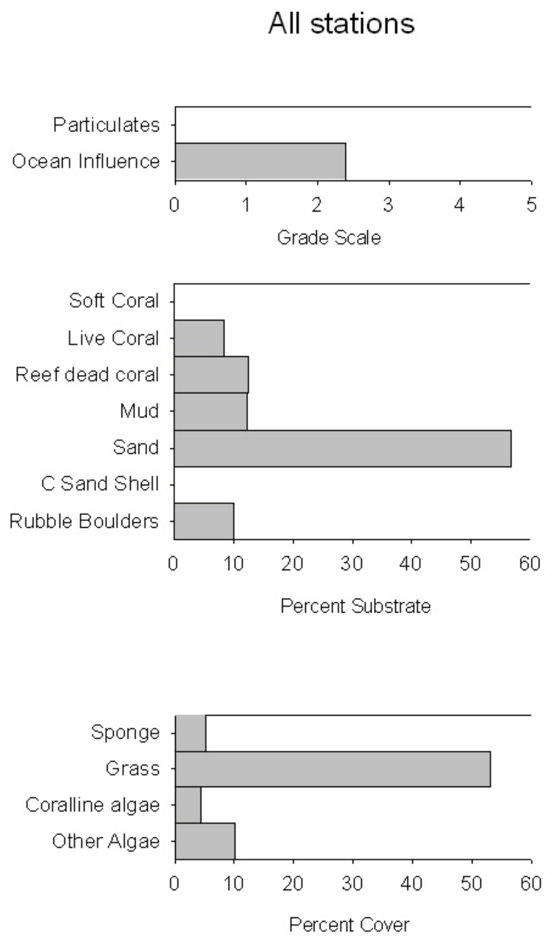
Species	Mean length (cm)	SE	n measured	n total
Holothuria atra	19.2	0.5	58	539
Holothuria edulis	16.6	0.7	22	37
Stichopus chloronotus	17.6	1.1	15	88
Trochus niloticus	10.2	0.6	12	12
Bohadschia graeffei	26.5	1.5	12	12
Thelenota anax	43.6	1.1	8	8
Tectus pyramis	6.3	0.4	6	6
Tridacna maxima	17.3	2.8	6	7
Bohadschia argus	24.0	2.1	4	11
Holothuria nobilis	24.0	0.6	3	3
Spondylus spp.	10.2	0.9	3	3
Tridacna squamosa	20.0		1	1
Linckia laevigata			0	736
Tripneustes gratilla			0	269
Echinothrix diadema			0	163
Echinometra mathaei			0	160
Acanthaster planci			0	28
Holothuria coluber			0	3
Conus spp.			0	3
Cypraea tigris			0	2
Stichopus hermanni			0	2
Synapta spp.			0	2
Lambis truncata			0	1
Panulirus versicolor			0	1
Stichodactyla spp.			0	1
Toxopneustes pileolus			0	1

4.2.10a Habitat descriptors for independent assessment – Muaivuso

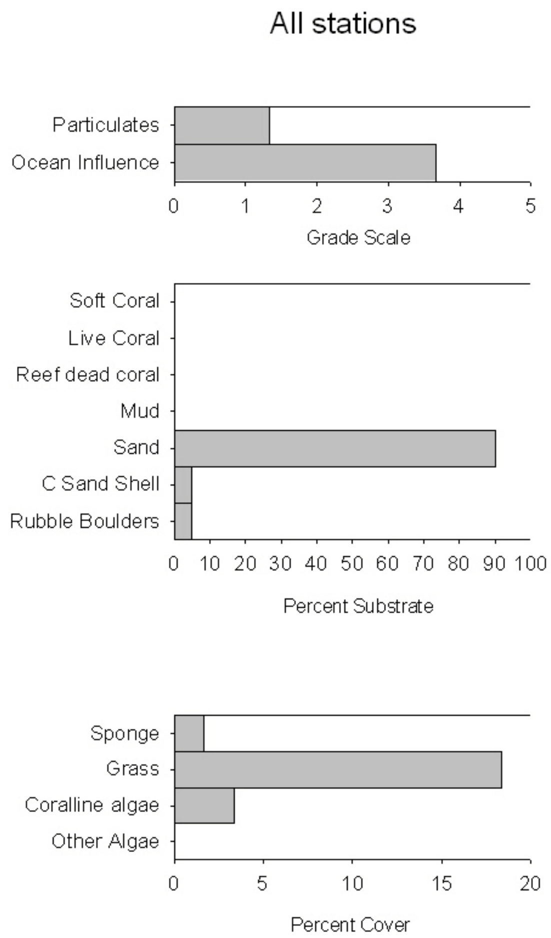


4.2.10a Habitat descriptors for independent assessment – Muaivuso (continued)

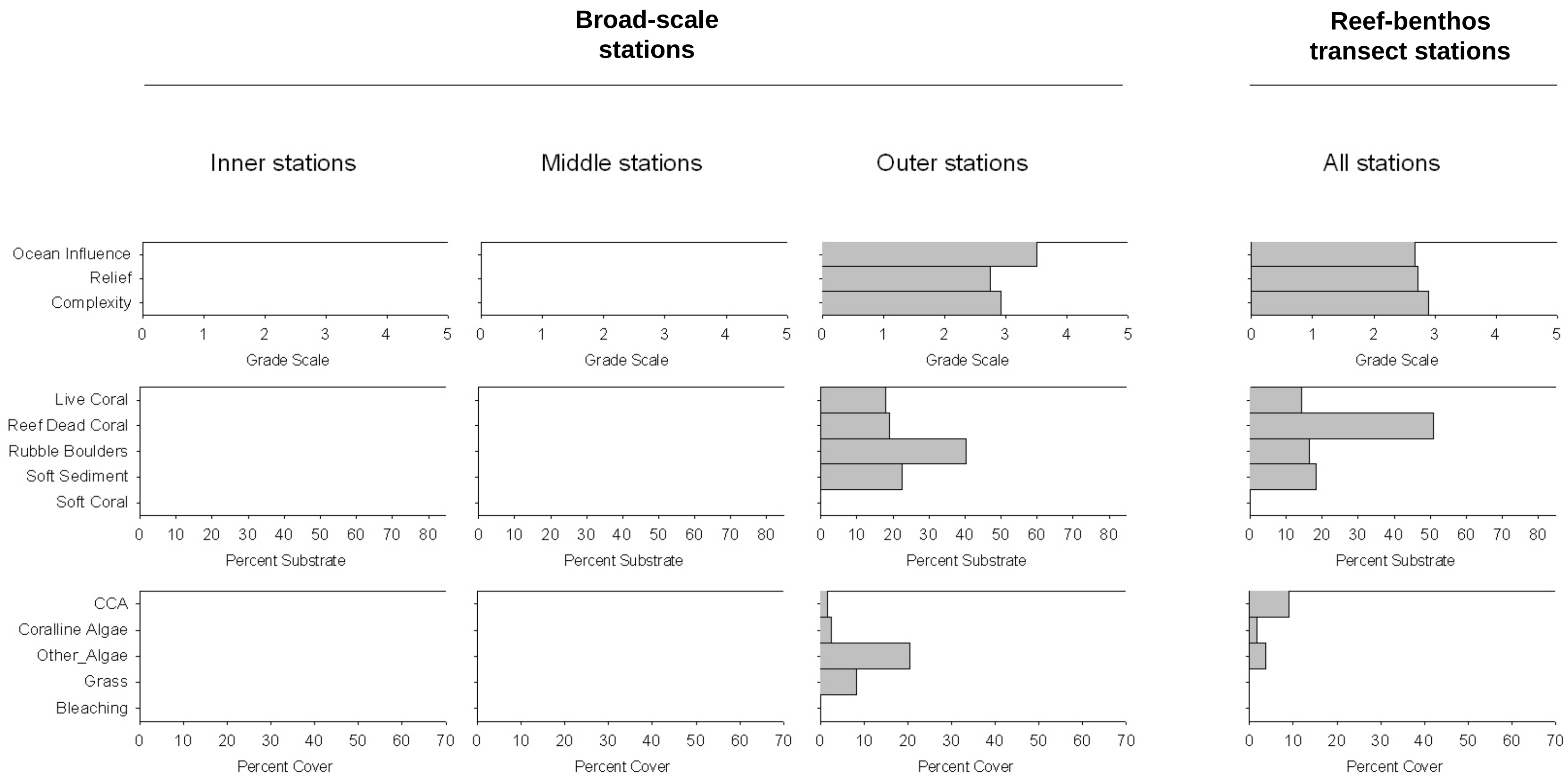
Soft-benthos transect stations



Soft-benthos quadrat stations

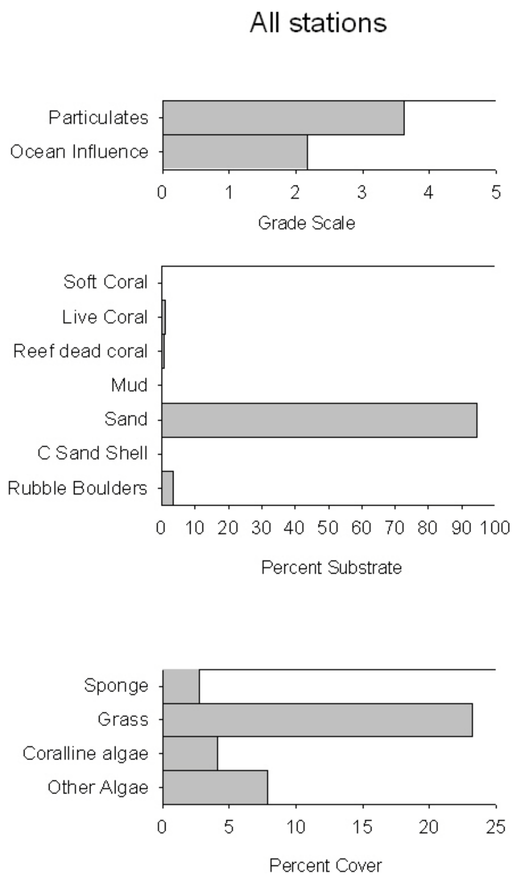


4.2.10b Habitat descriptors for independent assessments – Muaivuso 2009

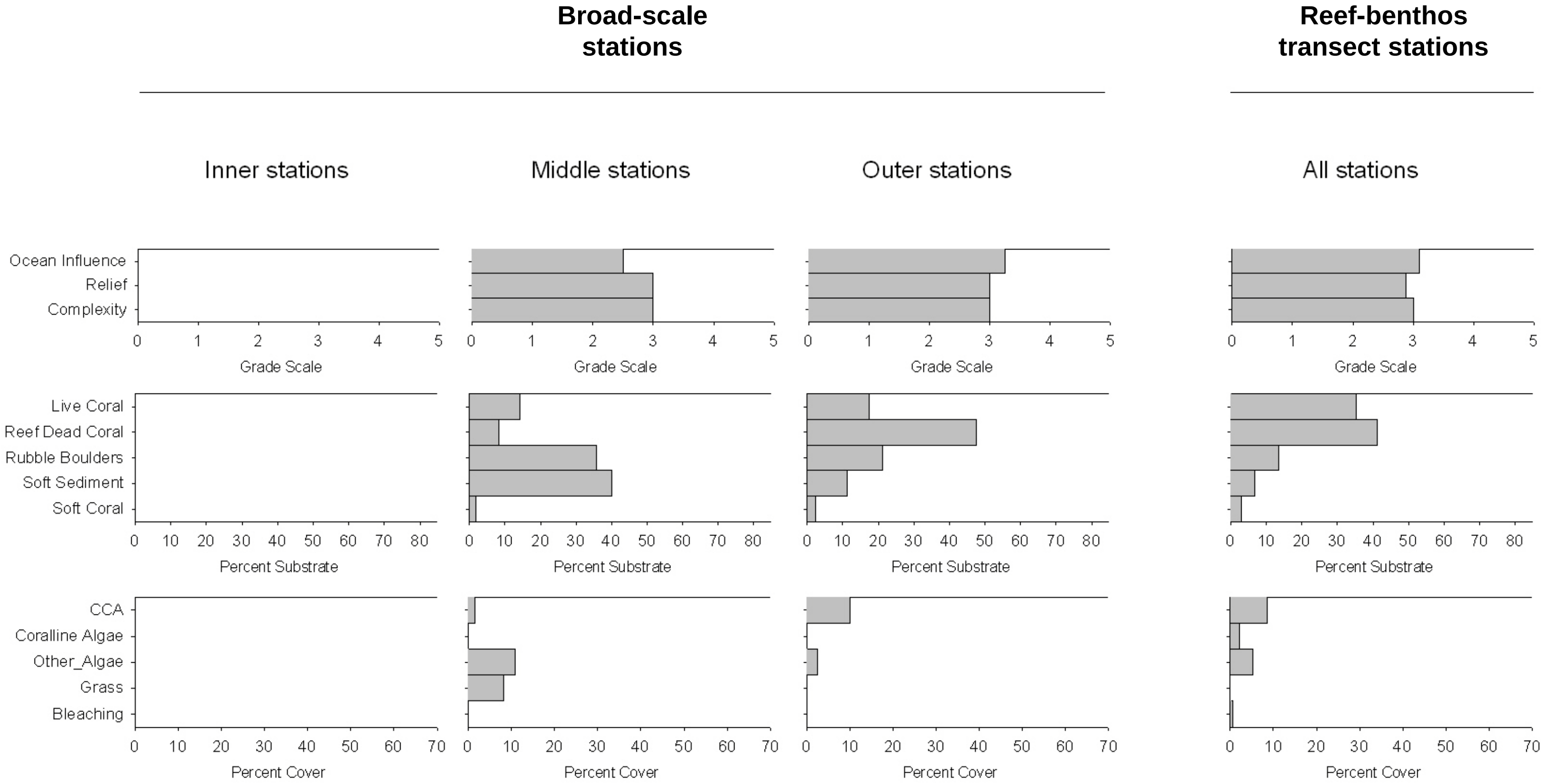


4.2.10b Habitat descriptors for independent assessments – Muaivuso 2009

Soft-benthos transect stations



4.2.10c Habitat descriptors for independent assessments – Muaivuso MPA 2009



4.2.11 Muaivuso 2003 catch assessment – creel survey – data review

Per fisher CPUE – catch per hour, Catches made on the 28 and 31 Jan 2003.

Fisher	**Time fishing (mins)**	***H. nobilis***	***T. crassus***	***T. gratilla***	***T. niloticus***	***O. cyanea***	***D. auricularia***	***Conus* spp.**	***L. lambis***	***T. pyramis***	***S. squamosus***	***C. tigris***	***B. vitiensis***
Titilia Vasemaca	60			7.0			7.0	1.0	2.0	1.0	1.0	2.0	2.0
Akenata Maala	150			192.8									
Alivena (from Waiqanake)	180	0.7*		193.3									
Amelia Muriceva	120			298.5									
Aqela Raicou	150			118.8		0.8***							
Joe Cama	180			49.7									
Litiana Bagasau (from Nabaka)	150		8.8**		1.6								
Lusia Tinai	210			63.7									
Nemia Bale	150			326.0									
Rajeli Marama	180			74.3									

* two pieces - 18 cm and 15 cm in length
** average size of *T. crassus* was 6.3 cm ±0.1 – in perfect tide and low swell conditions can collect 4–5 kg, collected approximately 15–20 days a year.
*** not peak season - in peak season later in the year can collect 5–15 per trip (sold on strings; 3–4 per string for FJD10)

4.3 Mali invertebrate survey data

4.3.1a Invertebrate species recorded in different assessments in Mali in 2003

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga mauritiana*				+
Bêche-de-mer	*Bohadschia argus*	+	+		
Bêche-de-mer	*Bohadschia graeffei*	+			+
Bêche-de-mer	*Bohadschia vitiensis*	+	+		
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria coluber*	+	+		
Bêche-de-mer	*Holothuria edulis*	+	+		
Bêche-de-mer	*Holothuria fuscogilva*				+
Bêche-de-mer	*Holothuria fuscopunctata*	+			
Bêche-de-mer	*Holothuria nobilis*		+		
Bêche-de-mer	*Stichopus chloronotus*	+	+		
Bêche-de-mer	*Stichopus hermanni*	+			
Bêche-de-mer	*Synapta* spp.		+		
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Atrina* spp.	+			
Bivalve	*Atrina vexillum*	+	+		
Bivalve	*Chama* spp.		+		
Bivalve	*Hyotissa* spp.	+			
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus squamosus*	+			
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		+
Cnidarian	*Cassiopea* spp.	+			
Crustacean	*Panulirus* spp.	+			
Crustacean	*Panulirus versicolor*				+
Gastropod	*Conus ebraeus*		+		
Gastropod	*Conus flavidus*		+		
Gastropod	*Conus frigidus*		+		
Gastropod	*Conus miles*		+		
Gastropod	*Conus* spp.	+	+		
Gastropod	*Cypraea caputserpensis*		+		
Gastropod	*Cypraea* spp.		+		
Gastropod	*Cypraea tigris*		+		
Gastropod	*Drupa* spp.		+		
Gastropod	*Lambis lambis*	+	+		
Gastropod	*Lambis* spp.	+			
Gastropod	*Lambis truncata*	+			
Gastropod	*Latirolagena smaragdula*		+		
Gastropod	*Tectus pyramis*	+	+		+
Gastropod	*Thais aculeata*		+		
Gastropod	*Thais* spp.		+		
Gastropod	*Thais tuberosa*		+		
Gastropod	*Trochus maculata*		+		
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.		+		
Gastropod	*Turbo chrysostomus*		+		

+ = presence of the species.

4.3.1a Invertebrate species recorded in different assessments in Mali in 2003 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Turbo crassus*		+		
Gastropod	*Vasum ceramicum*		+		
Gastropod	*Vasum* spp.		+		
Gastropod	*Vasum turbinellum*		+		
Octopus	*Octopus cyanea*	+			
Star	*Acanthaster planci*	+			
Star	*Choriaster granulatus*	+	+		
Star	*Culcita novaeguineae*	+			
Star	*Linckia laevigata*	+	+		
Urchin	*Diadema* spp.	+			
Urchin	*Echinometra mathaei*		+		
Urchin	*Echinothrix diadema*	+	+		

+ = presence of the species.

4.3.1b Invertebrate species recorded in different assessments in Mali in 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Holothuria atra*	+	+		+
Bêche-de-mer	*Holothuria edulis*	+	+		
Bêche-de-mer	*Holothuria fuscogilva*		+		
Bêche-de-mer	*Holothuria nobilis*		+		+
Bêche-de-mer	*Stichopus chloronotus*	+	+		
Bêche-de-mer	*Thelenota ananas*				+
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Atrina vexillum*	+			
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Tridacna maxima*	+	+		+
Bivalve	*Tridacna squamosa*	+	+		+
Crustacean	*Panulirus versicolor*				+
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Conus litteratus*	+	+		
Gastropod	*Conus marmoreus*		+		+
Gastropod	*Conus* spp.		+		
Gastropod	*Cypraea tigris*		+		
Gastropod	*Lambis lambis*	+	+		
Gastropod	*Mitra mitra*		+		+
Gastropod	*Strombus luhuanus*	+	+		
Gastropod	*Tectus conus*		+		
Gastropod	*Tectus pyramis*	+	+		+
Gastropod	*Thais aculeata*				+
Gastropod	*Trochus niloticus*	+	+		+
Gastropod	*Trochus* spp.				+
Gastropod	*Turbo argyrostomus*				+
Gastropod	*Tutufa bubo*				+
Gastropod	*Tutufa rubeta*				+
Gastropod	*Vasum ceramicum*		+		
Star	*Acanthaster planci*		+		
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*		+		+
Urchin	*Echinothrix diadema*				+

+ = presence of the species.

4.3.1c Invertebrate species recorded in different assessments in Mali MPA in 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Bohadschia graeffei*	+			
Bêche-de-mer	*Bohadschia vitiensis*	+	+		
Bêche-de-mer	*Holothuria atra*	+	+		
Bêche-de-mer	*Holothuria coluber*		+		
Bêche-de-mer	*Holothuria edulis*	+	+		
Bêche-de-mer	*Stichopus chloronotus*	+	+		
Bêche-de-mer	*Stichopus hermanni*	+			
Bivalve	*Atrina vexillum*	+			
Bivalve	*Chama* spp.	+			
Bivalve	*Lioconcha* spp.		+		
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Spondylus* spp.	+			
Bivalve	*Trachycardium* spp.		+		
Bivalve	*Tridacna maxima*	+	+		
Bivalve	*Tridacna squamosa*	+	+		
Cnidarians	*Stichodactyla* spp.		+		
Gastropod	*Cerithium nodulosum*	+			
Gastropod	*Conus litteratus*	+			
Gastropod	*Lambis lambis*	+			
Gastropod	*Tectus pyramis*		+		
Gastropod	*Trochus niloticus*		+		
Gastropod	*Trochus* spp.		+		
Star	*Acanthaster planci*	+	+		
Star	*Culcita novaeguineae*	+			
Star	*Linckia laevigata*	+	+		

4.3.2a Mali 2003 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	1.8	0.7	90	20.2	3.7	8	1.8	1.0	15	5.4	2.3	5
Atrina spp.	0.3	0.3	90	28.6		1	0.3	0.3	15	4.8		1
Atrina vexillum	3.3	0.9	90	20.0	3.1	15	3.3	1.4	15	7.1	2.1	7
Bohadschia argus	1.0	0.4	90	15.1	0.8	6	1.0	0.4	15	3.0	0.5	5
Bohadschia graeffei	0.6	0.3	90	14.3	0.0	4	0.6	0.4	15	4.8	0.0	2
Bohadschia vitiensis	1.0	0.4	90	14.3	0.0	6	1.0	0.3	15	2.4	0.0	6
Cassiopea spp.	1.3	0.6	90	19.8	2.9	6	1.3	0.6	15	4.0	0.9	5
Choriaster granulatus	1.9	0.6	90	17.1	1.9	10	1.9	1.0	15	7.1	2.6	4
Conus spp.	1.6	0.7	90	20.4	6.1	7	1.6	0.8	15	4.8	1.5	5
Culcita novaeguineae	3.5	0.9	90	19.6	2.6	16	3.5	1.5	15	7.5	2.5	7
Diadema spp.	0.2	0.2	90	14.3		1	0.2	0.2	15	2.4		1
Echinothrix diadema	0.2	0.2	90	14.3		1	0.2	0.2	15	2.4		1
Holothuria atra	54.6	7.2	90	86.1	9.1	57	54.5	13.8	15	68.1	14.8	12
Holothuria coluber	1.0	0.6	90	28.6	8.2	3	1.0	0.8	15	7.1	4.8	2
Holothuria edulis	59.2	10.5	90	93.4	14.8	57	59.2	20.9	15	68.3	23.1	13
Holothuria fuscopunctata	0.8	0.5	90	25.4	8.8	3	0.8	0.7	15	6.3	3.2	2
Hyotissa spp.	11.4	2.6	90	42.9	6.3	24	11.4	4.4	15	19.0	6.2	9
Lambis lambis	2.9	1.0	90	23.4	4.4	11	2.9	1.4	15	8.6	3.0	5
Lambis spp.	0.3	0.3	90	28.6		1	0.3	0.3	15	4.8		1
Lambis truncata	0.2	0.2	90	14.3		1	0.2	0.2	15	2.4		1
Linckia laevigata	233.9	24.3	90	309.6	26.2	68	233.7	52.1	15	233.7	52.1	15
Octopus cyanea	0.3	0.2	90	14.3	0.0	2	0.3	0.3	15	4.8		1
Panulirus spp.	0.6	0.3	90	14.3	0.0	4	0.6	0.3	15	2.4	0.0	4
Pinctada margaritifera	1.2	0.5	90	15.6	1.4	7	1.1	0.4	15	2.8	0.4	6
Spondylus squamosus	0.2	0.2	90	14.3		1	0.2	0.2	15	2.4		1
Stichopus chloronotus	4.9	1.3	90	26.1	3.7	17	4.9	2.2	15	12.3	4.1	6
Stichopus hermanni	1.0	0.4	90	14.3	0.0	6	1.0	0.4	15	2.9	0.5	5
Tectus pyramis	0.3	0.2	90	14.3	0.0	2	0.3	0.2	15	2.4	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.2a Mali 2003 broad-scale assessment data review (continued)

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Tridacna maxima	4.7	1.1	90	21.2	2.6	20	4.6	1.8	15	8.7	2.8	8
Tridacna squamosa	2.7	0.9	90	20.2	3.7	12	2.7	1.1	15	5.1	1.6	8
Trochus niloticus	0.6	0.5	90	28.6	14.3	2	0.6	0.6	15	9.5		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.2b Mali 2009 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
Atrina vexillum	1.9	1.3	18	16.7	0.0	2	1.9	1.9	3	5.6		1
Conus litteratus	2.8	2.0	18	25.0	8.3	2	2.8	1.6	3	4.2	1.4	2
Holothuria atra	13.0	5.0	18	38.9	7.0	6	13.0	11.6	3	19.4	16.7	2
Holothuria edulis	3.7	1.7	18	16.7	0.0	4	3.7	1.9	3	5.6	0.0	2
Lambis lambis	2.8	2.0	18	25.0	8.3	2	2.8	2.8	3	8.3		1
Linckia laevigata	80.6	26.5	18	111.5	33.0	13	80.6	43.1	3	80.6	43.1	3
Pinctada margaritifera	3.7	2.2	18	22.2	5.6	3	3.7	3.7	3	11.1		1
Stichopus chloronotus	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Strombus luhuanus	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Tectus pyramis	9.3	3.1	18	23.8	3.4	7	9.3	5.6	3	13.9	5.6	2
Tridacna maxima	4.6	1.8	18	16.7	0.0	5	4.6	0.9	3	4.6	0.9	3
Tridacna squamosa	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Trochus niloticus	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.2c Mali 2009 MPA broad-scale assessment data review

Station: Six 2 m x 300 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Atrina vexillum	13.9	5.4	18	35.7	9.2	7	13.9	11.2	3	20.8	15.3	2
Bohadschia graeffei	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Bohadschia vitiensis	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Cerithium nodulosum	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Chama spp.	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Conus litteratus	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Culcita novaeguineae	3.7	2.9	18	33.3	16.7	2	3.7	3.7	3	11.1		1
Holothuria atra	252.8	40.9	18	252.8	40.9	18	252.8	64.0	3	252.8	64.0	3
Holothuria edulis	40.7	8.1	18	52.4	8.0	14	40.7	13.6	3	40.7	13.6	3
Lambis lambis	1.9	1.9	18	33.3		1	1.9	1.9	3	5.6		1
Linckia laevigata	223.1	40.0	18	236.3	40.1	17	223.1	63.1	3	223.1	63.1	3
Pinctada margaritifera	2.8	1.5	18	16.7	0.0	3	2.8	1.6	3	4.2	1.4	2
Spondylus spp.	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Stichopus chloronotus	12.0	4.8	18	36.1	8.0	6	12.0	3.3	3	12.0	3.3	3
Stichopus hermanni	0.9	0.9	18	16.7		1	0.9	0.9	3	2.8		1
Tridacna maxima	3.7	1.7	18	16.7	0.0	4	3.7	2.4	3	5.6	2.8	2
Tridacna squamosa	1.9	1.3	18	16.7	0.0	2	1.9	0.9	3	2.8	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.3a Mali 2003 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
Atrina vexillum	36.1	14.0	90	361.1	84.5	9	36.1	16.7	15	77.4	29.4	7
Bohadschia argus	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
Bohadschia vitiensis	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Chama spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Choriaster granulatus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Conus ebraeus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Conus flavidus	41.7	19.5	90	750.0	136.9	5	41.7	28.5	15	312.5	20.8	2
Conus frigidus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Conus miles	11.1	5.5	90	250.0	0.0	4	11.1	8.6	15	83.3	41.7	2
Conus spp.	41.7	14.4	90	375.0	67.2	10	41.7	17.7	15	89.3	29.4	7
Cypraea caputserpensis	61.1	29.1	90	916.7	263.5	6	61.1	42.4	15	458.3	83.3	2
Cypraea spp.	8.3	6.2	90	375.0	125.0	2	8.3	8.3	15	125.0		1
Cypraea tigris	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Drupa spp.	19.4	12.6	90	583.3	220.5	3	19.4	14.6	15	145.8	62.5	2
Echinometra mathaei	1672.2	708.5	90	9406.3	3450.1	16	1672.2	1581.5	15	6270.8	5844.3	4
Echinothrix diadema	22.2	12.9	90	500.0	176.8	4	22.2	22.2	15	333.3		1
Holothuria atra	444.4	49.6	90	689.7	54.8	58	444.4	94.8	15	555.6	93.2	12
Holothuria coluber	19.4	12.0	90	583.3	166.7	3	19.4	11.4	15	97.2	27.8	3
Holothuria edulis	300.0	39.1	90	574.5	47.4	47	300.0	68.7	15	375.0	70.3	12
Holothuria nobilis	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Lambis lambis	22.2	8.5	90	285.7	35.7	7	22.2	9.8	15	66.7	16.7	5
Latirolagena smaragdula	100.0	33.7	90	900.0	145.3	10	100.0	68.3	15	750.0	41.7	2
Linckia laevigata	872.2	75.3	90	1189.4	69.1	66	872.2	158.8	15	1189.4	102.1	11
Pinctada margaritifera	13.9	6.1	90	250.0	0.0	5	13.9	5.2	15	41.7	0.0	5
Stichopus chloronotus	47.2	12.4	90	303.6	28.5	14	47.2	12.8	15	70.8	14.0	10
Synapta spp.	11.1	5.5	90	250.0	0.0	4	11.1	4.9	15	41.7	0.0	4
Tectus pyramis	102.8	33.7	90	840.9	144.1	11	102.8	69.0	15	513.9	246.9	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.3a Mali 2003 reef-benthos transect (RBt) assessment data review (continued)

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Thais aculeata	13.9	10.0	90	625.0	125.0	2	13.9	13.9	15	208.3		1
Thais spp.	5.6	3.9	90	250.0	0.0	2	5.6	5.6	15	83.3		1
Thais tuberosa	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Tridacna maxima	105.6	21.3	90	380.0	41.1	25	105.6	33.7	15	143.9	40.3	11
Tridacna squamosa	36.1	10.9	90	295.5	30.5	11	36.1	12.1	15	67.7	15.6	8
Trochus maculata	19.4	12.0	90	583.3	166.7	3	19.4	19.4	15	291.7		1
Trochus niloticus	25.0	10.5	90	375.0	55.9	6	25.0	14.0	15	125.0	24.1	3
Trochus spp.	13.9	9.1	90	416.7	166.7	3	13.9	13.9	15	208.3		1
Turbo chrysostomus	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
Turbo crassus	72.2	22.4	90	590.9	77.4	11	72.2	47.2	15	361.1	160.2	3
Vasum ceramicum	25.0	16.3	90	750.0	288.7	3	25.0	25.0	15	375.0		1
Vasum spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Vasum turbinellum	13.9	8.2	90	416.7	83.3	3	13.9	11.3	15	104.2	62.5	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.3b Mali 2009 reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	7.6	5.3	66	250.0	0.0	2	7.6	5.1	11	41.7	0.0	2
Cerithium nodulosum	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Conus litteratus	11.4	11.4	66	750.0		1	11.4	11.4	11	125.0		1
Conus marmoreus	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Conus spp.	11.4	6.5	66	250.0	0.0	3	11.4	11.4	11	125.0		1
Cypraea tigris	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Echinometra mathaei	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Holothuria atra	68.2	19.1	66	346.2	45.1	13	68.2	24.0	11	125.0	26.4	6
Holothuria edulis	30.3	12.7	66	333.3	52.7	6	30.3	26.4	11	166.7	125.0	2
Holothuria fuscogilva	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Holothuria nobilis	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Lambis lambis	15.2	7.4	66	250.0	0.0	4	15.2	11.6	11	83.3	41.7	2
Linckia laevigata	151.5	29.0	66	400.0	43.3	25	151.5	52.8	11	277.8	56.6	6
Mitra mitra	7.6	5.3	66	250.0	0.0	2	7.6	5.1	11	41.7	0.0	2
Pinctada margaritifera	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1
Stichopus chloronotus	15.2	15.2	66	1000.0		1	15.2	15.2	11	166.7		1
Strombus luhuanus	534.1	191.1	66	3916.7	720.5	9	534.1	421.4	11	2937.5	1645.8	2
Tectus conus	7.6	5.3	66	250.0	0.0	2	7.6	7.6	11	83.3		1
Tectus pyramis	45.5	17.0	66	375.0	66.8	8	45.5	19.0	11	100.0	25.0	5
Tridacna maxima	15.2	9.2	66	333.3	83.3	3	15.2	11.6	11	83.3	41.7	2
Tridacna squamosa	15.2	7.4	66	250.0	0.0	4	15.2	11.6	11	83.3	41.7	2
Trochus niloticus	53.0	16.7	66	350.0	40.8	10	53.0	30.8	11	194.4	60.5	3
Vasum ceramicum	3.8	3.8	66	250.0		1	3.8	3.8	11	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.3c Mali 2009 MPA 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	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Bohadschia vitiensis	125.0	60.2	24	750.0	102.1	4	125.0	99.2	4	250.0	166.7	2
Holothuria atra	312.5	118.7	24	750.0	223.6	10	312.5	185.2	4	416.7	216.5	3
Holothuria coluber	72.9	43.8	24	583.3	166.7	3	72.9	72.9	4	291.7		1
Holothuria edulis	364.6	115.6	24	972.2	169.0	9	364.6	255.4	4	729.2	354.2	2
Linckia laevigata	927.1	267.7	24	1483.3	359.8	15	927.1	531.5	4	927.1	531.5	4
Lioconcha spp.	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Pinctada margaritifera	20.8	14.4	24	250.0	0.0	2	20.8	20.8	4	83.3		1
Stichodactyla spp.	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Stichopus chloronotus	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Tectus pyramis	135.4	67.3	24	650.0	203.1	5	135.4	121.9	4	270.8	229.2	2
Trachycardium spp.	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Tridacna maxima	41.7	41.7	24	1000.0		1	41.7	41.7	4	166.7		1
Tridacna squamosa	52.1	21.2	24	250.0	0.0	5	52.1	39.4	4	104.2	62.5	2
Trochus niloticus	41.7	32.5	24	500.0	250.0	2	41.7	29.5	4	83.3	41.7	2
Trochus spp.	20.8	20.8	24	500.0		1	20.8	20.8	4	83.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.4 Mali 2009 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
Conus marmoreus	1.5	1.5	27	41.7		1	1.2	1.2	4	4.6		1
Echinometra mathaei	1.5	1.1	27	20.9	0.0	2	1.7	1.7	4	7.0		1
Echinothrix diadema	0.8	0.8	27	20.9		1	0.6	0.6	4	2.3		1
Mitra mitra	0.8	0.8	27	20.9		1	0.6	0.6	4	2.3		1
Tectus pyramis	3.9	1.9	27	26.1	5.2	4	3.2	2.2	4	6.4	2.9	2
Thais aculeata	0.8	0.8	27	20.9		1	0.6	0.6	4	2.3		1
Tridacna maxima	0.8	0.8	27	20.9		1	0.9	0.9	4	3.5		1
Tridacna squamosa	0.8	0.8	27	20.9		1	0.6	0.6	4	2.3		1
Trochus niloticus	3.1	1.5	27	20.9	0.0	4	2.9	1.0	4	3.9	0.4	3

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.5 Mali 2003 reef-front search by walking (RFs_w) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	16.7	10.5	6	50.0	0.0	2	16.7		1	16.7		1
Tridacna maxima	8.3	8.3	6	50.0		1	8.3		1	8.3		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.6a Mali 2003 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
Bohadschia graeffei	1.2	1.2	30	37.5		1	1.2	1.2	5	6.2		1
Panulirus versicolor	2.5	1.7	30	37.5	0.0	2	2.5	2.5	5	12.5		1
Tectus pyramis	1.2	1.2	30	37.5		1	1.2	1.2	5	6.2		1
Tridacna maxima	7.5	2.8	30	37.5	0.0	6	7.5	2.3	5	9.4	1.8	4
Tridacna squamosa	1.2	1.2	30	37.5		1	1.2	1.2	5	6.2		1
Trochus niloticus	6.2	3.2	30	46.8	9.4	4	6.2	3.9	5	15.6	3.1	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.6b Mali 2009 mother-of-pearl search (MOPs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria atra	1.6	1.6	24	37.5		1	1.6	1.6	4	6.2		1
Panulirus versicolor	1.6	1.6	24	37.5		1	1.6	1.6	4	6.2		1
Tectus pyramis	34.3	11.5	24	103.0	17.0	8	34.3	11.0	4	34.3	11.0	4
Tridacna maxima	6.2	2.9	24	37.5	0.0	4	6.2	2.5	4	8.3	2.1	3
Trochus niloticus	25.0	5.8	24	49.9	5.3	12	25.0	8.5	4	25.0	8.5	4
Trochus spp.	4.7	4.7	24	112.4		1	4.7	4.7	4	18.7		1
Turbo argyrostomus	1.6	1.6	24	37.5		1	1.6	1.6	4	6.2		1
Tutufa rubeta	4.7	3.4	24	56.2	18.7	2	4.7	3.0	4	9.4	3.1	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.7a Mali 2003 sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria fuscogilva	4.4	4.4	6	26.5		1	4.4		1	4.4		1
Thelenota anax	4.4	2.8	6	13.2	0.0	2	4.4		1	4.4		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.7b Mali 2009 sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria nobilis	1.1	1.1	12	13.2		1	1.1	1.1	2	2.2		1
Thelenota ananas	2.2	1.5	12	13.2	0.0	2	2.2	2.2	2	4.4		1
Thelenota anax	1.1	1.1	12	13.2		1	1.1	1.1	2	2.2		1
Trochus niloticus	1.1	1.1	12	13.2		1	1.1	1.1	2	2.2		1
Tutufa bubo	1.1	1.1	12	13.2		1	1.1	1.1	2	2.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.3.8a Mali 2003 species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Holothuria atra	19.6	0.2	503	503
Holothuria edulis	20.0	0.2	480	480
Tridacna maxima	13.7	0.7	74	74
Stichopus chloronotus	21.3	1.0	42	48
Tectus pyramis	5.8	0.1	38	40
Tridacna squamosa	20.8	1.8	31	31
Turbo crassus	5.8	0.2	26	26
Conus spp.	7.0	0.7	25	25
Trochus niloticus	9.4	0.7	18	18
Lambis lambis	13.4	0.7	16	26
Conus flavidus	4.4	0.5	15	15
Pinctada margaritifera	14.4	0.8	11	12
Vasum ceramicum	6.8	0.6	9	9
Bohadschia argus	25.1	2.3	9	9
Bohadschia vitiensis	19.0	0.7	8	8
Trochus maculata	2.5	0.2	7	7
Stichopus hermanni	32.5	2.3	6	6
Bohadschia graeffei	26.6	2.5	5	5
Trochus spp.	2.4	0.2	5	5
Holothuria fuscopunctata	35.0	3.2	5	5
Thais aculeata	5.2	0.3	5	5
Holothuria coluber	21.3	1.3	4	13
Conus miles	5.9	0.7	4	4
Panulirus spp.	7.5	2.5	4	4
Drupa spp.	3.6	0.0	3	7
Turbo chrysostomus	3.5	0.4	3	3
Cypraea spp.	3.7	0.7	3	3
Cypraea caputserpensis	5.1	0.0	2	22
Thais spp.	3.7	0.1	2	2
Holothuria fuscogilva	35.0	0.0	2	2
Panulirus versicolor	15.0	0.0	2	2
Thelenota anax	48.5	3.5	2	2
Cypraea tigris	8.2	0.2	2	2
Vasum turbinellum	6.1		1	5
Vasum spp.	3.8		1	1
Lambis truncata	38.0		1	1
Conus frigidus	4.2		1	1
Conus ebraeus	5.2		1	1
Chama spp.	6.0		1	1
Thais tuberosa	8.7		1	1
Holothuria nobilis	22.0		1	1
Linckia laevigata				1777
Echinometra mathaei				602
Hyotissa spp.				72
Latirolagena smaragdula				36
Atrina vexillum				34
Culcita novaeguineae				22
Choriaster granulatus				13

4.3.8a Mali 2003 species size review — all survey methods (continued)

Species	Mean length (cm)	SE	n measured	n total
Acanthaster planci				11
Echinothrix diadema				9
Cassiopea spp.				8
Synapta spp.				4
Atrina spp.				2
Octopus cyanea				2
Lambis spp.				2
Actinopyga mauritiana				2
Diadema spp.				1
Spondylus squamosus				1

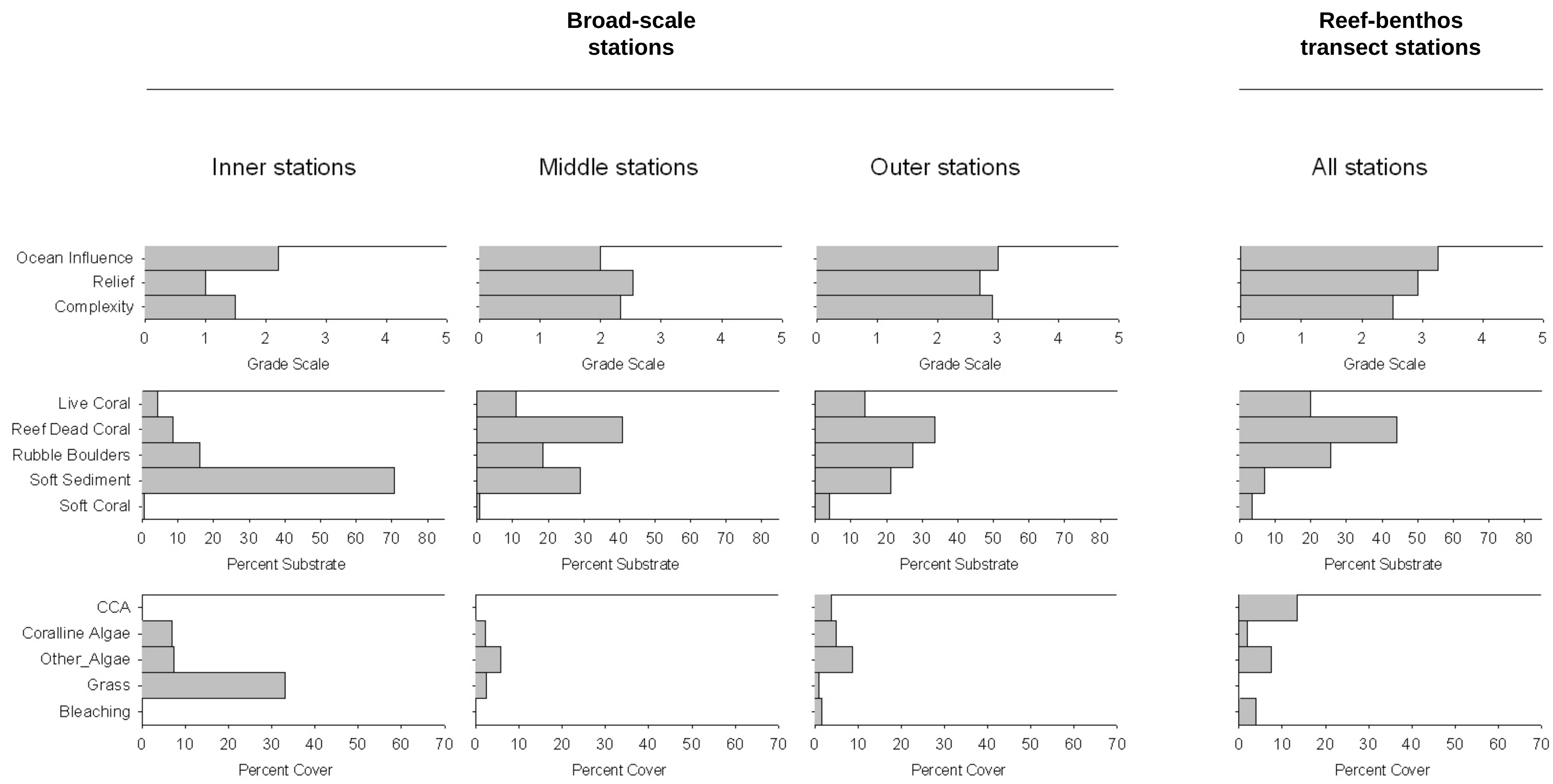
4.3.8b Mali 2009 species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Trochus niloticus	8.6	0.4	31	36
Tectus pyramis	6.0	0.2	12	49
Holothuria atra	22.2	2.2	11	33
Tridacna maxima	18.3	2.0	10	14
Holothuria edulis	19.4	1.1	8	12
Lambis lambis	11.5	1.7	4	7
Tridacna squamosa	20.5	1.8	4	6
Stichopus chloronotus	8.0	1.2	4	5
Conus litteratus	9.0	0.0	3	6
Tutufa rubeta	23.7	2.3	3	3
Holothuria nobilis	24.0	8.0	2	2
Thelenota ananas	45.0	10.0	2	2
Pinctada margaritifera	15.0		1	5
Mitra mitra	6.0		1	3
Cypraea tigris	8.0		1	1
Tutufa bubo	22.0		1	1
Holothuria fuscogilva	35.0		1	1
Cerithium nodulosum	5.0		1	1
Thelenota anax	35.0		1	1
Strombus luhuanus				142
Linckia laevigata				127
Echinometra mathaei				3
Conus marmoreus				3
Trochus spp.				3
Conus spp.				3
Tectus conus				2
Atrina vexillum				2
Acanthaster planci				2
Thais aculeata				1
Vasum ceramicum				1
Panulirus versicolor				1
Turbo argyrostomus				1
Echinothrix diadema				1

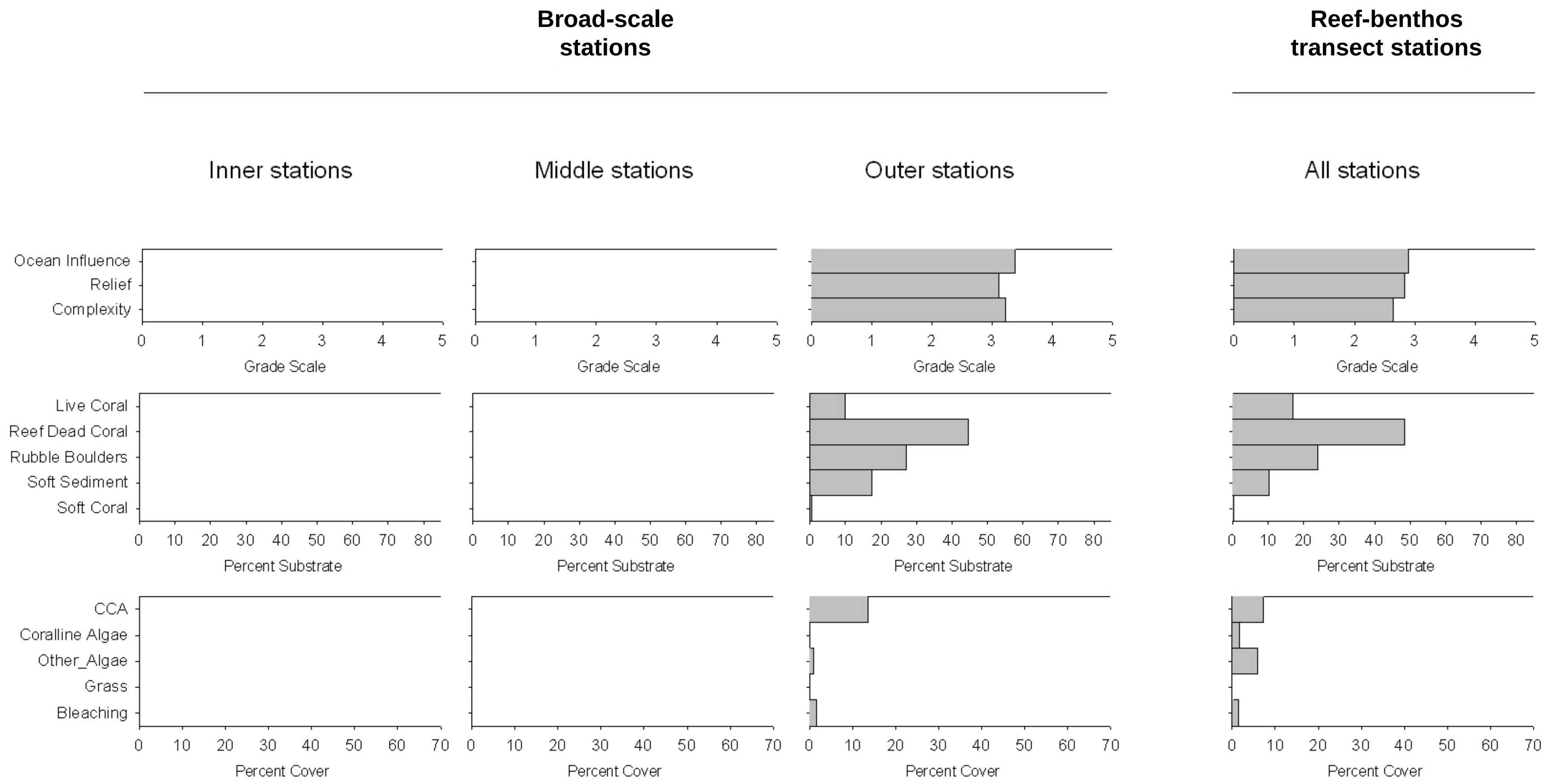
4.3.8c Mali 2009 MPA species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Tectus pyramis	5.3	0.2	5	13
Tridacna squamosa	20.4	3.6	5	7
Trochus niloticus	7.1	1.3	4	4
Holothuria edulis	16.5	3.5	2	79
Holothuria atra	16.0		1	303
Stichopus chloronotus	12.0		1	14
Tridacna maxima	8.0		1	8
Pinctada margaritifera	15.0		1	5
Linckia laevigata			0	330
Atrina vexillum			0	15
Bohadschia vitiensis			0	13
Holothuria coluber			0	7
Culcita novaeguineae			0	4
Lambis lambis			0	2
Trochus spp.			0	2
Acanthaster planci			0	2
Lioconcha spp.			0	1
Stichodactyla spp.			0	1
Conus litteratus			0	1
Chama spp.			0	1
Stichopus hermanni			0	1
Trachycardium spp.			0	1
Cerithium nodulosum			0	1
Spondylus spp.			0	1
Bohadschia graeffei			0	1

4.3.9a Habitat descriptors for independent assessments – Mali 2003

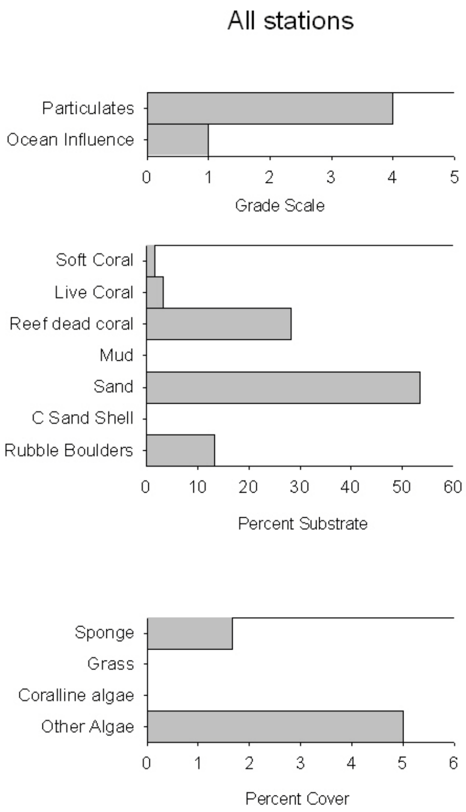


4.3.9b Habitat descriptors for independent assessments – Mali 2009

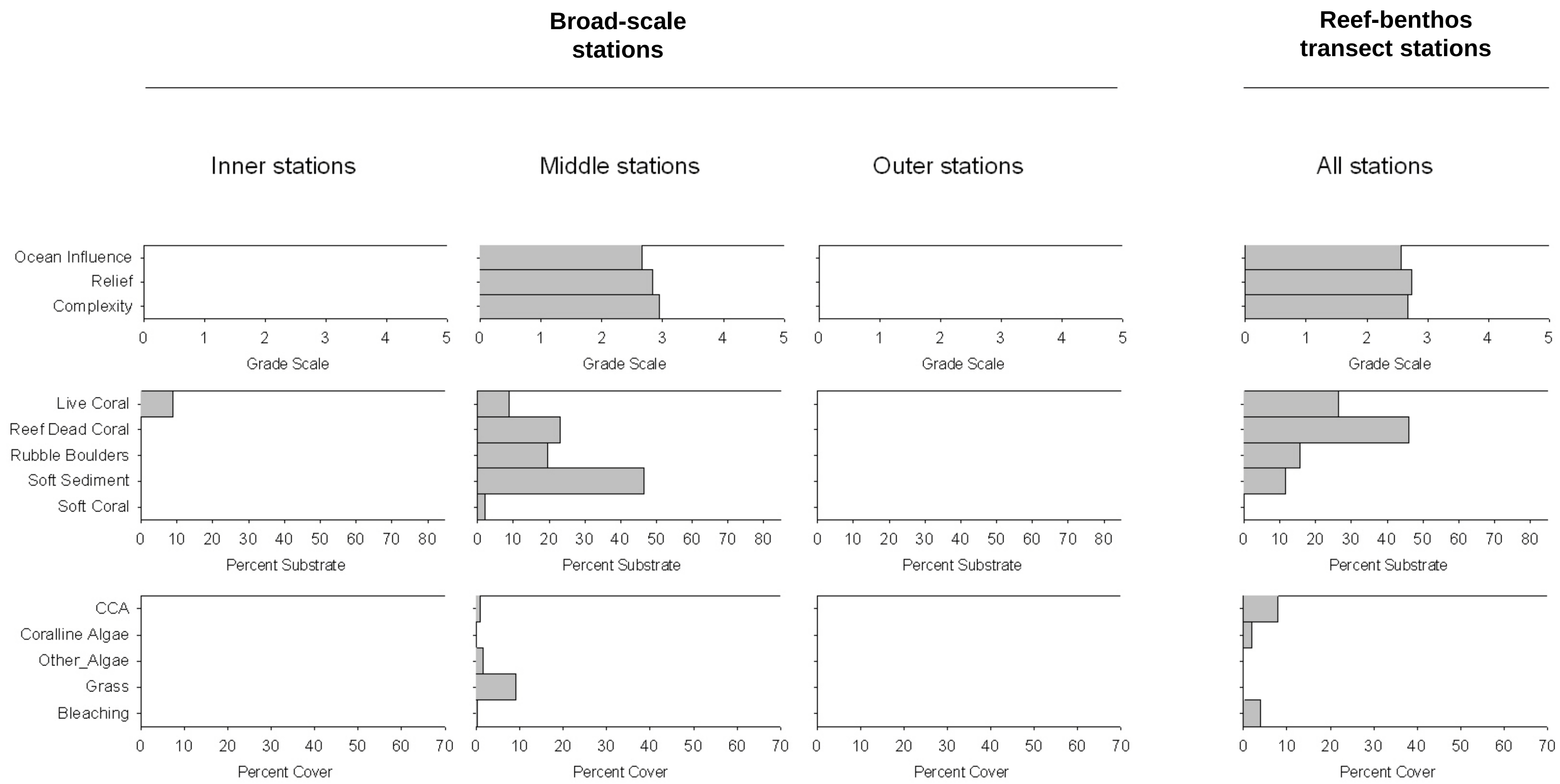


4.3.9b Habitat descriptors for independent assessments – Mali 2009 (continued)

Soft-benthos transect stations



4.3.9c Habitat descriptors for independent assessments – Mali MPA 2009



4.3.10 Mali 2003 catch assessment – creel survey – data review

Catch assessment – Creel Survey – number of individuals caught per hour. data review from shallow reef fishing (14 June 2003).

Fishers	Time	*A. lecanora*	*A. miliaris*	*H. nobilis*	*P. margaritifera*	*A. vexillum*	*C. ramosus*	*C. litteratus*	*C. tigris*
Diana Buisena	180	0	0	0	0	0	0	0	0
Fulori Ranadi Viviana	180	0	0	0	0	1.3	0	0.3	0.3
Laite Robinson	180	0	0	0	0	0	0	0	0
Loame Kosoniu	180	0.3	0.3	0.3	0	2.3	0	0	0
Lousa LagaAia, Diana Lomawai & Setaita Bayanivalu	180	0	0	0	0	0.3	0.3	0	1.7
Miliakere Marau	180	0	0	0	0	0	0	0	0
Nesi Keleiwai	180	0	0	0	1	0	0	0	0

Fishers	Time	***Lambis*** **spp.**	***Spondylus*** **spp.**	*T. maxima*	***T.*** **spp.. ***	*T. squamosa*	*Heteractis sp*	*T. gratilla*
Diana Buisena	180	0	0	0.3	5.3	0.3	0	0
Fulori Ranadi Viviana	180	2.3	0	0	2.3	0	0	0
Laite Robinson	180	0	0	1.3	2.3	0	0	0
Loame Kosoniu	180	0	0	1	0.3	3.3	0.3	0.3
Lousa LagaAia, Diana Lomawai & Setaita Bayanivalu	180	3.3	0.3	0	5.3	0	0	0
Miliakere Marau	180	0	0	0.3	0	2.7	0	0
Nesi Keleiwai	180	0.7	0	0	0	0.3	0	0

*Giant clam meat

Catch assessment – Creel Survey - number of individuals caught per hour. data review from shoreline gleaning (17 June 2003).

Fisher	Time	*Heteractis sp*	*C. tigris*	*N. albicilla*	*N. polita*	*N. plicata*	*N. undata*	*L. scabra*	*T. cinereus*	*A. gemmata*	*E. sebana*	*Scylla serrata*	*G. albolineatus*
Diana Buisena	60	0	1	290	19	20	8	148	184	0	0	0	0
Adiwala Kotiniwai	60	0	0	0	0	0	0	0	0	40	0	0	0
Louisa Laga aia	60	2	0	0	0	0	0	0	0	0	1	1	1

4.4 Lakeba invertebrate survey data

4.4.1a Invertebrate species recorded in different assessments in Lakeba in 2003

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga lecanora*	+			+
Bêche-de-mer	*Actinopyga mauritiana*				+
Bêche-de-mer	*Actinopyga miliaris*			+	+
Bêche-de-mer	*Bohadschia argus*	+			
Bêche-de-mer	*Bohadschia graeffei*	+			+
Bêche-de-mer	*Bohadschia similis*			+	
Bêche-de-mer	*Bohadschia vitiensis*	+			
Bêche-de-mer	*Holothuria atra*	+		+	
Bêche-de-mer	*Holothuria coluber*	+		+	
Bêche-de-mer	*Holothuria edulis*	+		+	
Bêche-de-mer	*Holothuria fuscogilva*	+			
Bêche-de-mer	*Holothuria fuscopunctata*	+			
Bêche-de-mer	*Holothuria scabra*			+	
Bêche-de-mer	*Stichopus chloronotus*	+			
Bêche-de-mer	*Stichopus hermanni*	+			
Bêche-de-mer	*Stichopus horrens*				+
Bêche-de-mer	*Synapta* spp.			+	
Bêche-de-mer	*Thelenota ananas*	+			
Bivalve	*Anadara antiquata*	+		+	
Bivalve	*Anadara* spp.			+	
Bivalve	*Atrina* spp.	+			
Bivalve	*Atrina vexillum*	+		+	
Bivalve	*Hyotissa* spp.	+			
Bivalve	*Modiolus* spp.			+	
Bivalve	*Pinctada margaritifera*	+			
Bivalve	*Pinna* spp.			+	
Bivalve	*Pitar prora*			+	
Bivalve	*Spondylus* spp.	+			
Bivalve	*Tridacna maxima*	+			+
Bivalve	*Tridacna squamosa*	+			+
Cnidarian	*Cassiopea andromeda*			+	
Cnidarian	*Cassiopea* spp.			+	
Crustacean	*Panulirus* spp.	+			+
Crustacean	*Panulirus versicolor*	+			+
Gastropod	*Cerithium aluco*			+	
Gastropod	*Charonia tritonis*	+			
Gastropod	*Conus flavidus*			+	
Gastropod	*Conus litteratus*			+	
Gastropod	*Conus* spp.	+		+	
Gastropod	*Cypraea caputserpensis*			+	
Gastropod	*Cypraea tigris*	+		+	
Gastropod	*Lambis lambis*	+		+	
Gastropod	*Lambis* spp.	+			
Gastropod	*Lambis truncata*	+			
Gastropod	*Strombus gibberulus gibbosus*			+	
Gastropod	*Tectus pyramis*	+			+

+ = presence of the species.

4.4.1a Invertebrate species recorded in different assessments in Lakeba in 2003 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Trochus niloticus*				+
Gastropod	*Turbo argyrostomus*				+
Gastropod	*Turbo crassus*				+
Gastropod	*Tutufa bubo*	+			
Octopus	*Octopus cyanea*	+			
Star	*Acanthaster planci*	+			+
Star	*Choriaster granulatus*	+			
Star	*Culcita novaeguineae*	+			
Star	*Linckia laevigata*	+		+	
Urchin	*Diadema* spp.	+			+
Urchin	*Echinometra mathaei*	+			+

+ = presence of the species.

4.4.1b Invertebrate species recorded in different assessments in Lakeba in 2009

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Bêche-de-mer	*Actinopyga lecanora*	+			
Bêche-de-mer	*Actinopyga mauritiana*				+
Bêche-de-mer	*Bohadschia argus*		+		
Bêche-de-mer	*Bohadschia graeffei*	+	+		
Bêche-de-mer	*Bohadschia similis*			+	+
Bêche-de-mer	*Bohadschia vitiensis*				+
Bêche-de-mer	*Holothuria atra*	+	+	+	+
Bêche-de-mer	*Holothuria coluber*		+		
Bêche-de-mer	*Holothuria edulis*	+	+	+	
Bêche-de-mer	*Holothuria fuscopunctata*	+	+		
Bêche-de-mer	*Holothuria nobilis*	+			+
Bêche-de-mer	*Holothuria scabra*			+	
Bêche-de-mer	*Stichopus chloronotus*	+	+		+
Bêche-de-mer	*Stichopus hermanni*		+		+
Bêche-de-mer	*Stichopus horrens*			+	
Bêche-de-mer	*Thelenota ananas*	+			+
Bêche-de-mer	*Thelenota anax*				+
Bivalve	*Anadara antiquata*			+	
Bivalve	*Anadara* spp.			+	
Bivalve	*Atrina vexillum*	+			
Bivalve	*Pinctada margaritifera*	+	+		
Bivalve	*Tridacna maxima*		+		+
Bivalve	*Tridacna squamosa*		+		
Cnidarian	*Stichodactyla* spp.	+	+		+
Crustacean	*Panulirus versicolor*		+		
Gastropod	*Cassis cornuta*	+			
Gastropod	*Cerithium nodulosum*		+		
Gastropod	*Conus litteratus*	+			
Gastropod	*Conus marmoreus*	+	+	+	
Gastropod	*Conus miles*			+	
Gastropod	*Conus* spp.		+	+	

+ = presence of the species.

4.4.1b Invertebrate species recorded in different assessments in Lakeba in 2009 (continued)

Group	Species	Broad scale	Reef benthos	Soft benthos	Others
Gastropod	*Conus striatus*		+		
Gastropod	*Cypraea tigris*	+	+		
Gastropod	*Dolabella auricularia*			+	
Gastropod	*Drupa* spp.		+		
Gastropod	*Lambis lambis*		+	+	+
Gastropod	*Lambis truncata*	+	+		
Gastropod	*Mitra mitra*		+		
Gastropod	*Strombus luhuanus*		+		
Gastropod	*Tectus pyramis*		+		+
Gastropod	*Trochus niloticus*		+		+
Gastropod	*Turbo argyrostomus*				+
Gastropod	*Turbo chrysostomus*		+		
Gastropod	*Turbo* spp.		+		
Star	*Acanthaster planci*	+			
Star	*Culcita novaeguineae*	+	+	+	
Star	*Linckia laevigata*	+	+		
Urchin	*Echinometra mathaei*	+	+		+
Urchin	*Echinothrix diadema*	+	+		

4.4.2a Lakeba 2003 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	0.8	0.6	76	28.6	14.3	2	0.7	0.7	13	9.5		1
Actinopyga lecanora	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1
Anadara antiquata	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1
Atrina spp.	0.2	0.2	76	14.3		1	0.3	0.3	13	3.6		1
Atrina vexillum	4.4	1.4	76	25.5	5.1	13	4.3	2.6	13	11.1	5.7	5
Bohadschia argus	1.2	0.5	76	15.4	2.8	6	1.2	0.6	13	3.8	1.3	4
Bohadschia graeffei	0.5	0.3	76	13.3	1.0	3	0.5	0.4	13	3.3	1.4	2
Bohadschia vitiensis	0.6	0.4	76	21.4	7.1	2	0.5	0.4	13	3.6	1.2	2
Charonia tritonis	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1
Choriaster granulatus	0.9	0.5	76	17.9	3.6	4	1.1	0.7	13	7.1	0.0	2
Conus spp.	1.1	0.4	76	14.3	0.0	6	1.1	0.4	13	2.9	0.5	5
Culcita novaeguineae	5.0	1.2	76	22.5	2.5	17	5.1	2.6	13	11.1	4.6	6
Cypraea tigris	0.6	0.3	76	14.3	0.0	3	0.5	0.3	13	2.4	0.0	3
Diadema spp.	7.1	2.0	76	38.6	5.2	14	6.8	3.9	13	17.7	8.4	5
Echinometra mathaei	9.0	6.3	76	137.1	84.0	5	8.8	6.4	13	57.1	21.4	2
Holothuria atra	28.9	5.9	76	73.3	10.7	30	28.8	10.2	13	41.5	12.5	9
Holothuria coluber	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1
Holothuria edulis	92.7	40.9	76	281.7	116.8	25	90.7	77.4	13	168.4	141.8	7
Holothuria fuscogilva	1.0	0.6	76	25.1	7.0	3	1.0	0.6	13	4.2	1.2	3
Holothuria fuscopunctata	0.5	0.3	76	13.3	1.0	3	0.5	0.4	13	3.3	1.4	2
Hyotissa spp.	4.9	1.6	76	37.1	5.7	10	5.9	3.3	13	12.8	6.2	6
Lambis lambis	1.5	0.5	76	14.3	0.0	8	1.5	0.6	13	3.8	1.0	5
Lambis spp.	0.6	0.4	76	21.4	7.1	2	0.5	0.4	13	3.6	1.2	2
Lambis truncata	1.1	0.4	76	13.3	0.6	6	1.0	0.5	13	3.3	0.6	4
Linckia laevigata	177.9	25.6	76	211.3	28.5	64	177.5	54.5	13	192.3	57.0	12
Octopus cyanea	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1
Panulirus spp.	0.6	0.3	76	14.3	0.0	3	0.5	0.4	13	3.6	1.2	2
Panulirus versicolor	0.8	0.4	76	14.3	0.0	4	0.7	0.3	13	2.4	0.0	4

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.2a Lakeba 2003 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
Pinctada margaritifera	1.4	0.5	76	13.1	0.8	8	1.3	0.4	13	2.5	0.1	7
Spondylus spp.	1.3	0.6	76	17.1	2.3	6	1.3	0.7	13	4.3	1.3	4
Stichopus chloronotus	1.7	0.7	76	21.4	3.2	6	1.6	0.9	13	5.4	2.3	4
Stichopus hermanni	0.4	0.3	76	14.3	0.0	2	0.4	0.2	13	2.4	0.0	2
Tectus pyramis	0.7	0.4	76	17.1	2.9	3	0.7	0.4	13	2.9	0.5	3
Thelenota ananas	0.5	0.3	76	12.7	1.6	3	0.5	0.4	13	3.2	1.6	2
Tridacna maxima	1.4	0.5	76	15.1	2.3	7	1.4	0.7	13	5.9	0.7	3
Tridacna squamosa	0.8	0.4	76	12.8	1.0	5	0.8	0.3	13	2.1	0.2	5
Tutufa bubo	0.2	0.2	76	14.3		1	0.2	0.2	13	2.4		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.2b Lakeba 2009 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	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Actinopyga lecanora	0.5	0.5	36	16.7		1	0.8	0.8	7	5.6		1
Atrina vexillum	1.9	0.9	36	16.7	0.0	4	2.0	1.0	7	4.6	0.9	3
Bohadschia graeffei	1.9	1.1	36	22.2	5.6	3	1.6	1.6	7	11.1		1
Cassis cornuta	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Conus litteratus	6.0	2.3	36	31.0	5.7	7	5.2	3.7	7	18.1	6.9	2
Conus marmoreus	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Culcita novaeguineae	2.8	1.2	36	20.0	3.3	5	3.2	1.8	7	7.4	2.4	3
Cypraea tigris	1.9	0.9	36	16.7	0.0	4	1.6	0.8	7	3.7	0.9	3
Echinometra mathaei	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Echinothrix diadema	5.1	3.5	36	61.1	29.4	3	4.4	3.9	7	15.3	12.5	2
Holothuria atra	22.7	7.4	36	58.3	14.8	14	31.3	20.3	7	36.6	23.2	6
Holothuria edulis	11.1	7.6	36	100.0	55.3	4	18.7	18.2	7	65.3	62.5	2
Holothuria fuscopunctata	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Holothuria nobilis	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1
Lambis truncata	2.8	1.2	36	20.0	3.3	5	2.4	2.0	7	8.3	5.6	2
Linckia laevigata	75.5	25.9	36	135.8	42.4	20	90.5	50.8	7	90.5	50.8	7
Pinctada margaritifera	1.4	0.8	36	16.7	0.0	3	1.2	0.8	7	4.2	1.4	2
Stichodactyla spp.	0.9	0.6	36	16.7	0.0	2	0.8	0.5	7	2.8	0.0	2
Stichopus chloronotus	2.8	1.9	36	33.3	16.7	3	4.4	3.9	7	15.3	12.5	2
Thelenota ananas	0.5	0.5	36	16.7		1	0.4	0.4	7	2.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.3 Lakeba 2009 reef-benthos transect (RBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia argus	5.1	3.6	99	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Bohadschia graeffei	2.5	2.5	99	250.0		1	1.7	1.7	16	27.8		1
Cerithium nodulosum	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1
Conus marmoreus	7.6	4.3	99	250.0	0.0	3	6.9	3.8	16	37.0	4.6	3
Conus spp.	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1
Conus striatus	5.1	3.6	99	250.0	0.0	2	5.2	5.2	16	83.3		1
Culcita novaeguineae	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1
Cypraea tigris	15.2	7.0	99	300.0	50.0	5	13.0	7.3	16	69.4	13.9	3
Drupa spp.	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1
Echinometra mathaei	37.9	17.0	99	468.8	145.1	8	31.3	16.8	16	100.0	40.8	5
Echinothrix diadema	27.8	13.9	99	550.0	145.8	5	22.6	15.5	16	180.6	13.9	2
Holothuria atra	60.6	22.7	99	666.7	138.2	9	62.5	45.8	16	333.3	196.9	3
Holothuria coluber	7.6	7.6	99	750.0		1	7.8	7.8	16	125.0		1
Holothuria edulis	42.9	16.5	99	425.0	105.7	10	44.3	28.1	16	177.1	89.0	4
Holothuria fuscopunctata	2.5	2.5	99	250.0		1	1.7	1.7	16	27.8		1
Lambis lambis	5.1	3.6	99	250.0	0.0	2	5.2	3.6	16	41.7	0.0	2
Lambis truncata	10.1	6.1	99	333.3	83.3	3	10.4	6.0	16	55.6	13.9	3
Linckia laevigata	156.6	31.0	99	516.7	65.6	30	159.7	54.5	16	232.3	69.2	11
Mitra mitra	10.1	8.0	99	500.0	250.0	2	10.4	10.4	16	166.7		1
Panulirus versicolor	15.2	10.7	99	500.0	250.0	3	15.6	10.7	16	83.3	41.7	3
Pinctada margaritifera	7.6	4.3	99	250.0	0.0	3	6.9	3.8	16	37.0	4.6	3
Stichodactyla spp.	5.1	3.6	99	250.0	0.0	2	5.2	5.2	16	83.3		1
Stichopus chloronotus	35.4	15.2	99	437.5	122.7	8	36.5	26.6	16	194.4	113.7	3
Stichopus hermanni	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1
Strombus luhuanus	68.2	24.3	99	562.5	134.6	12	68.6	26.0	16	182.9	35.0	6
Tectus pyramis	53.0	11.5	99	276.3	18.1	19	48.6	13.7	16	70.7	15.9	11
Tridacna maxima	25.3	7.6	99	250.0	0.0	10	25.2	8.3	16	57.5	9.3	7
Tridacna squamosa	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.3 Lakeba 2009 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
Trochus niloticus	48.0	13.3	99	339.3	42.3	14	40.8	17.5	16	81.6	28.8	8
Turbo chrysostomus	7.6	5.6	99	375.0	125.0	2	5.2	5.2	16	83.3		1
Turbo spp.	2.5	2.5	99	250.0		1	2.6	2.6	16	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.4a Lakeba 2003 soft-benthos transect (SBt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga miliaris	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Anadara antiquata	338.9	78.8	90	1051.7	185.9	29	338.9	137.6	15	635.4	210.1	8
Anadara spp.	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Atrina vexillum	11.1	5.5	90	250.0	0.0	4	11.1	7.6	15	83.3	0.0	2
Bohadschia similis	22.2	9.4	90	333.3	52.7	6	22.2	14.6	15	111.1	50.1	3
Cassiopea spp.	8.3	4.8	90	250.0	0.0	3	8.3	6.0	15	62.5	20.8	2
Cassiopea andromeda	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Cerithium aluco	5.6	3.9	90	250.0	0.0	2	5.6	5.6	15	83.3		1
Conus flavidus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Conus litteratus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Conus spp.	11.1	5.5	90	250.0	0.0	4	11.1	6.4	15	55.6	13.9	3
Cypraea caputserpensis	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
Cypraea tigris	8.3	4.8	90	250.0	0.0	3	8.3	4.5	15	41.7	0.0	3
Holothuria atra	1463.9	221.2	90	2159.8	286.4	61	1463.9	467.3	15	1829.9	535.3	12
Holothuria coluber	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Holothuria edulis	47.2	16.2	90	425.0	75.0	10	47.2	31.5	15	236.1	111.1	3
Holothuria scabra	30.6	12.4	90	392.9	74.3	7	30.6	20.5	15	152.8	73.5	3
Lambis lambis	44.4	14.0	90	363.6	51.8	11	44.4	16.0	15	95.2	21.7	7
Linckia laevigata	5.6	3.9	90	250.0	0.0	2	5.6	5.6	15	83.3		1
Pinna spp.	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Pitar prora	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	41.7	0.0	2
Strombus gibberulus gibbosus	2.8	2.8	90	250.0		1	2.8	2.8	15	41.7		1
Synapta spp.	5.6	3.9	90	250.0	0.0	2	5.6	3.8	15	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 of individuals; SE = standard error.

4.4.4b Lakeba 2009 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
Conus marmoreus	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Conus miles	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Culcita novaeguineae	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1
Holothuria atra	41.7	28.8	24	500.0	0.0	2	41.7	41.7	4	166.7		1
Holothuria edulis	208.3	87.3	24	625.0	194.8	8	208.3	121.5	4	416.7	41.7	2
Holothuria scabra	10.4	10.4	24	250.0		1	10.4	10.4	4	41.7		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.5a Lakeba 2003 soft-benthos quadrats (SBq) assessment data review

Station: 8 quadrat groups (4 quadrats/group).

Species	Quadrat group			Quadrat group _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Anadara antiquata	2.69	0.51	144	3.03	0.51	54	2.69	0.51	18	3.03	0.51	16
Atrina vexillum	0.06	0.06	144	1.00	0.00	2	0.06	0.06	18	1.00	0.00	1
Bohadschia similis	0.03	0.03	144	0.50	0.00	1	0.03	0.03	18	0.50	0.00	1
Modiolus spp.	0.50	0.16	144	1.00	0.22	13	0.50	0.16	18	1.00	0.22	9
Pinna spp.	0.08	0.05	144	0.50	0.00	3	0.08	0.05	18	0.50	0.00	3
Pitar prora	0.03	0.03	144	0.50	0.00	1	0.03	0.03	18	0.50	0.00	1
Strombus gibberulus gibbosus	0.14	0.10	144	1.25	0.25	4	0.14	0.10	18	1.25	0.25	2

Mean = mean density (numbers/m²); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.5b Lakeba 2009 soft-benthos quadrats (SBq) assessment data review

Station: 8 quadrat groups (4 quadrats/group).

Species	Quadrat group			Quadrat group _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Anadara antiquata	9.50	5.39	72	28.50	8.84	53	9.50	5.39	9	28.50	8.84	3
Anadara spp.	7.78	3.53	72	17.50	4.25	53	7.78	3.53	9	17.50	4.25	4
Bohadschia similis	0.39	0.29	72	1.75	0.75	5	0.39	0.29	9	1.75	0.75	2
Conus spp.	0.06	0.06	72	0.50	0.00	1	0.06	0.06	9	0.50	0.00	1
Dolabella auricularia	0.17	0.17	72	1.50	0.00	2	0.17	0.17	9	1.50	0.00	1
Holothuria atra	0.94	0.64	72	1.70	1.08	10	0.94	0.64	9	1.70	1.08	5
Lambis lambis	0.06	0.06	72	0.50	0.00	1	0.06	0.06	9	0.50	0.00	1
Stichopus horrens	18.61	12.59	72	83.75	15.75	16	18.61	12.59	9	83.75	15.75	2

Mean = mean density (numbers/m²); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.6a Lakeba 2003 reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	3.5	2.5	18	31.3	10.4	2	3.5	2.0	3	5.2	1.7	2
Panulirus spp.	2.3	1.6	18	20.9	0.0	2	2.3	2.3	3	7.0		1
Panulirus versicolor	1.2	1.2	18	20.9		1	1.2	1.2	3	3.5		1
Tridacna maxima	1.2	1.2	18	20.9		1	1.2	1.2	3	3.5		1
Trochus niloticus	12.7	4.8	18	38.2	6.4	6	12.7	8.1	3	19.1	8.7	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.6b Lakeba 2009 reef-front search (RFs) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Actinopyga mauritiana	1.7	1.7	12	20.9		1	1.7	1.7	2	3.5		1
Echinometra mathaei	8.7	6.0	12	52.1	10.4	2	8.7	8.7	2	17.4		1
Stichodactyla spp.	1.7	1.7	12	20.9		1	1.7	1.7	2	3.5		1
Tectus pyramis	1.7	1.7	12	20.9		1	1.7	1.7	2	3.5		1
Tridacna maxima	7.0	4.7	12	41.7	0.0	2	7.0	7.0	2	13.9		1
Trochus niloticus	3.5	2.3	12	20.9	0.0	2	3.5	0.0	2	3.5	0.0	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.7a Lakeba 2003 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
Tectus pyramis	18.7	8.4	6	37.5	0.0	3	18.7		1	18.7		1
Tridacna maxima	12.5	7.9	6	37.5	0.0	2	12.5		1	12.5		1
Tridacna squamosa	18.7	8.4	6	37.5	0.0	3	18.7		1	18.7		1
Trochus niloticus	31.2	6.2	6	37.5	0.0	5	31.2		1	31.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.7b Lakeba 2009 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
Stichopus chloronotus	6.2	6.2	6	37.5		1	6.2		1	6.2		1
Tectus pyramis	74.9	30.6	6	74.9	30.6	6	74.9		1	74.9		1
Trochus niloticus	6.2	6.2	6	37.5		1	6.2		1	6.2		1
Turbo argyrostomus	6.2	6.2	6	37.5		1	6.2		1	6.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.8 Lakeba 2003 mother-of-pearl transect (MOPt) assessment data review

Station: Six 1 m x 40 m transects.

Species	Transect			Transect _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Bohadschia graeffei	10.4	7.2	24	125.0	0.0	2	10.4	10.4	4	41.7		1
Diadema spp.	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Echinometra mathaei	296.9	171.0	24	2375.0	473.2	3	296.9	296.9	4	1187.5		1
Tectus pyramis	10.4	7.2	24	125.0	0.0	2	10.4	10.4	4	41.7		1
Tridacna maxima	10.4	7.2	24	125.0	0.0	2	10.4	6.0	4	20.8	0.0	2
Trochus niloticus	72.9	19.8	24	175.0	20.4	10	72.9	27.6	4	97.2	18.4	3
Turbo argyrostomus	5.2	5.2	24	125.0		1	5.2	5.2	4	20.8		1
Turbo crassus	15.6	15.6	24	375.0		1	15.6	15.6	4	62.5		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.9a Lakeba 2003 sea cucumber night search (Ns) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Acanthaster planci	5.7	5.7	12	68.5		1	5.7	5.7	2	11.4		1
Actinopyga lecanora	11.4	7.7	12	68.5	0.0	2	11.4	11.4	2	22.8		1
Actinopyga miliaris	17.1	8.9	12	68.5	0.0	3	17.1	17.1	2	34.2		1
Diadema spp.	3424.7	1032.6	12	6849.3	0.0	6	3424.7	3424.7	2	6849.3		1
Echinometra mathaei	6849.3	0.0	12	6849.3	0.0	12	6849.3	0.0	2	6849.3	0.0	2
Stichopus horrens	108.4	23.0	12	118.3	22.8	11	108.4	5.7	2	108.4	5.7	2

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.9b Lakeba 2009 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 similis	11.4	11.4	6	68.5		1	11.4	11.4	2	22.8		1
Bohadschia vitiensis	22.8	14.4	6	68.5	0.0	2	22.8	0.0	2	22.8	0.0	2
Holothuria atra	11.4	11.4	6	68.5		1	11.4	11.4	2	22.8		1
Lambis lambis	34.2	34.2	6	205.5		1	34.2	34.2	2	68.5		1
Stichopus hermanni	11.4	11.4	6	68.5		1	11.4	11.4	2	22.8		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.10 Lakeba 2009 sea cucumber day search (Ds) assessment data review

Station: Six 5-min search periods.

Species	Search period			Search period _P			Station			Station _P		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Holothuria nobilis	2.2	2.2	6	13.2		1	2.2		1	2.2		1
Thelenota ananas	4.4	2.8	6	13.2	0.0	2	4.4		1	4.4		1
Thelenota anax	2.2	2.2	6	13.2		1	2.2		1	2.2		1

Mean = mean density (numbers/ha); _P = result for transects or stations where the species was located during the survey; n = number of individuals; SE = standard error.

4.4.11a Lakeba 2003 species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Holothuria atra	13.9	0.2	670	681
Holothuria edulis	20.9	0.1	506	510
Anadara antiquata	6.2	0.1	218	220
Lambis lambis	13.2	0.8	24	24
Trochus niloticus	10.1	0.5	19	30
Modiolus spp.	3.4	0.1	16	18
Tridacna maxima	20.0	1.7	12	13
Holothuria scabra	15.7	1.5	11	11
Linckia laevigata	18.0	0.0	10	951
Conus spp.	10.4	0.3	10	10
Stichopus chloronotus	18.3	1.0	9	9
Bohadschia similis	12.7	1.1	9	9
Pinctada margaritifera	15.9	0.5	8	8
Tridacna squamosa	16.3	1.4	8	8
Bohadschia argus	30.9	1.6	7	7
Holothuria fuscogilva	25.5	3.3	7	7
Lambis truncata	30.3	1.3	6	6
Strombus gibberulus gibbosus	3.5	0.2	6	6
Tectus pyramis	6.3	0.5	5	9
Panulirus spp.	5.0	0.0	5	5
Panulirus versicolor	5.0	0.0	4	5
Bohadschia graeffei	29.8	3.0	4	5
Cypraea tigris	6.7	0.3	3	6
Turbo crassus	7.0	0.0	3	3
Lambis spp.	16.3	0.3	3	3
Bohadschia vitiensis	29.7	7.3	3	3
Pitar prora	3.7	0.7	3	3
Holothuria fuscopunctata	27.8	2.2	3	3
Thelenota ananas	32.5	2.5	2	3
Cerithium aluco	7.0	0.5	2	2
Stichopus hermanni	35.0		2	2
Actinopyga miliaris	7.0		1	4
Holothuria coluber	5.5		1	3
Conus litteratus	5.5		1	1
Turbo argyrostomus	6.0		1	1
Charonia tritonis	30.0		1	1
Conus flavidus	8.5		1	1
Anadara spp.	6.1		1	1
Tutufa bubo	22.0		1	1
Echinometra mathaei				1305
Diadema spp.				637
Atrina vexillum				29
Culcita novaeguineae				27
Hyotissa spp.				26
Stichopus horrens				19
Spondylus spp.				7
Pinna spp.				5
Acanthaster planci				5

4.4.11a Lakeba 2003 species size review — all survey methods (continued)

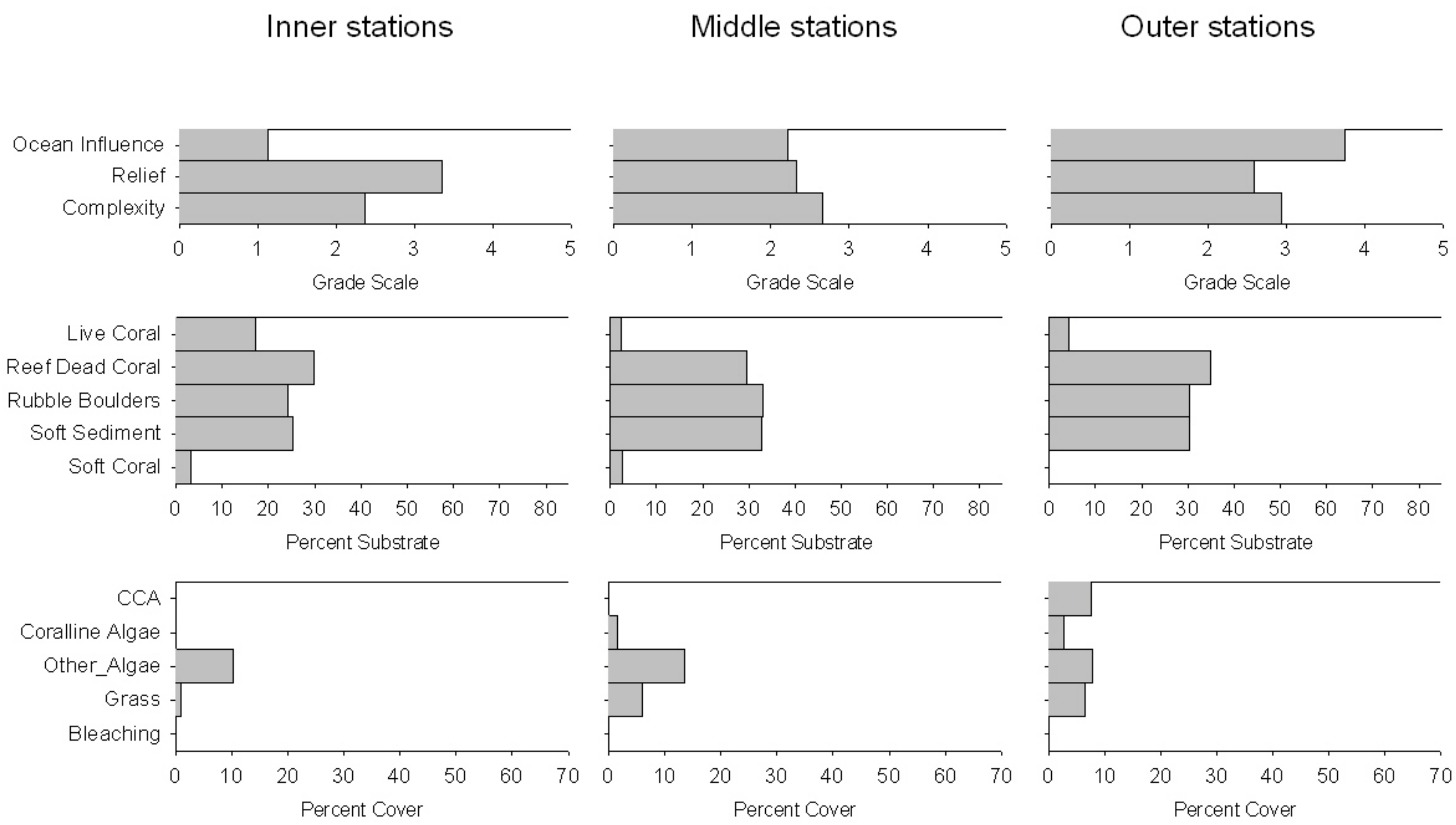
Species	Mean length (cm)	SE	n measured	n total
Choriaster granulatus				5
Actinopyga lecanora				3
Cassiopea spp.				3
Actinopyga mauritiana				3
Cypraea caputserpensis				3
Synapta spp.				2
Atrina spp.				1
Octopus cyanea				1
Cassiopea andromeda				1

4.4.11b Lakeba 2009 species size review — all survey methods

Species	Mean length (cm)	SE	n measured	n total
Anadara antiquata	5.7	0.1	155	171
Anadara spp.	5.3	0.1	140	140
Holothuria atra	14.8	0.8	37	95
Holothuria edulis	14.8	0.7	37	61
Tectus pyramis	6.0	0.2	28	34
Strombus luhuanus	4.9	0.1	27	27
Trochus niloticus	8.7	0.7	22	22
Stichopus chloronotus	18.4	1.3	15	21
Tridacna maxima	20.1	1.7	14	14
Cypraea tigris	8.0	0.2	6	10
Lambis truncata	24.3	1.8	4	10
Conus marmoreus	6.6	0.7	4	5
Mitra mitra	11.4	0.6	4	4
Lambis lambis	16.3	2.0	3	6
Pinctada margaritifera	14.0	1.2	3	6
Thelenota ananas	41.3	4.7	3	3
Holothuria coluber	30.0	0.0	3	3
Stichopus hermanni	21.0	3.0	2	2
Holothuria fuscopunctata	31.5	1.5	2	2
Bohadschia argus	29.0	7.0	2	2
Bohadschia vitiensis	17.5	0.5	2	2
Conus striatus	8.5	0.5	2	2
Bohadschia similis	17.0		1	8
Bohadschia graeffei	17.0		1	5
Holothuria nobilis	25.0		1	2
Turbo spp.	3.0		1	1
Conus miles	5.0		1	1
Tridacna squamosa	10.0		1	1
Actinopyga mauritiana	20.0		1	1
Holothuria scabra	26.0		1	1
Cerithium nodulosum	9.0		1	1
Thelenota anax	41.0		1	1
Turbo argyrostomus	5.0		1	1
Drupa spp.	4.0		1	1
Stichopus horrens				335
Linckia laevigata				225
Echinothrix diadema				22
Echinometra mathaei				21
Conus litteratus				13
Culcita novaeguineae				8
Panulirus versicolor				6
Stichodactyla spp.				5
Atrina vexillum				4
Turbo chrysostomus				3
Dolabella auricularia				3
Conus spp.				2
Actinopyga lecanora				1
Cassis cornuta				1
Acanthaster planci				1

4.4.12a Habitat descriptors for independent assessments – Lakeba 2003

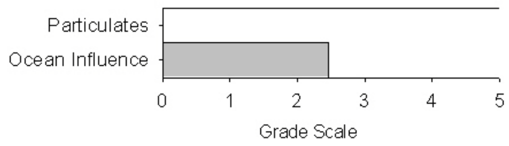
Broad-scale stations

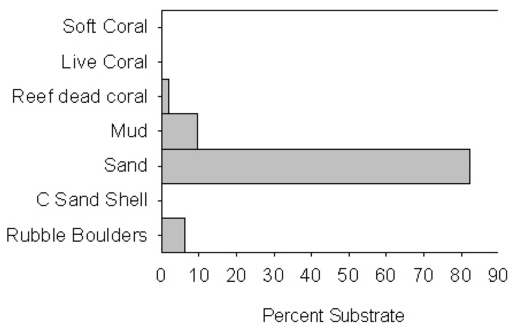


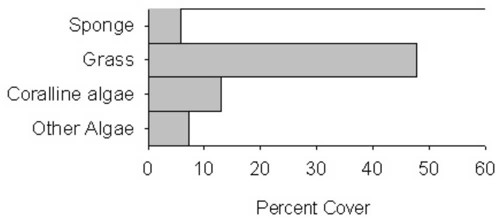
4.4.12a Habitat descriptors for independent assessments – Lakeba 2003 (continued)

Soft-benthos
transect stations

All stations

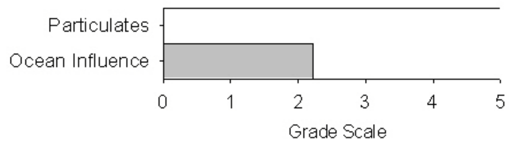


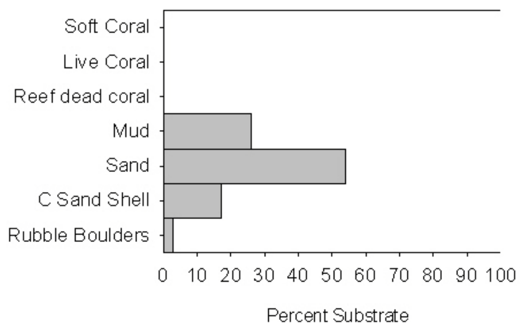


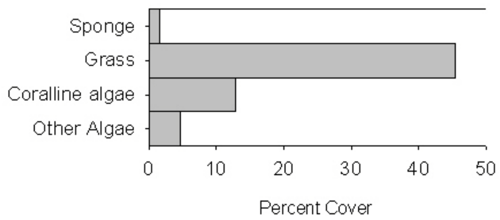


Soft-benthos
quadrat stations

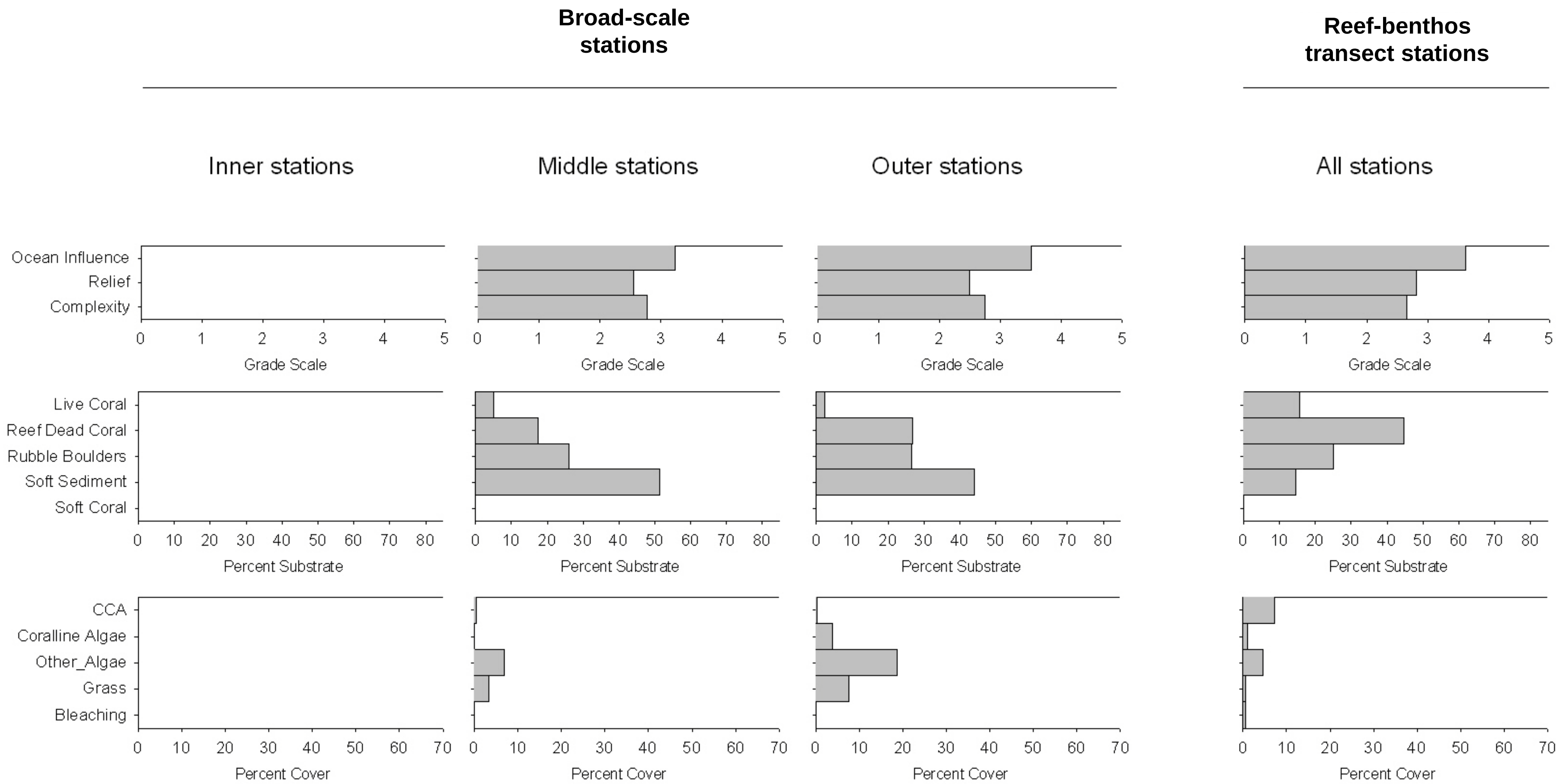
All stations





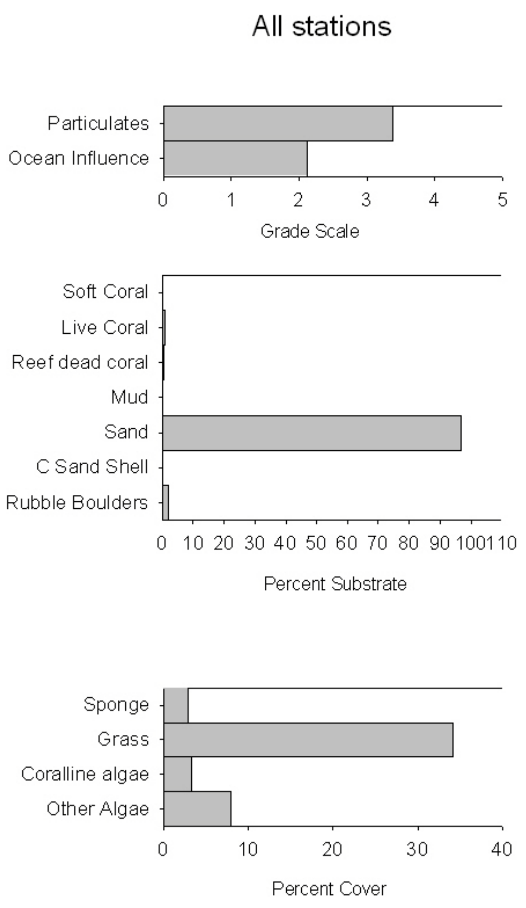


4.4.12b Habitat descriptors for independent assessments – Lakeba 2009

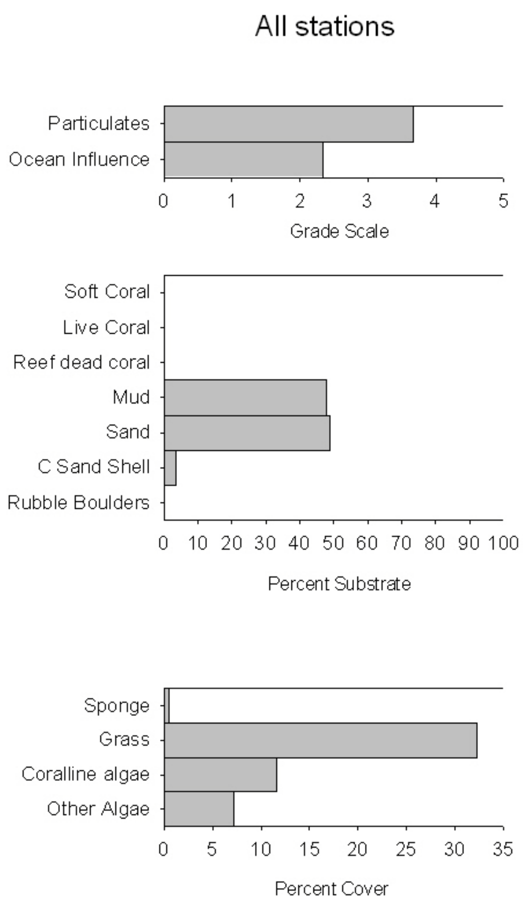


4.4.12b Habitat descriptors for independent assessments – Lakeba 2009 (continued)

Soft-benthos transect stations



Soft-benthos quadrat stations



4.4.13a Lakeba 2003 catch assessment – creel survey – data review

Catch assessment – Creel survey from MOP diving – data review

Fisher	Fishing time (min)	CPUE (number of *Trochus niloticus* per hour)
Emosi Loganimoce	180	17.0
Inia Vetakula	180	10.3
Jim Sukamavalu	180	20.7
Koila Yacadra	180	16.7
Laitia Vula	180	29.3
Masi Vidaune*	180	7.0

* Some specimens of sea cucumber were also taken as incidental catch: 1 black teatfish, 3 surf redfish and 1 prickly redfish

Catch assessment – Creel survey from soft bottom fishing – data review (CPUE per hour)

Date	**25 June 2003**				
Fisher	**Fishing time (min)**	***Anadara antiquata***	***Anadara* spp.**	***Gafrarium* spp.**	***Vasticardium* spp.**
Laete Matebalau	110	224.2	3.3	2.2	0.5
Mere Rasino / Alisi Bula	110	140.7	0	0	0
Date	**26 June 2003**				
Fisher	**Fishing time (min)**	***Anadara antiquata***	***Cerithium aluco***	***Lambis lambis***	***Periglypta puerpera***
Alisa Bula	Not recorded – 1 trip	411		5	
Asenaca Mae	Not recorded – 1 trip	607			
Laete Sipologa	Not recorded – 1 trip	621	19		1
Laete Viaturaga	Not recorded – 1 trip	378			

Catch assessment – Creel survey from mangrove fishing - data review (total collected or CPUE per hour)

Date	**24 and 25 June 2003**			
Fisher	**Fishing time (min)**	***Saccostrea cuccullata***	***Scylla serrata***	***Thalamita crenata***
Akuila Donuca	Not recorded – 1 trip			48
Laete Matebalau & Alisi & Mere	Not recorded – 1 trip	1		68
Karalaini Kusima	240		1.5	

4.4.13b Lakeba 2009 catch assessment – creel survey – data review

Catch assessment – Creel survey from sea cucumber gleaning – data review

Species	Date	Number of fishers in a group	Fishing time (min)	Total number of specimens caught (n)	CPUE
Holothuria atra	10/2/2009	1	60	14	14.0
Holothuria edulis	10/2/2009	1	60	10	10.0
Stichopus hermanni	10/2/2009	1	60	2	2.0
Bohadschia argus	11/2/2009	3	120	3	0.5
Holothuria atra	11/2/2009	3	120	21	3.5
Holothuria edulis	11/2/2009	3	120	20	3.3
Holothuria fuscogilva	11/2/2009	3	120	3	0.5
Holothuria nobilis	11/2/2009	3	120	2	0.3
Thelenota ananas	11/2/2009	3	120	3	0.5
Bohadschia argus	12/2/2009	4	180	1	0.1
Holothuria atra	12/2/2009	4	180	20	1.7
Holothuria fuscogilva	12/2/2009	4	180	2	0.2
Stichopus chloronotus	12/2/2009	4	180	11	0.9
Thelenota ananas	12/2/2009	4	180	1	0.1

APPENDIX 5: MILLENNIUM CORAL REEF MAPPING PROJECT – FIJI 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
Fiji Islands

For further inquiries regarding the status of the coral reef mapping of Fiji Islands and data availability (satellite images and Geographical Information Systems mapped products), please contact:

Dr Serge Andréfouët
IRD, Research Unit COREUS 128, BP A5, Nouméa Cedex,
98848 New Caledonia;
E-mail: serge.andrefouet@ird.fr

Reference: Andréfouët S, and 6 authors (2005), Global assessment of modern coral reef extent and diversity for regional science and management applications: a view from space. Proc 10th ICRS, Okinawa 2004, Japan: pp. 1732-1745.